AUBEA

CQUniversity AUSTRALIA

43RD AUBEA

AUSTRALASIAN UNIVERSITIES BUILDING EDUCATION ASSOCIATION CONFERENCE

BUILT TO THRIVE: CREATING BUILDINGS AND CITIES THAT SUPPORT INDIVIDUAL WELL-BEING AND COMMUNITY PROSPERITY

6-8 NOVEMBER 2019
RACV NOOSA RESORT, NOOSA QLD, AUSTRALIA

CONFERENCE PROCEEDINGS

Papers submitted to this conference have been peer reviewed before final acceptance to the conference. This process entailed detailed reading of the abstracts and papers, reporting of comments to authors, modification of papers by authors whose papers were not rejected by the reviewers, and re-evaluation of revised papers to ensure quality of content.

Conference Proceedings

Published by: Central Queensland University
Bruce Highway, North Rockhampton, Qld 4702, Australia

ISBN: 978-1-921047-51-0

PROCEEDINGS OF THE 43RD AUSTRALASIAN UNIVERSITIES BUILDING EDUCATION ASSOCIATION (AUBEA) CONFERENCE

6 – 8 November 2019, Noosa QLD, Australia

Editors

Xianbo Zhao, Pushpitha Kalutara, Ronald Webber

Central Queensland University, Australia

TABLE OF CONTENTS

PREFACE

The Australasian Universities Building Education Association (AUBEA), a membership-based non-profit organisation, was established in 1975 to promote and improve teaching and research in building through communication and collaboration. It comprises of academics representing all universities throughout Australasia which provide education in building-related fields in Australasia and beyond. AUBEA maintains a strong connection to industry and professional associations, and since its inception has organised annual conferences. The annual conference brings together building and construction researchers, educators, students, and industry from Australasia and other regions, and provides them with a strong platform for knowledge sharing, collaboration, disciplinary reflections, institutional exchange, and collective growth.

The 43rd Australasian University Building Educators Association Conference (AUBEA 2019) is held in Noosa, Australia from 6 to 8 November 2019, under the auspices of Central Queensland University. The conference theme is ‘Built to Thrive: creating buildings and cities that support individual well-being and community prosperity’. The theme explores various facets of creating built environment enhancing community satisfaction and social innovation. Various facets are captured through five sub-themes: ‘People and Skills’, ‘Theories and Principles’, ‘Learning and Teaching’, ‘Processes and Economics’ and ‘Regulations and Policies’.

To maintain and assure the quality of the conference proceedings, each abstract received was reviewed. The authors received anonymous reviewers’ comments on their abstracts and were invited to submit their initial full papers. All the full papers have been peer reviewed with anonymous reviewers’ comments before final acceptance to the conference. The accepted papers are included in the conference presentation programme and the proceedings.

SPONSORS

The AUBEA 2019 Conference would like to thank each of these organisations for their generous contribution:

Lunch Sponsors

Exhibition Sponsors

AUBEA Member University Sponsors

CONFERENCE COMMITTEE

AUBEA Chair

Josua Pienaar, *Central Queensland University*

Conference Chair

Ronald Webber, *Central Queensland University*

Organising Committee

Ronald Webber, *Central Queensland University*
Xianbo Zhao, *Central Queensland University*
Pushpitha Kalutara, *Central Queensland University*
Peter Lawrence, *Central Queensland University*
Stephanie Keedy, *Central Queensland University*
Kevin Stone, *Central Queensland University*
Neda Abbasi, *Central Queensland University*
Gina Jing, *Central Queensland University*
Stephanie Gatt, *Central Queensland University*
Nicole Puglisi, *Central Queensland University*
Gillian Hehir, *Central Queensland University*

Scientific Committee

Xianbo Zhao (Chair), *Central Queensland University*
Bo Xia, *Queensland University of Technology*
Craig Langston, *Bond University*
Jian Zuo, *The University of Adelaide*
Kerry London, *Western Sydney University*
Linda Kestle, *Unitec Institute of Technology*
Monty Sutrisna, *Massey University*
Ming Shan, *Central South University*
Peng Wu, *Curtin University*
Peter Smith, *University of Technology Sydney*
Pushpitha Kalutara, *Central Queensland University*
Rameez Rameezdeen, *University of South Australia*
Robin Drogemuller, *Queensland University of Technology*
Ron Wakefield, *RMIT University*
Ronald Webber, *Central Queensland University*
Sui Pheng Low, *National University of Singapore*
Suzanne Wilkinson, *Massey University*
Valerie Francis, *The University of Melbourne*
Willy Sher, *The University of Newcastle*
Wilson W.S. Lu, *The University of Hong Kong*
Xiaopeng Deng, *Southeast University*
Yingbin Feng, *Western Sydney University*
Yongjian Ke, *University of Technology Sydney*

DEVELOPMENT OF A DOMESTIC MARKET FOR CONSTRUCTION AND DEMOLITION WASTE IN AUSTRALIA

Salman Shooshtarian[1], Tayyab Maqsood[1], Peter S.P. Wong[1], Malik Khalfan[1], Rebecca J. Yang[1]

[1]School of Property, Construction and Project Management, RMIT University, Melbourne, Australia

Abstract

The growth in the generation of construction and demolition (C&D) waste in Australia and new China's waste policy have put pressure on the C&D waste and resource recovery industry. Therefore, new solutions need to be provided to minimize the adverse effects of C&D on the environment, society, and economy. One of the highly preferred options is to develop a domestic market for this waste stream. However, development of such a market is not straightforward and warrants a full investigation of influential factors such as legislative, technical and financial ones. Hence, this study, as a part of a bigger project entitled "*A National Economics Approach to Improved Management of Construction and Demolition waste*", aims to review the major factors that impede or boost C&D waste market development in Australia. The results are expected to guide future attempts in creating an effective national C&D waste management in Australia.

Keywords

National approach; Waste management; Legislative framework; China's waste policy; Construction industry

Introduction

The construction industry in Australia has grown significantly in the past two decades in the wake of population growth, migration and expansion in the tertiary education industry. The growing population has necessitated extensive property development, better public transport, and improved infrastructure. The range of construction activities initiated in response involve businesses that are involved in creating residential and non-residential buildings (including renovations and additions), engineering structures, and associated trades and services (ABS 2006). The industry is identified as the fourth largest contributor to growth domestic product (GDP) (Trading Economics 2018); more than 1 million people work in the industry. Unsurprisingly, this volume of construction brings about a huge volume of waste, known in the industry as "construction and demolition (C&D) waste". In 2016-17, approximately 20.4 Mt of C&D waste was produced in the Australian construction industry, which accounts for 38% of the total core waste (solid non-hazardous waste and hazardous waste including liquids, and generated in the municipal, C&D and C&I sectors, generally excluding primary production) generated in Australia (NWR 2018).

Statistics have shown that, between 2016 and 2017, more than 6.7 Mt of C&D waste was transferred into landfills across Australia. Waste landfilling is recognised to be the worst waste management strategy due to the adverse social, economic and environmental consequences it causes. Furthermore, a part of Australian waste materials is being sent overseas including Vietnam, India, Malaysia, Indonesia, China and Bangladesh (Blue Environment 2018). According to ABS (2018) in 2016-17 the total amount of metal waste export was 2.15 tonnes with Vietnam, India, and Malaysia being the main destinations. However, these situations will not remain the same and there are emerging movements to stop waste landfilling both in Australia and overseas. In Australia, the federal government along with state and territory governments have started to change the waste management status quo. They have provided funds to investors and researchers and passing progressive regulation to protect the environment. Foreign countries are also developing initiatives targeting the import of waste materials. For instance, China has introduced a new policy, called the 'National Sword Policy', bans the import of certain foreign waste materials, with a strict level of contamination, to benefit the national policy environment (Shooshtarian, Maqsood, Khalfan, Wong & Yang 2019). This seems to have similar objectives to another program called 'Operation Green Fence 2013', which aims to restrict the import of contaminated recyclable materials. Other countries have also started to become stricter in accepting waste materials.

Given all mentioned above, in dealing with the C&D waste issues Australia has to consider sustainable alternatives whereby all parties (i.e. waste producers, waste consumers, recycling and construction industries, landfill owners, regulatory authorities and public) gain proportional benefits. As a result, Australian jurisdictions are drawing on the concept of a circular economy to improve their waste management system. Unlike traditional linear 'take-use-dispose' approach, this concept focuses on the maximum usage of resource and energy during the lifecycle of one product. To achieve this goal, Australia needs to move towards the development of a market wherein individuals can legally trade their waste materials. The development of a market for salvaged and recycled waste materials (including C&D waste) has been frequently emphasised in different policies, strategies, waste management principles and guidelines in Australia. The circular economy of waste has 5 principles, the third of which is to 'increase the use of recycled material and build demand and markets for recycled products', that is, market development. In the National Waste Policy (2018), Strategy 14 places emphasis on market development and research. Estimations, based on the current solid waste generation rates in Australia, project that Australian recycling capacity must increase by 400% by 2040 to address the issue of solid waste in the future (Environment and Communications References Committee 2018).

This paper aims to review the main strategies that contribute to the development of the market for recycled C&D waste. The review informs a larger research project entitled 'A National Economic Approach to Improved Management of Construction and Demolition Waste', which is being conducted at RMIT University and supported by the Australia Built Environment National Research Centre. This project endeavours to foster a holistic national approach to address C&D waste issues. Its objectives include the development of a consistent approach to define and measure C&D waste, identification of influential economic factors that govern disposal/reduce/reuse/recycle of C&D waste, conducting a feasibility study on the creation of a marketplace for trading C&D waste, and identification of opportunities to integrate supply chains model in the management of C&D waste.

Method

Data collection, processing, and analysis

This review study is based on the secondary data that are publicly available. The study employed a document analysis technique to explore effective strategies and enablers to develop a marketplace with the aim of further reducing, reusing and recycling of C&D waste in Australia. The sources reviewed in this study mostly include policies, guidelines and other relevant previous studies that focus on the economic factors influencing C&D waste marketplace development. In total, 15 sources were shortlisted and analysed for informing efforts towards market development. These sources were shortlisted based on their close relevance to the study objectives and their currency.

Context of study and C&D waste regulation in Australia

Australia is a large country with a population of 25 million that are mostly settled in capital cities. Significant growth in migration and population in Australia generate demands for more construction activities. As a result, more infrastructure and new housing are needed to meet the requirements of this ever-increasing population (IBISWorld 2019). The statistics have shown that such activities generate a large quantity of C&D waste (NWR 2018). As such, the state governments attempt to regulate C&D

waste management by enforcing relevant legislation and voluntary schemes. As previously mentioned C&D waste legislation mostly takes place at the state and territory level. Australia has 6 states: Victoria (Vic), New South Wales (NSW), Queensland (Qld), South Australia (SA), Western Australia (WA) Tasmania (Tas) and 2 territories: Northern Territory (NT) and Australia Capital Territory (ACT). The main difference between state and territory government is that states have the power to pass laws in their own right whereas in territories the federal government modifies or revoke laws. The majority of regulations and policies that govern C&D waste are produced and administrated by state EPAs. The history of C&D waste legislation dates back to 1970s when the first EPA act (Environmental Protection Act 1970) came into effect in Victoria. A review on the C&D waste-related regulations in different Australian jurisdictions is provided before in Shooshtarian et al. (2019).

Results and Discussion

The following sections present the results of the review on the main mostly economic factors that have a noticeable impact on market development for recycled and salvaged C&D waste materials. In total seven factors were identified that are presented in Figure 1. These include regulatory support, extended producer responsibility, the establishment of the effective supply chain, sustainable procurement, investments in technology and infrastructure, research and development and landfill levy imposition.

Figure 1. Seven factors influencing marketplace development for C&D waste materials

Regulation

It is vital that waste regulatory frameworks are set to be in favour of local market development and implementation of an effective circular economy. The issues that must be addressed in this regard are as follows:

1) Consistency in jurisdictional waste regulations throughout Australia
2) Clarification on when waste becomes a source and is not liable for landfill levy
3) Illegal dumping and stockpiling activities are severely discouraged
4) Consistent reporting obligations

Extended producer responsibility

Extended producer responsibility (EPR), otherwise known as 'product stewardship' and 'take-back' schemes are strong motivators for the establishment of a marketplace for C&D waste materials. These schemes are policy instruments that prevent waste generation. These sachems are long adopted in countries for different waste streams (Hanisch 2000). Technically, EPR makes manufacturers responsible (financially and/or physically) for the entire lifecycle of their products during the supply chain of materials, including design, manufacture, recycling and final disposal (OECD 2016). However, PER policy development and implementation, particularly for C & D waste, is still at an early stage in Australia. It is recommended that these schemes be regulated and implemented nationally because many of the potential participants work across Australian jurisdictions.

Sustainable procurement

Sustainable procurement can provide an incentive for further waste recovery. It is claimed that the implementation of SP has a great impact on the flourishing of the C&D waste material market. In response to China's new waste policy, the Minister of Energy and Environment committed to supporting increased use of recycled materials in the goods procured by government, and to collaborate on creating new markets for recycled materials.

In Australia, reuse of recycled materials is strongly encouraged under Ecologically Sustainable Development (ESD) and Sustainable Procurement (SP) programs. At the national level, National Waste Policy (2018) sets a target to reduce waste generation through prevention, reduction, recycling, and reuse. This policy has also emphasised the application of the principles of a circular economy to support better and repeated use of the nation's resources. Two strategies to promote sustainable procurement in Australia are at the forefront of this policy: Strategy 8 (Sustainable Procurement by Governments) and Strategy 9 (Sustainable Procurement by Business and Individuals). These two strategies urge the public and private sectors to promote demand for recycled materials and products containing recycled content. The Environment and Communications References Committee suggests that local governments practice sustainable procurement policies to ensure strong domestic markets for recycled material.

The Australasian Procurement and Construction Council Australian and New Zealand Government Framework for Sustainable Procurement is implemented by the federal government to pursue three aims when procuring goods, services, works, and utilities. These aims involve the reduction of environmental impacts, social impact and economic impacts through the procurement process. This framework also shares some premises with the circular economy in considering alternatives to the 'take-make-dispose' approach. According to this framework, the government has a decisive role in providing a market driver for increased use of recycled materials in the goods and works that it procures. Therefore, the federal government and some local government developed SP guidelines to coordinate their decisions and actions towards SP and the purchasing of recycled materials. In 2012, the state government of South Australia was the first authority to release a Sustainable Procurement Guide. One year later, in 2013, the federal government also released the first Australian guideline on SP1. This work was further complemented by state-specific guidelines to tailor sustainable procurement requirements in the ACT (2015), NSW (2017) and WA (2017).

Supply chain

Providing an efficient and effective supply chain to the waste and resource recovery industry is instrumental in developing a local market for C&D waste. The supply chain for this purpose needs to consider the principles of the circular economy and be driven by the industrial ecology (symbiosis) concept[1]. An effective supply chain system can assist in the implementation of EPR and similar schemes, provision of stockfeed for waste recovery facilities, and motivating compliance with GS and GI tools requirements. The World Economic Forum acknowledges that the circular economy approach can be applied to supply chains functioning at a local level, as well as those supporting complex global multi-tier material flows (World Economic Forum 2014). Creating a supply chain is not a straightforward task, as it involves numerous actors, each playing their part in the delivery of supply chain objectives.

In Australia, a decade's worth of effort towards the creation of an effective supply chain has resulted in some limited success. NSW is the leading state in building a supply chain system for domestic waste. In 2009, this state established an organisation called the Australian Industrial Ecology Network to promote the concept of industrial ecology and identify the opportunities to make connections between waste producers and waste consumers. In 2012, the Department of Energy and Environment (then known as the Department of Sustainability, Environment, Water, Population and Communications) released a guideline on the supply chain of C&D waste materials. This document primarily aimed to promote industrial ecology in the C&D waste stream and secondarily to showcase successful examples of C&D waste trade in Australia. Some of these examples demonstrated the effective development of a supply chain system, particularly with respect to product stewardship application. The following are the key issues regarding building a supply chain system for C&D waste stream that are identified in different Australian based literature:

1. Initial resistance from stakeholders to accommodate new safety requirements for C&D waste trade
2. The inaccuracy of reporting of C&D waste such as stockpiles
3. Decentralised purchasing systems are a challenge for most local governments
4. Involvement of various subcontractors that limits control of builder or construction company over supply chain management
5. Lack of strategic procurement and partnerships as key inhibitors towards a supply chain management framework
6. Poor organisational communication across units to facilitate changes
7. The government's main concern was health issues of occupants, particularly with regard to the lack of quality control

Investments in technology and infrastructure

Advancements in waste recovery technology and infrastructure are advantageous to domestic market development. Building modern and efficient facilities not only addresses public social and environmental concerns but also provides better services to the waste and resource recovery industry through economies of scale. Government funding to improve waste and resource facilities together with effective law enforcement provides an impetus for further waste recovery activities and diminishes the reliance on waste export. An increase in the number of local infrastructures frees waste producers and collectors (waste responsible) from sending waste across the Australian states such that it would be easier to implement the proximity principle. Technically, a lot of waste minimisation practices and strategies, such as extended producer responsibility, depending on the availability of technologically advanced local infrastructures. Several waste management strategies in Australia have highlighted the need to keep pace with changes in technology for smarter and more efficient waste management. Many wastes and resource recovery stakeholders in Australia believe that hypothecating landfill levies should be invested towards developing new technologies and infrastructure. The use of new technologies, such as Building Information Modelling (BIM), Geographical Information Systems (GIS) and the online marketplace can solve several issues toward the successful establishment of a market for salvaged and recycled C&D waste material.

[1] The wastes or by-products of one industry are used as inputs in another industry, thereby closing the material loop of industrial systems and minimising waste.

Research and development

An integrated waste management system greatly benefits from research and development (R&D). Almost every single strategy, policy, action plan and regulation on waste management in Australia has highlighted the role of R&D alongside with encouragement and enforcement for an effective development and implementation of waste related plans. In Australia, authorities have recently started taking advantage of R&D benefits and hence have engaged research and consultation entities to provide the information required for regulation of C&D waste streams. To date, the product of such collaboration has partially contributed to the decision making processes on an extended range of issues. Table 1 presents some seminal examples of these studies that are commissioned by public authorities and are published in the form of publicly available reports:

Table 1. Summary of research reports released to inform legislation, decision making or raising awareness

Report	Ordering authorities	Objective(s)
Construction and Demolition Waste Status Report (2011)- Hyder Consulting Pty Ltd	*I. Department of Sustainability, Environment, Water, Population & Communities Queensland* *II. Department of Environment & Resource Management in accordance*	*Evaluation of the current conditions of C&D waste management in Australia & providing relevant reforms*
Waste definitions and classifications, report on issues, opportunities and information gaps(2012)– Hyder Consulting Pty Ltd	*Department of Sustainability, Environment, Water, Population & Communities*	*Review on (legal) definitions used for various waste streams in different jurisdictions*
An Investigation into the Performance (Environmental and Health) of Waste to Energy Technologies Internationally (2017)-WSP Global Pty Ltd	*Western Australia Department of Environment and Conservation*	*A review of legislative & regulatory frameworks, state of the art technologies and research on health and environmental impacts*
A review of the scientific literature on potential health effects in local communities associated with air emissions from Waste to Energy facilities (2018)-Environmental Risk Sciences	*EPA Victoria*	*Evaluation of potential issues associated with EfW technologies*
Global Landfill Regulation & Waste Levy Review (2012)-SLR Consulting Australia Pty Ltd	*I. Western Australian Department of Environment & Conservation* *II. Waste Authority*	*Review on landfill levy regulations in Australia and worldwide*
Waste to energy consultation and case study for Melbourne's West (2017)- Reincarnate Pty Ltd	*The Department of Environment, Land, Water & Planning*	*Investigation of the approved expansion of large residual waste landfills at Ravenhill & Werribee*
An investigation into the Transport of Waste into Queensland (2017)- a research team from different entities	*I. Environment & Heritage Protection* *II. National Parks & the Great Barrier Reef*	*To review and assess strategies to limit the transport of waste across Qld*
Construction & Demolition waste guide - recycling & re-use Across the supply chain (2012)- Edge Environment Pty	*Department of Sustainability, Environment, Water, Population & Communities*	*To identify the issues of supply chain and review some case study of existing C&D waste supply chain*

Note: the name of some of the authorities mentioned in this table may have now changed to other names.

The Australian legislation process is underpinned by consultations with the main stakeholders who are affected by developing regulations. Consultation drafts as a form of R&D call for submissions from industry, authorities, researchers and the public to ensure that any ensuing legislation provides a level playing field for all parties concerned. Universities are important players in providing research services to decision-makers, regulatory authorities, industry and wider communities. In a study in Spain, the role of universities, as a key new actor, in the enhancement of C&D waste management through the creation of a 3R model (reduce, reuse and recycle) was stressed. The researchers of this study noted that "*Studies on C&D waste often forget to include a key player in waste management… Universities can advance the possibilities of solving technical problems and applying new methods of recycling and new market-oriented applications according to the current legislation*" (Calvo, Varela-Candamio & Novo-Corti 2014, p. 422). According to this study, other contributions from universities in this respect include:

1. Availability of infrastructure and qualified academic staff to effectively develop R&D in this field so that the cost of concentrating research efforts can be reduced
2. An ability to demonstrate recycling achievements to be applied in the recycled market-endorsing C&D recycled materials
3. Training of professional staff for C&D waste and resource industry through postgraduate courses for construction

Another function of R&D is to raise public, industry and authorities' awareness. Indeed, several research studies demonstrated the positive role of evidenced-based awareness received through R&D activities. Then this awareness underpins management practices towards the development of a market for C&D waste materials. R&D can also be employed to explore new opportunities for re/use of C&D waste materials. For instance, a study report indicated that recycled brick and concrete could be used in the landscaping industry with competitive prices compared to alternatives. In the case of EfW, the research is needed to facilitate the use of energy produced in the local power grid.

Landfill levy

The approach to taking advantage of a landfill levy is not straightforward due to the role of varying factors in the effective management of waste. While in some circumstances a landfill levy is the best economic driver, it can act as a disincentive in other circumstances. In the literature, conflicting results are reported in response to the imposition of a landfill levy, both in domestic and international contexts. The mechanism and other characteristics of imposing a landfill levy in different Australian states and territories have been stated previously in Shooshtarian et al. (2019). In this section, the relevant literature is reviewed to understand the impact of this enforcement mechanism in Australia and elsewhere. In the first part of this section, worldwide evidence regarding the effectiveness of this mechanism is provided; the second part discusses the findings that show how landfill levies are perceived in Australia.

The Australian experience

In 2012, a C&D supply chain guide prepared for the Commonwealth Government of Australia (Edge Environment 2012) reported that many stakeholders had indicated that landfill costs (landfill operation and levies) are a significant driver for the use of salvaged and recycled C&D waste. In 2018, various respondents to the call for submissions to the Senate's Environment and Communicates References Committee expressed support for continuous imposition of landfill levies. The submissions highlighted that levy schemes can act as a disincentive for waste disposal. Further, they concluded that the ensuing revenue is an important source of funding for investment in waste and recycling management initiatives. The following table (Table 2) shows the examples of support from different submitters:

Table 2. The evidence of the effectiveness of landfill levies in Australia

Respondents	Indicative language
WA Government	There has been a notable diversion from landfill for two waste streams (i.e. C&D and C&I) since 2011 when levy rates were considerably increased.
Re.Group (http://www.re-group.com/)	NSW's relatively high recovery rate for two waste streams (i.e. C&D and household waste) has been driven by the landfill levy.
SA Government	Progressive increase of waste recovery (reduction in waste disposal) has been concurrent to a continuous increase in levy fee. The increase was more than 20% in 2015-2016 (81.6%) compared to 2003-2014 (60%).
The Western Australian Local Government Association	There is evidence that the landfill levy has been responsible for diverting inert material from landfill; however, it is not known where this waste is being diverted.
Envorinex (https://envorinex.com/)	Landfill levies should be priced high enough to encourage major business to send their waste to recyclers and not to landfill sites.

Source: Environment and Communications References Committee (2018)

In addition, to support from the submissions to this committee, there are some concerns about the unintended consequences that emerge from the improper design of levy schemes. These concerns express that the jurisdictional legislation levy should not give rise to unintended outcomes such as interstate waste transfer because of cost disparity, discouraging private investors to invest in recycling infrastructure, high administrative costs corresponding to the application of complex schemes and stockpiling and illegal dumping. Furthermore, some respondents provided evidence that shows that imposing a landfill levy did not achieve the intended goals (e.g. reduction in waste disposal or an increase in waste recovery activities). Indeed, this evidence demonstrates that there are limits to what can be achieved through the imposition of a landfill levy. Table 3 summarises these challenges associated with landfill levies.

Aside from the views tabulated above and beyond the scope of this report, several respondents indicated that levies have little impact on domestic waste generation patterns in Australian cities. It is found that, because councils charge households at a flat fee to recover the levy fees, which they pay on behalf of ratepayers, they have no motivation to reduce the amount of waste disposed of. In other words, basically, the price signal is not passed on through the rates directly. There is a lesson in this causality that can be transferred to the context of C&D waste management; the levy should be accompanied with other financial incentives to effectively target waste generation at the origin, for example, during the design and construction stages.

In response to the call made by the WA Department of Waste and Environmental Regulation for submission to a discussion paper on landfill levy several trends emerged. Some of the submissions presented different issues that were not considered in the relevant regulations and policies. The following are a selection of their responses to the latest levy regime in WA:

"*A levy, by its nature, is a penalty/cost impost. In what way is the payment of a levy an incentive? Those paying the levy have fewer funds available to put into their own research and subsequent implementation of their own waste reform policies and systems*".

"*In addition, we are concerned that this appears to be revenue-raising activity rather than a legitimate pursuit of better environmental outcomes for Western Australian*"

1. Levy should be articulated as the 'key environmental lever' not an 'economic policy lever'
2. A rebate system has to be in place for those who involved in landfill diversion
3. Allow alternative methods of calculating waste volumes, rather than just utilisation of weigh stations

Table 3. Unexpected results from the implementation of landfill levies in Australia

Submitter	Indicative language
The Law Council of Australia	Landfill levies can encourage stockpiling and illegal dumping.
GCS Consulting	During the period when the amount of the metropolitan New South Wales levy doubled, the NSW's C&D industry was found to have reduced its recycling rate, which is contrary to expected market behaviour and the efficacy of the levy as a pricing mechanism that was achieved when the levy was at much lower levels.
Unspecified submitters	Little effect on waste generation, as ratepayers have no direct financial incentive to reduce waste destined to landfill.
Adelaide Hills Region Waste Management Authority	Waste disposal levies do 'not act as a direct driver for the community to reduce waste generation or increase recycling habits' because any increase in waste levies is 'covered by general rate revenue'.
The Australian Sustainable Business Group	Highlighted that there is evidence that an increase in the landfill levy results in incurring additional costs for the recycling industry.
National Waste and Recycling Industry Council	A levy on the disposal of recycling residuals reduces the competitiveness of materials sold into the international market.
Centre of International Economics	In NSW, the waste levy of $ AU 120 reduced the profit margin of metal recyclers in 2011.
The Australian Council of Recycling	When recyclers are liable to pay the levy for the disposal of contaminants that have entered the recycling stream, they see it as a disincentive towards being involved in the recycling industry and instead it encourages shipping unprocessed waste overseas.
Re Group	The disposal of residuals generally represents a significant cost for recycling facilities, which can obviously create commercial incentives to seek lower disposal cost options. It also justifies transport waste to interstate locations with a lower disposal rate.
Visy, Owens-Illinois and SKM Recycling	Landfill levies penalise the recycling industry for the disposal of residual rubbish that enters the recycling stream.

Source: Environment and Communications References Committee (2018)

Another barrier to effective enforcement of landfill levies is to nationally harmonise gate fees. The support for harmonisation is abundant (Environment and Communications References Committee 2018) and it is believed it can substantially minimise inter-jurisdictional waste transfer. However, it should be remembered that such an arrangement might not produce the best results. Simple harmonisation may overlook the existing contextual conditions in each jurisdiction. It may also interfere with the specific waste management system implemented in different states and territories. Hence, it is better to set up the levy fees in a way that ensures the negative impact on the effective management of C&D waste across Australia is minimised. For instance, a rate disparity should be calculated to the extent that it does not prompt unnecessary long-distance waste transfer.

Conclusion

This study reviewed and presented the main factors that are believed to have an important impact on the development of the market for trading C&D waste in Australia. Development of a sustainable C&D waste market wherein everyone can benefit from a fair, legal and cost-effective trade cannot be achieved overnight. Indeed, it needs a fair amount of preparation activities including receiving support from different key stakeholders. In the past, there were several attempts to creating such a marketplace; however, these did not succeed in achieving the desired results. This study identified and discussed seven main strategies including 'regulation', 'extended producer responsibility', 'supply chain management', 'sustainable procurement', 'investment in technology and infrastructure', research and development', and 'landfill levy', It is expected that this study provides a platform for further research and development in order to remove barriers toward the development of a well-perceived market across Australia.

References

ABS 2006, *Australian and New Zealand Standard Industrial Classification* ABS.

—— 2018, *International Trade*.

Blue Environment 2018, *Data on exports of recyclables from Australia to China*.

Calvo, N, Varela-Candamio, L & Novo-Corti, I 2014, 'A dynamic model for construction and demolition (C&D) waste management in Spain: Driving policies based on economic incentives and tax penalties', *Sustainability*, vol. 6, no. 1, pp. 416-35.

Edge Environment 2012, *Construction and Demolition Waste Guide - Recycling and Re-Use Across the Supply Chain*, The Department of Energy and Environment Canberra, Australia.

Environment and Communications References Committee 2018, *Never waste a crisis: the waste and recycling industry in Australia*, Commonwealth of Australia 2018.

Environmental Protection Act 1970, *Environmental Protection Act 1970*, EPA, Melbourne, Australia

Hanisch, C 2000, 'Is extended producer responsibility effective?', *Environmental science & technology*, vol. 34, no. 7, pp. 170-5.

IBISWorld 2019, *Construction in Australia*, IBISWorld.

National Waste Policy 2018, *Less Waste. More Resources*.

NWR 2018, *Australian National Waste Report 2018*, Department of the Environment and Energy.

OECD 2016, *Extended Producer Responsibility: Updated Guidance for Efficient Waste Management*, Organisation for Economic Cooperation and Development, OECD Publishing, Paris.

Shooshtarian, S, Maqsood, T, Khalfan, M, Wong, P & Yang, R 2019, 'Managing construction and demolition (C&D) waste in Australia', paper presented to CIB World Building Congress 2019 'Constructing Smart Cities', Hong Kong, China, 17-21 June

Trading Economics 2018, *Australia GDP from Construction*, Trading Economics https://tradingeconomics.com/australia/gdp-from-construction.

World Economic Forum 2014, *Towards the Circular Economy: : Accelerating the scale-up across global supply chains*, Geneva, Switzerland.

GREEN CONSTRUCTION AND CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT IN AUSTRALIA

Salman Shooshtarian[1], Tayyab Maqsood[1], Peter S.P Wong[1], Malik Khalfan[1], Rebecca J. Yang[1]

[1]School of Property, Construction and Project Management, RMIT University, Melbourne, Australia

Abstract

The construction industry has faced issues regarding the proper management of Construction and Demolition (C&D) waste in Australia. As enshrined in many Australian waste strategy documents, waste is everyone's responsibility. Therefore, initiatives promoting the concept of shared responsibility are being paid attention in more recent waste managed system and policies. Green Construction (GC) is one of these concepts that, alongside other focus areas, advocate effective C&D waste in construction projects. GC for C&D waste is mainly implemented through the Green Star (GS) scheme (Green Building Council of Australia) and the Infrastructure Sustainability (IS) scheme (Infrastructure Sustainability Council of Australia). This study sought to better understand how these two rating systems are being implemented and could benefit the construction and resource recovery industries. In this study, the review of relevant literature including industry and organisational reports, guidelines and academic papers could provide insight into the position of GS in Australian jurisdictions. In total 7 case study reports were found to show positive results achieved by the application of IS and GS. The limited number of case reports, however, presents a limitation as to reaching a definitive conclusion on the benefits of GC programs. Hence, it is highly recommended that future research is undertaken to demonstrate GC programs' capacity in the effective management of C&D waste in a diverse range of construction projects. The results may inform policy development and encourage construction and waste recovery industries to adopt best management practices enshrined in these schemes.

Keywords

Waste strategy, Shared responsibility, Green star scheme, Infrastructure sustainability, Jurisdictions

Introduction

Rapid growth in construction activities in Australia in recent years has led to increased generation of construction and demolition (C&D). According to the latest statistics (NWR 2018), about 20.4 Mt of C&D waste was generated across Australia, which is equal to 30.5% of total waste generated, from which 33% is being disposed in landfill. With the existing rate of migration and population growth (Australian Bureau of Statistics 2018), it is expected that C&D waste generation will continue to grow steadily in the coming years. Failure in delivering effective management of C&D waste generated will have unintended economic, social, political and environmental repercussions (Park & Tucker 2017). Therefore, it is of particular importance to properly manage this growing issue at the national level. Effective management of C&D waste, however, is not straightforward and requires a contribution from various stakeholders in the construction and recycling industries. Several issues in the C&D waste management system have been found and strategies to overcome them have already been proposed in Australia (Park & Tucker 2017; Tam, Le, Wang & Illankoon 2018; Udawatta, Zuo, Chiveralls, Yuan, George & Elmualim 2018) and elsewhere (Menegaki & Damigos 2018; Wang, Li & Tam 2014). Among the many stakeholders, it seems that construction companies have an instrumental impact on C&D waste generation, re-using and recycling.

One way to encourage construction companies to contribute to further recycling, re-using and recovery of C&D waste is to design and implement environmental sustainability programs that award stars or rates to construction companies (Siew, Balatbat & Carmichael 2013). These rated awards are granted based on informed decisions and cautious activities that take place in construction projects that meet the awarding organisation's requirements. The award or rate can increase the construction company's reputation in the market, which is eventually translated to economic profit. Such profit is achieved through construction companies advertising campaigns to promote their environmental-friendly vision, design and product. This can increase the selling value of their buildings and add value to the property. For instance, a CEO of a property investment management company in the UK stated that, '*greening our portfolio over the next two years is not only environmentally the right thing to do, it also makes sound business sense'* (Lewry, Fisher & Holden 2018, p. 1). A review of case studies in the UK showed the increase in rentable value for such properties is between 5–10 per cent (Lewry et al. 2018). Another incentive for construction companies originates in the benefit gained from the demonstration of their commitment to the set requirements making them eligible or advantaged in public projects. Governments have started to include environmentally responsible construction practices in the evaluation criteria of tenderers in public construction projects.

The Green Construction (GC) concept, otherwise known as green building, sustainable building and high-performance building, refers to the combination of efforts towards reducing in part the impact of construction activities on the environment and society. GC in the context of C&D waste is referred to as a notion that intends to employ low waste building technologies and promote utilisation of C&D waste or recycled materials. There are about 40 green programs across the world (Siew et al. 2013; Thaickavil & Thomas 2019) that share similar principles. The seminal ones include 'Environmental Assessment Method' (BREEAM), the first and foremost green building rating system in the UK that is implemented in 76 countries worldwide (BREEAM 2019); Leadership in 'Energy and Environmental Design' (LEED), developed by the US Green Building Council that was launched in 1998 and is the most widely used green rating system with certifications in over 165 countries and territories; 'Comprehensive Assessment System for Built Environment Efficiency' (CASBEE), the green building rating system developed in Japan in 2001; 'Building Environmental Assessment Method' (BEAM) plus, the green building assessment system developed by the 'Hong Kong Green Building Council Limited; and the 'Green Rating for Integrated Habitat Assessment' (GRIHA) rating system 'developed by The Energy Research Institute (TERI), New Delhi, and Ministry of New and Renewable Energy, Government of India.

Australia is considered to be a leading country in the development and application of GC schemes to reduce the environmental impact of construction activities. However, there is limited research undertaken to study the extent to which application of GC programs could effectively achieve the benefits stated under the main Australian GC schemes. Therefore, this review study attempts to shed light on the green rating tools being implemented in Australia to better understand how they contribute to the management of C&D waste. The review informs a larger research project entitled 'A National Economic Approach to Improved Management of Construction and Demolition Waste', which is being conducted at RMIT University and supported by the Australia Built Environment National Research Centre. This project endeavours to foster a holistic national approach to address C&D waste issues. Its objectives include the development of a consistent approach to define and measure C&D waste, identification of influential economic factors that govern disposal/reduce/reuse/recycle of C&D waste, conducting a feasibility study on the creation of a marketplace for trading C&D waste, and identification of opportunities to integrate supply chains model in the management of C&D waste. The objectives are in relation to several strategies mapped out in the National Waste Policy 2018 (National Waste Policy 2018) and can provide a solution to tackle the issues raised in light of new changes in Chinese regulations that ban waste trade imports.

Methodology

Data collection, processing, and analysis

This review study is based on the secondary data that is publicly available. The document analysis technique was conducted to explore activities that aim to further reduce, reuse and recycle C&D waste through GC programs in Australia. The sources reviewed include policies and other relevant studies that focus on the relationship between a GC scheme and C&D waste management. In total, 10 academic papers and industry-based reports were analysed that provided information about GC and C&D waste in Australia. Microsoft Excel V. 2016 is used to analyse the data and visualise results.

Context of study and C&D waste regulation in Australia

Australia is a large country with a population of 25 million that is mostly settled in capital cities. The state and territory governments attempt to regulate C&D waste management by enforcing relevant legislation and voluntary schemes. C&D waste legislation mostly takes place at the state and territory level. Australia has 6 states: Victoria (Vic), New South Wales (NSW), Queensland (Qld), South Australia (SA), Western Australia (WA) Tasmania (Tas) and 2 territories: Northern Territory (NT) and Australia Capital Territory (ACT). The majority of regulations and policies that govern C&D waste are produced and administrated by state Environmental Protection Authorities (EPA). The history of C&D waste legislation dates back to the 1970s when the first EPA act (Environmental Protection Act 1970) came into effect in Victoria. A review on the C&D waste-related regulations in different Australian jurisdictions has previously been provided in Shooshtarian, Maqsood, Khalfan, Wong and Yang (2019).

Results

The concept of green construction was introduced in Australia in two main forms, the Green Star (GS) Program and the Infrastructure Sustainable (IS) rating system, by two authorities, the Green Building Council of Australia (GCBA) and the Infrastructure Sustainability Council of Australia (ISCA), respectively. The following sections deal with these two rating systems and explore how they consider C&D waste in their requirements.

The green star rating tool

Since its establishment (2002) as the nation's authority (non-for profit) on sustainable buildings, communities and cities, GCBA has developed sustainability programs to certify, educate and advocate green built environment projects in Australia. A year after the establishment of GCBA, it started providing the Green Star (GS) scheme, which is Australia's only national and voluntary rating system for buildings and communities. Currently, there are four internationally recognised rating tools under the GS Program, namely 'Communities', 'Design & As-Built', 'Interiors' and 'Performance'. These voluntary tools promote the efficient use of management practices of construction and fit-out materials and target C&D through 'Construction and Demolition Waste' credits. The C&D waste credit aims to encourage and reward management practices that minimise the quantity of C&D waste going to landfill from base building and/or interior fit-out works. The credits operate to engage verified waste contractors and processing facilities that comply with minimum standards of GCBA reporting that were developed in 2013. GCBA claims that green projects (buildings) recycled 96% of their C&D waste.

Generally, there are three areas of improvements in GS for C&D waste-related credits:

- Recycling of construction and demolition waste from the building
- Design of the storage for waste to encourage good recycling practices

- Use of recycled materials

According to the criteria, credit points are awarded when a project can prove that less than 4.5 kg/m2 of fit-out area have been sent to landfill. In particular, the following items can win credits for construction projects:

- **Reduction:** Reduction of C&D waste: 1 credit
- **Reuse:** Façade reuse (retained by 50%: 1 credit; retained by 80%: 2 credits), Structure reuse (retained by 30%: 1 credit, retained by 60%: 2 credits)
- **Aggregate:** Coarse aggregate is crushed slag aggregate or other alternative materials—at least 40% (0.5 credit), Fine aggregate is manufactured sand or other alternative materials—at least 25% by mass; in Australia, both of these two categories are sourced from C&D waste
- **Recycled content products:** 3% product (1 credit), 6% (2 credits), 9% (3 credits).

The following table presents the categories of GS rates and corresponding scores.

Table 1. Categories of Green Star (GS) rates

Score	Rating	Category
10-19	One Star	Minimum Practice
20-29	Two Star	Average Practice
30-44	Three Star	Good Practice
45-59	Four Star	Best Practice
60-65	Five Star	Australian Excellence
75+	Six Star	World Leadership

The evaluation of performance and effectiveness of GS in Australia has been the focus of several investigations in recent years (Table 2). A study in Australia (Park & Tucker 2017) has recommended the GS's C&D Waste credit to be mandatory; it also suggests that the additional costs that a client must incur to get a GS certificate should be reduced in future. A report (Green Building Council of Australia 2014) on the benefits of a decade's application of GS in Australia revealed that GS certified buildings are recycling 96% of their C&D waste. This report found that, in total, 37,600 truckloads of C&D waste have been diverted from landfill due to good waste management practices. Specifically, in one outfit project, the construction company could achieve a surprising rate of 0.35 kg/m^2 of C&D waste going to landfill. Another study in 2015 (Udawatta, Zuo, Chiveralls & Zillante 2015) reported decisions in construction projects are constrained by financial gains unless a special requirement to comply with GS or any similar schemes is in force. One of the interviewees in this study indicated that designers do not tend to consider opportunities for waste minimisation unless they are required to fulfil building rating tools such as GS. Overall, the authors of this research concluded that GBCA could improve its GS program to address the impacts of three main deterrents towards waste management practices: lack of economic interest, professional roles and less accountability of construction stakeholders.

Table 2. Summary of investigations on the impact of green construction on C&D waste management in Australia

Tool	Study	Project	Summary of waste management results
Green star	GBCA (2010)	SA Water	Diverted 98% of construction waste away from landfill, reducing waste processing costs and the strain on local waste facilities.
	Green Building Council of Australia (2014)	Report	GS certified buildings are recycling 96% of their C&D waste. In total, 37,600 truckloads of C&D waste have been diverted from landfill due to good waste management practices
		Frasers Property Australia's office fit-out)	This project only sent 0.35 kg/m^2 of C&D waste to landfill
	Green Building Council of Australia (2018)	Westfield Sydney	This project that applied GS principles could recycle 90% of the waste produced during demolition and construction activities
Infrastructure Sustainability	Bauer (2011)	Whitsunday's STP upgrades	Application of IS scheme requirements resulted in fewer construction materials (4,4000t fewer materials), application of green concrete in roads, 40% fly ash blend in asphalt and 100% reuse of excavated materials
	Bauer (2011)	Gold Coast Light Rail	Following IS principles, the project could cut down the need to excavate and relocate 68,200 tonnes of waste material, reduce reduction concrete and steel required by 40%, reduce embodied carbon emissions of 3,200 t CO_2-e, recycle sand from excavation, reduce costs for transport and recycling, and improve local beaches. The report also showed that the project owners could save 44,000 tonnes of materials, leading to a 55% reduction in embodied carbon emissions. It also resulted in the recycling of 156,000t of inert and non-hazardous construction waste. They also recycled 100% of spoil.
	MMRA (2016)	Melbourne Metro Tunnel	Adhering to ISCA and GC schemes guidelines this project sourced at least 95% of all timber from re-used timber and post-consumer recycled timber. The project managers ensured that greater than 95% by volume of reusable topsoil and spoil (general fill), greater than 90% by volume of inert and nonhazardous waste, and greater than 60% by volume of office waste is diverted from landfill.

The main stakeholders have questioned the practicality of achieving the GS scheme requirements. However, GCBA invites stakeholders to comment on the main issues and publishes their feedback through discussion papers periodically. The criticisms mostly refer to potential additional costs, the realism of targets, and the complexity of audit processes (Green Building Council of Australia 2013).

The sustainable infrastructure rating tool

In addition to GBCA, the ISCA (a non-for-profit industry council) developed a voluntary rating system called Infrastructure Sustainability (IS) for environmental assessment of infrastructures (nonbuilding projects) in terms of sustainability in 2007 (Diaz-Sarachaga, Jato-Espino, Alsulami & Castro-Fresno 2016). This scheme seeks to foster resource efficiency and reduction of waste and associated costs in infrastructure projects (ISCA 2019). Its equivalent programs in other countries include Envision (USA) and the Civil Engineering Environmental Quality (CEEQUAL) assessment (UK). Under the resource efficiency category of its environment component, this program aims to take a circular economy approach to resource management and thinks about resources holistically from reusing resources on-site to finding new and innovative used for 'waste' products (Newman, Hargroves, Desha, Kumar, Wilson, Farr, Whistler & Matan 2014). This tool credits infrastructure projects according to five credit categories: 'Management and governance', 'Using resources', 'Emissions, pollutions and waste', 'Ecology', 'People and place' and 'Innovation'; and in three phases, 'Design', 'Build' and 'Operation'. Following the planning and design phases, requirements for sustainability and performance during construction are appraised. The 'Build' rating is awarded at the conclusion of project construction and replaces the 'Design' rating. The point-based award categories consist of Commended (25-50 points), Excellent (50-75 points) and Leading (75-105 points).

ISCA has demonstrated the impact of IS scheme implication on the C&D waste management in two Australian projects (Bauer 2011). In the first project, an upgrade of two treatment plants at Proserpine and Cannonvale (Qld), the project owners could benefit from reusing recycled materials, clean fill and reduction in raw materials and embodied carbon emission (Table 2). The second case was a transport project in Qld, where adhering to IS requirements produced several economic benefits including cost saving in transport, excavation and use of raw materials, recycling fees and embodied carbon emissions. This report echoed the project success story of 90% recycling of inert and non-hazardous C&D waste produced during construction (Table 2).

Discussion

Impact of green construction programs on C&D waste management

Green construction programs are assumed to effectively improve C&D waste management in the Australian construction industry (Newman et al. 2014). In Australia, the results of a few studies have shown that, if properly managed, GC programs facilitate a substantial reduction in the construction waste generation, increase in reuse of recycled and salvaged C&D waste materials (Table 2). However, there is an emerging need to further demonstrate this capacity within various construction projects varying in size, purpose, build budget, etc. This demonstration should aim to encourage the main actors in the construction industry to further reduce C&D waste and increase the in waste-driven materials uptake during construction and demolition activities.

Barriers to the application of green construction schemes to reduce C&D waste

Despite the proven evidence for the economic benefits of GC programs all around the world (Kats 2003; Zhang, Shen & Wu 2011), several research studies have identified key barriers decreasing the willingness to follow GC principles (Samari, Godrati, Esmaeilifar, Olfat & Shafiei 2013). These barriers are wide-ranging and emerge from different sources. For instance, in Malaysia, it was found that the lack of credit resources to cover the upfront cost, risk of investment, lack of demand and greater final costs are the main barriers to GC implementation (Samari et al. 2013), issues that can be also traced in the Australian construction industry (Udawatta et al. 2015). In Australia, a case study in SA identified the main barriers in C&D waste management as the lack of economic interest, professional roles and less accountability of construction stakeholders (Udawatta et al. 2015). In removing these barriers, the authors believed that GS scheme could be of help, provided that GBCA improves its rating tool given these issues. Another study on the barriers to implementation of GC in Australia found that the initial enthusiasm for separating the C&D waste materials dissipated as the projects progressed (Wilson & Tagaza 2006). For instance, it was reported that recycling skips were found to contain a mix of materials, which can be related to ignorance, laziness or time pressures to complete a project and clean-up expediently. To tackle these issues, the appointment of an officer tasked to check practices or random on-site visits by project managers can be helpful. Furthermore, involving union representatives in site meetings to reinforce the benefits to workers of sustainable practices is another solution (Wilson & Tagaza 2006).

The role of government to promote green construction

Governments play a key role in promoting GC programs (Samari et al. 2013). Through adjusting legislation and providing financial incentives, a government can further encourage the construction industry to move towards the GC concept. However, these strategies should be designed in such a way that assures these companies that no additional on the base build costs will occur. For instance, governments can incentivise major stakeholders by aligning regulations governing C&D waste with GC program requirements. Relaxing regulations to provide the levy exemption for clean fill and providing discounted levy fees for C&D waste residuals in recycling facilities (Environment and Communications References Committee 2018) will provide a competitive advantage for those who intend to use recycled materials in their construction projects. Another example is to develop and promote sustainable procurement policies (Berry & McCarthy 2011). Currently, the Australian federal government, ACT, SA, NSW, Qld, and WA have their procurement policies in place.

Conclusion

This review study aimed to review the activities for the management of C&D waste in light of the requirements of GC programs in Australia. Currently, there are two rating voluntary systems (i.e. green star (GS) scheme and infrastructure sustainable (IS) tool) that are implemented in different Australian jurisdictions. Despite the limited number of case studies in Australia, the research could provide evidence on the positive impact of these two programs on the management of C&D waste in various construction projects. The limitation identified, however, may impede the efforts towards the promotion of these programs among public organisations and the industry. This limitation makes it difficult to arrive at a decisive, justifiable and transferable conclusion. Therefore, it is highly recommended that further studies be conducted to provide more information on how GC programs can contribute to reducing C&D waste generation, increasing uptake of recycled materials and reusing C&D waste in the construction industry as a whole. Particularly, future research should be directed towards the economic aspects of these programs in which the industry’s interest lies. If properly communicated, this can encourage more construction companies to join and implement such programs.

Acknowledgments

The authors would like to acknowledge the support of the Australia Sustainable Built Environment National Research Centre (SBEnrc), Project 1.65. However, the views expressed in this conference paper are those of the authors and do not necessarily represent the views of SBEnrc.

References

Australian Bureau of Statistics 2018, *Australian Demographic Statistics*, Canberra, Australia.

Bauer, K 2011, *ISCA and the IS rating scheme: Advancing sustainability in infrastructure planning, procurement, delivery and operation.*, Infrastructure Sustainability Council of Australia

Berry, C & McCarthy, S 2011, *Guide to sustainable procurement in construction*, CIRIA London.

BREEAM 2019, *BREEAM is the world’s leading sustainability assessment method for masterplanning projects, infrastructure and buildings*, https://www.breeam.com/.

Diaz-Sarachaga, JM, Jato-Espino, D, Alsulami, B & Castro-Fresno, D 2016, ‘Evaluation of existing sustainable infrastructure rating systems for their application in developing countries’, *Ecological Indicators*, vol. 71, pp. 491-502.

Environment and Communications References Committee 2018, *Never waste a crisis: the waste and recycling industry in Australia*, Commonwealth of Australia 2018.
GBCA 2010, *A Guide for Local Government: People are talking about green buildings... how can you get involved?, Building a Sustainable Future*, Green Building Council Australia
Green Building Council of Australia 2013, *Construction & Demolition Waste Management in Green Star Stakeholder Feedback Report*, Green Building Council of Australia.
—— 2014, *Green Building Market Report Australia New Zealand*, Green Building Council of Australia.
—— 2018, *Projects*, Green Building Council of Australia 2019, https://new.gbca.org.au/showcase/projects/.
ISCA 2019, *Infrastructure Sustainability*, http://www.isca.org.au/.
Kats, G 2003, *Green building costs and financial benefits*, Massachusetts Technology Collaborative Boston, MA.
Lewry, A, Fisher, J & Holden, M 2018, 'The value of sustainability', *Journal of Building Survey, Appraisal & Valuation*, vol. 7, no. 1, pp. 13-8.
Menegaki, M & Damigos, D 2018, 'A review on current situation and challenges of construction and demolition waste management', *Current Opinion in Green and Sustainable Chemistry*, vol. 13, pp. 8-15.
MMRA 2016, *Approach to Sustainability in Melbourne Metro*, Melbourne Metro Rail Project Environment Effects Statement Inquiry and Advisory Committee.
National Waste Policy 2018, *Less Waste. More Resources*.
Newman, P, Hargroves, C, Desha, C, Kumar, A, Wilson, K, Farr, A, Whistler, L & Matan, A 2014, *A literature review of sustainability performance assessment by road agencies for the sustainable built environment national research centre*, A Collaborative Project between Curtin University and Queensland University.
NWR 2018, *Australian National Waste Report 2018*, Department of the Environment and Energy.
Park, J & Tucker, R 2017, 'Overcoming barriers to the reuse of construction waste material in Australia: A review of the literature', *International Journal of Construction Management*, vol. 17, no. 3, pp. 228-37.
Samari, M, Godrati, N, Esmaeilifar, R, Olfat, P & Shafiei, MWM 2013, 'The investigation of the barriers in developing green building in Malaysia', *Modern Applied Science*, vol. 7, no. 2, p. 1.
Shooshtarian, S, Maqsood, T, Khalfan, M, Wong, P & Yang, R 2019, 'Managing construction and demolition (C&D) waste in Australia', paper presented to CIB World Building Congress 2019 'Constructing Smart Cities', Hong Kong, China, 17-21 June
Siew, YR, Balatbat, CM & Carmichael, GD 2013, 'A review of building/infrastructure sustainability reporting tools (SRTs)', *Smart and Sustainable Built Environment*, vol. 2, no. 2, pp. 106-39.
Tam, V, Le, K, Wang, J & Illankoon, I 2018, 'Practitioners Recycling Attitude and Behaviour in the Australian Construction Industry', *Sustainability*, vol. 10, no. 4, p. 1212.
Thaickavil, NN & Thomas, J 2019, 'Green Rating Credits for Waste Utilization in Construction', in *Green Buildings and Sustainable Engineering*, Springer, pp. 189-201.
Udawatta, N, Zuo, J, Chiveralls, K, Yuan, H, George, Z & Elmualim, A 2018, 'Major factors impeding the implementation of waste management in Australian construction projects', *Journal of Green Building*, vol. 13, no. 3, pp. 101-21.
Udawatta, N, Zuo, J, Chiveralls, K & Zillante, G 2015, 'Attitudinal and behavioural approaches to improving waste management on construction projects in Australia: benefits and limitations', *International Journal of Construction Management*, vol. 15, no. 2, pp. 137-47.
Wang, J, Li, Z & Tam, VW 2014, 'Critical factors in effective construction waste minimization at the design stage: a Shenzhen case study, China', *Resources, Conservation and Recycling*, vol. 82, pp. 1-7.
Wilson, JL & Tagaza, E 2006, 'Green buildings in Australia: drivers and barriers', *Australian Journal of Structural Engineering*, vol. 7, no. 1, pp. 57-63.
Zhang, X, Shen, L & Wu, Y 2011, 'Green strategy for gaining competitive advantage in housing development: a China study', *Journal of Cleaner Production*, vol. 19, no. 2-3, pp. 157-67.

PUBLIC-PRIVATE PARTNERSHIP FOR AFFORDABLE HOUSING DELIVERY IN GHANA: EXPERIENCE OF THE GHANA NATIONAL HOUSING PROJECT AND POLICY IMPLICATIONS

Robert Osei-Kyei[1], Albert P.C. Chan[2], De-Graft Owusu-Manu[3], Adabre Michael Atafo[2]; Ernest Effah Ameyaw[4]

[1]School of Computing Engineering and Mathematics, Western Sydney University, Sydney, Australia

[2]Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong

[3]Department of Construction Technology and Management, Kwame Nkrumah University of Science and Technology, Ghana

[4]Department of Architecture and Built Environment, Northumbria University, Newcastle Upon Tyne, UK

Abstract

The rapid population growth and urbanization have resulted to the increase in demand for housing units in developing countries. Therefore, most governments have sorted to the application of the public- private partnership (PPP) scheme. Like other developing countries, the Government of Ghana (GoG) has also attempted to implement the PPP policy for affordable housing with the high-profiled project; The Ghana National Housing Project (GNHP). However, this project failed, as it was not implemented. This paper aims to review the underlying challenges of implementing PPP policy for affordable housing delivery in Ghana by analysing the experience of the GNHP. From the case study analysis, a conceptual success model for implementing the PPP policy for affordable housing delivery in Ghana is proposed. The model consists of five categories of success factors; these are national policy on housing PPP, transparency and competition, capacity building, stakeholder engagement and the use of local labour and materials. The outputs of this study are considerably beneficial to policy makers and private housing developers. They inform practitioners on the investment strategies to adopt for future housing PPP projects in Ghana.

Keywords

Public-Private Partnership, PPP, housing affordability, housing units, housing industry, Ghana

Introduction

Housing is one of the fundamental social conditions which affect the quality of life of people and its adequate provision remains a great concern (UN-Habitat, 2012). The rapid growth of the world's population and urbanization has placed significant constraint in housing provision globally (UN-Habitat, 2009). According to the UN-Habitat (2014), it is estimated that approximately three billion people (40% of the world's population) will require proper housing infrastructure by 2030. This implies that 96,150 housing units will be required per day till 2030 (UN-Habitat, 2014). Given the increasing demand of housing due to the rapidly changing and urbanization of the world, it is worth noting that neither the private sector nor governments can solely address this increasing housing demand at an affordable rate (Mukhija, 2004; Abdul- Aziz and Kassim, 2011). Thus, a more collective and contemporary approach is essential to provide affordable housing units.

In recent times, partnerships between governments and private investors in affordable housing delivery have gained considerable attention both in the developed and developing countries (UN Habitat, 2011c). Public-private partnership (PPP) initiatives have enabled many local government authorities to deliver very cost efficient and quality housing units to many low-income earners.

Like many other governments, the Government of Ghana (GoG) has also shown interest in the PPP policy for affordable housing delivery (UN-Habitat, 2011b). Over the years housing units have been independently delivered either by the government through the State Housing Corporation and State Construction Corporation. Emphatically, this has not contributed to the growth of the Ghanaian housing market compared to other African peers including Nigeria and South Africa (Ibem, 2011; UN-Habitat, 2011a). Notwithstanding, the current housing deficit in Ghana is estimated at 1.7 million deficits, which require 170,000 housing units per annum over the next decade (MWRWH, 2013). This suggests that the unilateral effort from the government cannot bridge the housing gap; hence a collective effort with private developers is vital. Although, in the last couple of years, some measures including a drafted national housing policy have been undertaken by the Ghana government, the pace at which affordable housing PPP projects are procured by local housing authorities have been very slow (UN-Habitat, 2011b). Importantly, very few projects have been initiated, with most of the initiated ones failing to proceed successfully. This therefore calls for the need for a continuous thorough review and assessment of the suitability of PPP policy for affordable housing delivery in Ghana. This is vital because it would help both public housing authorities and private developers to be informed of the effective strategies to employ in delivering successful affordable housing PPP projects. Against this backdrop, this paper seeks to investigate the challenges of implementing PPP policy for affordable housing by reviewing the Ghana National Housing Project (GNHP), which failed in its implementation. Further, the paper provides engendering policy implications for future housing PPP projects. The findings of this paper provide in-depth insights on how to expedite the development of PPP practice in the Ghanaian housing industry. However, it is worth noting that although this paper offers a more country specific discussion, implications and policy directions provided are applicable to other developing countries particularly countries in the sub-Saharan Africa region. To put the paper in a context, the research approach is first presented. Second a general review of global practice of PPP for affordable housing delivery is discussed. Third, the analysis and discussions on the GNHP is presented. Finally, a conceptual success model for PPP policy implementation for affordable housing delivery is presented.

Research approach

The aim of the study was achieved primarily through a two-stage comprehensive review of literature on case study. This approach of reporting PPP projects experiences has been adopted by previous related studies including Osei-Kyei and Chan (2015); Cheung and Chan (2009) and Kumaraswamy and Zhang (2001). First, a large range of data and information which describes the GNHP experiences and features were drawn from the Ministry of Water Resources Works and Housing (MWRWH) reports and documentations, UN-Habitat reports and newsletters, Ministry of Finance and Economic Planning (MOFEP) documentations and newsletters, interviews and articles in local newspapers, project stakeholders' websites, project's related literature and media commentaries. Second, the content of the data and information retrieved were thoroughly analyzed to derive themes, which accurately represent the GNHP experiences. Also, a follow up correspondence with some project's participants were conducted to further gain insights and clarifications on the experiences of the GHNP. The findings are therefore presented in a discussion form in this paper, which is also informed by authors' experiences in Ghana's PPP practice.

It must be highlighted that the GNHP was selected because it is the first and only large-scale affordable housing PPP scheme to be attempted; hence it received high national and international attention (Oxford Business Group, 2011; Africa Elections Project, 2010, Baetens and Caiado, 2014). Also, the project exhibits unique characteristics and experiences of which useful lessons can be drawn for future affordable housing PPP projects delivery in Ghana (Mingle, 2010).

Global practice of Public-Private Partnerships for affordable housing

Over the past decades, the collective effort of governments and private developers in the delivery of affordable houses has gained grounds in some parts of the world particularly in Malaysia, the U.K, U.S, India, Russia and Canada (Abdul- Aziz and Kassim, 2011; Shelter Afrique, 2011). In essence, such efforts have facilitated the provision of houses to all levels of income earners (Abdul Aziz et al, 2007; Ibem, 2011). A notable example is the Toronto Community Housing project initiated in 2005. This affordable housing project was a partnership between the Toronto Community Housing Corporation (TCHC) and Daniels Corporation. Also, the Lets Build Programme introduced in 2000 is a PPP initiative towards affordable housing delivery in Canada (Griffin, 2004). Other PPP initiatives include the Executive Condominium Scheme (EC) in Singapore and the Hope VI Programme in the United States (Phang, 2013). In these initiatives, the government acts as both the enabler and facilitator of the housing market through the establishment of sound legislative, institutional and financial frameworks (Sengupta, 2006). The private developer also assumes the responsibility of financing, designing, constructing and operating the housing project at an agreed reasonable fee affordable to all groups of income earners (Bardhan and Barua, 2005; Thomas, 2009). In affordable housing PPP arrangement, one critical responsibility of the government is to make lands available either through a freehold or a leasehold arrangement (Awil and Abdul-Aziz, 2006). This obligation is very important towards the partnership deal because many delays of affordable housing PPP projects results from the unavailability of lands and litigations (Ibem, 2011; UN-Habitat, 2011a).

Undoubtedly, the major reasons for adopting the PPP concept in affordable housing delivery go beyond reducing housing deficit and budgetary constraints (UN-Habitat, 2006; 2011c). The private sector's expertise and skills have also been reported as very important drivers for the implementing the PPP concept in affordable housing delivery (Skietrys et al, 2008). However, it must be highlighted that different governments may have different reasons for engaging in partnership initiatives for housing delivery. Definitely, the reasons of governments in developing countries may differ from those in the developed countries. Risk management in housing PPP projects is very important to achieve success. Risks which have been reported to be very critical in housing PPPs include delay in the release of lands, change in demand and other risks related to the design and construction of the housing project (Hussin, 2001). However, with PPP schemes these risks are better managed. They are allocated to the party with better mitigation techniques (Ke et al, 2010). Value for money is guaranteed when affordable housing projects are delivered through PPP schemes. In essence, when private investors operate within a favourable investment environment, they are able to reduce the life cycle cost of a project and also complete on time (Grimsey and Lewis, 2002; Abdul – Aziz and Kassim, 2011). In spite of the benefits the PPP concept offers the global housing industry, several problems have been reported. These include lack of appropriate skills and expertise, lack of proper regulatory and policy framework, complex contractual arrangements, political interference, allegations of corruptions, lack of competition and transparency (Rondinelli, 2003; Sengupta, 2006). It is therefore important for these obstacles to be addressed so that the opportunities and benefits of the policy would be fully realized. estimated cost of the project was approximately US$ 10 billion, which was expected to be constructed in 4 phases starting from 2010.

Case Study

Background of GNHP

The GNHP was part of the affordable housing policy initiative by GoG in 2005. It was the first ever major PPP housing project to be initiated in the country's housing sector since mid-1960s (Mingle, 2010). It was a partnership deal signed between the GoG through its MWRWH and a Ghana- Korea private developer (STX Engineering and Construction Ghana Ltd). The housing project agreement was signed in 2009. The project was to provide 200000 housing units in the ten regional capitals of Ghana (Oxford Business Group, 2011a) and the estimated cost of the project was approximately US$ 10 billion, which was expected to be constructed in 4 phases starting from 2010.

The first phase involved the construction of 30,000 housing units, followed by 60,000 for the second phase and the remaining 110,000 were to be constructed over the remaining two phases. Out of the 200,000 housing units, 30,000 (first phase) was expected to be completed within 5 years spanning from 2010 to 2015 at approximately US$ 1.3 billion excluding taxes and duties based on lump sum fixed contract, whereas the remaining 170,000 were to be completed over the years. In fact, the intention of the government for the completion of the first phase (30,000 units) was to allocate the housing units to the security services across the ten regions of Ghana (Memorandum of Understanding, 2010).

The Contractual Arrangement

The GoG and the STX Engineering and Construction Ghana Ltd entered into an off-take arrangement for the project (Memorandum of Understanding, 2010). As agreed between the parties, the GoG was expected to purchase 90,000 (45%) of the 200,000 housing units constructed by the private developer (Off – Taker agreement, 2009). The remaining 110,000 (55%) housing units would be off take by a local mortgage financial institution (i.e HFC bank). However, the repayment of the off-take for the 45% to the private developer was expected to take 15 years (African Elections Project, 2010). The contractual agreement clearly spelt out the roles of the parties in the partnership. The private developer was obliged to;

i. Plan, design and construct the housing project according to international standards on the available sites construction of the housing project with the financial guarantee by the government.

ii. To utilize the local resources of Ghana with over 30% for executing the housing project and as well provide some training to local labour force employed in the project delivery.

Likewise, the public partner (i.e GoG) was to:

i. Make lands available for the construction of the project at no cost to the investor.

ii. Make available all necessary utilities such as water, electricity, roads, and any other relevant facility for the delivery of the project.

iii. Provide tax exemptions on incomes of sub-contractors and expatriate personnel, import duties on equipment, materials as well as machinery for the purpose of the housing delivery.

iv. Facilitate the processing of any approvals or granting of permits in relation to the project delivery (Off – Taker agreement, 2009).

The Project Finance

As mentioned earlier the estimated cost of the 200000 housing unit was US$10 billion with the first 30000 housing unit estimated to be approximately US$1.3 billion excluding taxes and duties based on lump sum fixed contract. In order to help the private developer raise adequate funds for the project, the government provided a sovereign guarantee towards the project. It was expected that with the sovereign guarantee the private developer could raise funds for the housing project from the global financial market. The sovereign guarantee had a maturity date of 20 years. It must be noted that the sovereign guarantee was given as part of the conditions on the off take agreement between the parties. In this regard the sovereign guarantee covered only the 90,000 (45%) housing units to be off take by the GoG. Further, it was still expected that the Korean Government through its Global Infra Fund (a sovereign fund established by the South Korean government to finance international infrastructure projects by South Korean firms) would be used as well as the collaborative efforts from other local and international financial institutions to support the private investor in financing the remaining 55% (110,000) housing units (Oxford Business Group, 2011; Africa Election Project, 2010).

Analysis and discussion on case study

The findings of the review are presented in two sections. The first section discusses the major reasons why the government attempted to enter into the partnership. The second section explores the underlying failure factors of the partnership.

Fundamental reasons for Government of Ghana opting to engage in the GNHP arrangement

Three major factors are identified as the major potential reasons why the GoG opted to enter in to the partnership arrangement. These include excessive national housing deficit, government budgetary constraint and satisfy political motive.

Excessive national housing deficit

The increasing housing deficit is a major global concern given the increasing rate of the world's population and rapid urbanization (UN, 2010). According to the World Bank (2009), over 90% of recent urbanization has occurred in developing countries with an estimated number of two billion people becoming urban residents in the next two decades particularly in Africa and South Asia. This has therefore contributed to the increasing housing infrastructure demand especially in developing economies. Ghana is no exception and one of the government's core priorities to embark on the GNHP was the increasing population and rapid urbanization, which has caused huge housing deficits in the country with social consequences. The huge housing deficit has over the years resulted in the creation of slum dwelling places particularly in the urbanized areas of the country (UN-Habitat, 2009). Ghanaians living in such dwellings do not have access to proper and quality housing facilities and this has affected the quality of life of the people living in such communities.

Further, the unilateral efforts of government and private developers towards providing affordable housing units over the years has not contributed significantly to the reduction of the huge housing deficit confronting the country (MWRWH, 2012). This is because most housing units from private developers tend to target high income earners who obviously form a low proportion of Ghana's population (UNDP-Ghana, 2012). A similar situation applies to effort by local housing agencies providing housing units. All these factors triggered the commitment by the government to enter into a partnership agreement with the private developer to build affordable housing units to all levels of income earners in the country (Trade Invest Africa, 2012). Although, the project could not have eradicated the housing deficit completely, but it was an attempt to initiate housing PPPs towards addressing Ghana's housing deficit.

Government budgetary constraints for affordable housing delivery

Another driving force for the initiation of the GNHP was the limited allocation of national budget to the housing sector. This factor has also been the motive of other government entering into housing PPPs including Malaysia, U.K, U.S, India, Australia and Canada (Pomeroy *et al*, 1998; Maguire and Malinovitch, 2004; Abdul – Aziz, 2011). It is obvious that governments globally particularly those in developing countries cannot meet the increasing demand on public infrastructure solely from budgetary allocations. Thus, leveraging the private sectors' capital is very important (Osei-Kyei *et al*, 2014). Emphatically, considering the estimated cost of the GNHP (US$ 10 billion), there was no way the Ghana government could have undertaken such housing project from the public purse. Essentially, for the past couple of decades, the government has had deficit budgets, where funds for public facilities are sourced from international financial institutions and donors (World Bank, 2011; Ameyaw and Chan, 2013). Attempts have been made in previous years by successive governments to fund affordable housing projects through budgetary allocations but all proved futile due to the constraints characterized with public budgets. A notable example was the affordable housing project initiated in 2005 by previous government. Although the project was progressing at the initial stages with funding from the public purse, a change in government in 2008 resulted in its abandonment. It was identified that the affordable housing projects relinquishment was due to the absence of a well-established funding for the project

(Mingle, 2010). In order not to repeat a similar public housing delivery approach, the newly-elected government rather opted to engage the private developer for affordable housing delivery. It is understandable because the private sector is well known to have better capacity to raise massive funds for large scale construction projects such as the GNHP.

Satisfy political objective / motive

Although the GNHP could have minimized the current housing deficit in Ghana, its initiation and attempt was also induced by political motive. In every democratic society particularly developing countries, the government in administration would want to undertake a unique project or policy that can attract positive political gains or credit for the subsequent national election (Mustapha and Whitfield, 2009).

This phenomenon is much particular in developing countries particularly Ghana, where two major political parties are in a keen contest for political power. Any of the two major political parties when in administration, is seeking to undertake or implement a unique and outstanding project or policy to gain positive political gains. In fact the commitment from the Ghana government in 2009 towards the GNHP was to set an outstanding history in partnership deal in the Ghanaian housing sector (GNA, 2010a). The successful implementation of the GNHP would have given a huge positive political credit to the government in the history of the housing industry. In essence, after the signing of the partnership agreement, one of the remarks made by a key government official at a press briefing was that;
"[...] remembering that we [government] are accountable……….. we are proud of this historic exercise" (GNA, 2010a)

Another assertion made by a key government official was that;

"[…] today government is recording positive history […] history will prove us right in the fullness of time" (Graphic Online, 2011)

The success of the housing PPP would have been recorded on the achievement list of the government in administration. However, it must be noted that such political games are part of the Ghanaian democratic culture and it is obvious the trend would continue for mega housing PPP deals in future regardless of the political party in public administration.

Underlying problems of the GNHP

Five underlying factors are identified to have contributed to the failure of the GNHP. These include weak private consortium structure, strong political opposition, absence of competitive procurement process, lack of experience in handling housing PPP deals and Unavailability of funds for project delivery

Weak private consortium structure

The long-term and complex structure of PPP projects requires a very strong and potential project company for their successful delivery (Cheung et al, 2012). On the contrary, a weak multidisciplinary team of stakeholders and private partners in the Special Purpose Vehicle (SPV) would not be capable to successfully undertake such a complex and long term nature project (Chan et al, 2010).

The contention within the boardroom of the project company required to execute the GNHP contributed to the failure of the housing PPP (Owusu, 2011). The private consortium was a joint venture between a Ghanaian private company (G.K Airports Company Limited) and a South Korean construction firm (STX Construction Group) (Citifmonline, 2011). These companies formed a Special Purpose Vehicle (STX Engineering and Construction Ghana Limited) for the purpose of undertaking the GNHP. However after the signing of GNHP contract with the government and sod cutting to begin construction, a board room wrangling emerged between the local and foreign companies. The two parties begun arguing on the full ownership right of the project company. In fact, this in-house fighting ended up in an intense legal battle between the private parties (Dzawu, 2012). Major concerns raised by the parent partner (South Korean STX Construction Group) of the SPV was that the Ghanaian representative of the Project Company (STX Engineering and Construction Limited) had side-lined the parent partner during negotiations of the partnership agreement with the government (Benson, 2011). The South Korean partner claimed that their Ghanaian partner had not correlated with them properly on some of the details of the partnership agreement that was signed on behalf of the Project Company. They further asserted that most of the details of the partnership agreement with the government were known through media reports. Further, the parent partner claimed that their Ghanaian partner undertook some actions regarding the proposed project without their consents and notice (Dzawu, 2012). These claims by the South Korean partners elicited them to seek legal action to determine who the rightful owner of the SPV formed is and therefore the appropriate partner to execute the project.

On the other hand, the Ghanaian partner also sorted a legal action for the court to declare them as the lawful partner to execute the GNHP (Benson, 2011). This boardroom wrangling between the private parties delayed the commencement of the project close to six months after agreements have been signed. Therefore, the government realizing the conflicts decided to back out from the partnership agreement and began the due process to retrieve all national assets provided for the GNHP (Dzawu, 2012). The GNHP experience actually reinforces the assertion made that a strong multi-disciplinary consortium is very key in PPPs especially in developing countries where often local private developers partner foreign companies to undertake a housing PPP project.

Strong political opposition

In Ghana’s political setting, opposition political parties play crucial role in shaping incumbent government’s policies and initiated project deals, therefore most projects initiated by existing government are highly assessed and of great concern to the opposition parties (Mustapha and Whitfield, 2009). The GNHP received strong resistance from the opposition political parties. Although the opposition parties claimed they were not against reducing the increasing housing deficit of 1.7 million, their major concern was on the nature and structure of the housing project contract, and its ability to provide value for money for the public (Gyasiwaa, 2011).

The intense opposition towards the commencement of the project contributed to delays in the agreement of certain conditions raised by the political opponents in the contract. One key issue raised by the major opposition party was the numerous incentives given to the private developer for the execution of the project. Other issues include tax exemptions on incomes of expatriate personnel and subcontractors, exemptions of import duties on machinery, equipment and materials. In addition, the opposition parties lamented that a due diligence had not been conducted in awarding the contract. Moreover, they indicated that the government had agreed on a high interest rate and payment fees, which certainly are in favour of the private developer (GNA, 2010b). Essentially, the stiff opposition from the political front increased the general public’s perception of the GNHP as fraudulent and not beneficial. Notwithstanding, despite the agitation by the opposition party, some section of Ghanaians still believed that the GNHP is beneficial not only in addressing the housing deficit but it also strengthens the Ghanaian housing market due to its first kind (Mingle, 2010).

Absence of competitive procurement process

The GNHP was not subjected to any competitive bidding process (Amesimeku, 2013) but rather the project was introduced to the government by one of the directors of the Project Company (Benson, 2011). This therefore raised lots of arguments and concerns about the estimated cost of the project and the estimated end user charges (Daily Guide, 2010). Most professional bodies and policy experts emphasized that the project could be delivered at a much lower cost than the estimated cost by the selected private developer (GNA, 2010b). Moreover, with the numerous incentives and strong commitment from the government, many believed that given such support and opportunity, a competitive procurement process would have allowed the government to select a capable private investor with much lower estimated cost compared to the one agreed on by the government (Oxford Business Group, 2011b). Owing to this, it is realized that the absence of competition contributed to such high estimated cost of the GNHP and attracted public scrutiny and criticism. Indeed, GNHP affirms the assertion that the lack of competition in PPP procurement process results in rather high project cost and the absence of value for money assurance (Chan et al, 2010).

Lack of experience in handling housing PPP deals

PPP as a procurement approach is a growing concept globally and it requires experience and adequate understanding of how this concept operates to ensure its effective implementation (Li et al, 2005). PPP cannot be successfully implemented overnight; it however requires training to enhance public and private sectors' management skills in managing PPP projects (Morledge and Owen, 1998). Since its evolution in Ghana for construction projects in 2004, this concept is still developing and has not yet been fully explored and understood especially in the Ghanaian housing sector (UN-Habitat, 2011b). It would however require adequate capacity building for both public and private sectors in the housing industry to fully understand how this new procurement model operates in the local context.

The contractual management of the GNHP was poorly managed by the public and private sectors. Most contractual conditions were not properly and clearly agreed on by parties. Additionally issues pointed by external stakeholders (public/ users, opposition parties and professional bodies) were not properly addressed to allow the easy flow of the project. In some situations, some contract conditions and agreements were withdrawn from the Parliament of Ghana to be further reconsidered by the project parties (GNA, 2010b). This therefore generated public suspicion of corruptions concerning the housing PPP deal. This therefore contributed to the negative perceptions of the GNHP and delay of commencement of the project

Unavailability of funds for project delivery

Extant literature emphasis that one of most governments reasons for engaging the private sectors in public infrastructure delivery is due to the private sectors' ability to raise massive funds for public projects (Walker and Smith, 1995; Osei-Kyei et al, 2014). In deed this assertion did not really manifest in the GNHP. Although the government provided a sovereign guarantee to enable the Project Company raise funds, it was still challenging for the Project Company to raise substantial funds for the delivery of the project (Owusu, 2011).

Given the huge cost of project it was difficult for international financial institutions to provide credit without a good and clear negotiation of the terms and conditions of the contract. Moreover, the huge controversies around the project from stakeholders, public and opposition parties made some international financial institutions reluctant to invest in such facility (Statesman, 2011). These controversies considerably increased the financial risk of investing in such facility by financial institutions particularly when the concerns and arguments emanate from political fronts and users/ public.

Implications for future affordable housing PPP projects: Engendering Policy

The huge housing deficit in Ghana requires effective collaborative efforts from the Ghana government and private developers. However, because PPP is a relatively new concept in Ghana's affordable housing delivery, it is important for certain good practices to be observed learning from the GNHP. A conceptualized success model for affordable housing delivery in Ghana is proposed based on the experience of the GNHP (see Fig. 1). The model consists of five success measures; these include proper stakeholder management, use of local labour force and local materials, transparent and competitive procurement process, capacity building, and national policy on housing PPP.

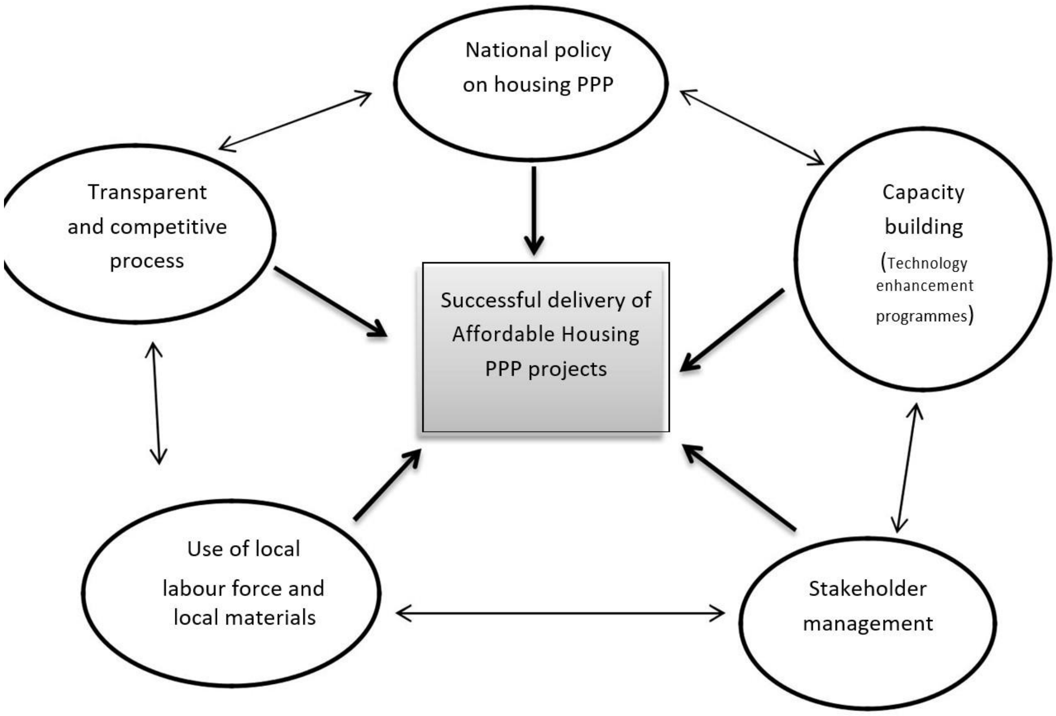


Fig. 1 Conceptualized success model for implementing the PPP policy for affordable housing delivery in Ghana

In housing PPPs, effective stakeholder management is very essential to allow the easy flow of the project (Nisar, 2013). As seen in the GNHP, external stakeholders including the public, professional bodies in the real estate industry, non-governmental organizations and political groups were not properly managed. Therefore, it is very important for future housing PPPs in Ghana to observe such management practice particularly for large-scale housing project. Further, issues raised by external stakeholders should be addressed before the commencement of the project.

The use of local labour force and local materials in Ghana's housing PPP delivery is very important. Ideally, the government should engage more local private developers. Public agencies should only allow locally based developers to bid for certain housing projects. In situations where international bidding is required, local developers should partner with the foreign companies. However, it is vital for local and foreign investors to agree on how investment returns would be shared. Also, investors should be mindful of the fact that as an SPV, no individual private developer owns the consortium; therefore, agreements cannot be made without the consent of other stakeholders. The use of local materials should be a requirement for housing projects. Importantly, this can form part of the output specifications for the housing project.

Transparent and competitive procurement process should not be undermined in delivering housing PPP projects in Ghana. Although competition leads to high transaction cost (Abdul – Aziz and Kassim, 2011), it guarantees value for money (Chan et al, 2010). At times, unsolicited proposals could be a means to initiate a project but learning from the GNHP, the use of unsolicited proposals should be limited. More importantly unsolicited proposals should still go through a competitive tendering process.

Because the PPP concept is at the infancy stage, capacity building such as technology enhancement programmes is required for all housing stakeholders. Public departments/agencies and the private developers need training which could be in the form of workshops and seminars on how to manage housing partnerships. In this way, practitioners will appreciate properly the PPP concept in providing affordable housing projects in Ghana.

Lastly, a national policy on housing PPP is vital to provide the necessary guidelines and procedures for engaging in housing PPPs. Currently, attempts are being made by the GoG to draft a housing PPP policy to facilitate its implementation (MWRWH, 2012). It is hoped that the policy would provide a clear and streamlined process for housing PPP projects in Ghana.

Conclusion

Public-Private Partnership has become popular in the global housing industry and since its inception in the early 1990's; some countries have successfully implemented it in their housing industry. The Ghana housing industry is yet to appreciate this new procurement approach in meeting the increasing housing demand. Since PPP introduction, attempts have been made by the Ghana Government to implement the PPP policy for affordable housing, with the recently attempted project; the Ghana National Housing Project (GNHP) signed in 2009. This paper has reviewed the experience of the GNHP by identifying the major failure factors of the GNHP. The results indicate five underlying factors; these include weak private consortium structure, strong political opposition, absenceof competitive procurement process, lack of experience in handling housing PPP deals and unavailability of funds for project delivery. Based on the experience of the GNHP, a conceptual success framework for affordable housing PPP projects is proposed. The model consists of five major success strategies: proper stakeholder management, use of local labour force and local materials, transparent and competitive procurement process, capacity building, and national policy on housing PPP. The outputs of this study inform practitioners (public and private) on the appropriate investment strategies to adopt for future affordable housing PPPs in Ghana.

References

Abdul Aziz, W. N., Hani, N. R., & Musa, Z. N. (2007). Public–Private Partnerships approach: A success story in achieving democracy in the home ownership for urban inhabitants in Kuala Lumpur Malaysia. Reviewed paper, Real CORP 007 Proceedings, Tagungsband, Vienna, May 20–23, 2007

Abdul-Aziz, A. R., & Jahn Kassim, P. S. (2011). Objectives, success and failure factors of housing Public–Private Partnerships in Malaysia. *Habitat International*, 35(1), 150-157.

African Elections Project (2010). Minister Outdoors Plan For STX Project.
Available from:
http://www.africanelections.org//ghana/postelections/news/page.php?news=451
(Accessed on 7th Nov. 2014)

Amesimeku E. (2013). Ghanaians Express Cautious Optimism On New Affordable Housing Project. Property Investor Africa, 23 December. Available from: (accessed on 1 Nov. 2014) https://propertyinvestorafrica.com/ghanaians-express-cautious-optimism-on-new-affordable-housing-project

Ameyaw E.E and Chan A.P.C (2013) Identifying public-private partnership (PPP) risks in managing Water supply projects in Ghana", *Journal of Facilities Management*, Vol. 11 Iss: 2, pp.152 – 182

Awil, A.-U., & Abdul-Aziz, A. R. (2006). Internationalisation of Malaysian housing developers: Case studies from India, South Africa, Cambodia and Australia. Paper presented at the international real estate research symposium (IRERS), Kuala Lumpur, 11-13 April

Babatunde, S. O., Opawole, A., & Akinsiku, O. E. (2012). Critical success factors in public-private partnership (PPP) on infrastructure delivery in Nigeria. *Journal of Facilities Management*, 10(3), 212-225.

Baetens Freya and Caiado Jose (2014). Frontiers of international economic law : legal tools to confront interdisciplinary challenges. Leiden : Brill Nijhoff

Bardhan, A. D., & Barua, S. K. (2005). Real estate industry: creating value through public-private partnerships. In S. Morris (Ed.), India infrastructure report 2004: Ensuring value for money (pp. 103e114). Oxford: Oxford University Press.

Benson Ivy (2011). STX Deal to start at last. The Chronicle, November 16. Available from: http://thechronicle.com.gh/stx-deal-to-start-at-last/ (accessed on 23rd Oct. 2014)

Chan, A. P., Lam, P. T., Chan, D. W., Cheung, E., & Ke, Y. (2010). Critical success factors for PPPs in infrastructure developments: Chinese perspective. *Journal of Construction Engineering and Management*, 136(5), 484-494.

Cheung Esther and Albert P.C. Chan, (2009) "Is BOT the best financing model to procure infrastructure projects?: A case study of the Hong Kong-Zhuhai-Macau Bridge", *Journal of Property Investment &Finance*, Vol. 27 Iss: 3, pp.290 – 302

Cheung Esther, Albert P.C Chan and Kajewski S. (2012), "Factors contributing to successful public private partnership projects, Comparing Hong Kong with Australia and the United Kingdom", *Journal of Facilities Management* Vol. 10 No. 1, pp. 45-58

Citifmonline (2011). BK Asamoah: I'm Still STX Ghana Boss. Available from: (accessed on 2 Oct. 2014) http://www.ghanaweb.com/GhanaHomePage/NewsArchive/artikel.php?ID=216675

Daily Guide (2010). GREDA chickens out of opposition to STX housing deal. Available from: http://www.modernghana.com/news/283489/1/greda-chickens-out-of-opposition-to-stx-housing-de.html (Accessed on 16th Nov. 2014)

Dzawu Moses Mozart (2012). Ghana Backs Out of Housing Deal With S.Korea's STX, Graphic Says. *Bloomberg news* Apr 12, 2012, Available from: (accessed on 8th Nov. 2014) http://www.bloomberg.com/news/2012-04-12/ghana-backs-out-of-housing-deal-with-s-korea-s-stx-html

Ibem Eziyi Offia (2011). The contribution of Public–Private Partnerships (PPPs) to improving accessibility of low-income earners to housing in southern Nigeria. *Journal Housing and the Built Environ* 26:201–217

Gatti, Stefano (2013) (2nd ed). Project Finance in Theory and Practice, Second Edition: Designing, Structuring, and Financing Private and Public Projects. London: Academic Press

Ghana News Agency (2010a). Ghana and Korea sign agreements on STX deal. Available from: http://ghananewsagency.org/social/ghana-and-korea-sign-agreements-on-stx-deal-23407 (accessed on 12th Nov. 2014)

Ghana News Agency (2010b). Issues criticized in STX housing deal not addressed – Minority. Available from: http://www.ghananewsagency.org/print/18673 (accessed on 5th Nov. 2014)

Graphic Online (2011). Housing The People - STX Deal Kicks Off. Available from: http://www.modernghana.com/news/314288/1/housing-the-people-stx-deal-kicks-off.html (accessed on 2nd Nov. 2014)

Griffin, L. (2004). Creating affordable housing in Toronto using publiceprivate partnerships. FES Outstanding Graduate Student Paper Series, 9(2). Available from: http://www.yorku.ca/fes/research/students/outstanding/docs/LaraGriffin.pdf (accessed on 5th Nov 2014)

Grimsey, D. and Lewis, M.K. (2002). Evaluating the risks of public private partnerships for infrastructure projects, *International Journal of Project Management*, Vol. 20, pp. 107-18.

Gyasiwaa Adwoa (2011). Akyena Brentuo: STX deal will happen. Myjoyonline, August 22. Available from: http://politics.myjoyonline.com/pages/news/201108/71540.php (accessed on 4th Nov. 14)

Hussin, R. (2001). Project finance concept (smart partnership): viability of implementation in housing projects with special emphasis in risk management and academic analysis, viewpoint and framework's proposal. *The Malaysian Surveyor*, 36(2), 23-34.

Jefferies M and McGeorge WD. (2009). Using public-private partnerships (PPPs) to procure social infrastructure in Australia. *Engineering Construction Architectural Management*. 16:415–437.

Jefferies, M., Gameson, R. and Rowlinson, S. (2002), Critical success factors of the BOOT procurement system: reflections from the stadium Australia case study, *Engineering Construction and Architectural Management*, Vol. 9 No. 4, p. 352.

Ke, Y., Wang, S., Chan, A. P., & Lam, P. T. (2010). Preferred risk allocation in China‟s public–private partnership (PPP) projects. *International Journal of Project Management*, 28(5), 482-492.

Li, B., Akintoye, A., Edwards, P.J., Hardcastle, C. (2005) "Critical success factors for PPP/PFI projects in the UK construction industry", *Construction Management and Economics*, Vol.23 No.5 pp 459-71 Maguire, G., & Malinovitch, A. (2004). Development of PPPs in Victoria. *Australian Accounting Review*, 14(2), 27-33

Memorandum of Understanding (MOU) (2010). Available from: (accessed on 17th Nov. 2014) http://danquahinstitute.org/docs/STX-MOU.pdf

Mingle Justice (2010). Commentary on STX housing project. Ghana Broadcasting Corporation. Available from: http://gbcghana.com/kitnes/cache/dynamic/1156360.htm (accessed on 25th Oct.14)

Ministry of Water Resources, Works and Housing (2013). Annual Progress Report; Report on the status of implementing of the Ghana shared growth and Development Agenda (GSGDA), 2010 - 2013. Government of Ghana.

Morledge, R. and K. Owen (1998). Critical success factors in PFI projects. Proceedings of the 14th ARCOM Annual Conference, (AAC' 98), University of Reading, pp: 565-574.

Mukhija, V. (2004). The contradiction in enabling private developers of affordable housing: A cautionary case from Ahmedabad, India. *Urban Studies*, 41(11), 2231–2244.

Mustapha, A. R., & Whitfield, L. (2009). *Turning points in African democracy*. N.Y: Boydell & Brewer.

Nisar, T. M. (2013). Implementation constraints in social enterprise and community Public Private Partnerships. *International Journal of Project Management*, 31(4), 638-651

Off – Taker agreement (2009). Available from: danquahinstitute.org/docs/STX-Off-TakerAgreement.pdf (accessed on 12th Nov.14)

Osei-Kyei R, Dansoh, A., & Ofori–Kuragu, J. K. (2014). Reasons for adopting Public–Private Partnership for construction projects in Ghana. *International Journal of Construction Management*, (ahead-of-print), 1-12.

Owusu William Yaw (2011). STX Cheques Bounced. Daily Guide, 22 August. Available from: http://www.modernghana.com/news/346347/1/stx-cheques-bounced.html (accessed on 1st Nov.14)

Oxford Business Group (2011a). The Report: Ghana 2011. London: Oxford Business Group Publications.

Oxford Business Group (2011b). Ghana: No place like home. Available from: http://www.oxfordbusinessgroup.com/news/ghana-no-place-home (accessed on 3rd Oct. 14)

Payne, G. (2000). The contribution of partnerships to urban development and housing. Paper presented in international forum on cities and management of public housing, Bogota City Hall, Metro Vivienda, 5- 9 Oct.

Pomeroy, S., Lampert, G., Wallace, J., & Sheehan, R. (1998). The role of publice- private partnerships in producing affordable housing: assessment of the U.S experience and lessons for Canada. Research report, prepared for the Canadian Mortgage and Housing Corporation

Rondinelli, D. A. (2003). Partnering for development: government and private sector cooperation in service provision. In D. A. Rondinelli, & G. S. Cheema (Eds.), Reinventing government for the 21st century: State capacity in a globalising society (pp. 219-239). Bloomfield, CT: Kumarian Press

Sengupta, U. (2006). Government intervention and public-private partnerships in housing delivery in Kolkata. *Habitat International*, 30(3), 448-461.

Shelter Afrique (2011). Mortgage Finance for increased access to housing in Africa. Available at: www.shelterafrique.org (accessed on 20th Nov. 2014)

Skietrys E, Raipa A and Bartkus EV. (2008). Dimensions of the efficiency of public-private partnership.
Engineering Economics. 3:45.

Statesman (2011). Bagbin: Yes, we have secured STX funds, from Stanchart, no, I mean, Barclays. Available from:
http://www.ghanaweb.com/GhanaHomePage/NewsArchive/artikel.php?ID=213071 (accessed on 12th Oct. 14)

Thomas, H. (2009). The local press and urban renewal: a South Wales case study. *International Journal of Urban and Regional Research*, 18(2), 315-333.

Trade Invest Africa (2012). Ghana renews efforts to tackle housing deficit. Available from:

http://www.tradeinvestafrica.com/feature_articles/1345870.htm (accessed on 17th Oct. 14)

UN - Habitat (2009). *Housing Finance Mechanisms in Zimbabwe, Nairobi*. Nairobi: United Nations Human Settlements Programme (UN-Habitat). Available from: http://mirror.unhabitat.org/pmss/getElectronicVersion.aspx?nr=2641&alt=1 (accessed on 7th Nov.14)

UN- Habitat (2012). Sustainable Housing for Sustainable cities: A policy framework for developing countries. Nairobi: United Nations Human Settlements Programme (UN-Habitat). Available from: http://peoplebuildingbettercities.org/wp-content/uploads/2013/06/Sustainable-Housing-Policy-Framwork.pdf (accessed 12th Nov. 14)

UN- Habitat (2014). Housing & slum upgrading. Available from: http://unhabitat.org/urban-themes/housing-slum-upgrading. (accessed on 10th Oct. 14)

UN-Habitat (2006). Public–Private Partnerships in enabling shelter strategies. Review of experience from two decades of implementation. Nairobi: United Nations Human Settlements Programme (UN-Habitat)Available from: (accessed on 11th Nov.14) http://www.unhabitat.org/programmes/housingpolicy/documents/HS-785.pdf

UN-Habitat (2011a). Affordable Lands and Housing in Africa. Nairobi: United Nations Human Settlements Programme (UN-Habitat)

UN-Habitat (2011b). Ghana housing profile. Nairobi: United Nations Human Settlements Programme (UN-Habitat)Available from: (accessed on 13 Nov. 14) http://mirror.unhabitat.org/pmss/listItemDetails.aspx?publication ID=3258.

UN-Habitat (2011c).Public-Private Partnership in housing and urban development. Nairobi: United Nations Human Settlements Programme (UN-Habitat) Available from: http://www.unhabitat.org. (accessed on 12th Nov. 14)

United Nations (2010). World Urbanization Prospects The 2009 Revision. New York: United Nations Publication. Available from : http://www.ctc-health.org.cn/file/2011061610.pdf (accessed on 19th Oct.14)

United Nations Development Programme- Ghana (2012). 2010 Ghana Millennium Development Goals Report. Available from: (accessed on 12 Oct.14) http://www.gh.undp.org/content/dam/ghana/docs/Doc/Inclgro/UNDP_GH_IG_2010MDGreport_18102013

Walker, C., & Smith, A. J. (1995). Privatized infrastructure: the BOT approach. England: Thomas Telford

World Bank (2011). PPIAF assistance in Ghana. Public-Private Infrastructure Advisory Facility (PPIAF). Washington D.C. : The World bank

World Bank (2009). Systems of cities: harnessing urbanization for growth and poverty alleviation. Washington, DC: World Bank.

A BRIEF ESSAY ON SOCIO-CULTURAL FACTORS AND BUILDING SAFETY IN THE CONSTRUCTION SECTOR

Festival Godwin Boateng[1]

[1]School of Global, Urban and Social Studies, RMIT University, Melbourne, Australia

Abstract

Current level of knowledge on the impact of socio-cultural factors on building collapses in the construction sector is limited. Such phenomena are studied mainly as ***'engineering'*** problems. Encouragingly, today, there is a growing momentum towards a socio-cultural approach to safety in the sector. The approach, however, focuses only on health and safety management concerns in the context of physical construction. Little or no attention is given to accidents caused by built structures. This essay argues that the principles of health and safety in the construction sector apply to not only those who are engaged in work; they also apply to those who are placed at risk by work activities, including members of the public. Therefore, limiting the impact of socio-cultural factors on safety in the sector to only worker safety obscures the impact of the factors on another vantage area of safety in the sector: the dangers posed by completed structures such as buildings to public health. The essay argues that a socio-cultural grounding for building safety/accidents in the construction sector is warranted. A socio-cultural approach to building collapse could be worthwhile, in complementing the engineering focal approach, for identifying pathways to avoidance.

Keywords

building accidents/collapse; construction safety; forensic structural engineering; social context; wider societal/socio-cultural factors

Introduction

Current level of knowledge on the impact of socio-cultural factors on building collapse is limited. Two main reasons account for the dearth of socio-cultural grounding for building collapse. The first reason pertains to the study of such phenomena in the domain of forensic structural engineering. Forensic structural engineering approaches failures as consequences of flaw(s) in the system of professional practice (Subbarao, 2016; Heywood, 2010). Emphasis is, therefore, placed on technical/physical causes (Kwasniewski, 2010; Fu, 2009; 2010). The de-emphasis of socio-cultural factors is, therefore, not an oversight, but a reflection of central assumptions.

The second reason relates to the way the influence of socio-cultural factors on safety is framed in the construction sector: The scholarly discourses on societal or socio-cultural factors in the construction sector focus only on their impact on worker safety – i.e. health and safety management concerns during construction or at construction sites (Peckitt et al., 2004; Rowlinson 2004; He et al., 2016; Tutt et al, 2013; Jia et al., 2016; 2017). Their impact on accidents caused built structures or the ***products*** of the construction industry is barely engaged.

This essay makes the following observations regarding the dearth of socio-cultural grounding for building collapse: First, while important, it is not only, often not at all, engineering considerations that influence construction decisions, practices and processes. Rather, socioeconomic, culture and other factors tend to play impactful roles (Hewitt, 1997; Tam et al., 2000). Indeed, it is long established in the social production of built forms literature that buildings and for that matter, built structures in general, are essentially socio-cultural products or artefacts (Habraken, 1988; Lawrence & Low, 1990; Low, 1996; Rapoport, 1969; 1973; 1980; 1982; Moffat & Kohler, 2008; King, 1980; Smiley & Dainty, 2014).

This implies that whatever is the challenge to structural integrity or safety, the wider societal influences of poor construction practices and processes are what may cumulate to undermine it. Consequently, approaching building collapses without recourse to the wider societal or socio-cultural influences of suboptimal construction processes and building use practices (i.e. the engineering focal approach) risks context minimization error–the tendency to ignore the impact of such factors on phenomena. This limits the potential of arriving at theoretically comprehensive understanding of the complex circumstances that collectively lead to such incidents and any systematic search for the technical as well as the social lessons needed to avoid repetition.

The second observation the essay would make is that the principles of health and safety in the construction sector apply to not only those who are engaged in work; they also apply to those who are placed at risk by work activities, including members of the public. Therefore, limiting the analysis of the impact of socio-cultural factors on safety in the construction sector to only worker safety, as being pursued currently (Peckitt et al., 2004; He et al., 2016), obscures the impact of the factors on another vantage area of safety in the sector: the dangers posed by completed structures such as buildings to public health.

The essay would suggest that a deeper focus on the impact of socio-cultural factors on building collapse has the potential for enhancing our understanding of how such factors operate, shape and dictate the demand and supply, design, construction, utilization and adaptation of buildings as well as the regulation and management of the underlying processes and culminate into the technical/engineering problems that, albeit rather belatedly, become the subject of forensic examination when disasters occur. Thus, a socio-cultural grounding for building safety in the construction sector could be worthwhile for identifying and addressing most of the problems that culminate into the technical/engineering deficiencies that, albeit rather belatedly, become the subject of forensic examination when collapse incidents occur. The rest of the essay is directed to ground the message.

Background

In his perceptive book: *Managing the risks of organizational accidents*, James Reason argued that the relative importance of the impact of the different levels of analysis of safety culture is crucial in understanding, predicting and controlling industrial risks (Reason, 1997). Reason identified four levels of factors: individual, workplace, organizational and societal factors in the causation of major accidents and speculated that of these different causal factors, organizational culture, processes and the workplace are the critical indicators of explanatory, predictive, and remedial value. He ranked individual factors second to organizational factors, followed closely by regulation and society, to which he imputed little remedial value.

However, in the construction sector, S.J. Peckitt, A.I. Glendon and R.T. Booth showed that the influence of wider societal factors on safety is far more critical than Reason envisaged. In *Societal influences on safety culture in the construction industry*, the trio analyzed several models of accident etiology in the construction sector to demonstrate that root causes of such accidents are embedded within the construction process and the societies within which the construction activity takes place. Drawing on the situations of the UK and the Caribbean, Peckitt et al (2004) highlighted the role of societal culture in influencing the health and safety culture of the construction industry.

Their analysis brought to the fore prominently the impactful implications of wider socio-cultural factors on safety in the construction sector. Peckitt et al (2004) originally applied the approach to worker safety, subsequent applications have, therefore, been limited to that line of inquiry (See, for instance, He et al., 2016; Tutt et al, 2013; Jia et al., 2016; 2017; Rowlinson & Jia, 2015; Rowlinson, et al., 2014; Pink et al., 2010).

However, to build on the theoretical and analytical contributions the socio-cultural approach brings to safety research in the construction sector, it is important for safety researchers in the sector to find ways to draw on the strength of the approach to give voice to aspects of safety in the sector about which it has had little or nothing to say – the message this correspondence seeks to convey. To situate the message within the broader theoretical discourses on safety in the construction sector, it is worth reviewing the dimensions of safety in the sector.

Dimensions of safety in the construction sector

Two important but distinct foci for safety are decipherable in the construction sector: **(a)** safety in the context of the construction process and **(b)** safety regarding the dangers that completed structures pose to the public. The former dimension of safety relates to health and safety management concerns in the course of construction or at construction sites, while the latter pertains to the health and safety concerns of completed structures. As noted earlier, the ongoing scholarly conversations on the impact of wider societal factors on safety in the sector address only the former dimension of safety (He et al., 2016; Tutt et al, 2013; Jia et al., 2016; 2017; Rowlinson & Jia, 2015). The latter has largely been ignored or overlooked.

This is striking not least because building (and for that matter structural) collapses are a marked feature of the construction sector. The centrality of such risks to safety concerns in the construction sector could be traced as far back to 2200 B.C., when the King of Hammurabi of Babylon passed a law stipulating penalty for houses collapsing and killing their inhabitants (Zhou et al, 2015). The broader point here is that the principles of health and safety in the construction sector apply to not only those who are engaged in work (Rowlinson, 2004; McDermott et al., 2018); they also apply to those who are placed at risk by work activities, including members of the public (Hayes, 2017; Hackitt, 2018; Boateng, 2019).

Hayes (2017) conveys this point better: Everyone agrees that safety is paramount and, therefore, significant effort must go into systems of work that are designed to ensure that construction workers go home safely at the end of every shift. This is obviously important. However, limiting safety considerations to the construction process obscures another vantage area of safety: the dangers posed by completed structures such as buildings to those who occupy it or public health in general.

Currently, there is little by way of systematized studies in the construction sector that take a wider societal approach to the analysis of building accidents. Such phenomena have long been engaged in the domain of forensic structural engineering. However, as explained below, the engineering focal approach to the study of building collapses is not only reactionary, but it is also inadequate for identifying pathways to avoidance as it offers limited insights into the social context or the wider influences in society that generate vulnerability for such risks.

The engineering focal approach to building collapse/safety

The collective knowledge and wisdom of humans can increase by the discovery of new facts and the proper dissemination of the findings already known. In their endeavour to modify, control the environment and develop complex systems, humans generally prefer to take a cautious approach as any mistakes or misunderstandings of the physical world often lead to disastrous consequences. Such incidents constitute ‘lessons’ learnt which are passed on to avoid repetition in the future (Dechy et al, 2012; Dien, 2012). Therefore, it is important to evolve scientific methods for investigating the causes of disasters and disseminate the information effectively to the concerned fraternity. The branch of engineering that does this is forensic engineering (Subbarao, 2016; Noon, 2001; Carper, 2001).

The foremost precept of forensic engineering is that failures are consequences of flaw(s) in the system of professional practice rather than isolated incidents that could have been easily avoided (Subbarao, 2016; Heywood, 2010). Therefore, the discourses on structural failures, accidents or incidents are often framed around technical causes. Forensic structural engineers rely mostly on the actual physical evidence found at the scene, verifiable facts related to the failure, and apply well-proven scientific principles and methods to interpret them to arrive at the relevant conclusions or the technical/physical causes of the accident (Heywood, 2010; Ratay; 2010; Delatte, 2009; Carper, 2001; Noon, 2001).

Failure investigation is, thus, approached from the perspective of physical causation and the given object as designed and constructed in the light of technical knowledge and professional procedures (Carper, 2001; Noon, 2001). The scientific principles assist forensic engineers to logically explain and identify the technical cause/s of structural failures through careful collection of verifiable physical evidence, the application of fundamental engineering principles, and the development and testing of hypotheses in a manner that avoids preconceived notions or bias (Heywood, 2010; Brady, 2012). The analysis or investigation of building collapse follows this engineering focal approach (Kwasniewski, 2010; Fu, 2009; 2010).

In the unfortunate event of a building collapse, horrified by the incidental destructions, attention tends towards the immediate factors: the engineering or technical causes disclosed by the incident. Such matters tend to be considered primary and paradigmatic (Blockley, 1980; Boateng, 2016; 2018). The key strength of the approach is that it provides robust analytical methods and precise calculation tools for arriving at the actual (technical) causes of collapse incidents. Institutionally, some of the technical lessons learned from major building failures or collapses have been incorporated as codes and standards over the years (Parfitt, 2012; Subbarao, 2016; EN 1991-1-7, 2006; US-DoD, 2002; General Services Administration, 2000 in Kwasniewski, 2010).

The problem with the engineering focal approach to building collapse

The engineering focal approach is not adequately suited for reliable building safety improvement for the following reasons. First, forensic structural engineering is by design retrospective or ex post facto in focus, which means that the causes of failures could only be known after the fact or after the harm has already been caused, and, hence, from a prevention point of view, unreliable and inadequate for safety improvement.

It may be argued that a systematic compilation of lessons from previous failures may over time or eventually provide a compendium of knowledge for preventing future events. Indeed, as noted earlier, institutionally, some of the technical lessons from major building failures have been incorporated as codes and standards over the years (Parfitt, 2012; EN 1991-1-7, 2006; US-DoD, 2002; General Services Administration, 2000 in Kwasniewski, 2010). While plausible, this argument does not attenuate the moral and ethical concerns inherent in building on safety innovations upon the foundations of hardships and adversities.

Second, undoubtedly, at the end of the day, every collapse incident inevitably will eventually be marked by a technical or engineering defect. But while important, it is not only, often not at all, engineering considerations that influence construction decisions, practices and processes. Rather, socioeconomic, culture and other factors tend to play impactful roles (Hewitt, 1997; Tam et al., 2000), and, therefore, influence not just the engineering components, but also the eventual structure that may emerge. Buildings are not just collections or assemblages of physical materials based on only architectural and/or engineering considerations, processes and specifications. Rather, they emerge from a much more complex interactive processes and level of actions between people and their environment (Boateng, 2018b; Lawrence & Low, 1990; Low, 1996; Rapoport, 1969; 1973).

King (1980) captures this point even better: Buildings, he noted, result from social needs and accommodate a variety of functions –economic, social, political, religious and cultural. Their size, appearance, location and form are governed not simply by physical factors (climate, materials or topography) but by a society's ideas, its forms of economic and social organization, its distribution of resources, its activities, beliefs and values. The built structure, as an object of study, then becomes a point of spatial articulation for the intersection of multiple forces: e.g. forces of economy; forces of society, and forces of culture.

Indeed, it is long established in the social production of built forms literature that buildings, and for that matter built structures in general, are essentially socio-cultural products or artefacts (Habraken, 1988; Lawrence & Low, 1990; Low, 1996; Rapoport, 1969; 1973; 1980; 1982; Moffat & Kohler, 2008; King,

1980; Smiley & Dainty, 2014). As Smiley and Dainty put it: *"The built environment, and the methods used to create it, reflect and embody* the *history, norms, values, social relations and level of development of the society in which they exist"* (Smiley & Dainty, 2014: 808). For instance, a bad brick, lintel or joist is made, it is purchased subject or not to architects and planning requirements and/or procedures.

The choice of materials may reflect personal economy; it may also reflect image and a person's sense of pride. The constructed structure, in this sense, is conceived not only as a product of structural integrity but also, of socio-cultural means (Blockley, 1980; Boateng, 2016; 2018).

This implies that whatever is the challenge to structural integrity or safety, the wider societal influences of poor construction practices and processes are what may cumulate to undermine it. Consequently, approaching building accidents without recourse to the wider societal or socio-cultural influences of suboptimal construction processes and building use practices (i.e. the engineering focal approach) risks context minimization error–the tendency to ignore the impact of socio-cultural factors on phenomena (Boateng, 2017; 2018). This limits the potential of arriving at theoretically comprehensive understanding of the complex circumstances that collectively lead to such accidents and any systematic search for the technical as well as the social lessons needed to avoid repetition.

What this means overall is that it is difficult to think adequately about building safety or accidents in isolation from the wider socio-cultural or societal influences of the demand and supply, design, construction, utilization and adaptation of buildings and the regulation of such processes and practices. Nonetheless, currently, there is little by way of systematized studies in the construction sector that take a socio-cultural approach to the analysis of building accidents. The discourses on the impact of such factors on safety in the sector, as noted earlier, tend to focus only on accidents that occur at construction sites – i.e. construction or worker safety (Peckitt, et al., 2004; He et al., 2016; Tutt et al, 2013; Jia et al., 2016; 2017; Rowlinson & Jia, 2015; Rowlinson, et al., 2014; Pink et al., 2010). Little or no attention is given to accidents caused by built structures.

Conclusion

Scholars operating in the construction sector regularly develop and explore new theories and perspectives to assist and guide practitioners in the management of safety in the sector. One of such theoretical enterprises is the growing momentum towards wider societal or socio-cultural approach to the analysis of safety pioneered in the work of Peckitt et al (2004). While gaining traction in safety research in the sector, the approach is currently applied to only safety considerations or concerns during physical construction (Jia et al., 2016; 2017; Rowlinson & Jia, 2015; Rowlinson, et al., 2014; Pink et al., 2010). It is rarely applied to the study of buildings accidents – a marked feature of the construction sector.

The review has argued that the omission is substantial for the following reasons. First, the health and safety principles in the construction sector apply to not only those who are engaged in work; they also apply to those who are placed at risk by work activities, including members of the public. Therefore, limiting the analysis of the impact of socio-cultural factors on safety in the sector to only health concerns at construction sites discounts the impact of the factors on another area of safety: the dangers posed by completed structures such as buildings to those who occupy it or public health in general.

Second, not only is forensic structural engineering – the extant approach to the analysis of building accidents/safety – reactionary, but it is also, from a prevention point of view, inadequate for reliable building safety improvement as it offers limited insights into the social context or the wider influences in society that generate vulnerability for such risks. Thus, the extant engineering focal approach limits the potential of arriving at theoretically comprehensive understanding of the complex circumstances that collectively lead to building disasters/accidents and any systematic search for the technical as well as the social lessons needed to avoid repetition.

A deeper focus on socio-cultural factors has the potential for deepening our understanding of how such factors operate, shape and dictate the demand and supply, design, construction, utilization and adaptation of buildings as well as the regulation and management of the underlying processes and culminate into the technical/engineering problems that, albeit rather belatedly, become the subject of forensic examination when disasters occur. Thus, a socio-cultural grounding for building safety could be worthwhile for identifying pathways to avoid, if not all, most of the catastrophic building collapses that tend to undermine public health.

Declaration

The work did not receive any funding and the author has no conflict of interest to declare.

References

Boateng, F. G. 2016. 'The Collapse of Buildings in Cities in Ghana: Reasoning Beyond 'Scientism''. In *Refereed Proceedings of TASA 2016 Conference*. Chou, M. (2016) (ed). Melbourne, Australia pp. 7-12.

Boateng, G. 2017. 'Implications of Building Accidents in Urban Settings for Building Safety Studies'. In *41st Australasian Universities Building Education Association Conference 2017* (pp. 427-438).

Boateng, F. G. 2018. 'Why the de-emphasis of wider societal factors in construction failures analysis is fatal'. *Proceedings of the Institution of Civil Engineers-Forensic Engineering*, 1-6.

Boateng, F.G. 2018. 'Exploring the collapse of buildings in urban settings'. *Proceedings of the Institution of Civil Engineers–Municipal Engineer*. doi:10.1680/jmuen.17.00033

Boateng, F. G. 2019. 'A brief case for an organizational grounding for structural safety in the construction sector'. *Construction Management and Economics*, *37*(8), 472-473. doi.org/10.1080/01446193.2019.1591629

Brady, S. P. 2012. 'Role of the forensic process in investigating structural failure'. *Journal of performance of* constructed *facilities*, *26*(1), pp. 2-6.

Carper, K. L. (2nd Ed.). 2001. '*Forensic Engineering'*. New York: CRC Press

Dechy, N., Dien, Y., Funnemark, E., Roed-Larsen, S., Stoop, J., Valvisto, T., & Arellano, A. L. V. 2012. 'Results and lessons learned from the ESReDA's accident investigation working group: Introducing article to "safety science" special issue on "Industrial events investigation"'. *Safety Science*, *50*(6), 1380-1391.

Delatte, N. J. 2009. '*Beyond Failure – Forensic Case Studies for Civil Engineers'*. Virginia: American Society of Civil Engineers Press.

Dien, Y., Dechy, N., & Guillaume, E. 2012. 'Accident investigation: From searching direct causes to finding indepth causes–Problem of analysis or/and of analyst?' *Safety science*, *50*(6), 1398-1407.

Fu, F. 2009. 'Progressive collapse analysis of high-rise building with 3-D finite element modeling method'. *Journal of Constructional Steel Research*, *65*, 1269-1278.

Fu, F. 2010. '3-D nonlinear dynamic progressive collapse analysis of multi-storey steel composite frame buildings — Parametric study'. *Engineering Structures*, *32*, 3974-3980.

Habraken, N. J. 1988. 'Type as a Social Agreement'. *In refereed proceedings of the Asian Congress of Architects*. Seoul, South Korea. Pp. 1 – 18

Hackitt, J. 2018. 'Building a Safer Future'. *Independent Review of Building Regulations and Fire Safety: Interim Report*.

Han, Y., Feng, Z., Zhang, J., Jin, R., & Aboagye-Nimo, E. 2018. 'Employees' Safety Perceptions of Site Hazard and Accident Scenes'. *Journal of Construction Engineering and Management*, *145*(1). Doi:10.1061/%28ASCE%29CO.1943-7862.0001590

Hayes, J. 2017. 'Disaster incubation: Grenfell Tower's unnecessary lessons'. *Construction Research and Innovation*, *8*(3), 76-79. https://doi.org/10.1080/20450249.2017.1367559

He, Q., Dong, S., Rose, T., Li, H., Yin, Q., & Cao, D. 2016. 'Systematic impact of institutional pressures on safety climate in the construction industry'. *Accident Analysis & Prevention*, *93*, 230-239. https://doi.org/10.1016/j.aap.2015.11.034

Hewitt, K. 1997. '*Regions of Risk: A Geographical Introduction to Disasters'*. Edinburgh Gate, Harlow: Addison Wesley Longman Limited

Heywood, R. J. 2010. 'Responding to failure: An introduction to forensic structural engineering'. *Australian Journal of Structural Engineering*, *11*(1), 1-9.

Jia, A. Y., Rowlinson, S., Loosmore, M., Xu, M., Li, B. and Gibb, A. 2017. 'Institutions and institutional logics in construction safety management: the case of climatic heat stress'. *Construction Management and Economics*, 35(6), 338-367. https://doi.org/10.1080/01446193.2017.1296171

Jia, Y. A., Rowlinson, S., & Ciccarelli, M. 2016. 'Climatic and psychosocial risks of heat illness incidents on construction site'. *Applied ergonomics*, *53*, 25-35. https://doi.org/10.1016/j.apergo.2015.08.008

King, A. [ed] 1980. '*Buildings and Society: Essays on the Social Development of the Built Environment'*. London: Routledge & Kegan Paul.

Kwasniewski, L. 2010. 'Nonlinear dynamic simulations of progressive collapse for a multistory building'. *Engineering Structures*, *32*(5), 1223-1235.

Lawrence, L. D. and Low, S. M. 1990. 'The Built Environment and Spatial Form', *Annual Review of Anthropology*, Vol. 19, pp. 453-505.

Low, S. M. 1996. 'The Anthropology of Cities: Imagining and Theorizing the City', *Annual Review of Anthropology*, Vol. 25, pp. 383-409.

McDermott, V., Zhang, R. P., Hopkins, A., & Hayes, J. 2018. 'Constructing safety: investigating senior executive long-term incentive plans and safety objectives in the construction sector'. *Construction Management and Economics*, *36*(5), 276-290.

Moffat, S., and Kohler, N. 2008. ‘Conceptualizing the built environment as a social-ecological system’, *Building Research & Information*, Vol. 36, No. 3, pp. 248 –268.

Noon, R. K. (2001). '*Forensic Engineering Investigation'*. New York: CRC Press

Parfitt, M. K. 2012. 'Why Buildings Fail: Are We Learning From Our Mistakes?' *Buildings*, *2*(3), 326-331.

Peckitt, S. J., Glendon, A. I., & Booth, R. T. 2004. 'Societal influences on safety culture in the construction industry'. *Construction Safety Management Systems* pp.14 – 46

Pink, S., Tutt, D., Dainty, A. and Gibb, A. 2010. 'Ethnographic methodologies for construction research: knowing, practice and interventions'. *Building Research and Information*, 38(6), 647-659. doi.org/10.1080/09613218.2010.512193

Rapoport, A. 1969. '*House form and culture'*. London: Prentice-Hall International Press.

Rapoport, A. 1973. 'An Approach to the Construction of Man-Environment Theory’ *The Environmental Design Research Association EDRA 4: Fourth International EDRA Conference*, Vol. 2, pp. 124 – 135

Rapoport, A. 1980. ‘Vernacular architecture and the cultural determinants of form’, pp. 283 - 305 in King, A. [ed] (1980) *Buildings and Society: Essays on the Social Development of the Built Environment*, London: Routledge & Kegan Paul.

Rapoport, A. 1982. *The Meaning of the Built Environment*, London: SAGE Publications

Ratay, R. T. (2nd Ed.) 2010. *Forensic Structural Engineering Handbook*. NY: McGraw-Hill.

Reason, J. 1997. *Managing the Risks of Organizational Accidents*. Aldershot: Ashgate.

Rowlinson, S. (Ed.). 2004. *Construction safety management systems*. London: Spon Press.

Rowlinson, S., & Jia, Y. A. 2015. 'Construction accident causality: An institutional analysis of heat illness incidents on site'. *Safety science*, *78*, 179-189. https://doi.org/10.1016/j.ssci.2015.04.021

Rowlinson, S., YunyanJia, A., Li, B., & ChuanjingJu, C. 2014. 'Management of climatic heat stress risk in construction: a review of practices, methodologies, and future research'. *Accident Analysis & Prevention*, *66*, 187-198. doi.org/10.1016/j.aap.2013.08.011

Smiley, J-P., Fernie, S. and Dainty, A.R.J., 2014 ‘Understanding construction reform discourses’, *Construction Management and Economics*, Vol. 32, No. 7-8, pp. 804 – 815

Subbarao, H. 2016. 'Editorial'. *Forensic Engineering*. Vol. 169 (4), 121 – 122

Tam, C. M., Deng, Z. M., Zeng, S. X., & Ho, C. S. 2000. 'Quest for continuous quality improvement for public housing construction in Hong Kong'. *Construction Management & Economics*, *18*(4), 437-446.

Tutt, D., Pink, S., Dainty, A. R. J. and Gibb, A. 2013. '‘In the air’ and below the horizon: migrant workers in UK construction and the practice-based nature of learning and communicating OHS'. *Construction Management and Economics*. https://doi.org/10.1080/01446193.2012.756145

Zhou, Z., Goh, Y. M., & Li, Q. 2015. 'Overview and analysis of safety management studies in the construction industry'. *Safety science, 72*, 337-350. doi.10.1016/j.ssci.2014.10.006

A CONCEPTUAL INQUIRY INTO BUILDING COLLAPSE IN CITIES IN DEVELOPING COUNTRIES

Festival Godwin Boateng[1], Renee Wright[1]

[1]School of Global, Urban and Social Studies, RMIT University, Melbourne, Australia

Abstract

Building collapses are becoming a common, tragic occurrence in cities in developing countries – particularly Africa and Asia. This does not bode well for urban sustainability given the rapid growth and concentration of more and more people in cities in those parts of the world. The growing number of climate-related hazards portends an even higher disaster-risk as more buildings could collapse in such places subsequent to hydro-meteorological hazards. This raises the need for conversations toward unravelling and addressing the underlying causes. This review draws on contemporary as well as historic documents on housing and construction, media, scholarly and investigative reports on building collapses and other cognate materials on the growth and development of cities across diverse locations to confer insight into the phenomenon. In summary, it was found that, accelerated demand for buildings triggered by urban expansions provides the context for how the creation of unsafe buildings arise in developing countries' cities and are thus central to understanding the deleterious consequences of building collapses in those parts of the world. The implications of the findings for control are discussed. The review provides an exploratory reference for empirical research into the situations of specific countries and cities.

Keywords

building collapse; developing countries; sustainable cities; urbanization

Introduction

Figure 1 above is a sadly familiar image in many developing countries' media reports: people frantically searching the rubble of a collapsed building for dead and surviving victims. The information is disparate and scattered. However, what is known confirms a clear trend: that building collapses are becoming a common, tragic occurrence in cities in developing countries – particularly Africa and Asia (Boateng, 2017; 2019). In Kampala, Uganda, Alinaitwe and Ekolu (2014) counted 54 building collapse deaths and 122 injuries in just four years (between 2004 and 2008). In Nigeria, Windapo & Rotimi (2012) compiled over one hundred and twelve (112) cases between December 1978 and April 2008 in Lagos alone, the largest city in Nigeria and on the African continent. Just recently (March 15, 2019), a four-story multipurpose building reportedly collapsed and killed twenty people at the Ita-Faji area of the Lagos Island district (Akwagyiram, 2015).

Indeed, other Nigerian cities including Port Harcourt, Abuja, Enugu and Ibadan have also suffered similar incidents. By way of illustration, on August 17, 2018, a building collapsed and buried so many people (two were feared dead) at Abuja, the capital of Nigeria (Premium Times, 2018). Other countries on the continent, too, have recorded a number of such fatal incidents in recent years. For instance, a World Bank study (Moullier, 2015) noted what it referred to as a particularly strong pattern of spontaneous building collapses in Kenya over the past 20 years predominantly in the cities. For instance, on June 13 2017, a 7-storey building reportedly collapsed in the capital, Nairobi (BBC Africa, 2017) even as another 6-storey had collapsed, killed forty-nine (49) and injured several others in the City in April 2016 (Reuters, 2016).

Figure 1:People gather to look at the debris from a building that collapsed in Nairobi, Kenya in June 2017. EPA/DAI KUROKAWA

Tchamba & Bikoko (2016), Alinaitwe and Ekolu (2014), to cite but a few, have reported on the situations of cities in Cameroon and some East African countries' including Uganda and Tanzania. The situation in Ghana is not different – the incidents recorded in the West African country are largely concentrated in the cities – particularly Accra (the capital) and Kumasi, the second biggest city and their environs (Asante & Sasu, 2018; Boateng, 2016; 2017b; 2018).

As noted earlier, this is not a uniquely African problem. It occurs in other rapidly urbanizing parts of the developing world as well. In Asia – another hotbed for the phenomenon – some of the headline cases include the collapse of the Royal Plaza building in the city of Nakhon Ratchasima (Korat) in Thailand, which killed 137 people and injured another 227. In April 2013, an eight-story building collapsed at Dhaka, the capital of Bangladesh. The incident led to 1,129 deaths and 2,515 injuries (Moullier, 2015; Hodgson et al, 2016). Around the same time, their neighbours in India, Mumbra, had also experienced the worst building collapse incident in the area. About 74 people died, including eighteen children. The incident location is a home to about one 1 million people. The year before (i.e. 2012), according to Moullier (2015), India saw more than 2,600 deaths and 850 injuries because of the spontaneous collapse of 2,737 building structures.

Other headline cases in Asia include the Selangor incident in Malaysia, where an apartment collapsed and killed about 48 people. Selangor (home to over 6 million people) is one of the states on the west coast of Peninsular Malaysia, encircling the capital, Kuala Lumpur. In November 2015, a building collapsed in Lahore, the capital of Pakistani province of Punjab and killed about 45 people. Feifei (2014) and Lyu et al (2018) have also compiled some cases in China and the trend shows that they usually occur in urban China.

Building collapse in developing countries' cities is concerning not least for two reasons. First, while some may not be able to cause high enough damage at a time to meet the criteria to be categorized as "disasters" in national and international databases, as noted by Moullier (2015), their accumulated impacts are usually just as much if not greater than those of large disasters that result from extreme events. Second, the 21st century is marked by the rapid growth and concentration of large numbers of people in cities in developing countries: 2.5 billion more people are joining the world's urban population by 2050 – 90 percent are to reside in developing countries, particularly Asia and Africa, where, reportedly, buildings also collapse the most. The growing number of climate-related hazards portends an even higher disaster-risk as more buildings could collapse in such places subsequent to hydro meteorological hazards. It is obvious that building collapse in developing countries' cities constitutes one of the critical threats to the future of a healthy urban society. However, the phenomenon has remained very much under researched.

Urban pathologists have long argued that the spatial concentration of people and socio-economic activities in cities affect the extent to which social problems occur and the particular forms they take in those places (See Pitcher, 1997; Herbert & Smith, 1989; Haynes et al., 1985, for instance, for a review). As a first step to gaining a deeper understanding, and to provide direction for future research, this review sought to capitalize on the principles and methods accrued in the urban pathology literature to explore building collapse in cities in developing countries. Specifically, it sought to examine the range of agencies and causes that underlie the creation of unsafe buildings in cities in developing countries, and to that end the reason for the rampant collapse incidents in such places. The study was guided by the following question:

To what extent and in what ways do urban expansions implicate on the creation of unsafe buildings in developing countries' cities and, therefore, contribute to the occurrence of building collapses in such places?

The study was approached this way: The qualitative method of document analysis was deployed to explore literature on contemporary as well as historic documents on housing and construction, media, scholarly and investigative reports on building collapses and other cognate materials on the growth and development of cities across diverse geographical locations to theorize building collapse in cities. Consistent with urban pathologists' claim that, the social, economic, environmental and other problems experienced in urban habitats are usually inextricably linked to the multifaceted processes of urbanization, it emerged from the literature review that building collapse in the urban context is linked to urban expansions.

The more people come to the city, the more demand for buildings is amplified – for accommodation and other purposes. The pressures of demand often engender shoddy construction and building use practices. Buildings are hastily built. Existing ones are hastily converted for uses that were not built into the original design. Extra floors are added atop old buildings. Usually, city authorities would step in to enforce safe building regulations and guard against these practices. But too often in the developing world, institutional cultures like corruption and political interference undermine authorities' responsibilities. Add to that a dearth of building inspectors or other resources, and unsafe building practices multiply. In the end, huge stocks of unsafe buildings are created, sometimes in hazard-prone locations. This, then, can lead to disaster.

The findings underscore the influence of urbanization processes on the social and spatial distribution of vulnerability to humans, but the core is the social/political/economic factors that operate, shape and dictate adverse construction and building use practices in the context of heightened demand and supply of building needs and services as a result of urban expansions. Based on this analysis, the commonly held notion that vulnerability for building collapses in developing countries could be addressed administratively through the enforcement of technical regulations and codes is ineffective. Interventions to reduce such risks must be broad, more-wider reaching and involve initiatives that address not only direct compliance and enforcement of technical regulations. They must also target structural issues including the broader socio-political economic conditions that underlie and shape access and distribution of resources and the pursuit of building needs in ways that generate risk or force some people to build themselves into disasters. The rest of the article presents the materials relied upon and the findings.

Materials for study

It is common knowledge that many more buildings collapse in developing countries than in advanced countries (see Soane, 2016; Moullier, 2015; Asante & Sasu, 2018, for instance). A simple keyword search for "incidents of building collapse"; "building collapse in developing countries"; "incidents of building collapse in developing countries" return various scholarly, media and other reports on the phenomenon in particularly Africa and Asia and countries like Nigeria, Kenya, Uganda and Ghana; China, India, Turkey and Bangladesh as the places where they mostly occur.

In qualitative document analysis (Bowen, 2009), the approach the study adopted, the basis for materials selection is not to fulfil the representative requirements of statistical inference but to provide substantial contributions to the understanding of the structure and character of the phenomenon under investigation (Polkinghorne, 2005). This presupposes that the investigator must strategically target where s/he could access the appropriate materials that could illuminate on the phenomenon under review.

Applying this methodological insight, in searching for materials, cases and examples to illustrate arguments and support analysis, the review purposively focused or targeted the two regions and the countries mentioned above. Search terms like “building collapse in Nigeria”; “incidents of building collapse in China”; “building collapse in Ghana”; “incidents of building collapse in Kenya” “the collapse of buildings in India” returned the cases used to illustrate arguments. Nonetheless, additional materials, examples and cases are drawn from other developing regions and countries to provide a wider context, as appropriate.

Further, historical methodologists have long counselled social scientists to explore contemporary questions always in comparison with the relevant aspects of past societies. This methodological standpoint has roots in sociological traditions such as the works of C. Wright Mills (Tuchman, 2003). The Good Book captures it even better in Ecclesiastes 1:9: there is nothing new under the sun. The broader philosophical point of historic methods is that the problems of the day usually have precedents, analogues, and examples in the past. Historic methods, therefore, helps investigators to identify and establish the interconnectedness and the larger relationships between the events, issues and factors underlying the phenomenon under study.

The review juxtaposes the situation of today’s urban experience regarding incidents of building collapse to that of two historic urbanizations that commonly feature in social scientific discourses on urbanism: Ancient Roman and 18/19th century Britain urban civilizations. In so doing, it offers a comprehensive insight that places the phenomenon of building collapse in the urban context within the larger historical and contemporary discourses on the topic.

A caveat is offered beforehand that the parallels drawn between contemporary and historic urbanizations do not assume simplicity or disregard the meaningfulness of contextual differences. In no simple sense, can we read the developments then as neatly similar to that of today. The parallels are drawn with regard to only how the processes of demographic and economic expansions created incentives, causes and motivations for deleterious adaptation of construction processes and buildings in ways that tend to undermine public health then and now.

Pressures of accelerated urban building needs and building collapse in cities

This section analyzes how rapid growth in urban population engenders accelerated demand for buildings, which, in turn, generates inappropriate construction and building use practices and, hence, the creation of unsafe buildings in cities that result in collapse incidents. The overall insight here is that a high growth in urban population, which also comes with corollary developments such as increased economic activities, usually occasions building need pressures, which, then, engender adverse construction and building use practices and, for that matter, widespread creation of defective buildings. Such buildings collapse in the event but also even in the absence of physical hazards.

The nexus between accelerated demand for buildings incidental to urban expansion and the occurrence of building collapse incidents is explored under two sub-themes: suboptimal constructions engendered by urban building need pressures and suboptimal building use practices influenced by urban political economy pressures.

Suboptimal constructions engendered by urban building need pressures

Buildings are of utmost importance to society – they are one of humankind's most ancient pursuits. They are complex assets, with links to culture; livelihoods; health; education; security; social and family stability (Sparke, 2004). Society's response to building needs is influenced heavily by social changes such as population pressures. At the micro level, families seek new bigger homes, apartments or adapt old ones to make more spaces for new members as the size grows. Similar dynamics play out at the macro level as population growth also comes with increased need for buildings for housing and other purposes (Lawrence & Low, 1990).

However, the challenge in the urban context is that, the exigencies of stratospheric upsurge in the demand for buildings subsequent to population growth usually influence urban dwellers to respond to building needs in ways that lead to insufficient focus on safety, wellbeing and longevity imperatives. The less emphasis on safety, sustainability and wellbeing imperatives manifests as widespread suboptimal or unsustainable construction practices, such as using substandard materials; low-skilled labor; hasty constructions; reducing the required inputs and siting buildings in unsafe locations, which then lead to collapse incidents in the event or even in the absence of physical hazards.

This way of theorizing vulnerability for building collapse in cities just as much reflects the situation of contemporary cities as historic ones. For instance, studies show that while the early Romans were proficient builders (evidenced by the many infrastructures they left behind – Beard, 2015), heightened building need pressures propelled by accelerated growth in Rome's population proliferated adverse construction practices, which led to collapse and other catastrophic incidents such as conflagration (Closs, 2013). Not just Rome, similar developments were evident in the 18th and 19th century Britain. In the case of Britain, the rapid factories-driven industrialisation of the late 18th and early 19th centuries propelled a phenomenal rise in populations in many of its industrialising cities (Nevell, 2011; Hartwell, 2001), which led to the so-called "housing question" (Kemp, 1989).

For instance, between 1773 and 1821, housing need in Manchester alone rose from 3,446 to 17,257 and nearly 50, 000 houses by 1851 (Kidd, 2002). The attempt to meet the phenomenal rise in building needs led to a widespread decline in the quality of construction –many dwellings in the new and growing towns and cities were poorly designed and/or constructed, and with shoddy materials (Nevell, 2011; Symonds, 2005). For instance, the rapid growth in the urban population meant that there was pressure on urban lands leading to the piling of stories on old stories as the use of banned construction materials also ratcheted up. This led to widespread creation of structurally suspect buildings and rampant collapse incidents (Hurst, 2001; 2006).

Drive forward to contemporary times, the housing deficits experienced in Hong Kong because of high growth in Hong Kong's urban population and influx of migrants in the 1960s occasioned widespread suboptimal and illegal constructions, which also led to several incidents of building collapse (BD, 2007). Further, studies suggest that Chinese cities are experiencing significant suboptimal construction and building use practices resulting in several cases of shoddy work failures – a development that has been linked to building need pressures occasioned by the country's ever-growing urban population (He & Wu, 2016). Lyu et al (2018), for instance, show how accelerated demand for buildings due to high influx of rural migrants incentivized dangerous building practices such as the construction of extra floors atop old buildings by landlords in the City of Wenzhou leading to the collapse of four (three six-stories, and one two-story) residential buildings. The incident, which occurred on October 10, 2016, killed twenty-two (22) migrant labourers.

The fundamental point here pertains to how the pressures of stratospheric upsurge in building needs incidental to accelerated growth in urban populations influence the proliferation of dubious construction and building use practices and for that matter widespread creation of unsafe buildings. Nonetheless, economic factors also play impactful roles. Thus, the unsustainable manner in which building needs are pursued subsequent to accelerated growth in urban populations are just as much influenced by population pressures as economic pressures/incentives.

As noted by Watt (2007), the building process involves design, construction, utilization and adaptation of the structure in response to future needs. However, at every stage, economic and safety considerations fiercely compete such that if the right balance is not achieved, structural integrity could be adversely affected (Blockley, 1980). Clients generally do not have access to infinite supply of money and as a result, however paramount safety considerations may be to the design process, the designer may as well have to give economy a firm thought. Effectively, the resources available for the project could pose a powerful counterweight to safety and structural integrity considerations (Boateng, 2016; 2018b).

Built environment practitioners are enjoined to hold paramount, the safety, health, and welfare of the public against all other considerations. For the building and designing professions Mason notes, the incalculable value of human life demands nothing less than the highest moral considerations from those who might risk it otherwise. Thus, engineers, architects, project managers and contractors have a fundamental duty to uphold professional conscience (Fleddermann, 1999). However, their work is also a business, which has to survive: it is a way of earning a living. As noted by Blockley (1980), naturally, the pressures of business are ever-present and sometimes can become so great that engineers may easily lose the wider view of their role in society and see their function only in a straightforward materialistic business sense.

High emphasis on economic returns or cost of inputs could undermine safety considerations and lead to unintended disastrous outcomes. Indeed, there is the growing concern in the construction sector that a lot of the careless designs and inadequate construction practices that cause problems are not due to the inevitable difficulty with technology or its lack thereof. They, however, result from the growing socioeconomic and other pressures on the players in the construction industry to reduce costs or cut corners (Tam et al, 2000; Alinaitwe & Ekolu, 2014). Thus, there is the tendency to focus mainly on immediate gains–meeting production schedules, quota and cost targets (the ever-present iron triangle problem in construction project management –Atkinson, 1999; Ogunlana, 2010) relegating safety, sustainability, and well-being imperatives to the background which then lead to unintended disastrous outcomes.

While universal, the evidence suggests that, these problems are more pronounced in the developing world where regulation is usually weak (more on this shortly). An exemplifying incident in point is the collapse of the six-story building that reportedly killed about 49 people in April 2016 in Nairobi, the Kenyan capital. The report was that the building did not have occupancy permit. Apparently, there is high demand for buildings in Nairobi, and the owners of the facility are part of the many developers in the City who bypass regulations to cut down cost with the view to maximizing profit. The accounts on the incident pointed out that the structure had been built "shoddily" within a few months (Associated Press, 2016; The Guardian, 2016) and the 126 single rooms were being rented out at a monthly rate of $35 (£24)[1]. In Uganda, it was established that similar problems regarding uncontrolled speedy construction and poor workmanship led to the collapse of the BBJ building that killed eleven (11) people and injured twenty-six (26) others in Kampala, the capital, circa September 2004 (Alinaitwe & Ekolu, 2014).

A subtle dimension of the problem relates to how socio-economic inequalities impede certain segments of the urban population from accessing housing in planned areas thereby exposing or forcing them to undertake practices that increase disaster risk and insecurity. The key underlying issues include high cost of urban land and unfavourable mortgage and credit schemes. Urban lands are now under pressure everywhere because of increased demand and speculation (Moullier, 2015). There are two major consequences related to excessive and speculative land prices with adverse implications for building safety.

First, for the many low-income urban dwellers, the high cost involved in buying or renting a piece of land absorbs the bulk of financial resources available for housing. This, in turn, limits their capacity to invest in safer building materials, construction, and skilled labourers, even where these would be available at a reasonable price. Second, a significant portion of the urban population (read low income people yet again) who are usually not creditworthy and cannot afford buildings in planned locations due

[1] While this fee may not be considered exorbitant in advanced countries, in developing countries' context, it is substantial.

to high cost of mortgage schemes are forced to construct and/or patronize low cost but unsafe tenements and often in hazard-prone zones.

For instance, in the Philippines, high land prices is considered as one of the main factors driving about 40 percent of people to live in informal settlements, which are often unsafe. A detailed investigation found that the average cost of a house in an informal settlement costs roughly 10 percent of the price of a comparable unit in the formal sector (Moullier, 2015). Creating structurally suspect buildings and in hazard prone zones only increase insecurities and vulnerability and the experience is that such developments usually lead to disastrous outcomes (Moullier, 2015; Lyu et al, 2018; Wisner et al, 2003; Pelling, 2003).

This was true of the case of Ancient Rome and 18th century Britain. For instance, Nicols (n.d.) accounts show that not only did the housing pressure in Rome lead to many people taking accommodation on the streets but also it led to the construction of poor quality tenements –the rents for safer alternatives were too high. In the case of 18th century Britain, as the urban population grew, space was at a premium within city walls; therefore, stories were piled on old stories to create housing for lower class people (Hurst, 2001; 2006). The downside of such developments, however, is that they come with public health challenges. What happened in Hong Kong in the 1960s exemplifies this point.

High growth in Hong Kong's urban population in the 1960s (driven by natural increase and high influx of migrants) created a large cohort of low-income people in need of housing. Without adequate resources to access the relatively safer but expensive houses, they heavily patronized the many illegal buildings that were being constructed. The scale of the development overwhelmed the Hong Kong city authorities who could not bring it under control until the buildings began collapsing beginning from the 1990s through to 2002. By 2001, the rate of the collapses had surged, forcing the City's Buildings Department to undertake a series of clearance operations, which led to the demolishing of over 255, 000 unsafe buildings (BD, 2007). Similar dynamics underlined the recent collapse of four buildings in the Wenzhou City of China circa October 2016, which killed twenty-two (22) migrant labourers (See Lyu et al, 2018).

Suboptimal building use practices influenced by urban political economy pressures

The previous theme underscored how urban crisis such as rising urban housing deficits and urban poverty engender a range of agencies, causes and motivations for the demand and supply of buildings to play out in ways that place inadequate focus on safety and lead to unintended disastrous outcomes. However, as established in the pathology of urban processes literature, not all pathological phenomena are created by crisis. Some urban pathologies are influenced by what may otherwise be considered as 'benign' developments or processes (Kuklinski, 1985). This view of pathology of urban processes is true of building collapse in cities.

The growth and agglomeration of people in cities attract investments and generate commercial activities, which, in turn, amplify infrastructural demand to support them. The urbanists' accounts suggest that, in such cases, pressures on urban lands, institutional and planning failures to designate planned commercial spaces/infrastructure to contain/support the heightened business activities usually engender the conversion of especially residential buildings to commercial uses (Oosterbaan et al, 2012). This development is discernible in the mega cities growing rapidly in the developing world including Cairo, Lagos, Johannesburg, Rio de Janeiro, Buenos Aires, Santiago, Hanoi, Accra and even smaller cities like Cochabamba. (For a review, see Sutton & Fahmi, 2001; Quang & Kammeier, 2002; Barredo, & Demicheli, 2003; Oosterbaan et al, 2012; Coen et al, 2008).

The discourses on the development usually focus on its adverse implications for urban planning and housing deficits (Oosterbaan et al, 2012; Cobbinah & Niminga-Beka, 2017). Its implications for the many building collapse incidents occurring in those parts of the world are seldom explored. However, since such structures originally were not meant for commercial use, the design considerations, regarding their fit for purpose, would normally not include the subsequent additional imposed loads associated with the new (commercial) use. Therefore, using them commercially could exert further pressure on the structural members, cause fatigue and eventual collapse just as attempts to make the necessary structural adjustments to suit the new purpose, if not properly done, could also lead to structural integrity erosion and eventual collapse.

The pathological effects of inappropriate commercialization of buildings in cities (as factories, wholesale, retail and other purposes) are being felt in many parts of the developing world including Pakistan, Bangladesh, China, Nigeria and Ghana where such practices have led to disastrous consequences. However, the infamous collapse of Rana Plaza in April 2013 in the Savar Upazila of Dhaka District, Bangladesh, which killed 1,129 and injured 2,515 people, respectively manifests all the trappings of this rather disturbing building use practice.

Dhaka has become one of the world's most populous and rapidly urbanizing places, driving up the price of land and straining the country's power systems. The shortage of land and a propensity for flooding in Bangladesh has prompted many factory owners to build up, rather than out – thus, additional unapproved floors often are hastily added to old structures with little care for structural integrity considerations. For instance, in the case of Rana Plaza, the original approval for the building was five stories. However, at the time of the collapse, a ninth story was being added (Hodgson et al, 2016).

Furthermore, to keep up with the increased demands of Western retailers, factory owners convert residential and other buildings into makeshift garment factories – due to the high cost involved in putting up new buildings and limited access to utilities, thereby creating even more risks of collapse (Ifedolapo, 2015). The inappropriate commercialization of buildings in cities in developing countries bears watching given the rate of urbanization in those parts of the world for as the places continue to urbanize, more and more buildings will be indiscriminately converted to commercial uses.

Deficient construction governance and urban management

The review's findings suggest that the problem goes beyond urbanization-induced building need pressures engendering adverse construction and building use practices in cities. Even more is the failure of cultural protections. The broader point here is that even as buildings enhance humankind's life, they also pose real risks to life and the environment. Society, therefore, devises or have devised cultural protections to, if not entirely prevent, reduce the potentiality of buildings affecting life and the environment adversely. Generally, these protections (usually expressed as statutory and non-statutory demands–building regulations and codes) undergird how buildings should be or are designed, built, managed, repaired, maintained, occupied and even demolished (He & Wu, 2016; Boateng, 2018b).

Advanced countries have relied in large part on effective and efficient building regulatory systems (Moullier, 2015; Soane, 2016) to improve their built environment sector. The same cannot be said for developing countries, however. A review of the literature on the situation of the developing world suggests that, in some cases, the regulations themselves even contribute to building safety problems. In some countries, the codes are colonial inheritance and/or imported wholesale from the advanced world and, therefore, not fully appropriate for local conditions. For instance, the usage of British building standards was found to have contributed immensely to hurricane losses in Jamaica (Pelling, 2003) and the collapse of a four-story building at Kuala Lumpur on October 19, 1968 (Aini et al, 2005).

Even more important is low compliance and non-enforcement of building safety regulations. The point here is that most developing countries have some moderate to good building codes and regulations on their books. The problem, however, is that they exist only as that – good regulations and codes on paper. Studies upon studies have reported that rarely are building regulations enforced in those parts of the world (Asante & Sasu, 2018; Moullier, 2015; Lewis, 2005; Berlinski, 2011; Boateng, 2019). A number of reasons are proffered to explain this state of affair of which bribery and corruption feature prominently. In most developing countries, contractors and other building needs and services providers have little to no trouble in finding willing accomplices to their substandard construction practices in the form of unscrupulous public officials tasked with the regulation of construction activities and development control.

Studies suggest that developers easily obtain building permits through bribes and political favors or pay inspectors to turn blind eyes to designs and building practices that deviate from code specifications (Moullier, 2015; Lewis, 2005; Berlinski, 2011). Thus, both public and private sector corruption undermine all aspects of regulation enforcement and compliance. This leads to the construction of inferior public infrastructure, private buildings, and housing units, which ultimately fail, often in the face, but even also in the absence, of physical hazards leading to greater death tolls than would occur in the absence of corruption (Moullier, 2015; Lewis, 2005; Berlinski, 2011).

Furthermore, and similar to the critical role played by political clientelism in land and housing access (Arku et al., 2016); regulation enforcement efforts are frequently undermined by *"big men"* or individuals with strong social and political connections and influence. They easily get away with noncompliance on their personal properties, as well as on the properties of others in their locality or elsewhere who seek their intervention. For instance, some city officials interviewed for a study in Ghana (Asante & Sasu, 2018) bemoaned that most of the structures that had collapsed in their jurisdictions had been earmarked for demolition. However, due to political interference, the developers were allowed to continue with construction.

Other impediments to regulation enforcement include the large scale ongoing construction developments in most cities in the developing world, which further undermine their usually under resourced capacity (personnel and equipment) to exercise efficient oversight and ensure development control (Asante & Sasu, 2018; Yeboah & Obeng-Odoom, 2010; Arku et al, 2016). In short, the challenges of building regulations enforcement are increased in the cities where the will to develop exceed the will to be prudent. In the end, a thriving climate is created for the pursuit and the provision of building needs and services to play out in ways that are deleterious to public safety.

Summary of key highlights & discussion

The review proposed to explore the following question: *To what extent and in what ways do urban expansions implicate on the creation of unsafe buildings in developing countries' cities and, therefore, contribute to the occurrence of incidents of building collapse in such places*? Taken together, the findings align with the broader discourses on the influence of urbanization processes on the social and spatial distribution of vulnerability to humans – i.e. the pathologies of urban processes literature (Kuklinski, 1985; Haynes et al., 1985). Rapid growth in urban population, the findings suggest, usually generate a cascading upsurge in the demand for buildings–for accommodation, commercial and other purposes. The pressures of the accelerated demand for buildings incidental to the rise in the urban population, in turn, engender a range of agencies, motivations and causes that encourage suboptimal construction and building use practices.

The responsibility to uphold public health and wellbeing usually lies with cities' authorities to enforce the relevant building safety regulations against the inappropriate construction and building use practices. However, in the developing world, institutional cultures such as corruption and political interference further undermine their usually under-resourced capacity to enforce the regulations (which, in most cases, are colonial legacies and/or imported wholesale from elsewhere and, therefore, inappropriate for local conditions) against the widespread adverse construction and building use practices. In the end, a precarious climate is created in which the pursuit and the provision of building needs and services play out in ways that tend to undermine public safety.

Per the foregoing, as summarized into figure 2, building collapse in developing countries' cities could be theorized as the unintended maladaptive effect of suboptimal construction and building use practices engendered by the exigencies of accelerated demand for buildings, subsequent to rapid urban expansions, in which weak regulation plays key roles and contributes or reinforces the prevalence of the inappropriate construction and building use practices that lead to the incidents.

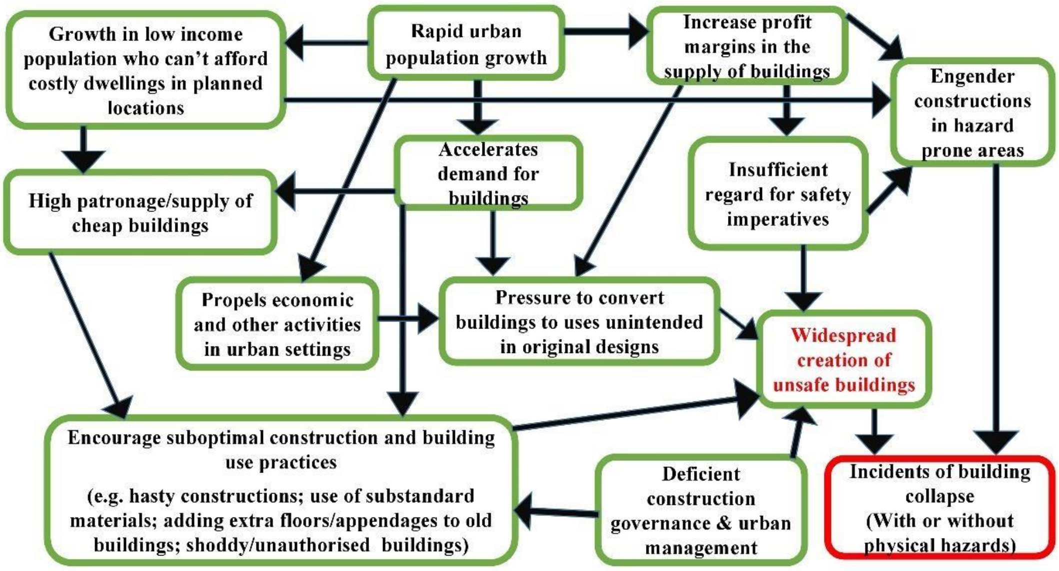


Fig. 2: Conceptual framework of influences of vulnerability for building collapse in cities in developing countries

Thus, the incidents are a pathological feature of urbanization: the contingent (albeit unintended) outcome of the interplay of the inappropriate construction and building use practices in urban settings engendered by accelerated demand for buildings subsequent to rapid demographic and economic expansions in such places. At issue is how urbanization-induced accelerated demand for buildings influence, shape and/or dictate the demand and supply, design, construction, utilization and adaptation of buildings and the regulation of such processes and practices in urban settings in ways that tend to undermine safety, sustainability, wellbeing and longevity imperatives. The review, thus, underscores how the pressures of stratospheric upsurge in building needs incidental to urban expansions influence the proliferation of dubious construction and building use practices and, hence, widespread creation of structurally defective buildings that tend to undermine public health.

The analysis provided herein raises issues with the commonly held notion that vulnerability for building collapses in developing countries could be addressed administratively through the enforcement of technical regulations and codes. The point here is that at the end of the day, every collapse incident inevitably will eventually be marked by a technical or engineering defect. And since the engineering imperatives that undergird how buildings should be or are designed, built, managed, repaired, maintained, occupied and even demolished are usually embodied in statutory and non-statutory demands: building regulations and codes (Watt, 2007; Asante & Sasu, 2018), it is commonly argued that building collapses could be administratively addressed through the enforcement of such regulations and codes. Indeed, the high incidence of building risks in developing countries as compared to the advanced world is usually explained on the account of inadequate enforcement of building regulations and codes (See Berlinski, 2011; Lewis, 2005; Moullier, 2015; Soane, 2016 – to name but a few of such studies).

Undoubtedly, every collapse incident would eventually be due to noncompliance and/or non-enforcement of the appropriate safety regulations underlying the construction and use of buildings. However, as the analysis herein has shown, the challenge with building safety in developing countries does not seem to be just a matter of engineering that can easily or mainly be dealt with through the enforcement of technical regulations. What the phenomenon represents, at least in the cities' context, is a symptom of a complex interaction of factors. These include but not limited to urban housing challenges, which disproportionately affect low-income people; rising cost of urban lands; institutional and planning failures to designate planned commercial spaces to contain the proliferation of informal businesses–just to mention a few of the underlying causes – of which compromised enforcement of regulations is only one of them.

This implies that interventions to reduce such risks must be broad, more-wider reaching, and involve initiatives that not only address direct compliance and enforcement of building regulations and codes, but also the structural socioeconomic conditions that underlie and shape access and distribution of resources and the pursuit of building needs in ways that generate risk or force some people to build themselves into disasters. For instance, the review has underscored that an insidious dimension of the problem relates to how socioeconomic inequalities associated with urbanization processes impede low-income urban dwellers from finding safe, sturdy accommodation. This exposes them to tremendous risk, forcing them to either rely on or undertake inherently unsafe construction practices. Two issues could be addressed to ease this problem: the high cost of urban land and unfavourable mortgage and credit schemes that lock people out of accessing building or accommodation finance. Put simply, unless conscious efforts are made to address the building needs of the urban poor, the creation of unsafe (illegal) buildings in hazard-prone areas cannot be prevented.

Concluding remarks

The health of the many cities growing rapidly in the developing world is being threatened by rampant incidents of building collapse raising the need for conversations toward unravelling and addressing the underlying causes. This review has opened with the conversation on the subject by providing insight into how urban expansions trigger a range of agencies, motivations and causes that shape and dictate the pursuit and the provision of building needs and services in ways that lead to insufficient focus on safety, longevity and wellbeing imperatives. Thus, accelerated demand for buildings subsequent to demographic and economic expansions provides the context for how the creation of unsafe buildings arise in developing countries' cities and are thus central to understanding the deleterious consequences of building collapses in those parts of the world.

It is suggested that interventions to reduce such risks must be broad, more-wider reaching and involve initiatives that address not only direct compliance and enforcement of building regulations. They must also target structural issues including the broader socio-political economic conditions that underlie and shape access and distribution of resources and the pursuit of building needs in ways that generate or expose people to risks or force some people to build themselves into disasters.

This exploratory study is only a first step to gaining a deeper understanding of the very much under researched issue of building collapse in cities in the developing world. It hopes to stimulate empirical studies into the situations of specific cities and/or countries. Such an enterprise would be useful not just for developing a stronger understanding of the phenomenon but also for unravelling contextual differences between and among cities and countries to inform well-targeted interventions.

Declaration

The author declares no competing interest.

References

Aini, M. S., Fakhru'l-Razi, A., Daud, M., Adam, N. M., & Abdul Kadir, R. 2005. Analysis of Royal Inquiry Report on the collapse of a building in Kuala Lumpur: Implications for developing countries. *Disaster Prevention and Management: An International Journal*, *14*(1), 55-79

Alinaitwe HM and Ekolu S. 2014. Failure of structure in East Africa with focus on the causes of failures in the construction phase. In *Construction Materials and Structures – Proceedings of the First International Conference on Construction Materials and Structures* (Ekolu SO, Dundu M and Gao X (eds)). IOS Press, Amsterdam, the Netherlands, vol. 1, pp. 76–85.

Arku, G., Mensah, K. O., Allotey, N. K., & Addo Frempong, E. 2016. Non-compliance with building permit regulations in Accra-Tema city-region, Ghana: exploring the reasons from the perspective of multiple stakeholders. *Planning Theory & Practice*, *17*(3), 361-384

Asante, L. A., & Sasu, A. 2018. The Challenge of Reducing the Incidence of Building Collapse in Ghana: Analyzing the Perspectives of Building Inspectors in Kumasi. *SAGE*

Open, *8*(2).https://doi.org/10.1177/2158244018778109 Associated Press (AP) .2016. 'Officials: Collapsed Kenyan building had no occupancy permit'. See: https://apnews.com/0d55d932ee1b46c390f75ab7c2ddc44c (Accessed: 18.07.19).

Atkinson, R. 1999. Project management: cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria. *International journal of project management*, *17*(6), 337-342.

Bankoff, G., Freks, G. and Hilhorst, D. 2004. *Mapping Vulnerability*. London: Earthscan

Barredo, I. J. & Demicheli, L. 2003. Urban sustainability in developing countries' megacities: Modelling and predicting future urban growth in Lagos, *Cities*, 20(5), pp. 297–310.

BBC Africa. 2017. Kenya building collapse: Rescue teams search for missing people: https://www.bbc.com/news/av/world-africa-40257620/kenya-building-collapse (Accessed: 18/07.19)

Buildings Department (BD). 2007. Buildings Department Determined to Tackle Unauthorized Building Works [Press release]. BD, Hong Kong, China. Available from: http://www.bd.gov.hk/english/documents/ news/20070220ae.htm [Accessed 18.07.19].

Beard, M. 2015. *S.P.Q.R.: A History of Ancient Rome.* New York: W. W. Norton & Company, Inc.

Berlinski, C. 2011. 1 Million Dead in 30 Seconds: Retrieved from: http://www.city-journal.org/html/1-milliondead-30-seconds-13396.html (Accessed: 18.07.19)

Blockley, D. I. 1980. *The Nature of Structural Design and Safety.* New York: Halsted Press

Boateng, F. G. 2016. The Collapse of Buildings in Cities in Ghana: Reasoning Beyond 'Scientism'. In *Refereed Proceedings of TASA 2016 Conference*. Chou, M. (2016) (ed). Melbourne, Australia pp. 7 – 12.

Boateng, F.G. (2017). Why we need to start talking about the social context of building accidents. *Planning News*, Vol. 43, No. 8. pp 18 – 19.

Boateng, F.G. 2017b. Implications of building accidents in urban settings for building safety studies. In *Refereed Proceedings of Australasian Universities Building Education Association 2017 Conference.* pp. 427 – 438.

Boateng, F.G. 2018. Why the De-Emphasis of Wider Societal Factors in Construction Failures Analysis is Fatal. *Proceedings of the Institution of Civil Engineers – Forensic Engineering*. Doi: 10.1680/jfoen.17.00019.

Boateng, F.G. 2018b. Exploring the collapse of buildings in urban settings. *Proceedings of the Institution of Civil Engineers – Municipal Engineer*. doi.org/10.1680/jmuen.17.00033

Boateng, F.G. 2019. Knowing what leads to building collapses can help make African cities safer. https://theconversation.com/knowing-what-leads-to-building-collapses-can-help-make-african-citiessafer-118423 (Accessed: 18.07.19)

Bowen, A. G. 2009. Document analysis as a qualitative research method. *Qualitative Research Journal, 9*(2), 2740.

Closs, V. M. 2013. *While Rome burned: Fire, leadership, and urban disaster in the Roman cultural imagination* (Doctoral thesis). University of Pennsylvania.

Cobbinah, P. B., & Niminga-Beka, R. 2017. Urbanisation in Ghana: Residential land use under siege in Kumasi central. *Cities*, *60*, 388-401.

Coen, S. E., Ross, N. A. & Turner, S. 2008. 'Without tiendas it's a dead neighbourhood': The socio-economic importane of small trade stores in Cochabamba, Bolivia, *Cities*, 25, pp. 327–339

Feifei F 2014. Overview of Building Collapses in China. http://www.chinadaily.com.cn/china/201404/04/content_17408943.htm. (Accessed 18.07.19).

Fleddermann, C. B. 1999. *Engineering ethics*. Upper Saddle River, NJ: Prentice Hall.

Hartwell, C., 2001. *Pevsner Architectural Guides. Manchester.* London*:* Penguin Books.

Haynes, K.E., Kuklinski, A. & Kultalahti, O. 1985. *Pathologies of Urban Processes.* Helsinki: Finnpublishers

He J. & Wu J. 2016. Doing well by doing good? The case of housing construction quality in China. *Regional Science and Urban Economics* 57: 46–53.

Herbert, D.T. & Smith, D.M. 1989. *Social Problems and the City: New Perspectives,* New York: Oxford University Press.

Hodgson, R. L., Khan, I. A., Haynes, R., & Arnold, J. 2016. Rapid structural assessment of garment factories in Bangladesh. *Proceedings of the Institution of Civil Engineers-Forensic Engineering*, 169(4), 133-142.

Hurst, L. 2001. *The Custom House collapse*, pp. 11-17, in *Learning from construction failures*, ed Peter Campbell, Latheronwheel: Whittles Publishing.

Hurst, L. 2006. The rise and fall of the use of bond timbers in brick buildings in England. In *Proceedings of the Second International Congress on Construction History*.

Ifedolapo, B.H. 2015. Building Collapse: Causes and Policy Direction in Nigeria. *International Journal of Scientific Research and Innovative Technology.* Vol. 2 No. 8

Kemp, P. 1989. The Housing Questions in Herbert, D.T. & Smith, D.M. (1989). *Social Problems and the City: New Perspectives.* New York: Oxford University Press.

Kidd, A., (3rd Ed.) 2002. *Manchester.* Edinburgh University Press

Kuklinski, A. 1985. 'Guidelines for a conference on the pathology of urban processes: Ustronie vision'. In Haynes, K.E., Kuklinski, A. & Kultalahti, O. (1985). *Pathologies of Urban Processes.* Helsinki: Finnpublishers

Lawrence, L. D. and Low, S. M. 1990. The Built Environment and Spatial Form. *Annual Review of Anthropology*, Vol. 19, pp. 453-505.

Lewis, J. 2005. Earthquake destruction: Corruption on the fault line. *Transparency International, Global corruption report*, *2005*, 23-30.

Lyu, H. M., Cheng, W. C., Shen, J. S., & Arulrajah, A. 2018. Investigation of collapsed building incidents on soft marine deposit: Both from social and technical perspectives. *Land*, *7*(1), 20.

Moullier, T. 2015. *Building regulation for resilience: Managing risks for safer cities.* Washington: World Bank

Nevell, M. 2011. Living in the industrial city: housing quality, land ownership and the archaeological evidence from industrial Manchester, 1740–1850. *International Journal of Historical Archaeology*, *15*(4), 594-606.

Nicols, J. n.d. Roman Life 2: Urban Life for the Ancient Romans: Living in the city of Rome. University of Oregon Ogunlana, S. O. 2010. Beyond the 'iron triangle': Stakeholder perception of key performance indicators (KPIs) for large-scale public sector development projects. *International journal of project management*, *28*(3), 228-236.

Oosterbaan, C., Arku, G., & Asiedu, A. B. 2012. Conversion of residential units to commercial spaces in Accra, Ghana: a policy dilemma. *International Planning Studies*, *17*(1), pp. 45-66.

Pelling, M. 2003. *The Vulnerability of Cities: Natural Disasters and Social Resilience*. London: Earthscan Publications.

Pitcher, B. L. 1997. "Urban Pathology". *SSWA Faculty Publications.* Paper 442.

Polkinghorne, D. E. 2005. Language and meaning: Data collection in qualitative research. *Journal of counseling psychology*, *52*(2), 137.

Premium Times 2018. "Two feared dead, many trapped in Abuja building": https://www.premiumtimesng.com/news/headlines/280574-developing-story-two-feared-dead-manytrapped-in-abuja-building-collapse.html (Accessed: 18.07.19).

Quang, N. & Kammeier, H. D. 2002. Changes in the political economy of Vietnam and their impacts on the built environment of Hanoi, Cities, 19(6), pp. 373–388.

Reuters. 2016. Death toll in Kenya building collapse rises to 49: police: http://www.reuters.com/article/us-kenyaaccident-idUSKCN0XZ0IZ (Accessed: 18.07.19).

Soane, A. 2016. Learning from experience to avoid collapse. *Proceedings of the Institution of Civil EngineersForensic Engineering*, *169*(4): pp. 127-132.

Sparke, P. 2004. Studying the modern home. *The Journal of Architecture*, 9: 4, 413 – 417

Subbarao, H. 2016. Editorial. *Forensic Engineering*. Vol. 169 (4), 121 – 122

Sutton, K. & Fahmi, W. 2001. Cairo's urban growth and strategic master plans in the light of Egypt's 1996 population census results, Cities, 18(3), pp. 135–149.

Symonds, J. 2005. ‘Dirty Old Town? Industrial archaeology and the Urban Historic Environment’, in Gwyn D & Palmer M, (eds), *Understanding the Workplace. A Research Framework for Industrial Archaeology in Britain*. Industrial Archaeology Review XXVII, 57-66.

Tam, C. M., Deng, Z. M., Zeng, S. X., & Ho, C. S. 2000. Quest for continuous quality improvement for public housing construction in Hong Kong. *Construction Management & Economics*, *18*(4), 437-446.

Tchamba, J. C., & Bikoko, T. G. L. 2016. 'Failure and Collapse of Building Structures in the Cities of Yaoundé and Douala, Cameroon from 2010 to 2014'. *Modern Applied Science*, *10*(1), 23. The Guardian. 2016. ‘Owners of collapsed Nairobi building 'had no occupancy permit'. See: https://www.theguardian.com/world/2016/apr/30/owners-collapsed-nairobi-building-kenya-nooccupancy-permit (Accessed: 18.07.19).

Tuchman, G. 2003. ‘Historical Methods’. In Lewis-Beck, M., Bryman, A. E., & Liao, T. F. (2003). *The Sage encyclopedia of social science research methods*. Sage Publications.

Watt, D. S. 2007. *Building Pathology: Principles and Practice*. Oxford: Blackwell Publishing Limited

Windapo, A. O., & Rotimi, J. O. 2012. 'Contemporary issues in building collapse and its implication for sustainable development'. *Buildings, 2*, 283-299.

Wisner, B. Blaikie, P. Cannon, T. & Davis, I. 2003. *At Risk: Natural Hazards, People’s Vulnerability and Disasters.* New York: Routledge

Yeboah, E., & Obeng-Odoom, F. 2010.' 'We are Not the Only Ones to Blame': District Assemblies' Perspectives on the State of Planning in Ghana'. *Commonwealth Journal of Local Governance*, pp. 78 – 98

SMALL-SIZED CONTRACTOR'S CAPACITY AND COMPETITIVENESS: INDONESIA CASE FOR ROAD REHABILITATION PROJECTS

Muhamad Abduh, Adhi Prabowo, Fauziah SCS Maisarah

Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Bandung, Indonesia

Abstract

Categorized as small, small-sized contractors face many challenges to build their capacities as well as their existences due to small portion of profit they can earn yearly and very competitive environment they operate. However, their numbers are majority in Indonesia, i.e., about 89% of total registered contractors. This paper discusses a study on small-sized contractor's needed capacity and competitiveness in Greater Bandung area to support road rehabilitation projects in the area. Factors related to competitive measurements were developed based on literatures and validation to the Indonesia's construction industry environment. the needed capacity is developed based on the factors. The interview and survey to 15 small-sized contractors of road rehabilitation works was used as the methodology of this study. Results of this study show influencing factors to the competitiveness and the needed capacity that suit to small-sized contractors. Proposed updates on classification criteria and requirements for permit to establish new contractor businesses is necessary based on this study.

Keywords

Capacity, competitiveness, construction, contractor, road rehabilitation, small-sized

Introduction

Indonesian construction sector has been growing rapidly in the last 5 years due to significant additional portion of government budget given to infrastructures. Its growth has reached 6.8% per year and contribution to GDP was 10.4% that were considered as the highest and very significant, compared to previous year and with Indonesia's economic growth of 5.2% in 2018 (Statistics Indonesia 2019). This has been majorly due to rapid development of infrastructure by the government with value more than twice of previous periods; government spending (including state-owned companies) on infrastructure takes 81% of total infrastructure development and the rest of 19% was contributed by private sectors. This may mean good business opportunity for contractors in Indonesia.

The number of contractors in Indonesia is considered high. The latest data on the National Board for Construction Service Development (LPJK), the total registered construction companies are 141,959; only 987 firms or 3% are categorized as large and 8% or 18.631 firms were categorized as medium, while most of the registered construction firms are small-sized (89%). However, some of the small-sized construction firms are unable to sustain in business, with very competitive market, less than 10% of the construction market. Most of the small-sized contractors operate to support individual owners in private sectors and to support rehabilitation works for government's public infrastructure. Around 87% of the construction market is controlled by the large contractors, while small-sized contractors take as much as 6% of the construction market in Indonesia (CNBC 2018). On the other hand, the number of registered construction companies is decreasing.

The same picture is applied on the regional small-sized contractors, such as in West Java Province where the Greater Bandung area is located and the research was taken place, as depicted in Figure 1. The percentage of small-sized contractors has been decreasing since 2016 (8,895 out of 10,560 in total), despite infrastructure investment by government was growing since 2015. In the Greater Bandung itself the small-sized contractors' number decreased from 1,325 to 1,297 and then to 445 in the last three years since 2014. Most of the small-sized contractors work on residential house projects for private sector and individual and road rehabilitation projects funded by the local government. It was believed by some practitioners that the decrease shows the phenomenon of struggling small-sized contractors in their competitive market.

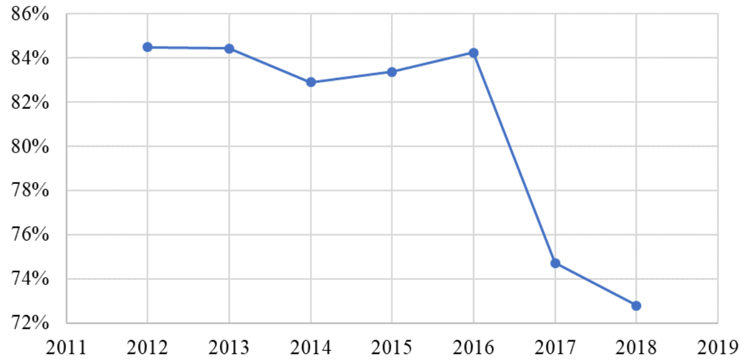


Figure 1: Registered Small-sized Contractors in West Java Province (Statistics Indonesia 2018)

In order to sustain in their businesses, small-sized contractors must improve their capacities to be competitive in their market. As the basis, there is a need to investigate capacity and competitiveness of small-sized contractors, and to identify factors that influence their competitiveness. By knowing the factors influencing the competitiveness of small-sized contractors, government could properly regulate this contractor's market to suit with their capacities.

Small-sized Construction Business

Based on the Indonesia's law concerning Construction Services, qualification and sub-qualification for contractors are established. A small-sized contractor could be a business entity that belongs to individual or a firm, and in the form of legal and non-legal entity. The small-sized contractor qualification, as mentioned in the Construction Services Act, has 3 sub-qualifications, i.e., K1, K2, and K3. The determination of the sub-qualifications of the business entity is based on the requirements issued by the LPJK; including net worth, experience and manpower or human resources, as shown in Table 1. Moreover, the determination of sub qualifications also provides limitations on the sub qualification group based on their abilities. These limits are based on the ability to carry out work, the limit on the value of one job, the number of work packages that can be taken, and the maximum number of classifications and sub classifications as shown in Table 2.

It is interesting to see the requirements for qualification, as mentioned above, are not related directly to the capacity of the contractors, such as capability to do the business in relation with suppliers. Raghavan and Kumar (2015) have mentioned that small-sized contractors are vulnerable to changes in the company's cash flow and commodity cost fluctuations. One of the factors to reduce commodity cost fluctuations according to Zhou and Zhao (2013) is a good purchasing strategy; the consideration of choosing suppliers for purchasing commodities prioritized by small contractors is location, price, speed, and quality of suppliers. This strategy may differ from one contractor that have ability to build a certain type of structure to others that have ability in building other type of structures. Johannesen (2009), the type of dominant work carried out by small-scale contractors is the construction and renovation of simple buildings, rehabilitation of road infrastructure, and specific occupational specialties.

Table 1: Requirements for setting up a small-sized contractor qualification

Sub qualification	Net worth (IDR)	Experience	*PJK*	*PJT*	*PJBU*
K1	50 Million to 500 Million	Not required	Can be combined between *PJBU* and *PJT*	1 person with a minimum certification of skills level 3	Can be combined between *PJK* and *PJT*
K2	200 Million to 500 Million	For each subclassification, the cumulative value of the works for 10 years is at least IDR 1 Billion in K1	Can be combined between *PJBU* and *PJT*	1 person with a minimum certification of skills level 2	Can be combined between *PJK* and *PJT*
K3	350 Million to 500 Million	For each subclassification, the cumulative value of the works for 10 years is at least IDR 1.75 billion in K2	Can be combined between *PJBU* and *PJT*	1 person with a minimum certification of skills level 1	Can be combined between *PJK* and *PJT*

Note: PJK: owner; PJT: technical personnel; PJBU: business administrator.

Table 2: Limitation of small qualification construction service business entities based on ability.

Sub qualification	Ability to finish the work (IDR)	One job value limitation (IDR)	Number of momentary packages	Maximum number of classifications and sub-classifications
K1	0 to 1 Billion	1 Billion	5	Maximum 4 sub-classifications in 2 different classifications
K2	0 to 1.75 Billion	1.75 Billion	5	Maximum 6 sub-classifications in 2 different classifications
K3	0 to 2.5 Billion	2.5 Billion	5	A maximum of 8 sub-classifications in 2 different classifications

Research Objective and Method

The objective of this research is to identify the needed capacity and competitiveness of small-sized contractors in Indonesia. The method of this research is exploratory descriptive that aims to be able to describe a phenomenon in more depth and to prove the existence of the phenomenon. The research was done using interview method to small-sized contractors that work for road rehabilitation projects in the Grater Bandung area.

To measure the level of competition of the small-sized contractor's market, this research used Five Forces model from Porter (1979). In this model, a description of the level of competition and the attractiveness of an industry will be obtained from the industry's profitability. To analyse the level of competition of an industry, there are five variables, which are the forces of the environment around the industry that can affect its ability to serve consumers and make a profit. The five variables referred to are as follows:

1. User's bargaining power (U). Strong consumers can gain benefit by asking the business entity to reduce prices or to improve the quality of their products and services by comparing them with other business entities. Consumers will try to reduce prices, which will reduce the profitability of business entities.
2. Supplier's bargaining power (S). Strong suppliers can obtain benefit by setting high prices, limiting the quality and service they provide, and transferring costs to the businessmen. Suppliers will tend to have strong bargaining power if business entities have a dependency on the products they offer.
3. Competition between existing companies (C). Competition among existing competitors can be seen in various forms including discounts, introduction of new products, advertising, and service improvement. High competition can limit the profitability of an industry.
4. The threat of new arrivals (A). A profitable market will bring in many new business competitors who will try to get a share in the industrial market. This will reduce profitability for all business entities in the industry unless, the existed business entity could handle the new competitor to enter the market with barriers to entry.
5. Threats of substitute products or services (T). The existence of substitute products/services can cause consumers to switch to alternative products/services. This resulted in reduced market share in the industry so that it would reduce the existing profitability.

Moreover, to identify the factors that could affect the level of competition of each force, a model from Yazýcý and Emrah (2006) is used. Therefore, there are 13 factors that could influence the level of competition in small-sized contractors, as show in Figure 2.

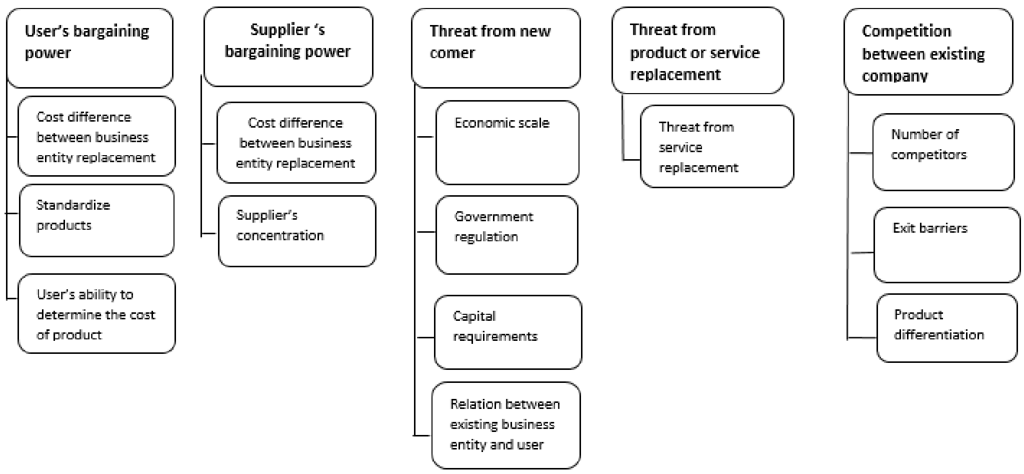


Figure 2: Factors for the Porter's five forces model (adopted from Yazýcý and Emrah 2006)

Data collection was done using interview survey method. A questionnaire was developed to guide the interview session and contained a series of questions that illustrate the factors of competition level based on the Porter's five forces model in the form of open questions. The target respondents of this study were 20 small-sized contractors in the Greater Bandung area.

The data obtained from the survey were processed further in order to convert the qualitative data gathered by the questionnaire into quantitative data. Furthermore, assessments are given to determine the level of factors affecting the competition of small-sized contractors with scores of 0 and 1; has an effect = 1, does not have an effect = 0. The value of the level of factor influencing the level of competition can then be obtained using average score of each factor with the following equation:

$$MS = \frac{\sum(f \ x \ s)}{n} \qquad \textit{Equation 1}$$

Where MS = the average score of each factor (%), f = the number of respondents who chose a factor, s = the value of the score, n = the maximum number of scores. Furthermore, to assess whether a factor affect the level of competition could be done using the following table.

Table 3: The assessment scale of factor influenced level to competition level

MS scale	Level of factor that influence the level of competition
0% - 20%	No effect
21% - 40%	Low
41% - 60%	Moderate
61% - 80%	High
81% - 100%	Highest

Research Findings

There were initially 20 small-sized contractors that are engaged in the construction of road rehabilitation in the Greater Bandung area to be interviewed, but only 15 respondents considered valid to be used in this research, since some respondents were identified to be the owners of the other companies that have been interviewed. The respondents were the owner (PJK), technical personnel (PJT), and business administrator (PJBU) of the responded companies who understand the competition of the small-sized construction market. Those contractors are mostly working for local government in rehabilitating local roads which mostly consist of overlay of flexible and rigid pavements. The complexity of the works is considered low, with high dependency to the availability of equipment and material provided by suppliers, i.e., asphalt mixing plant and concrete mixing plant. As depicted in Figure 3, there is no concentration in the small-sized contractors' market of the local government's road rehabilitation works.

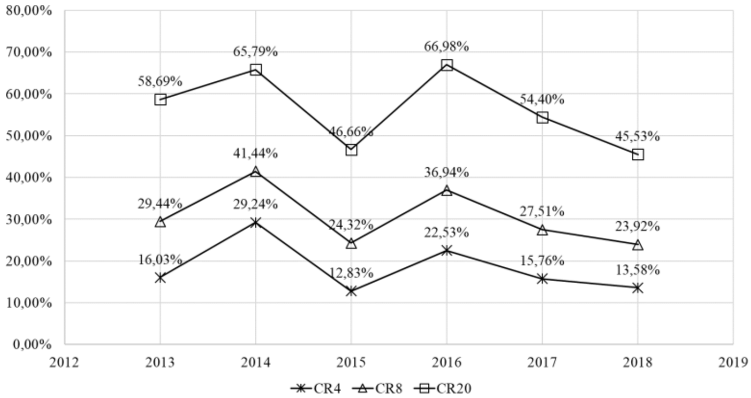


Figure 3: Concentration ratio of small-sized contractors for local government road rehabilitation projects in Greater Bandung area

The average score of each force in aggregate is shown in Table 4. While more detailed information on the average score of each factor, already ranked, is shown in Table 5.

Table 4: MS score for each force of the Porter's five forces

No.	Five forces	MS	Level
1	Threat from new arrivals (A)	40.83%	Low
2	Suppliers' bargaining power (S)	62.22%	High
3	User's bargaining power (U)	71.11%	High
4	Competition between existing companies (C)	68.89%	High
5	Substitute of product or service (S)	33.33%	Low

Table 5: Ranked factors influencing the level of competition

Rank	Factor	MS	Level
1	User ability to determine the cost of product (U)	100%	Highest
2	Standardize products (U)	100%	Highest
3	Product differentiation (C)	100%	Highest
4	Government regulation (A)	73.3%	High
5	Cost difference between supplier replacement (S)	73.3%	High
6	Number of competitors (C)	60%	Moderate
7	Capital requirement (A)	53.3%	Moderate
8	Exit barrier (C)	46.7%	Moderate
9	Threat from service replacement (T)	33.3%	Low
10	Economic scale (A)	26.7%	Low
11	Cost difference between business entity replacement (U)	13.3%	Low
12	Relation between existing business entity and user (A)	10%	Low
13	Supplier's concentration (S)	6.7%	Low

Discussion

It can be seen from Table 4 that the intensity of user's bargaining power force (U) is high and relatively the highest (71.11%) compared to other four forces. Two other forces that are considered high are competition between rivalry (C), that is 68.89%, and supplier's bargaining power (S), that is 62.22%. While the threat from new arrivals (A) and substitute of products (T) are considered low.

Since small-sized contractors in this research are operating in road rehabilitation projects from local government, there is a high dependency to the government's procurement system. There are almost no other users that demanded road rehabilitation works, except the local government. Therefore, it is obvious that the local government's bargaining power (U) is considered high and the highest compared to other forces. Moreover, the factors related to user's bargaining power, which are user's ability to determine cost of product and standard product have maximum score of MS (100%) and considered as the highest; ranked as 1 and 2 (see Table 5).

In the Indonesia government procurement procedure, the owner's estimate (OE) becomes the highest value for the contractors to offer. Moreover, very low quotation, lower than the OE 80%, will be considered as unacceptable. Moreover, the road rehabilitation works, especially overlay works for rigid and flexible pavements, are considered not complicated and have been standardized by the ministry of public works in Indonesia, therefore many contractors could perform the works relatively easy.

However, the other factor of user's bargaining power, i.e., cost difference between business entity replacement, is considered low one (13.3%). This is related to the procurement system of the government that would not let the change of contractors during the execution happen; the contractors will face harsh consequence if not performing well and changed during the execution of the contract, such as penalty, claimed performance bond, and black listed. However, those threats from government for not well performing are not considered to have high influence on the competition. It may due to low entry barrier set up by the government, so a blacklisted contractor still can operate with a new set up company or borrowing other company to get future works.

From the point of view of competition between existing companies (C), the product differentiation is considered as highest as reflected by the standardized product of road rehabilitation works. With majority of the existing companies could perform well to meet the standards given by the local government for road rehabilitation works, therefore there will be no chance to have product differentiation that will lead to more competitive market.

There are two factors that are considered high in Table 5, i.e., government regulation and cost difference between supplier replacement (73.3%). The government regulation factor is related to entry barrier to new arrivals, which is considered as easy and therefore the entry barrier is low. With this situation, many newcomers will jump into the market and compete with the existing companies. This also relates to the requirements for qualification and sub qualification of the small-sized contractors set up by the LPJK; in other words, the requirements are too easy and not reflecting the capabilities needed.

The supplier's bargaining power is considered high, mostly due to high influence of the cost to change the supplier to the competition level. This is related also to the government's conditions of contract where the contractors cannot change the supplier easily after the contract signed. Any changes of supplier should have approvals from the owner. However, the owner, which is the local government, is very familiar to all suppliers available in the Greater Bandung area with their performances.

Based on the results above, the capabilities that the small-sized contractors operating in Greater Bandung area for road rehabilitation project, based on the highest influencing factors are suggested as shown in Table 6. As listed, the capabilities needed to embrace the factors that has high influence on the competitiveness are related to techniques, technology, project management, and supply chain management. It means that requirements for qualification and sub qualification should be evaluated to accommodate the need to have small-sized contractors that capable and therefore could be competitive in their markets. The potential revisions for the requirements of qualification and sub qualification are more on the specifications for technical personnel (PJT) and business personnel (PJBU). This leads to the need to have specific experience in trainings and education for such personnel requirements.

Based on the results, more research is needed to identify the same issues with other classification of the small-sized contractors in the Greater Bandung area, i.e., residential buildings, that is also occupied by large number of small-sized contractors. However, this market is mostly regulated by private and individual. Therefore, less data available is expected to support such research in the future.

Table 6: Capabilities to embrace the high influencing factors to competitiveness

No.	Factors influencing competition	Capability
1	User ability to determine the cost of product (U)	Cost estimation method, direct quotation from the supplier, risk identification
2	Standardize products (U)	Technical skills, construction method, equipment, long relationship with supplier
3	Product differentiation (C)	Enhancement in delivery and services, quality assurance
4	Government regulation (A)	Long term relationship with users
5	Cost difference between supplier replacement (S)	Long term relationship with suppliers for strategic commodities

Conclusion

The paper discusses the needed capabilities and competitiveness of small-sized contractors operating in Greater Bandung are for road rehabilitation projects. User's bargaining power, competition within the market, and supplier's bargaining power are considered the forces that shape the competitiveness of the market. However, factors that have high influence on the level of competition are user ability to determine the cost of product; standardized products; product differentiation; government regulation; and cost difference between supplier replacement. Some capabilities were suggested to embrace the factors influencing the level of competition that should be considered as potential revisions to the requirements of qualification and sub qualification of small-sized contractors.

References

CNBC Indonesia 2018, 'IDR 100 Billion Construction Project Restriction Overcome Gaps', *CNBC Online*, https://www.cnbcindonesia.com/news/20180115103227-4-1456/pembatasan-proyek-konstruksi-rp-100-miliar-atasi-kesenjangan, accesed on August 20, 2019.

Johannessen, B. 2009, *Training Guidelines: Contracting Local Infrastructure Works*. ILO (International Labour Organization).

Porter, M. E. 1979, 'How Competitive Forces Shape Strategy', *Harvard Business Review 57*, No. 2, page 137–145.

Raghavan, V.S., Kumar, K. 2015, 'Problem Faced by Small Scale Contractors in India', *International Research Journal of Engineering and Technology (IRJET)*, Volume: 02 Issue: 02. page 105-107.

Statistics Indonesia 2018, 'Construction in Numbers, West Java 2017', *West Java Statistics*, BPS, Bandung.

Statistics Indonesia 2019, 'Construction Indicator, Quarter III – 2018', *Statistics Indonesia*, BPS, Jakarta.

Yazýcý E.O, Emrah A. 2006, 'Competitive Micro Environment Of Small Residential Building Contractors', 1st International CIB Endorsed METU Postgraduate Conference Built Environment & Information Technologies, Ankara.

Zhou, H., Zhao J. 2013, 'Analysis on Factor to Cause the Price Changed of Building Material', *Advanced Material Research*, Vol 683, Trans Tech Publication, Switzerland, page 668-672.

INFLUENCING FACTORS IN EXTENSION OF TIME CLAIMS

Nahiyan Al-Azad[1], Wallace Imoudu Enegbuma[2], Jibril Adewale Bamgbade[3], Chukwuka Christian Ohueri[3]

[1]Faculty of Engineering, Universiti Malaysia Sabah, Kota Kinabalu, Malaysia

[2]School or Architecture, Victoria University of Wellington, Wellington, New Zealand

[3]Faculty of Engineering, Computing and Science, Swinburne University of Technology, Kuching, Malaysia

Abstract

Construction delay is a critical determining element in project success. These delays lead to cost, schedule, quality, and safety escalation and in some cases abandonment. Large amount of extension of time (EOT) claims arise during the execution phase of projects. Given the vast amount of delay factors, it is of immense importance to examine the casual relationship among delay factors which cumulate to claims for EOT. This study also seeks to identify the root causes of delay spread into other factors along the EOT spectrum. Quantitative approach was applied through a nonprobability snowball survey of construction industry professionals who regularly engage in EOT claims. Decision making trial and evaluation laboratory (DEMATEL) is applied to examine the casual relationship among the factors. The results depict that incomplete documents have the highest impact on other factors while mistakes in construction method has the least impact on other factors. The findings of this study is pivotal to the stakeholders in making strategic decisions that will significantly reduce the snowball effect of various delay causes. Also, it will enable the project managers to monitor changes and take adequate precautionary steps during execution phase to stem the likelihood of delays.

Keywords

Construction, delays, extension of time (EOT), DEMATEL, project manager (PM).

Introduction

The issues of delays in the construction industry is a global phenomenon. The construction industry in Malaysia is an important sector due to its huge contribution to the country's economic development, Foreign Direct Investments (FDI) and employment opportunity. Malaysia GDP from the construction industry is seen to have an increasing trend by the 1st quarter of 2018 which is expected to continue to rise in the months ahead (Trading Economics 2018). In Malaysia, the definition of a successful construction project is determined by project completion within the allocated time, budget, and in line with the project stakeholders' requirement. Besides, benefit to contractors, functionality, absence of claims and court proceeding and "fit for purpose" for the user have also been used as way of measurement of success in a project (Jatarona et. al 2016). Nevertheless, about 70% of the project in the construction industry are delayed due to various causes. Despite the proper planning done to complete the project within the allocated timeframe, it is extremely rare that a project is completed within the allocated timeframe (Ghenbasha, Sabki, Ayoob 2016). The nature of the delays in construction industry is such that it is not due to a single event occurrence but in fact it is due to the multiple event that develop slowly during the construction phase (Acharya, Kim, Lee 2014).

Figure 1: Malaysia GDP from construction (Department of Statistics, 2018)

As a result, the project will experience issues such as unexpected cost escalation. Once a project is delayed, contractors files a claim for Extension of Time (EOT). As some delays are beyond the control of the contractors, the contractors are compensated with the time that has been lost and this compensation is what is termed as EOT. Most building contracts contain a short clauses of time extension which is to be granted by the architect. These provisions of EOT is stated in the standard form of contract in clause 23 of the Malaysia Architect Association (PAM) 2006, and clause 43 of Public Works Department (PWD) 203A. In these clauses, the architect has the right to grant the EOT to the contractor. However, granting EOT is difficult as the issue is that contractors does not provide much information to the architect on the reasons why they should be granted with EOT (Yusuwan and Adnan 2013). What it supposed to be a profitable project turns into a money losing project. This pose serious consequences for the investors and stakeholders that are involved in the project (Samarghandi et. al 2016). According to Zwikael (2016), high-quality project planning is necessary for a project to be successful. Further to that statement, it was found that construction industry uses a high quality of project planning to ensure a higher percentage of success rate. However, this statement does not reflect the current situation that is occurring in the construction industry. It is reported by Jatarona et. al (2016) that there are 191 delayed project overall in the Malaysian construction industry that has obtained EOT. After project completion, project team publishes post-mortem report of the project/lesson learnt report. However, there are evidence that shows that repetition of the same problem (Jatarona et. al 2016). Therefore, to solve this issue, the causes of delay should be tackled from its roots. This study aims to analyse the causal relationship between the extension of time (EOT) influencing factors by using the decision-making trial and evaluation laboratory (DEMATEL) approach. This will be achieved by the following objectives of identifying the root cause of factors influencing EOT, examining the causal relationship between EOT influencing factors and recommending mitigation strategies to prevent EOT root causes.

Extension of time

Choudhry et. al (2017) conducted a research on the major causes of discrepancies in building construction. The results show that the provision of incomplete data to designers, lack of interest by approving authorities to carefully check the design, and owner-proposed changes due to financial problems are the top three causes of discrepancies. Alade et. al (2016) explores the major causes and effects of delay in the execution of construction projects in Nigeria. The research identified 30 causes of construction delays. The analysis of the result reveals the three most important causes of delay are poor site management and supervision, contractor inexperience and client's financial difficulties. Oke, Aigbavboa & Khangale (2017) conducted a study to examine the general effects of skill shortages in the construction industry. The study reveals that shortage of skilled worker impacts on cost increase, time overrun, decrease quality, high accidents rate and more rework. A study was conducted by Subhi, Dinesh, & Resmi (2017) to review the various symptoms & causes of construction defects which occurs in construction project. The result of their study found that a defective work may cause the client to be dissatisfied. Furthermore, poor workmanship was also found to be an influencing factor to defective work. It was also highlighted that defective work may pose an impact to the financial situation on the contractor's side.

Sweis et. al (2014) study evaluated the factors affecting contractor's performance specifically in public projects. The outcome of the research found that financial difficulties faced by contractors, manpower shortage, and excessive change orders from the client are the leading factors that directly affects contractor performance on construction projects. Gamil & Rahman (2017) conducted a theoretical review by examining the causes and effects of poor communication among management team in the construction industry which is found to be one of the most challenging factors that causes a failure of a project. By using the frequency technique, out of 33 causes of poor communication, it was found that the most prevailing reason for poor management is lack of effective communication. Whereas, out of the 21 effects from poor communication, it was found that the highly repeated effect is time overrun of project.

Staiti, Othman & Jaaron (2016) research on the impact of change orders on project performance in the West Bank of Palestine reveals that change order strongly affects all the projects performance. Therefore, they conducted a research on the main causes of changes order in the West Bank by highlighting the potential effects of change orders on the Palestinian construction industry. The research discusses the effect of change order from client and consultant point of view. From the clients' perspective, the change order arises due to financial problems, change in decision or noncompliant design with clients' requirements. Consultant on the other hand issues change orders due to errors and omissions in designs, specifications or due to conflict in contract documents. On another study on change order, Desai, Pitroda, & Bhavsar (2015) conducted a research on identification of causes and effects of change order. Their research reveals that change orders are usually issued to cover discrepancy in scope of work, material quantities, and design errors by imposing a serious impact on the quality, time, and cost of projects. Lopez & Love (2011) research on the effects of design change and its impact on construction project reveals that adversely influence project performance and can contribute to project failures, worker accidents, and loss of life. The study also focused on the effect of design error associated with cost. Their research reveals that design errors affect the client by 6.85 and 7.36% of the contract value. This result was generated based on a questionnaire survey of 16.85 and 7.36% of contract value 39 respondents.

Zannah et. al (2017) performed a study to identify the causes of workers' low productivity in construction projects in Nigeria. The research reported that low wages of skilled, lack of sufficient skill acquisition centres and lack of incentive schemes for skilled workers were the most significant causes of workers' low productivity in the Nigerian construction industry. This corresponds with Ohueri et. al (2018) study which stressed the providing financial incentives to workers will increase their productivity and in turn reduce time overrun. Muiruri & Mulinge (2014) research focusses on the relationship between workers' health and safety with improper planning by the management. The purpose of their research was to investigate the health and safety measures used on construction sites, evaluate the enforcement mechanisms of health and safety regulations on construction sites and to examine the challenges encountered by the management of health and safety in construction project sites. Findings of the research revealed that the employer should take full responsibility for their workers' welfare and safety. Rauzana (2016) conducted a research through literature review to identify the factors of conflict on the construction project. The research discussed that there are many consultants from various discipline involved in a construction project, hence every consultant has different input towards the project. However, despite the differences, the consultants have one common goal which is project completion on time, and not exceeding the budget and requirement. 21 factors that influence conflict among parties has been identified and those factors were classified into three categories namely owner, consultant, and contractual. The findings of the research recommend conflict resolution. Similarly, Femi (2014) conducted a research on the cause and effects of conflict in the Nigerian construction industry.

The study identified 10 most important causes of crisis among other important factors and 5 most severe effects of conflict in the Nigerian construction industry.

Abdul-Rahman, Takim, & Min (2009) research addresses the issues of financial related delays in construction projects. The study identifies the root causes and suggest the suitable mitigation actions of financial-related project delays. Four main factors were identified from the research's literature, namely late payment, poor cash flow management, insufficient financial resources and financial market instability. The findings indicate that clients play the most important role in reducing the impact of financial problems towards the extent of project's delay. Ali & Wen (2011) research investigate the workmanship performance of construction projects associated with the number of defects occurred for new completed building. The research explores the factors that contributes to poor workmanship and possible measures to minimise the problem, and the relationship between measures identified with the factors. The research concludes that construction projects suffered from low performance of workmanship by the contractors. The most significant factor contributing to poor performance is lack of experience and competency of labours. Attar, Gupta, & Desai (2015) conducted a research on factors affecting labour productivity in the construction industry. Their research reports the survey that was directed to project managers and experienced engineers of building projects in Sangli, Kolhapur & Pune districts in India. The respondents were required to rate based on their experience on how the factors affect productivity with respect to time, cost and quality. The survey was conducted out by a set of questionnaires that identified ten most significant factors affecting labour productivity for small, medium and large companies.

Ramachandra & BamideleRotimi (2015) explored the key causes of payment delays and losses in the New Zealand construction industry. The purpose of factor analysis was to enable clustering of the inter-related causes of payment delays and losses in order to find reduced number of causes. Accordingly, the research discovered that payment issue is mainly related to contractual issues, financial strength of industry players, disputes, and shortcomings of payment processes. Ansah (2011) conducted a study to identify the causes and effects of delayed payments for completed work in the Ghanaian construction industry. The relative importance index was used and found that employers' poor financial management, conflict between parties, and delay in approval are some of the potential causes of delay in payment. Furthermore, the study suggests that delaying the payment could create financial difficulty for the construction companies and its impacts are sometimes extreme that some companies have to close down.

Extension of Time Provisions in Malaysian Contracts

The provision of delay in the Malaysian construction industry is reflected in the PAM 2006 contracts and PWD 203A. These two forms of contracts are commonly used in Malaysia. Government sector projects in Malaysia prefer to use the PWD 203A.

Extension of time (PAM 2006)

The clause 23 of the PAM 2006 discusses in detail on the issue of extension of time. The sub- clauses of clause 23 discusses information such as the process involved in assessing the extension of time, the information required to file the claim, and the acceptable causes to grant extension of time. Clause 23.8 outlines the relevant events that are acceptable in order for EOT to be granted. There are 24 events that are acceptable to grant EOT under the PAM 2006 contract

Figure 2. Delay clauses (PAM, 2006)

Extension of Time (PWD 203A)

The PWD 203 A, form of contract is commonly used by the public-sector project. It is quite similar to the PAM 2006 form of contract when it comes to the EOT section. However, it differs with PAM 2006 in terms of the number of acceptable events to grant EOT. In PWD 203A, there are only 11 events that are acceptable which is outlined under clause 43.

Figure 3. Delay clauses (PWD 203A)

Research Methodology

The first step of this study was to define the problem statement. An extensive literature review was performed to explore the factors influencing EOT. Based on these factors, a questionnaire was developed and distributed to the industry experts. The returned questionnaires were then analyzed by using the Decision Making Trial and Evaluation Laboratory (DEMATEL) method. This research uses a sampling method known as snowball sampling. Snowball sampling is a special nonprobability method for developing a research sample where existing respondents are obtained from the researcher's acquaintances. According to Katz (2006), this sampling technique is often used in hidden populations which are difficult for researchers to access, or in cases where a sampling frame is hard to establish. It is assumed that respondents are affiliated through links that can be exploited to locate other respondents based on the existing ones. According to Bell & Water (2014), a questionnaire should utilize seven (7) types of question which are verbal or open, list, category, ranking, quantity, grid, and scale. Therefore, the design of the questionnaire includes the elements as suggested by Bell & Waters (2014). The influencing factors were gathered through the literature and categorised into five (5) categories namely client, consultant, contractor, and contractual relationship. The questionnaire consists of section A and section B where section A is the demographic study of the respondents while section B is the respondents' response on the influence relationship of EOT. The influence is rated in a scale of 0 to 3 where 0 being no influence and 3 being very high influence. This scale is the standard rating scale used for DEMATEL technique (Sumrit & Anuntavoranich (2013). DEMATEL method was originally developed between 1972 to 1979 by the Science and Human Affairs Program of the Battelle Memorial Institute of Geneva. The purpose of DEMATEL is to study the complex and intertwined problematic group. It has been widely accepted as one of the best tools to solve the cause and effect relationship among the evaluation criteria. This method is applied to analyse and form the relationship of cause and effect among evaluation criteria or to derive interrelationship among factors. DEMATEL has been widely used in various field such as medical, supply chain, business, or even construction (Parchami, Jalal, & Shoar, 2017; Ortíz, Felizzola, & Isaza, 2015; Amiri et. al, 2011).

Step 1: Gather experts' opinion and calculate the average matrix Z

A group of m experts and n factors are used in this step. Each expert is asked to view the degree of direct influence between two factors based on pair-wise comparison. The degree to which the expert perceived factor *i* affects on factor *j* is denoted as x_{ij}. The integer score is ranged from 0 (no influence), 1 (low influence), 2 (noteworthy influence), and 3 (high influence), respectively. For each expert, an *n x n* non-negative matrix is constructed as $X^k = [x_{ij}^k]$, where *k* is the expert number of participating in evaluation process with $1 \leq k \leq m$. Thus, X^1, X^2, X^3,.., X^m are the matrices from m experts. To aggregate all judgments from m experts, the average matrix $Z = [z_{ij}]$ is shown below.

$$z_{ij} = \frac{1}{m}\sum_{i=1}^{m} x_{ij}^k \qquad \textit{Equation 1}$$

Step 2: Calculate the normalized initial direct- relation matrix D

The normalized initial direct-relation matrix $D = [d_{ij}]$, where value of each element in matrix *D* is ranged between [0, 1]. The calculation is shown below.

$$D = \lambda * Z \qquad \textit{Equation 2}$$

Where

$$\lambda = Min\left[\frac{1}{max\ 1 \leq i \leq n \sum_{j=1}^{n} |z_{ij}|}, \frac{1}{\max 1 \leq i \leq n \sum_{i=1}^{n} |z_{ij}|}\right] \qquad \textit{Equation 3}$$

Based on Markov chain theory, D^m is the powers of matrix *D*, e.g. D^2, D^3,…, D^∞ guarantees the convergent solutions to the matrix inversion as shown below.

$$\lim_{m\to\infty} D^m = [0]_{nxn} \qquad \textit{Equation 4}$$

Step 3: Derive the total relation matrix T

The total-influence matrix *T* is obtained by utilizing Eq. (6), in which, *I* is an *n x n* identity matrix. The element of t_{ij} represents the indirect effects that factor *i* had on factor *j* therefore, the matrix *T* reflects the total relationship between each pair of system factors by the equation below.

$$T = D(I - D)^{-1} \qquad \textit{Equation 5}$$

Step 4: Calculate the sums of rows and columns of matrix T

In the total-influence matrix T, the sum of rows and the sum of columns are represented by vectors r and c, respectively.

$$r = [r_i]_{nxl} = (\sum_{j=1}^{n} t_{ij})_{nxl} \qquad \textit{Equation 6}$$

$$c = [c_j]'_{lxn} = [\sum_{j=1}^{n} t_{ij}\ ]'_{lxn} \qquad \textit{Equation 7}$$

where$[c_j]'$ is denoted as transposition matrix.

Let r_i be the sum of i^{th} row in matrix *T*. The value of r_i indicates the total given both directly and indirectly effects, that factor i has on the other factors. Let c_j be the sum of the j^{th} column in matrix *T*. The value of c_j shows the total received by both effects directly and indirectly, that all other factors have on factor *j*. If $j = i$, the value of $(r_i + c_i)$ represents the total effects both given and received by factor *i*. Meanwhile, the value of $(r_i\text{-}c_i)$ shows the net influence by factor *i* on the system. Moreover, when $(r_i\ \text{-}c_i)$ is positive, the factor *i* was a net cause while $(r_i\ \text{-}c_i)$ is negative, factor *i* is a net receiver

Step 5: Set a threshold value (α)

The threshold value (α), was computed by the average of the elements in matrix T, as computed by Eq. (8). The calculation of the threshold is done to eliminate some minor effects elements which appears in matrix T. (Yang et al., 2008).

$$\alpha = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}[t_{ij}]}{N} \qquad \textit{Equation 8}$$

where N is the total number of elements in the matrix T.

Step 6: Generating a cause and effect relationship diagram

The cause and effect diagram is constructed by mapping all coordinate sets of (r_i +c_i, r_i -c_i) to visualize the complex interrelationship and provide information to analyse the most important factors and how affects the other influencing factors. The factors where the t_{ij} is greater than α, are selected to be shown in cause and effect diagram (Yang et al., 2008).

Results and Discussion

Respondent Demographics

100 questionnaires were distributed, and 80 questionnaires were returned back. Therefore, a response rate of 80% has been achieved for this research. The focus group of respondents that involved in this research are 69% consist of contractors and another 31% are consultants (Figure 4) who are in these type of position engineer (41%), architect (28%), project manager (20%), and quantity surveyor (11%) (Figure 5). The number of respondents also has been categorized according to their working experiences in construction industry as it reflects that the longer, they have been working with construction industry, the more experiences and information they possess. 44% of respondents have 11 to 15 years' experience, 25% of the respondents have been working less than 5 years, about 19% of the respondents have been working for over 15 years, and 12% of the respondents have been working in construction industry for about 5 to 10 years (Figure 6). The respondents also have been dealing with various types of projects. Based on Figure 7, mostly which is 81% of them are working under the building and infrastructure, followed by 13% of them working in the infrastructure only, and the remaining 6% of them are working with other projects that related to construction industry such as oil and gas. Based on the information given by the respondents in Figure 8, 56% of them agreed that every project takes them about 19 to 24 months to complete, another 25% of them found that the duration of a project completion took about 12 to 18 months and the other 19% of them could finish their project in a short time which is below 12 months. Moreover, 37% of respondents experienced projects delayed from 7 to 9 months, 19% of them faced delays in completing their projects from 3 to 6 months, and 19% of them had their project delayed for less than three months. Additionally, 13% of respondents said that their projects can also possibly delays till more than 12 months and the rest which is 12% of them said that some of their projects delayed for about 10 to 12 months (Figure 9).

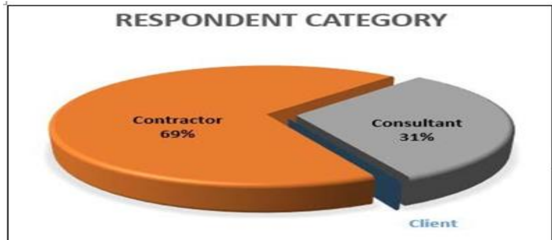


Figure 4: Respondent category

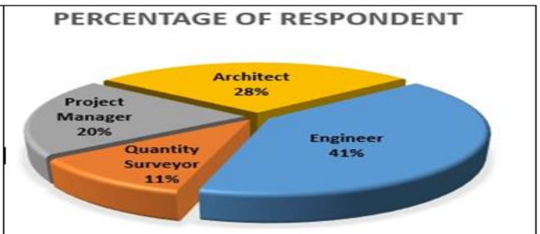


Figure 5: Percentage of respondent

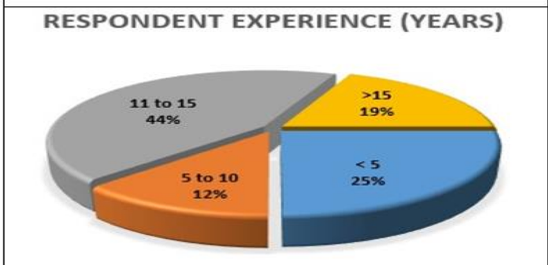


Figure 6: Respondent experience

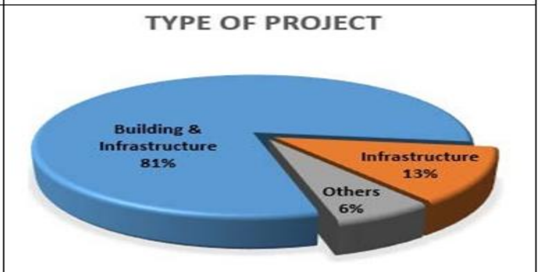


Figure 7: Type of project

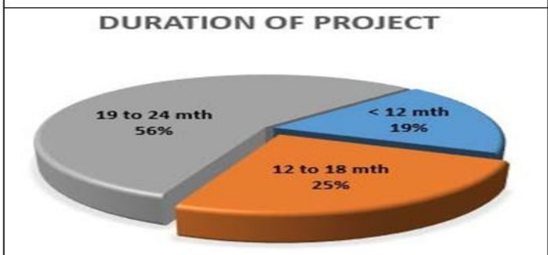


Figure 8: Duration of project

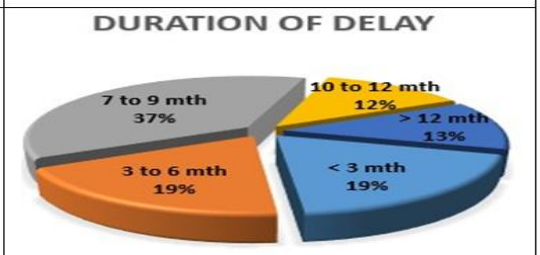


Figure 9: Duration of delay

DEMATEL Ranking

Figure 10 shows the overall result of the DEMATEL analysis. According to the graph, incomplete documents/drawing, financial difficulties of client, lack of skilled labour, defective works, shortage of manpower, poor site management and supervision, mistakes during construction, change order, labour injuries/accident in site, changes in drawings/specifications, improper planning, conflict between parties, poor subcontractor performance are under the cause category. Meanwhile slow payment, contractor's financial difficulty, low productivity, slow inspection, and approval delay are under the effect category. The highest influencing factor that causes delay for Kuching is incomplete document while the lowest is approval delay.

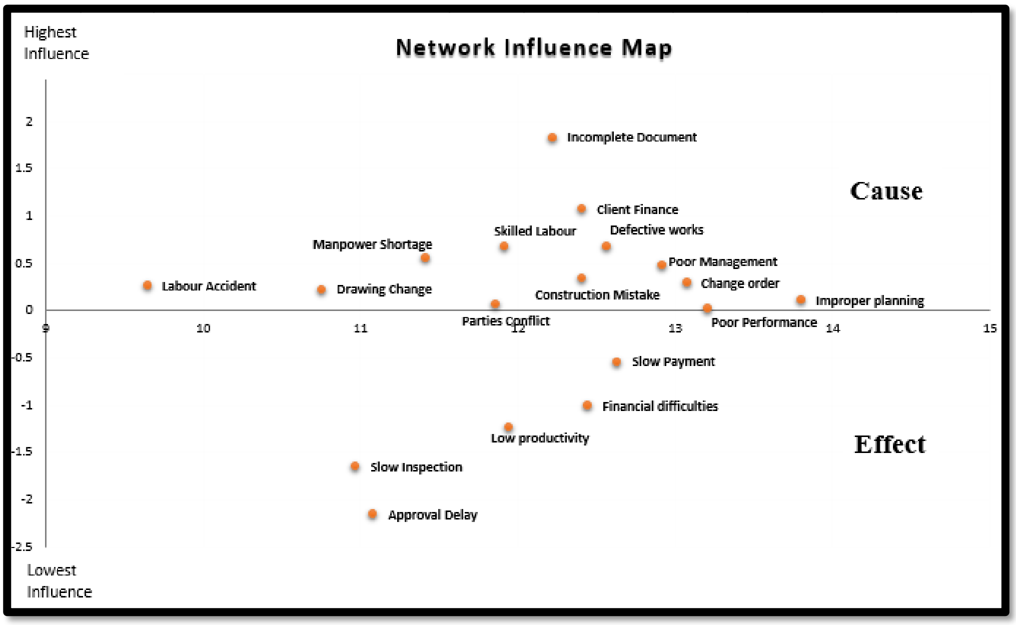


Figure 10: Network Influence Map

Incomplete Document

Figure 11 shows the 11 issues of EOT that have been affected by incomplete document which includes: change in drawing, manpower shortage, lack of skilled labour, difficulties in client's financial situation, defective works, mistake in construction method, conflict between parties, poor performance of subcontractor, improper planning, poor management, and change order. These influencing factors relationship are consistent with Choudhry et. al (2017) as it mentioned that incomplete document may lead to changes in drawing as it could arise from discrepancies between actual site condition and the planned design which also lead to sudden financial difficulty to client as the budget allocated by them may not be consistent. Incomplete documents affecting slow inspection, approval delay, low productivity, financial difficulties by contractor, and slow payment of completed work (Choudhry et. al 2017). Labour accident was found to be an outlier where incomplete documents had no effects on this element. However, according to a guide on safer construction (Charles, Pillay & Ryan 2007), they found that incomplete documents led to some labour injuries. These labour injuries are due to certain safety factor that are not factored into the design. According to Lee (2018), construction professionals involve careful documentation in safety planning in Kuching construction industry according to Construction Industry Transformation Programme (CITP) since 2015 as being spearheaded by the Works Ministry and the Construction Industry Development Board Malaysia (CIDB).

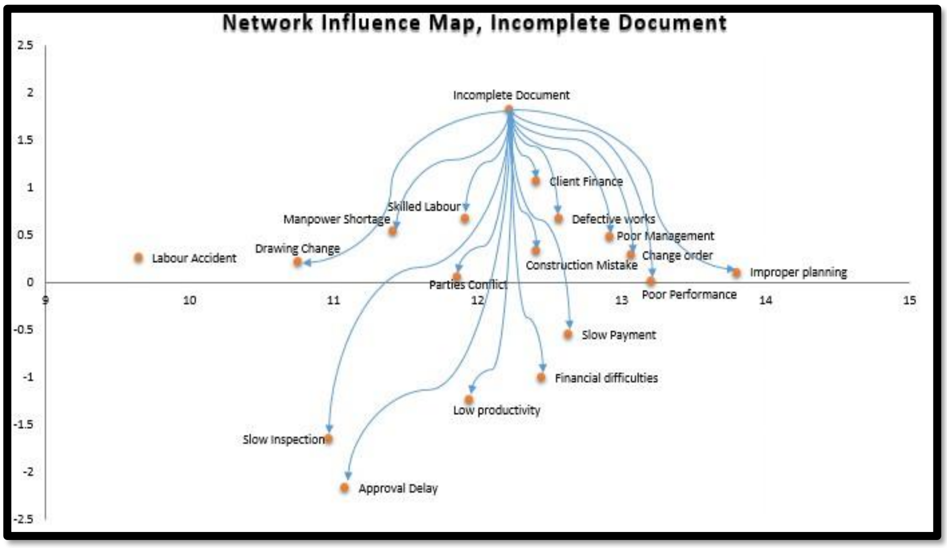


Figure 11: Network influence for incomplete document

Financial Difficulties of Client

Figure 12 shows that the client's financial difficulties lead to manpower shortage, lack of skilled labour, construction mistake, poor subcontractor performance, improper planning, poor management, and defective works. These relationships have been consistent with the research conducted by Choudhry et. al (2017) and Alade et. al (2016). However, Alade et. al (2016) stated that client's has insufficient fund may cause changes in drawing to match client's budget. The effects of clients' financial difficulty are more severe than the causes as suggested by Alade et. al (2016). As client's financial issue may cause financial difficulties to the contractors to continue the work which matches with this research where the financial difficulties could cause low productivity in the workplace. Thus, work progresses slowly due to client's insufficient funding which in turn leads to slow inspection by the consultant due to incomplete work (Alade et. al, 2016). Another factor in this research that is contrary to previous researcher's findings is slow payment. Client's financial difficulty resulting into slow payment as indicated by Abdul-Rahman, Takim & Min (2009) and Akinsiku & Ajayi (2016). In their research, client's financial difficulty ranks as the number one (1) and number two (2) respectively for late and slow payment.

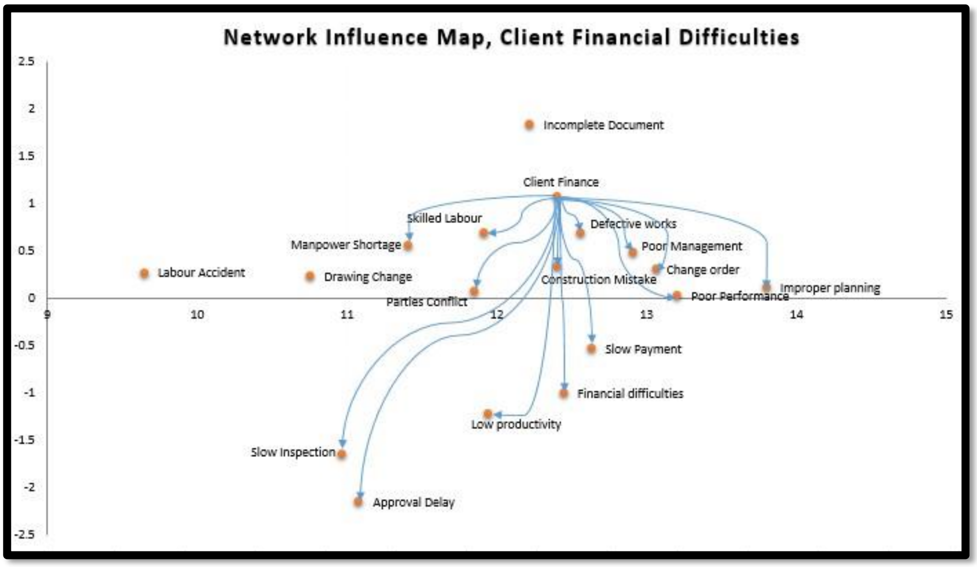


Figure 12: Network influence for financial difficulties of client

Lack of Skilled Labour

Figure 13 explains on the network influence map for lack of skilled labour. Lack of skilled labour ranked as the 3rd highest influencing factor in Kuching construction industry. Issues with lack of skilled labour may causes conflict between parties, construction mistake, defective works, change order, improper planning, poor performance, and poor management. The study conducted by Oke, Aigbavboa & Khangale (2017) outlined that having shortage in skilled labour may cause poor performance, construction mistake and defective work. Similarly, lack of skilled labour was found to cause labour injuries which is contradict to the results in this research. Lack of skilled labour was found to have no effect on labour injuries in this study due to the compulsory safety training requirement before the start of construction works in Kuching (CIDB 2018). Therefore, the labours are aware of safety related matter while at work. The effects of lack of skilled labours also agreed with the research of Oke, Aigbavboa & Khangale (2017) where it may cause the project to have cost overrun which concerns with financial difficulties and slow payment, low productivity and slow inspection. However, there is no research evidence showing that there is approval delay causes by lack of skilled labour. This perhaps occurs in Kuching construction industry due to lack of consultants or qualified individual to assess the on-going activity. As most of the projects in this research are building and infrastructure which it requires lift or escalator. In Kuching, there are only a few specialists in lift and escalator service provider which needs to cover whole Sarawak region. Limited number of lift specialist is difficult to oversee works in the whole Sarawak.

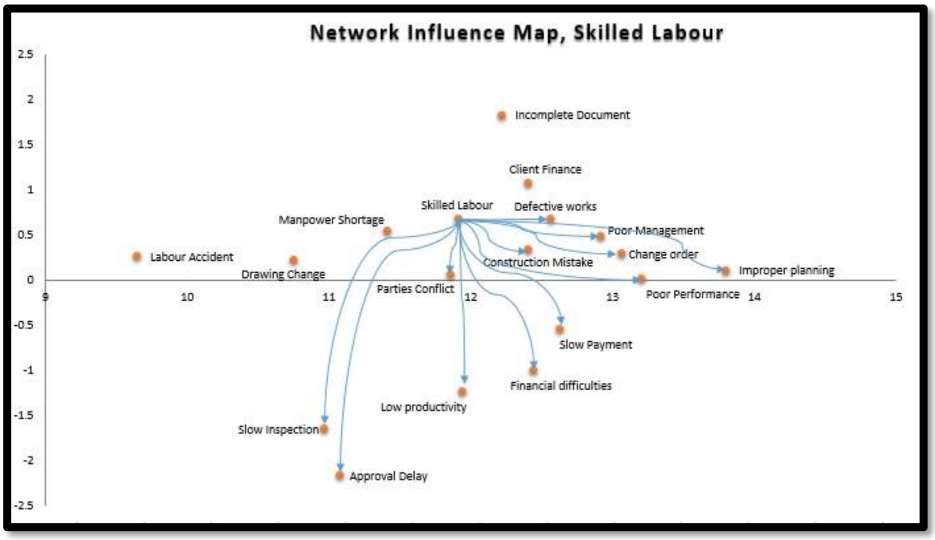


Figure 13: Network influence map of lack of skilled labour

Defective Works

As shown in Figure 14 below, defective work triggers eight (8) other issues that could cause project delay such as client finance, lack of skilled labour, manpower shortage, conflict between parties, change order, poor performance, poor management, and improper planning. A defective work majorly appears after the handover of project occurs. Once a defect appears, in certain cases, client will bear the cost if the defect appears after the liability of defect period. This cause client dissatisfaction disrupting the client's financial situation. Change order might arise due to a defective work as this will unlikely to be accepted by the client if it is due to wrong construction method or poor workmanship. This will contribute to project delay as more time will be put in for the rectification work. These two situations agrees well with finding of Subhi, Dinesh & Resmi (2017). For a subcontractor, this type of work could cause them to perform poorly especially during the rectification work. This is due to manpower shortage as the nature of the subcontractor, they might work on multiple sites, re-allocating them back to the site for rectification work which is challenging for the manager. This issue also would lead to an improper planning of work for rectification. In some cases, a defective work could cause a conflict between parties. This has been reflected in the case of *Cordon Investments Pty Ltd v Lesdor Properties Pty Ltd (2012) NSWCA 184* where the dispute arose between the two parties regarding the defective and incomplete works. It is observed that there is no connection between defective works and labour injury. However, in the construction of Hyatt Place in Nebraska, a partial slab collapsed and injured three workers who are working directly below the slab (U.S. Department of Labour 2003). Perhaps in Kuching, such case has not occurred yet. Therefore, it explains the absence of such relationship. Defective work brings some effect such as slow payment, financial difficulty for the contractor, low productivity, approval delay, and slow inspection. Subhi, Dinesh & Resmi (2017) research is consistent with these effects as their studies has emphasized that defective will lead to rectification of work, the cost will usually be bear by the contractor hence cause a financial trouble for the contractor. A low productivity also could happen among the workers perhaps due to the incompetency of the labour in the rectification work that involved.

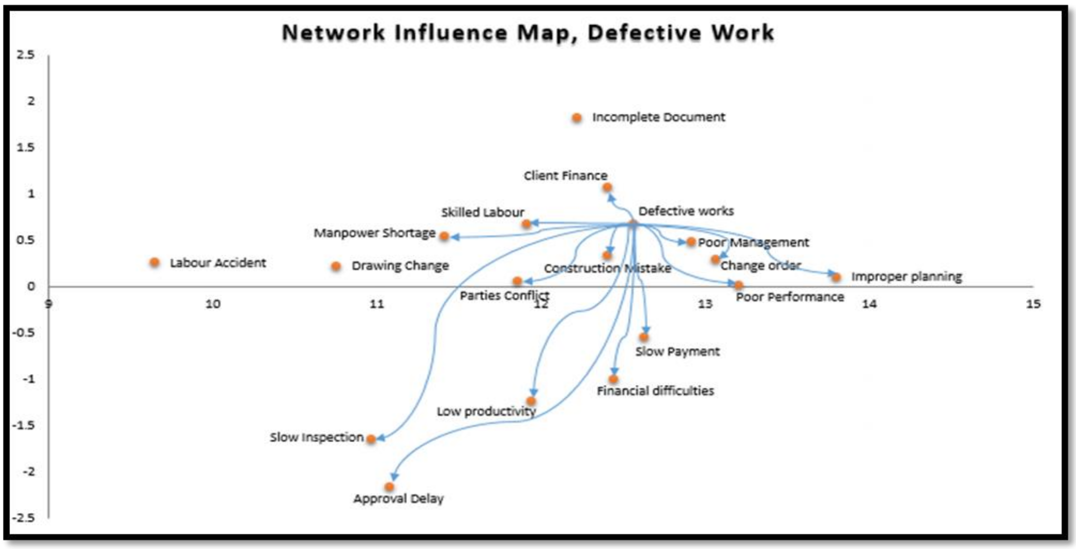


Figure 14: Network influence map of defective work

Manpower Shortage

Manpower is the key to a successful project completion within the construction period. Based on Figure 15, manpower shortage causes five (5) issues such as poor performance, improper planning, construction mistake, poor management, and defective works. Lack of manpower may affect the performance of a subcontractor in terms of financial, and reputation. This influencing factor is consistent with Sweis et. al (2014). One of the roles of managers in construction industry is to plan their manpower allocation. If there is a shortage of manpower, it might cause a difficulty in planning the task division. Based on Figure 15, manpower shortage produces effects such as low productivity, financial difficulties, slow payment, slow inspection and approval delays. Manpower shortage is found to be one of the demotivating factors for low productivity among construction worker (Sweis et al 2017). Due to manpower shortage, some workers are required to perform twice the amount of work to cover the incomplete task. This has direct link to their productivity. Hence, contractor might experience financial difficulties to pay the worker with higher rate. An effective manpower management and is a critical need for reducing labour costs and thereby it increases the profits for a contractor (Rahman, Memon & Karim 2013).

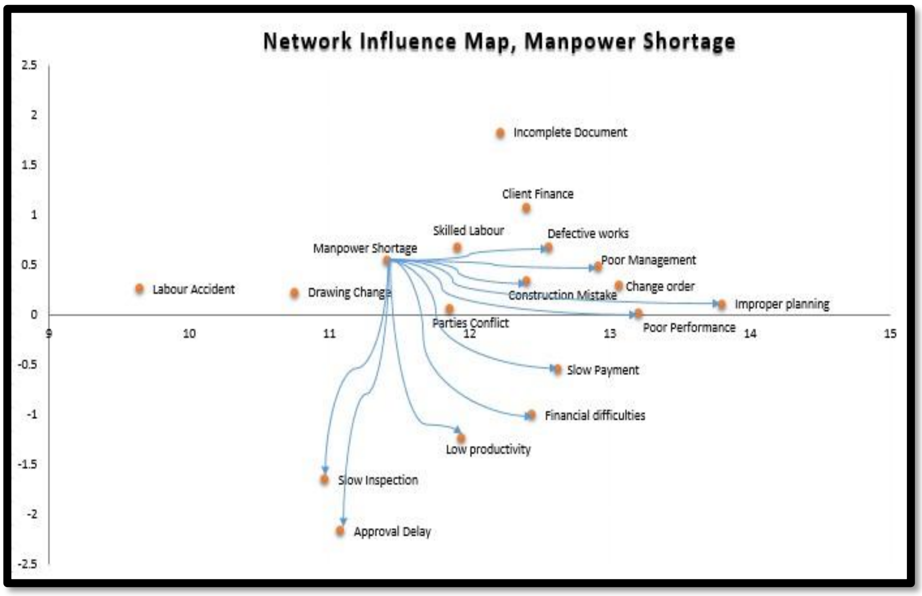


Figure 15: Network influence map of manpower shortage

Poor Management

Based on Figure 16, poor management cause six (6) other cause of delay to arise such as conflict between parties, lack of skilled labour, defective works, client finance, improper planning, and poor performance. These results are in line with Gamil and Rahman (2017) where they found in their research that poor management leads to project time overrun and it ranked the highest among the effects that they identified. Their research also reveals that there are possibilities of conflict between parties to occur due to miscommunication issues because poor management can cause improper planning due to lack of communication (Lessio et. Al 2009; Gamil & Rahman 2017; Tanko et. al 2018). Apart from that, cost overrun also occurs which will disrupt the client's finances. Rework that ranked the 4th highest could happen due to defects in work and poor performance due to poor teamwork in managing projects (Emuze & James 2013; Gamil & Rahman 2017). However, in this research, there appears to be no connection between poor management and labour accident. In other research, there are evidence linking poor management and labour accidents (Ali, Kammaruzzaman & Sing 2010; Liy et. al 2016; Gamil & Rahman 2017). According to Husin, Adnan & Jusoff (2008), construction industry in Kuching are very strict on safety management for quality construction. Therefore, the management are highly aware of safety related issues therefore there is no evidence in the connection of poor management and labour accidents. The effects of poor management could be severe as well as it might lead to project abandonment (Gamil & Rahman 2017). In this research, poor management is found to cause low productivity, financial difficulties, slow payment, slow inspection, and approval delay. Ali and Wen (2011) found that poor management may cause low productivity for a project. This is due to the management's effort of not motivating the workers. Ramachandra and Bamidele Rotimi (2015) highlighted that poor management is the main reason for contractor to experience financial difficulty and slow payment process. However, there is no evidence in other research that slow inspection and approval delay are caused by poor management.

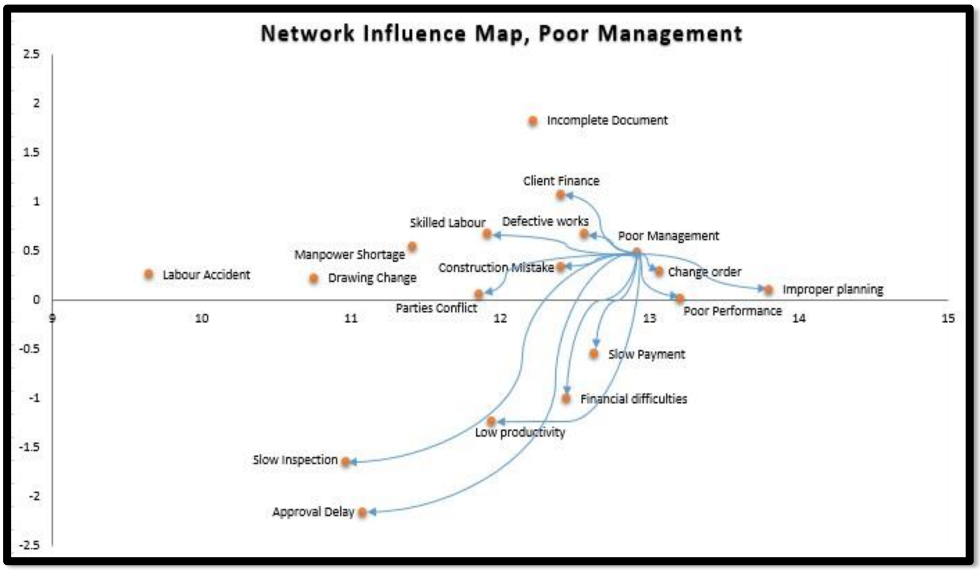


Figure 16: Network influence map for poor management

Conclusion and Recommendation

Incomplete document has the highest ranking on the reason for project delay in Kuching. It can cause seventeen (17) other influencing factors to be triggered. Every party should be careful when dealing with documents related to construction as it may cause severe effect on project delay. Low productivity ranks the lowest as it causes two (2) other influencing factors to be triggered. Issues on low productivity of worker should be taken seriously as workers' strength is one of the keys to a successful completion of a project. Some issues may cause a loop of problems hence repetition of the factors of delayed project will occur, therefore corrective action must be taken when one (1) of the eighteen (18) influencing factor arises. As this research is aimed for client and contractors, therefore, the recommendation will be given according to the categories of influencing factors. Based on the research, clients are found to cause change order, financial difficulties, and slow payment. These three (3) are related to financial situation therefore it is recommended to the clients that an understanding in cash flow and budgeting should be understood and executed in a proper way.

Consultant are found to cause changes in drawing, providing incomplete data, slow inspection of completed work, and delay approval. The link between these four (4) is the level of attention to detail and productivity of the consultants. To avoid changes in drawing and incomplete data to occur, every document should be checked by another consultant. As for consultants' productivity, perhaps the consultants could prioritise tasks that are considered critical for inspection. Contractors ability are one the key drivers for a project to be on track. However, they are found to cause poor management, financial difficulties, mistake during construction, defective works poor performance, and improper planning. All of these causes have a common root cause which is improper planning. Therefore, it is recommended that the contractors should be more careful in making their planning and should utilise risk management techniques from time to time.

The labour forces are one of the keys for an efficient and productive output of construction works. Labour issues are related to lack of manpower, low productivity, and safety related matters. Therefore, it is the contractors' role and responsibility to ensure that a constant output is maintained together with the workers are protected from safety and welfare point of view. The last categories of factors are the contractual relationship factors which causes a conflict between parties. Conflicts are caused due to various reasons which has been discussed above and the results may cause severe negative consequences to a projects reputation. However, the root cause for a conflict to occur is mainly due to communication misunderstanding. Therefore, it is suggested to the stakeholders of project to keep on improving communication between all stakeholders to avoid this issue.

References

Abdul Rahman, I., Memon, A. and Abd. Karim, A. 2012. Relationship between Factors of Construction Resources Affecting Project Cost. *Modern Applied Science*, 7(1).

Abdul-Rahman, H., Takim, R. and Min, W. 2009. Financial-related causes contributing to project delays. *Journal of Retail & Leisure Property*, 8(3), pp.225-238.

Abdul-Rahman, H., Yap, J. and Chen, W. 2015. Impacts Of Design Changes on Construction Project Performance: Insights From A Literature Review. In: *14th Management In Construction Research Association (MiCRA 2015) Conference and Annual General Meeting*.

Acharya, N., Kim, S. and Lee, Y. 2014. Factors affecting timely completion of construction projects. In: *Proceedings of the Fifth Asia Pacific Industrial Engineering and Management Systems Conference*.

Akinsiku, O. and Ajayi, O. 2016. Effects of delayed payment of contractors on construction project delivery in Nigeria. In: The Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors. London: Royal Institution of Chartered Surveyors.

Alade, K., Lawal, A., Omonori, A. and Olowokere, E. 2016. Causes and effects of delays in construction projects in Akure, Ondo State, Nigeria. *Futa Journal of Management and Technology*, pp.29-37.

Ali, A. and Wen, K. 2011. Building defects: possible solution for poor construction workmanship. *Journal of Building Performance*, 2(11), pp.59-69.

Ali, A., Kamaruzzaman, S. and Sing, G. 2010. A Study On Causes Of Accident And Prevention In Malaysian Construction Industry. *Journal Design + Built*, 3, pp.95-104.

Amiri, M., Salehi Sadaghiyani, J., Payani, N. and Shafieezadeh, M. 2011. Developing a DEMATEL method to prioritize distribution centers in supply chain. *Management Science Letters*, 1(3), pp.279-288.

Ansah, S. 2011. Causes and effects of delayed payments by clients on construction projects in Ghana. *Journal of Construction Project Management and Innovation*, 1(1), pp.27-45.

Attar, A., Gupta, A. and Desai, D. 2012. A Study of Various Factors Affecting Labour Productivity and Methods to Improve It. *IOSR Journal of Mechanical and Civil Engineering*, 1(3), pp.11-15.

Bell, J. and Waters, S. 2014. Doing your research project. 6th ed. New York: Open University Press, pp.136-155.

Choudhry, R., Gabriel, H., Khan, M. and Azhar, S. 2018. Causes of Discrepancies between Design and Construction in the Pakistan Construction Industry. *Journal of Construction in Developing Countries*, 22(2), pp.1-18.

Cordon Investments Pty Ltd v Lesdor Properties Pty Ltd [2012]184 (NSWA).

Desai, J., Pitroda, J. and Bhavsar, J. 2018. A review on change order and assessingcauses affecting change order in construction. *Journal of international academic research for multidisciplinary*, 2(12), pp.152-160.

Emuze, F. and James, M. 2013. Exploring communication challenges due to language and cultural diversity on South African construction sites. *Acta Structilia*, 20(1), pp.44-65.

Femi, O. 2017. Causes and effects of conflict in the Nigerian construction industry. *International Journal of Technology Enhancements and Emerging Engineering Research,* 2(6), pp.7-16.

Fleming, T., Ryan, N. and Wakefield, R. 2007. Guide to Best Practice for Safer Construction: Literature review 'From concept to completion'. Icon.Net Pty Ltd, pp.36-41.

Ghenbasha, M., Sabki, W. and Ayob, A. 2017. Causes of construction delay in developing countries: a theoretical review. In: *The 1st International Conference on Invention & Design*.

Husin, H, Adnan, H & Jusoff, K 2018, ‘Management of Safety for Quality Construction’, *Journal of Sustainable Development*, viewed 1 June, 2018.

Jatarona, N., Yusof, A., Ismail, S. and Saar, C. 2016. Public construction projects performance in Malaysia. *Journal of Southeast Asian Research*, 2016, pp.1-7.

Katz, H. 2006. Global surveys or multi-national surveys? On sampling for global surveys.

Lee, R 2018, "Catalysts for transformation of the construction industry", The Edge Markets, viewed 2 June, 2018, <http://www.theedgemarkets.com/content/advertise/catalysts-for- transformation-of-the-construction-industry>.

Liy, C., Ibrahim, S., Affandi, R. and Rosli, N. 2016. Causes of Fall Hazards in Construction Site Management. In: *International Conference on Applied Science and Technology (ICAST)* 2016. pp.257-263.

Muiruri, G. and Mulinge, C. 2014. Health and Safety Management on Construction Projects Sites in Kenya A Case Study of Construction Projects in Nairobi County. *In: FIG Congress 2014*. pp.2-14.

Ohueri, C. C., Enegbuma, W. I., Wong, N. H., Kuok, K. K., & Kenley, R. (2018). Labour productivity motivation framework for Iskandar Malaysia. Built Environment Project and Asset Management, 8(3), 293-304.

Oke, A., Aigbavboa, C. and Khangale, T. 2018. Effect of Skills Shortage on Sustainable Construction. In: *International Conference on Applied Human Factors and Ergonomics*.

Ortíz, M., Felizzola, H. and Isaza, S. 2015. A contrast between DEMATEL-ANP and ANP methods for six sigma project selection: a case study in healthcare industry. BMC Medical Informatics and Decision Making, 15(S3).

Parchami Jalal, M. and Shoar, S. 2017. A hybrid SD-DEMATEL approach to develop a delay model for construction projects. *Engineering, Construction and Architectural Management*, 24(4), pp.629-651.

Ramachandra, T. and Rotimi, J. 2015. Causes of Payment Problems in the New Zealand Construction Industry. *Construction Economics and Building*, 15(1), p.43.

Rauzana, A. 2016. Causes of Conflicts and Disputes in Construction Projects. *IOSR Journal of Mechanical and Civil Engineering*, 13(05), pp.44-48.

Samarghandi, H., Tabatabaei, S., Taabayan, P., Hashemi, A. and Willoughby, K. 2016. Studying the Reasons for Delay and Cost Overrun in Construction Projects: The Case of Iran. *Journal of Construction in Developing Countries*, 21(1), pp.51-84.

Staiti, M., Othman, M. and Jaaron, A. 2016. Impact of Change Orders in Construction Sector in The West Bank. In: *Proceedings of the 2016 International Conference on Industrial Engineering and Operations Management*. pp.1690-1698.

Sumrit, D. and Anuntavoranich, P. 2013. Using DEMATEL Method to Analyze the Causal Relations on Technological Innovation Capability Evaluation Factors in Thai Technology- Based Firms. *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies*, 4(2), pp.81-103.

Sweis, R., Bisharat, S., Bisharat, L. and Sweis, G. 2014. Factors Affecting Contractor Performance on Public Construction Projects. *Life Science Journal* 2014, 11(4s), p.28-.

Tanko, B. L., Abdullah, F., Mohamad Ramly, Z., & Enegbuma, W. I. (2018). An implementation framework of value management in the Nigerian construction industry. Built Environment Project and Asset Management, 8(3), 305-319.

Wegan Constructions Pty Ltd v Wodonga Sewerage Authority [1978]67 (VR).

Yang, C. 2014. Assessing the Influential Factors of Fire Rescue Using DEMATEL Method. International Journal of Innovation, Management and Technology.

Yusuwan, N. and Adnan, H. 2013. Issues Associated with Extension of Time (EoT) Claim in Malaysian Construction Industry. *Procedia Technology*, 9, pp.740-749.

Zannah, A., Latiffi, A., Raji, A., Waziri, A. and Mohammed, U. 2017. Causes of Low- Skilled Workers' Performance in Construction Projects. *Path of Science*, 3(6), pp.4.1-4.15.

CONTRACT DOCUMENTS APPRAISAL AND REWORK ROOT CAUSES CLASSIFICATION IN TENDERING STAGE OF PROJECTS

Ramin Asadi[1], Suzanne Wilkinson[1], James Olabode Bamidele Rotimi[1]

[1]School of Built Environment/ Massey University, Auckland, New Zealand

Abstract

This paper aims to identify rework root causes during the tendering stage of construction projects. Rework is a common issue for construction projects and companies are struggling to manage rework effectively. Rework has significant impacts on performance due to its influences on cost, time and quality. Rework factors are identifiable and can be used to develop a reduction model for avoiding negative impacts. Rework can be minimized by addressing their main sources. Using rework reduction approach in contract documents could enable project managers to have a better understanding of how rework occurs. This paper identifies rework causes in order to understand how they can be controlled through appropriate condition of contracts. Data analysis of rework root causes through the literature together with evaluation of contract documents was the method used for the result of this paper. Identified rework root causes from literature have been categorized and assessed in tendering stage as one of the major phases of project. Classification of rework root causes appears in the following categories of process, human resource, material/equipment, technical and other factors such as environmental and financial. Clauses and conditions of contract documents NZS3910:2013 are evaluated based on this classification. The paper suggests that rework can be managed through contracts.

Keywords

Rework causes, Contracts, Classification system, Construction projects, Tendering, NZS3910,

Introduction

Time and cost overruns have been experienced in numbers of construction projects in which rework is mostly the key factor responsible for these poor performances (Hwang et al. 2009). Construction Industry Institutes (CII) has conducted various research and studies about performance and the results show that the average direct cost of rework is about 5 percent of construction total cost. The number of studies and obtained results on relation between rework and performance in construction projects specifically in building industry are inadequate but majority of them have claimed that rework is the main cause of time and cost overrun (Love et al. 2004a; Hwang & Yang 2014). Thus, rework can be one of the main factors that influence construction performance in terms of costs and time. Mainly sources like changes, errors, omissions, failures and damage are the origins of rework. Rework also includes some changes in form of additional or missing of scope and some errors due to contractor and designers' mistakes in design stage or in construction process (Love et al. 2004).

The research on construction rework has become a core theme and contributed to the body of knowledge in construction management for recent years. Studies conducted in this field so far have focused mainly on aspects such as factors affecting rework, rework causes and impacts, mitigation and reduction models. Di Zhang et al. (2012) in their research say that investigated rework causes by other researchers have been mostly considered with two perspectives. Some believe that rework is generally linked with quality issues such as non-conformance (Abdul Rahman 1995), deviations (Burati et al. 1992; Davis et al. 1989), failures (Barber et al. 2000) and defects (Josephson & Hammarlund 1999). Some others such as Mc Tague & Jergeas (2002) and Hwang et al. (2009) have focused on rework impacts in project performance, construction practices and workforce assessment at the activity levels. In both categories rework as a non-value adding activity that seriously affect project performance are neglected by the construction industry (Shaik Ayaz Ahmed & B. Harish Naik 2016). Recently rework has been identified as a major problem that has constant contributions to schedule and cost overrun, productivity reduction, weak performance and increasing the likelihood of incidences related to safety issues in construction job sites (Love et al. 2016).

The two key factors that influence the development of construction industry are technology and management. Even though numbers of approaches in project management have emerged to improve construction performance, it is increasingly argued that the traditional approach to project management is no longer effective (Hertogh & Westerveld 2010; Priemus & van Wee 2013). Even though complexity and uniqueness are the most common known characteristic in construction industry, most of current projects still using methodologies that underestimate the dynamic environment influences (Jalali Sohi et al. 2016). Thus considering a new management methodology to help construction industry coping with problems such as rework which is raised from the nature of these kind of projects is required. Furthermore, “since last 40 years, although some new advanced technologies have been applied to some of the construction projects, still the industry’s efficiency remained low” (P. Koushki, K. Al-Rashid & N. Kartam 2005; H. Guo 2009). Obtained results from previous research simply shows that implementing an appropriate new technology is not enough solely and it should be accompanied by contemporary management concepts (Remon Fayek Aziz & Sherif Mohamed Hafez 2013).

According to (Horvath 2004; Fearne et al. 2006; Cheng et al. 2009) construction sector is one of the largest industry in most of countries with the least integration compared to other major industries. Such disintegration is maybe resulted from applying traditional approach of project management (Isnaini Janipha et al. 2015). Many of current contractors are performing modern projects and to deal with raised challenges it is time to shift from existing traditional concept to modern project management. One way to improve this situation can be attained by using standard type of contract documents and the current study will consider this key element of project to find out any relation between rework and contract clauses and its attachments. Limited evidences that initially focused on the rework causes and consequences in contract documents can be found in the empirical research literatures and it would be considered as a research gap, specifically with the viewpoint that says rework is known as an acceptable or regular feature in construction projects. This gap in the literature shows that not enough is known about the contractual terms and conditions for rework in construction projects.

On the other side, studies done on the legal contractual framework in deferent types show a potential need to make some changes in the form and condition of contracts and its relationships to improve construction sector performance. Procurement and contracting strategy plays a vital role in the success of construction projects as it establishes the foundation for cooperation amongst project parties (Chan & J.H.L 2017). Contractual agreement for construction projects acts as a permit to start the practical work after completing the procurement processes. Contract that is a confirmed document between parties is crucial as it determines the overall construction framework including responsibilities structure for each party, stakeholder‘s authorities, covering risks and any other relevant issues, which may happen during the execution of construction project. As a result, two aspects of the literature review that need to be carried out are construction contracts originated from procurement system and construction rework as a drawback in processes.

Shaik Ayaz Ahmed (2016) believes that little is known about the background and sources of rework and it has remained as an intrinsic problem. Several rework studies to identify and classify the main root causes of rework have been done and despite the facts that rework has a great impact on the project performance there are few concrete results have been reported comparatively (Hwang et al. 2009). In order to manage the impacts of rework on performance, rework root causes need to be identified and classified at the beginning of the project. However, most of construction companies are reluctant to acknowledge the existence of rework in their projects as it affects their reputation (Love et al. 2016). Hwang states that it is very important for project managers to recognize the various impacts of rework specifically when the cost is affected. There is a great need for project managers to minimize rework through a model that can effectively address main sources of rework (Hwang et al. 2009). Thus, proposing a reduction strategy without fully understanding of contributing factors related to rework occurrence will not be an effective way and to overcome this issue a comprehensive list of all identified rework root causes to make improvement is required. By using the new concept of project management this paper sets out to combine the literature on matters of construction contracts, including the terms and conditions "clauses and attachments of contract", and construction rework altogether in order to propose a practical contracting framework to manage rework in construction projects.

Literature Review

Contract definitions

Totterdill (2006) simply defines construction contract as a legally binding agreement between two parties, the owner that sometimes called employer or client and the contractor. In one side client defines the project, decides for the project requirement, gives instructions, supervise the whole processes, pays for the construction cost and finally possess the completed project. In the other side, contractor works on the project to build it and be paid for the job done. This agreement works as a guideline for controlling the relation of client and contractor. Contract specifies required procedures details, and changes may happen to work compare to the contractor‘s offer and the payment method from the employer side. It clearly refers to the bodies that have to be taken the responsibility of any unexpected problems that mostly results in delay and over budget. A contract needs to be clear without any uncertainty for parties; it should clearly define what is needed to be done, how schedule to be controlled and how much have to be paid for the project (Kelvin Xi Z. 2010).

Contracts type

Typically, a standard contract is including the following parts "Tender documents, offer, agreement, letter of acceptance, contract conditions, technical documents such as drawings, spec, bill of quantities, etc". Based on Broome‘s model there are two general sections of traditional contracts and relation contracts. When client specify all requirements of project not only including practical issues but, all individual participants, which is a purely traditional contract. This type is common in New Zealand known as standard contract condition of NZS3910 (Henderson 2004). Basically, non-traditional contracts' attention is on relation rather than other aspects. Henderson‘s survey (2004) showed 58 percent of New Zealand construction projects were commonly on traditional method of tendering, but later on Shestakova (2005) revealed a trend towards using procurement strategies with more relationship between partners.

Main standard contracts in New Zealand

NZS3910 - Condition of contracts for building and civil engineering construction, which is used as a current basic document for contracting in New Zealand construction industry is known as NZS3910 issued by Standards NZ and first published on August 2003. The main aim of this standard document is to produce a straightforward flexible document which includes all essential commercial provisions and which may be used for all types of engineering and building work with a variety of administrative arrangements. Different industry institutions have made some variations on NZS3910 for special purposes. New Zealand Registered Master Builders Federation (MBF) has raised the prompt for establishing such a standard contract variations to refer the contractual situation on comparatively straightforward projects with the absence of the engineer role. As an instance NZS3915 is a standard document for building and civil engineering construction when an architect, surveyor and other suitable person either a direct employee or another one is not available to act as Engineer to the contract. In addition to these two common standards for contracts there is three main other contracts developed by New Zealand Institute of Architects (NZIA) known as SCC "the standard condition of contract", NBC-G "the national building contract, General" and NBC-MW "the national building contract, Minor work".

Rework definitions

Oyewobi et al. (2011) say that rework has represent a new terminology in construction dictionary and it happens when an element of work fails to meet customer requirements, or when the completed work does not conform to the contract documents. According to (Love 2002) there are various interpretations of rework in the construction management literature, including quality deviations, nonconformance, defects, and quality failures, which all vary. Mills et al. (2009) reported that a lack of differentiation between these terms "error, fault, failure, defect, quality deviation, non-conformance, quality failure, snag and rework" can lead to inaccurate, incomplete measurements and cost determinations, and possibly inappropriate strategies for reducing their occurrence (Forcada et al. 2017). Therefore, there is a little evidence of a reduction in rework mainly because these terms are used interchangeably to describe imperfections in construction projects (Aiyetan 2013; Hwang et al. 2014; Kakitahi et al. 2014; Taggart et al. 2014; Jingmond & Agren 2015).

Some of the given definitions of rework by previous researchers are presented as the followings chronologically. "The process by which an item is made to conform to the original requirement by completion or correction or doing something at least one extra time due to non-conformance" (Ashford 1992). "Unnecessary effort of redoing a process or activity that was incorrectly implemented the first time" (Love et al. 2000). Activities in the field that have to be done more than once in the field, or activities that remove work previously installed as part of the project (Rogge et al. 2001). The same definition has been given by Robinson et al. (2004) with excluding change orders and scope changes by the owner. Activity that must be redone, because it was not done the first time following by the requirements (Hwang et al. 2009).

The nature of rework

Sommerville (2007) says that in construction industry, rework has become a norm and some researchers have looked at it as a right, which is inevitable and acceptable, however Hwang et al. (2009) believe that there is generally an absence of systems within projects to monitor and control rework. Although some innovative approaches have been developed to manage and control rework occurrence, rework in construction projects has nonetheless continued persistent (Simpeh et al. 2015). Despite the significance of rework, there are few industry standards available for defining, quantifying and classifying field rework. To find out more about rework root causes different perspective and breakdown structures have been used by previous studies. In most of them, rework root causes have been classified through conducting a quantitative analysis using statistical state for measuring rework impacts on performance and there is little common aspects have been addressed to find an appropriate rework mitigation approach (Zhang et al. 2012).

In addition, according to (Love et al. 2004) there have been numerous government initiatives such as Australian Procurement and Construction Council (APCC) reports that have criticized the industry for its fragmented nature, lack of coordination and communication between participants, adversarial contractual relationships, lack of a customer supplier focus, price based selection, and ineffective use of technology. Such poor organizational and management practices have contributed to time wastage, unnecessary costs, increased errors, and misunderstandings, which have invariably resulted in rework occurring in projects (H. Abdul Rahman 1993; M. Cnudde 1991; P.E. Josephson & Y. Hammarlund 1999). Meanwhile construction tasks are typically divided between two or more groups such as professional and trade entities like contractors and subcontractors, which frequently operate independently of each other. Such an environment provides the ground for rework occurrence and construction organizations should give more attention on improving the processes that affecting rework.

Sources of rework

The discussions presented by Love et al. (2005) about flow of project information suggest that the major cause of rework is uncertainty. Koskela & Huovila (2000) emphasized that this uncertainty is generated by poor information, the information which often is missing, unreliable, inaccurate and conflicting (Simpeh et al. 2015). Another major source of rework is Non-Conformance that defined as deviation in terms of quality during construction. Whenever there is a deviation in quality, a non-conformance report (NCR) is issued. This report leads to rectification, repair or rework of an activity that ultimately result in time and cost overrun (Maheswari et al. 2016). Numbers of reasons and items have been identified as rework causes since the year 1988. More detail of each of these items for tendering stage with reference to the most recent studies in last ten years will be presented in this paper to provide a comprehensive list of identified rework root causes for that particular phase of project.

Impacts of rework on project performance

Love (2002) reported that the costs of rework in civil and heavy industrial engineering projects have been source of worries for construction stakeholders because the costs are gradually increasing. The adverse consequences of rework include reduced profit, loss of market share, damaged reputation, increased turnover of management and workforce, lower productivity, higher costs, and finally, costly litigation between participants over responsibility for overruns and delays (Love et al. 2004). Rework is produced as a result of poor management practices and week organizational structures and these unwanted organizational and management practices have contributed to time wasting, unnecessary costs, increased errors and misunderstandings, which have invariably resulted in rework occurring in projects (Abdul Rahman; 1993, Josephson & Hammarlund 1999; Love et al. 2004). Such rework may result in overtime, additional hiring of resources, schedule slippage, or reductions in project scope or quality. Palaneeswaran et al. (2006) argued that the direct impact of rework on the project is identified to consist of: additional time to carry out the rework, additional cost to rectify the occurrence, more materials for rework and wastage, as well as consequential increase in labor cost to fix the defect plus related extension of manpower supervision. In addition, Wasfy (2010) believes that rework leads to clients and contractors dissatisfaction and Oyewobi et al. (2011) in reference to many reported cases claim that rework has a negative impact on the performance of projects in terms of cost overrun, time overrun and dissatisfaction of the participants in the project.

Rework classification systems

According to Hwang et al. (2009) analysts have suggested that rework is often due to the complicated characteristics of the construction processes. Many of vary methods and definitions of rework extracted from previous studies did not address how construction rework is identified as it happens in the field.

Occurrence of rework in construction industry is very common and significantly project success is affected by this phenomenon and construction companies are not able to control this issue mainly because rework reasons and causes have been remained unknown (Gui Ye et al. 2014). Fayek et al. (2004) claimed that having a precise field rework definition in construction projects and an industry wide standard in order to classifying and measuring rework impacts is required.

To classify identified rework and its root causes, different approaches have been used in recent years. For example, Burati et al. (1992) have proposed a system including main project activities like design, construction, fabrication, transportation and operability at first level and rework causes and its source at second and third level. Following by that Robinson (2004) presented a rework classification system based on Cause and Effect (CE) diagram in five categories consisting of engineering, construction planning, leadership and communication, material and equipment, and human resources. Furthermore another classification system shows rework root causes in three categories of Client related, Design related, and Contractor related factors, including subcontractor and site management (Love & Edwards 2004). Similarly, Ibrahim Mahamid (2016) conducted a study in the west bank in Palestine to analyze rework and identify most influential rework causes in residential building projects. He has classified the causes in 4 groups of contractor related causes, client related causes, consultant related causes and environmental causes.

Rework reduction strategies

Love et al. (2005) claimed that the occurrence of rework in construction is system orientated, and until rework is eliminated, attention must be given to preventing it from happening. In addition, organizations should focus attention on improving the processes of affecting rework. Thus, managers need to accept that rework will occur, but the extent to which it occurs must be controlled and minimized. As a result, project management roles can provide an effective means for tracking rework occurrences and thereby implementing suitable management measures to reduce the impacts on productivity and project performance (Palaneeswaran 2006). Hereafter some of the strategies and methods applied by previous researchers in order to reduce or minimize rework in construction industry have been presented that will consist of some important scholars from 1989 to 2017.

Burati et al. (1989) argued that rework can be significantly reduced or eliminated when total quality management (TQM) is applied in conjunction projects with reward schemes. Then (Faniran, et al 1999) reported that effectiveness of efforts in planning within contractor and its subcontractors and suppliers pushes projects to be more succeeded because design related rework in the form of change orders is the major source of rework in construction projects. Sterman (2000) used system dynamics models to captures the change in projects through the rework cycle formulation and later on Love et al. at the same year employed the causal loop diagrams to gain insight into the cause and effect relations between scope changes and construction project outcomes (Kiavash Parvan 2012). A Design and Construction Rework Minimization (DECOREM) model had been developed and applied by Love et al. (2000) to simulate a number of practical scenarios that can be used to reduce design errors and rework. DECOREM aim was to provide an insight and better understanding of the factors that influence the occurrence of design errors in contracts documentation. Pena Mora & Li (2001) proposed a framework to overlap two sequential activities to minimize the risk of rework in downstream activity using the concept of upstream evolution rate and downstream sensitivity to change in upstream parameter (MA. Hossain & Chua DKH 2013). To reduce rework in projects Love et al. (2004) proposed number of design and production management strategies such as understanding client requirement, auditing contract documentation, implementation of quality management practices and use of last planner approach. Furthermore, Blacud et al. (2009) described a framework of characterizing the sensitivity of downstream construction activities to minimize the risk of construction rework. In the same year Hwang et al. advised that pre project and quality management plans should be drafted with an understanding of the causes of rework in order to minimize its impact.

In the year of 2012 Di Zhang developed a generalized conceptual model for a rework reduction program (RRP) to reduce rework by managing a continuous improvement loop with four functional processes of tracking and cause classification, evaluation of rework and its causes, corrective action planning and integration of changes into the total management system. Hossain MA & Chua DKH (2013) conducted a research to propose an optimization approach leading to minimize rework by choosing a strategy on overlapping design and construction activities incorporating early information sharing in design phase. Ying Li & Timothy R.B. Taylor (2014) by implementing system dynamics methodology examined the impact of design rework on construction project performance as it clearly illustrates the dynamics of design error induced rework in the construction project development process. In the same year Taggart et al. (2014) conducted an action research approach about the role of the supply chain in the elimination and reduction of construction rework and defects as an action research approach. The results of their research indicated that the supply chain participants, when adopting more collaborative and proactive approaches, can identify root causes and suggest possible cost effective solutions to avoid future repetition. In addition, Love et al. (2016) emphasized that by having an authentic leadership as well as actively engaging with contractors and focusing on continuous improvement rework could be significantly reduced. Following by that Forcada et al. (2017) used regression model for rework prediction based on original project conditions which enabled them to put strategies in place prior to the start of construction. This helped them to minimize uncertainties and reduce the impact on project cost and schedule, and thus improve productivity and performance.

To summarize and in order to having minimum of rework occurrence or to reduce it in construction projects some actions can be taken such as changes controlling, value management, use of information technology, design scope freezing, supervisors training, quality control plan, and project inspection (Moataz Ahmed Farouk Wasfy 2010). Meanwhile, to prevent rework, various approaches are being used, which include visualization enabled technologies (building information modeling (BIM), modularization, lean construction, constructability reviews between design and construction teams, and relationship based procurement (RBP) (Love et al. 2016). Although much literature exists concerning rework reduction, there is a need for further analysis, validation, and improvement of rework reduction methods (Zhang et al. 2012). With this background it can be mentioned however, different methods have been used to control rework, yet investigating contract process and its documents to manage rework has not been fully explored and this paper will open this new angle to provide initial bases for future studies by the following of the method that is offered in methodology section.

Research methodology

To find out more details of rework root cause within the life cycle of projects all previous research approaches around the subject of rework were reviewed throughout literatures published from 1988 to 2018. All identified rework causes and their roots obtained from various perspectives were combined together to provide a comprehensive list of rework root causes. Since some of the identified rework root causes had been repeated over again in different ways only seven of the most recent published in last ten years have been considered for current study based on two key criteria of:

1. Paper has been published in a well-known academic journal in the fields of construction and engineering. These papers were chosen from Journal of Performance of Constructed Facilities, Journal of Building Performance, Journal of Construction Engineering and Management, Journal of Construction Project Management and Innovation, Journal of Management Engineering, Jordan Journal of Civil Engineering, International Journal of Sustainable Construction Engineering and Technology

2. Papers that showing lists of rework root causes in various classification systems consisting of different phases of project. List of specific sources used in this paper are as follows indicating with abbreviations of R1 to R7.

R1: A path model of rework for building and civil engineering projects (Love et al. 2009)

R2: Factors influencing rework occurrence in construction (L.O. Oyewobi & D.R. Ogunsemi 2010)

R3: Construction small projects rework reduction for capital facilities (Zhang et al. 2012)

R4: Using system dynamics principles for conceptual modeling to resolve causes of rework in construction projects (Olatunji Ayodeji Aiyetan & Dillip Das 2014)

R5: Analyzing causes for reworks in construction projects in China (Gui Ye et al. 2014)

R6: Analysis of rework in residential building projects in Palestine (Ibrahim Mahamid 2016)

R7: Factors contributing rework and its impact on construction project performance (Enshassi et al. 2017)

However, these sources have been considered to provide a comprehensive list of all identified rework root causes throughout the life cycle of project, this paper only shows related items in tendering stage. More details of applied methodology for connecting rework root causes with contract documents of NZS3910 are explained in the following sections.

Selection of a model for rework classification

From the life cycle perspective of project the main study analyzed all those literatures that covered any of three main phases of Design, Procurement/tendering and Construction. The numbers of identified rework root causes from selected literatures were about 316 items. The first priority for analyzing all these causes was to design a classification system in which same items could be categorized in one section. In order to achieve such system first the approaches used in previous research were assessed and then to cover all identified items a classification system was proposed. The main classification approaches from seven selected sources in this paper are listed hereafter.

Design cost, Client, Design team, Site management, and Subcontractor causes (42 items in the source R1); Technical, Quality management, and Human resources factors (77 items in the source R2); Process, and Human performance groups (18 items in the source R3); Design related, Client related, and Contractor related factor (39 items in the source R4); Source R5 are including 39 items without following a certain classification system; Client, Consultant, Contractor, and Environmental related causes (43 items in the source R6); Human resources, Construction process, Material/Equipment supply, Client, Design, Contractor, and External environment rework impact (58 items in the source R7)

<table>
<tr><td rowspan="2">Level 1</td><td rowspan="2">Contract parties</td><td>Client</td></tr>
<tr><td>Contractor</td></tr>
<tr><td rowspan="3">Level 2</td><td rowspan="3">Project phases</td><td>Design</td></tr>
<tr><td>Procurement / Tendering</td></tr>
<tr><td>Construction</td></tr>
<tr><td rowspan="5">Level 3</td><td rowspan="5">Rework root causes classification</td><td>Process related factors</td></tr>
<tr><td>Human resource related factors</td></tr>
<tr><td>Material/Equipment related factor</td></tr>
<tr><td>Technical related factors</td></tr>
<tr><td>Other related factors</td></tr>
</table>

Figure 1: Model of applied rework classification

In order to cover comprehensive list of identified rework root causes within life cycle of project a model that is shown in figure 1 was used in current study. Other related factors in this classification system can be included as financial, environmental, governmental policies and etc. This model has been designed following by the combination of the most recent studies contents mentioned in this section and adjusted based on some other diagrams from previous literatures such as Robinson et al. (2004).

Propose a model for evaluation of contract documents

To find out either the contract document of NZS3910:2013 covers the groups of classified rework root causes, the study were customized through the following steps to provide a conceptual framework for investigating connection areas between the contract documents and the subject of rework.

Step 1- Checking whether these rework root causes be considered as contractual issue or not?
Step 2- Dose this group of causes led to variations “Clause 9 of contract condition”?
Step 3- Which contract clauses or attachments of contract is related to this group of rework root causes?
Step 4- Dose revising the relevant contract clause will cover this group of rework root causes?
Step 5- Dose making change in the attachments of contract will cover this group of rework causes?

A conceptual model to show all these steps is presented in figure 2 that finally is pointed to a research study for developing a new approach to manage rework in construction projects based on contract documents of NZS3910.

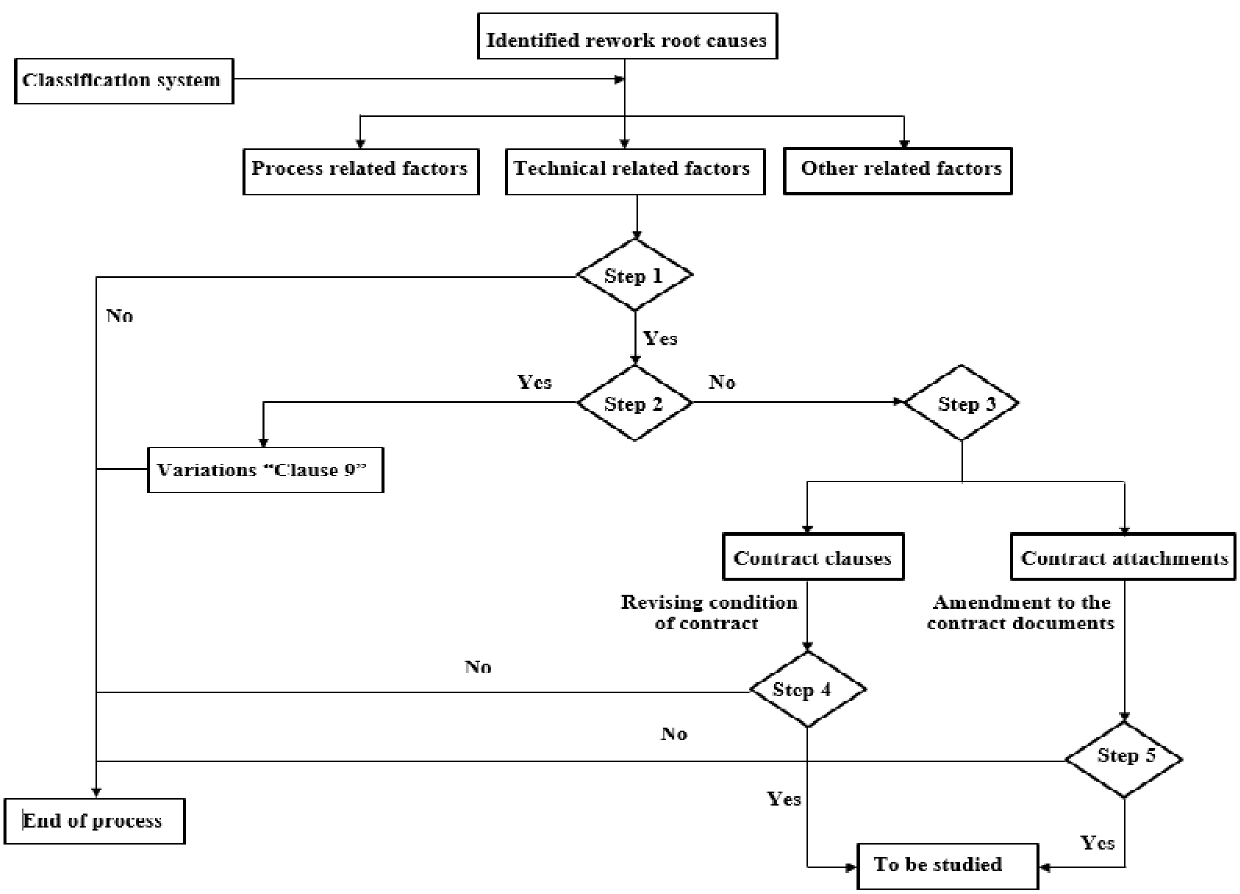


Figure 2: Flowchart of rework root causes and evaluation of contract documents

Findings

According to the initial results on the basis of chosen methodology, the total identified rework root causes in the life cycle of project were 316, which are presented in Table 1.

Table 1: Overview of identified rework root causes distributed within the project life cycle

Project Phase / Stage	*R1*	*R2*	*R3*	*R4*	*R5*	*R6*	*R7*	*Total in phase*
Design	*17*	*15*	*15*	*10*	*6*	*17*	*22*	*102*
Procurement (Tendering)	*5*	*4*	*0*	*1*	*4*	*3*	*1*	*18*
Construction	*20*	*58*	*3*	*28*	*29*	*23*	*35*	*196*
Total numbers of root causes	*42*	*77*	*18*	*39*	*39*	*43*	*58*	*316*

After reviewing the literatures and employed the classification model in tendering stage of project the total numbers of 18 identified rework root causes were presented in table 2 as the major outputs of this paper. Since there were 3 items common in literatures and to avoid repeating their contents the final total numbers of rework root causes of tendering stage in table 2 is shown as 15.

Table 2: List of identified rework root causes from the literatures with referencing to relevant resources

Classification of rework root causes in tendering stage	*R1*	*R2*	*R3*	*R4*	*R5*	*R6*	*R7*
Process related factors							
Client side							
1 Incomplete design at the time of tender	√					√*	
2 Procurement method		√					
3 Contractor selection method		√					
Contractor side							
4 Inadequate procurement methods							√
5 Improper subcontractor selection						√	
6 Poor contract execution					√		
Technical related factors							
Client side							
7 Errors made in the contract documentation	√						
8 Omissions of items from the contract documentation	√						
9 Poor quality contract documentation		√		√*			
10 Incomplete documentation at the time of award		√					
Contractor side							
11 Lack of clear definition of contract documentation for working content					√		
12 Ambiguity of items from contract documentation					√		
Other related factors							
Client side							
13 Payment of low fees for preparing contract documentation	√						
14 Insufficient time to prepare contract documentation	√					√*	
Contractor side							
15 Payment of low contract fees or delay in paying contract fees					√		

Discussion

Each contract generally has minimum of two parties and all relevant tasks and responsibilities will be divided between these two parties. In this paper client and all subsidiaries organizations such as consultants companies have been set in one side of contract and the main contractor and all relevant subcategories such as subcontractors and suppliers have been considered in the other side of contract. In the main study of conducting current research, previous identified rework root causes within the whole life cycle of project are categorized in three major stages of design, tendering (procurement) and construction. The standard contract document of NZS3910 as common used contract document in New Zealand are assessed among all identified rework root causes to find out which items will be covered by contract clauses and contract attachments. However the term of rework has not been mentioned in contract documents, some part of rework root causes such as changes can be covered by clause 9 of contract condition as “Variations”. In other words, rest of rework root causes still need to be looked over. In this paper only tendering stage of project has been assessed, so the paper only has identified and classified the construction rework root causes under tendering stage of project. Results from the assessment of the rework root causes that embedded in contract documents of NZS3910 will be presented in anther paper. Thus, further study to understand what possible contractual changes are required to manage rework in construction projects is suggested. Apart from the summarized factors in conclusion part of this paper, assessing other general factors of tendering stage in future research projects would probably make a new contribution to the body of knowledge, factors such as “lack of manpower, staff motivation, inadequate knowledge and experience from category of human resources factors, lack of information technology use and lack of attention to quality from category of technical factors in addition to political effects from category of other related factors”.

Conclusion

In total, Investigation and analysis of a construction rework within a set of contract documents together with a suggested model of rework management to achieve higher performance will contribute to the body of knowledge. Results of this research more likely lead to development of professional practice in contracting step of construction projects. Under each stage of project life cycle, rework root causes are classified in five major factors as process, human resource, equipment/material, technical and others. Based on the obtained evidences from literature reviews of this paper, all identified rework root causes in tendering stage can only be classified in three categories of process related factors, technical related factors and other related factors. As the paper result indicates there are no items can be classified under human resources related factors and material/equipment related factors which more likely are acceptable as these two categories are not involve in this stage of project directly, but needs more investigation. The summary of other three categories as the final output of this paper are presenting as the followings. This summary would be the fundamental structure for the future study of evaluating contract documents in relation to the matter of rework in tendering stage of project.

1- Process related factors are those items that involving in practical work. These factors are included procurement method, contractor selecting process and incomplete design at the time of tender by client, improper subcontractor selection method by contractor and poor contract execution by both parts.

2- Technical related factors are among those items that are not essential part of practical work but can affect the process directly. Poor quality of contract documents prepared by client such as ambiguity due to lack of clear definition for working content, errors and missing contractual parts due to incomplete design documentation, any deviation and errors in proposal documents prepared by contractor are among those major technical items that has the potential of rework.

3- Other related factors that can be categorized under this stage of project are included financial issues such as payment of low fees for preparing contract documentation, payment of low contract fees or delay in payment to contractor plus insufficient time to prepare contract documentation by client and consultant.

References

Ahmed Shaik Ayaz & B.Harish Naik 2016, 'Rework Management in Construction Projects and Comparision with Time and Cost' *International Journal of Innovative Research in Science, Engineering and Technology*, Vol 5, Issue 10, pp 17973-17980

Aziz R.F. & Hafez S.M. 2013, 'Applying Lean Thinking in Construction and Performance Improvement' *Alexandria Engineering Journal*, vol. 52 no. 4, pp. 679-695

Burati J. L., Farrington J.J. & Ledbetter W. B. 1992, 'Causes of quality deviations in design and construction' J. Constr. Eng. Manage., 118(1), 34-49.

Chan D.W.M. & Chan J.H.L. 2017, 'Pilot Case Study of New Engineering Contracts (NECs) in Hong Kong, Joy or Tears?'

Enshassi Adnan, Matthias Sundermeier & Mohamed Abo Zeiter 2017, 'Factors Contributing to Rework and their Impact on Construction Projects Performance' *International Journal of Sustainable Construction Engineering and Technology* (ISSN: 2180-3242) Vol 8, No 1, 2017

Eric K. Simpeh, Ruben Ndihokubwayo, Peter E.D. Love & Wellington Didibhuku Thwala 2015, 'A rework probability model: a quantitative assessment of rework occurrence in construction projects' *International Journal of Construction Management*,

Hossain M.A. & D.K.H. Chua 2013, 'Overlapping design and construction activities and an optimization approach to minimize rework' *International Journal of Project Management* 32 (6)

Hwang B. & Yang S. 2014, 'Rework and schedule performance' *Engineering Construction and Architectural Management*, vol. 21 (2), pp. 190-205.

Hwang B., Thomas S., Haas C. & Caldas C. 2009, 'Measuring the impact of rework on construction cost performance' *Journal of Construction Engineering and Management*, vol.135 (3), pp. 187-198

Ibrahim Mahamid 2016, 'Analysis of Rework in Residential Building Projects in Palestine' *Jordan Journal of Civil Engineering*, Volume 10, No. pp 197-208

Jalali Sohi Afshin, Marcel Hertogh, Marian Bosch-Rekveldt & Rianne Blom 2016, 'Does lean and agile project management help coping with project complexity' *Procedia - Social and Behavioral Sciences* 226 (2016) 252-259

Kelvin Xi ZUO 2010, 'Procurement and contractual arrangement for post disaster reconstruction' (PhD Thesis)

Kiavash Parvan 2012, 'Estimating the impact of building information modeling (BIM) utilization on building project performance' (PhD Thesis)

Love P.E.D., F. Ackermann, B. Carey, J. Morrison, M. Ward & A. Park 2016, 'Praxis of Rework Mitigation in Construction' *Journal of Management in Engineering*,

Love P.E.D., Edwards D., Watson H. & Davis P. 2010, 'Rework in Civil Infrastructure Projects, Determination of Cost Predictors' *Journal of Construction Engineering and Management*, 136(3): 275-282.

Love P.E.D., Edwards D.J., Irani Z. & Walker D.H.T. 2009, 'Project pathogens: The anatomy of omission errors in construction and engineering projects' *IEEE Transactions on Engineering Management*, 56(3), 425-435

Love P.E.D., Edwards D., Smith J. & Walker D. 2009, 'Divergence or congruence? A path model of rework for building and civil engineering projects' *Journal of Performance of Constructed Facilities*, vol. 23 (6), pp.480-488

Love P.E.D., Edwards D.J. & Irani Z. 2004, 'A rework reduction model for construction' *IEEE Transactions on Engineering Management*, 51 (4): 426-440

Love P.ED. & Edwards D. J. 2004a, 'Determinants of rework in building construction projects' *Engineering, Construction and Architectural Management*, 11 (4): 259-274

Love P.E.D. 2002a, 'Auditing the indirect consequences of rework in construction: A case based approach' *Managerial Auditing. Journal*, 17-3, 138-46

Maheswari J. Uma, V. Paul C. Charlesraj, G. Sandeep Kumara & S.P. Sreenivas Padala 2016, 'A Study on Assessment of Nonconformance Using Multiple Domain Matrix, A Case Study from Metro Projects' *International Conference on Sustainable Design, Engineering and Construction, Procedia Engineering* 145 (2016) 622-629

Mills A., Love P., Williams P. 2009, 'Defect Costs in Residential Construction' *Journal of Construction Engeneering Management* 135(1): 12-16

Nuria Forcada, Marta Gangolells, Miquel Casals & Marcel Macarulla 2017, 'Factors affecting rework cost in construction' *Journal of Construction Engineering and Management*, 2017, 20(4): 445-465

Nurul Afida Isnaini Janipha, Norizan Ahmad & Faridah Ismail 2015, 'Clients' Involvement in Purchasing Process for Quality Construction Environment' *Procedia - Social and Behavioral Sciences* 168 (2015) 30-40

Olatunji Ayodeji Aiyetan & Dillip Das 2014, 'Using system dynamics principles for conceptual modeling to resolve causes of rework in construction projects' *Journal of Construction Project Management and Innovation* Vol. 5 (2): 1266-1295

Oyewobi L.O. & Ogunsemi D.R. 2010, 'Factors influencing rework occurrence in construction: A study of selected building projects in Nigeria' *Journal of Building Performance, The Institution of Surveyors Malaysia*, 1 (1): 1-20

Oyewobi L.O., O.T. Ibironke, B.O. Ganiyu & A.W. Ola-Awo 2011, 'Evaluating rework cost- A study of selected building projects in Niger State' *Nigeria Journal of Geography and Regional Planning* Vol. 4(3), pp. 147-151, March 2011

Palaneeswaran E, 2006, 'Reducing rework to enhance project performance levels' *Proceedings of the one day seminar on recent developments in project management in Hong Kong, Centre for Infrastructure and Construction Industry Development, Hong Kong, 5.1-5.10. Recent Developments in Hong Kong*, pp.55-550

Robinson Fayek Aminah, Manjula Dissanayake & Oswaldo Campero 2004, 'Developing a standard methodology for measuring and classifying construction field rework' *Canada Journal of Civil Engeneering* 31: 1077-1089

Shestakova Y. 2005, 'The Analysis of the Use of Collaborative Procurement Systems in New Zealand Construction-Partnering, Alliancing, Joint Ventures' *Auckland, The University of Auckland*

Taggart M., Koskeal L. & O'Rourke J. 2014, 'The role of the supply chain in the elimination and reduction of construction rework and defects: an action research approach' *Construction Management and Economics*, 32(7/8): 829-842

Totterdill B. 2006, 'FIDIC user's guide: a practical guide to the 1999 red and yellow books' *London, Thomas Telford. Manchester Institute of Science and Technology (UMIST), Manchester, UK*

Wasfy M.A. 2010, 'Severity and impact of rework, a case study of a residential commercial tower project in the eastern province-KSA'

Ye G., Jin Z., Xia B. & Skitmore M. 2014, 'Analyzing causes for reworks in construction projects in China' *Journal of Management Engineering*

Ying Li & Timothy R. B. Taylor 2014, 'The Impact of Design Rework on Construction Project Performance'

Zhang D., Haas C., Goodrum P., Caldas C. & Granger R. 2012, 'Construction small-projects rework reduction for capital facilities' *Journal of Construction Engineering and Management*, vol. 138 (12), pp. 1377-1385

AN INVESTIGATION INTO HIGHER SUICIDE RATE IN AUSTRALIAN CONSTRUCTION INDUSTRY- CRITICAL REVIEW

Michael Bowles[1], Pushpitha Kalutara[2], Darryl O'Brien[3], Peter Lawrence[4], Phillip Harrison[5]

[1] Built Environment, School of Engineering & Technology, CQUniversity, Brisbane, Australia

[2,4]Built Environment, School of Engineering & Technology, CQUniversity, North Rockhampton, Australia

[3]Technical and Regulation, Victorian Building Authority (VBA), Melbourne, Australia

[5] Built Environment, School of Engineering & Technology, CQUniversity, Bunderberg, Australia

Abstract

Statistics showcase that Australian Construction industry has a higher suicide rate (40.3 per 100000) than Australia's general populous (27.6 per 100000). The issue has been even worse when compared with other industries of Australia in which Australian construction workers are 70% more likely to take their own lives than employees in other industries. Hence, this has been a serious issue for Australian construction industry in terms of not only human resource but also skills shortage, training and education and several other areas. Identifying critical factors contributing to the issue is the best way to approach the problem; hence, the current study conducts an extensive literature review following the PRISMA guidelines to pinpoint critical factors. The study then gives the focus into key strategies to be adopted to reduce the number of suicides in Australian construction industry. Finally, all findings will be collated to formulate guidelines and a framework to prevent suicides in Australian construction industry. The outcomes highly redound to the benefit of society and construction industry of Australia.

Keywords

Suicide rate, Australian construction industry, Extensive literature review, Critical factors, Key strategies, Guidelines and a framework to prevent suicides

Introduction

The statistical data shows deaths due to intentional self-harm, or in other words suicides, are rising as evidenced by the number of 3128 cases in 2017 while the figure is at 2866 in 2016 (Australian Bureau of Statistics, 2019). This is further confirmed by the fact that Intentional self-harm was ranked the 13th leading cause of death in 2017, moving up from 15th position in 2016. These deaths are not due to natural causes; hence, they can be prevented and as a result, the Australian government can include them into the country's human force rather than carrying social and economic burden due to their loss. Among these suicidal deaths, Milner, Niven & LaMontagne (2014) and Andersen *et al.* (2010) imply a considerable proportion from Australian construction industry referring to the results of the study of Heller, Hawgood & Leo (2007) in which 40.3 per 100000 suicide rate has been identified for Australian construction industry while that value was remained 27.6 per 100000 accounted to Australian general population. They subsequently stress suicide in the Australian construction industry or industries in general have remained in somewhat neglected field of research. Among all industries, Australian construction industry has been again prominent due to the fact that Australian construction workers are 70% more likely to take their own lives than employees in other industries (Raynold, 2017). Putting things in perspective, aim of this study is to investigate higher suicide rate in Australian construction industry identifying critical factors and ways of measures to reduce.

The research methods utilise a deductive approach focusing on both qualitative and quantitative data from a critical literature review. Critical analysis lead to derive three major factors influencing suicides in Australian construction industry; namely, work related stressors, personal status and financial issues. Literature review also identified limited research in broader ways to approach the focused issue of the current research. Hence, the current research emphasized the necessity of future research to come across with broader solution to the current issue. This was followed by the discussion given on strategies to reduce suicide in Australian construction industry. The discussion captured the importance of conducting mental health programs, awareness of suicide programs and similar programs to more importantly reduce the suicide in Australian construction industry. It is imperative that the government and construction companies should come forward; otherwise, the issue will turn worst to worst.

Literature review

Cambridge English Dictionary defines suicide as the act of killing yourself (oneself) intentionally. According to the World Health Organization (2019), worldwide suicide accounts for close to 800,000 people annually equating to one death every forty seconds. In broad sense, the number of suicide attempts is much higher than the number of actual suicide deaths each year (Our World in Data, 2015) leaving grave fears in case those attempts were successful. This has been much worst being the suicide the second leading cause of death among 15-29-year-olds (World Health Organization, 2019) leaving a clear message to the world to think of their future and young generation. Australians perspective, the most recent Australian data (ABS, Causes of Death, 2017) reports deaths due to suicide in 2017 at 3,128 was 9.1% increase compared to the previous year figure of 2866 (Australian Bureau of Statistics, 2019). It further suggests that the preliminary standardised death rate for 2017 which was 12.6 deaths per 100,000 persons (also equal with 2015) has recorded as the highest preliminary rate in the past 10 years. The situation is seemingly becoming worst to worst due to the fact that for every death by suicide, it is estimated that as many as 30 people attempt to end their lives that is approximately 65,300 suicide attempts each year (Lifeline Australia, n.d.). Australian Bureau of Statistics (2019) identifies that suicide remains the leading cause of death for Australians aged between 15 and 44 which means the issue cannot be lightly considered or ignored.

> For a death to be determined a suicide, it must be established by coronial enquiry that the death resulted from a deliberate act of the deceased with the intention of ending his or her own life (Intentional self-harm).
>
> (Australian Bureau of Statistics, 2006)

Suicide in the Australian construction industry has remained a relatively neglected area of research (Andersen *et al.*, 2010; Milner, Niven & LaMontagne, 2014). According to their research, the Australian construction industry accounted for 2.4% of all suicides (15-64 years) between 1995 – 2001, which equates to 40.3 suicides per 100000 people which is higher than the rate corresponding to Australian general population (27.6 suicides per 100000 people). Andersen *et al.* (2010) attempted to compare suicides referring only to Queensland, one state of Australia, and the summarised results are shown in Table 1. According to those results, the highest number of suicide incidence has reported from construction industry. The suicide rate of the construction industry is not the highest reported; however, that value is only second to transport and agriculture industries. Unlike other industries, construction suicides are only accounted to male deaths and not a single death of females; which is once again a convincing example for that Australian construction industry is male dominated. With the results, it can be discovered that Queensland construction suicide rate is well over the employed population suicide rate while it is in the same range as Queensland total population suicide rate. Although the findings can only be applied to one state of Australia, they imply the construction industry is a predominant sector to be considered when investigating suicides in Australia.

Table 1: Suicide incidence (1990-2006) and rates per 100000 in Queensland

Industry/ Area	**Persons**		**Male**		**Female**	
	Suicide incidence	**Suicide rate**	**Suicide incidence**	**Suicide rate**	**Suicide incidence**	**Suicide rate**
Construction	317	18.6	317	19.0	0	-
Transport	161	19.1	159	20.4	2	-
Agriculture	206	24.1	194	32.3	12	1.49
Artists	40	12.8	30	16.1	10	2.49
Cleaners	78	10.8	57	21.7	21	1.43
Education professionals	73	5.2	52	13.2	21	0.66
Nurses	52	9.0	12	23.7	40	2.37
Employed population	3010	10.6	2602	16.6	408	1
Total population	7652	18.5	6087	29.6	1565	2.37

Source: (Andersen *et al.*, 2010)

Nevertheless aligned with the same range of years, Heller, Hawgood & Leo (2007) have compared the suicide rate of the Australian construction industry with Australian and Queensland male population suicide rates referring to the statics from 1995 to 2001. The results are shown in Table 2. The results showcase that the construction industry is always ahead of the Australian and Queensland general public in terms of suicide. Between Australian and Queensland general public, it is obvious Queenslanders are slightly ahead over general Australians in terms of suicide. This provides some kind of justification to the previous implication that construction industry is a predominant sector to be considered when investigating suicides in Australia.

Table 2: Comparison of CBCI rates (per 100000) with Australian and Queensland male rates*

Year	**CBCI rate**	**Australia rate**	**Queensland rate**
1995	-	27.2	32.3
1996	-	27.3	35.4
1997	-	29.9	32.9
1995-1997	32.0	28.1	33.5
1998	57.8	30.2	35.5
1999	48.0	27.1	29.4
2000	39.6	25.0	30.3
2001	36.3	26.0	29.2
Total	40.3	27.6	32.2

Source: (Heller, Hawgood & Leo, 2007)
*- Commercial Building and Construction Industry

According to Australian Parliament House (2011), suicide is a complex issue with many underlying problems associated with it; however, it is preventable. These unfortunate deaths can have devastating effects on family and friends who are touched by suicide. This section will identify and critically analyse the factors that cause suicide in Australia's construction industry.

Factors

The Cole Royal Commission into the Building and Construction Industry was commissioned in 2001 and tasked with looking into the actions of the construction industry, specially pertaining to unlawful activities and inappropriate conduct (Australian Building and Construction Commission, 2018). Interestingly, the Cole Report also discovered some alarmingly suicide-related facts about the industry. The report detailed that in a 4-month period, 41% of the reported deaths were by suicide. According to the Australian Institute for Suicide Research and Prevention (2006), suicide has not been widely researched within specific occupational groups in Australia. This aligns with the research undertaken by

Andersen *et al.* (2010) and Milner, Niven & LaMontagne (2014) where they have determined that research in this area has been somewhat neglected. This is not only apparent to the Australian level but also research is limited at an international level. Järvholm & Stenberg (2002) can be included among the limited international research on suicide in construction industry. The study corresponds to the Swedish construction industry and special focus is given on electricians. Similarly, Liu *et al.* (1994) investigates suicides in Alabama, one state of USA, referring to statistics from 1980 to 1989 while Liu & Waterbor (1994) give a broad focus investigating suicides among different industrial groups/ occupations. Two international case studies by Koskinen *et al.* (2002) and Meltzer *et al.* (2008) applied to Finland and UK construction industry respectively also focus on occupational suicides and further investigate relevance to suicide by occupation.

The research undertaken by Järvholm & Stenberg (2002) showed that the suicide mortality rate was not higher among electricians in the Swedish construction industry compared to the general population. In fact, the outcome of the research was that they were at a decreased risk. The sample size of this study was over 389,000 and was tracked using a computer system with an agreement between unions and employers. Workers were offered regular health checks which allowed them to be monitored throughout the course of the research. Järvholm & Stenberg (2002) reported that a total of 33,719 men were licenced and registered electricians at the time of their health checks; however, inadequate registrations in women was an issue not to conduct a multivariate analysis between demographic groups. Similar trend has been identified in USA by Liu & Waterbor (1994) that suicides among electricians is at lower risk. These two studies, one is before 1994 and the other is before 2002, are seemingly obsolete and do not represent current and modern construction industry which is comparatively more complicated and their workers are facing many more challenges. In another perspective, a lower suicide risk in these overseas studies could be attributed to there being a higher proportion of people with illnesses and disabilities than people employed in the construction industry (Järvholm & Stenberg, 2002). Furthermore, since the cohort undertaking the health examinations in these studies were willing participants, people with mental illnesses, drinking and/or psychosocial problems might not have participated in the research making the comparison to the general population more biased (Järvholm & Stenberg, 2002).

The similarities between these literature can be attributed to the fact that suicide has a direct correlation with socio-demographic variables (Milner & Law, 2017). Further to Milner & Law (2017), when the worker was subjected to controlled variables including stable marital and financial statuses, the suicide rate will be diminished. Both domestic and international research has also focused on work related stressors (Gullestrup, Lequertier & Martin, 2011; Milner & Law, 2017; Milner, Niven & LaMontagne, 2014). Additionally, job insecurity due to short-term contracts and no guarantee of future work due to a fluctuating job market, workplace bullying, and high levels of drug and alcohol use were also apparent work-related stressors (Milner, Niven & LaMontagne, 2014). These findings drive to a conclusion that whilst work-related stressors contribute to suicide in the Australian construction industry, other contributing factors are those of a personal nature in the form of personal status/traits and financial issues (Australian Institute for Suicide Research and Prevention, 2006). Hence, the subsequent section will provide a critical analysis of three significant factors associated with suicide in the construction industry namely: personal status, financial issues and work-related stressors.

Personal status/ traits

Milner, Niven & LaMontagne (2014) identify that people who are in a healthy and stable relationship are less likely to commit suicide than people who are not. Sixty four suicide cases were taken into the study of Australian Institute for Suicide Research and Prevention (2006) and the researchers captured the details of their marital status as shown in Table 3. According to the results, there are still a considerable number of suicides in “Married or de-facto” relationship; however, combination of “Single” and “Separated or divorced” relationships tends to be vulnerable to suicide.

Table 3: Suicide ratio upon different relationships

Relationship	Suicide ratio
Married or de-facto	34.4%
Single	25.0%
Separated or divorced	20.3%
Unknown	20.3%
Total	100%

Source: (Australian Institute for Suicide Research and Prevention, 2006)

Research by Milner, Niven & LaMontagne (2014) and the (Australian Institute for Suicide Research and Prevention, 2006) suggest that the cause of marital breakdown is mainly due to long work hours which is common in the construction industry to cover up tasks of high demanding and scheduled in haste. Conflicts are unavoidable due to the unbalance of home life giving not enough dedication to look after the couple's children. Whilst this causes strain to the couple's relationship, it is often the male who suffered in silence. Working 5.5 days each week often led to the male worker feeling "lonely" as they often missed out on weekend activities with family and friends. This issue has similar attributes to that of the Australian Fly-in-Fly-out (FIFO) industry (Bourke, 2018). Whilst the locally based construction worker works on average 5.5 days each week, the FIFO worker is subjected to weeks away from their partner and loved ones, which causes varying degrees of psychological distress (Bourke, 2018). Furthermore, workers in Australia's remote mining industry work up to 13 hours per day often in social isolation. Workers and their families are becoming distressed not only because of the isolation of the work, but the roster patterns associated with the job. Common rosters include (Skills Australia, 2011; The Chamber of Minerals and Energy of Western Australia, 2011):

- 9 days on/ 6 days off
- 2 weeks on/ 1 week off
- 4 weeks on/ 1 week off (often applied to projects with a shorter duration)

According to a FIFO worker "Mitch", whilst the money is appealing at first, it puts too much personal strain on the worker and their family. Whilst the above FIFO roster examples might appear to give the worker a longer break between shifts, the truth is that the worker travels to and from work in their own time; making their days off even shorter (Bourke, 2018). Bowers *et al.* (2018) undertook a survey using 1124 employees at remote construction locations across South and Western Australia. The goal of the survey was to see if there was any correlation with working away in remote locations for long periods of time and psychological distress and mental health effects on the worker and their family. The results showed that 93.5% were men, whom were badly affected and that of majority were aged between 25-44 years. Additionally, 28% of the participants retuned a K10 score indicating extremely high psychological distress, compared to 10.8% for Australian in general. Kessler Psychological Distress Scale (K10) involves 10 questions about emotional states each with a five-level response scale (Kessler *et al.*, 2003). The most frequent reported stressor was that of missing special family events; 86% of all participants recorded this as being their major stressor. This is in line with the findings by (Milner, Niven & LaMontagne, 2014) and (Australian Institute for Suicide Research and Prevention, 2006). This scenario is quite prevalent in Australian FIFO industry (Pickles, 2015). Workers building Australia's Chevron's Gorgon liquified natural gas (LNG) project in Western Australia, working a 26 days on/9 day off roster, take home $150,000 to $180,000 of average salary working a 12-hour shift a day (Pickles, 2015). However, workers in Western Australia are campaigning to take a wage cut in exchange for more flexible working rosters (Pickles, 2015).

Milner, Niven & LaMontagne (2014) and Australian Institute for Suicide Research and Prevention (2006) also state that separation and divorce is high in the Australian construction industry which causes women to develop a bad stigma of the industry. It is made more difficult when children are involved (Australian Institute for Suicide Research and Prevention, 2006). Having the burden of paying child support, coupled with having strict visitation rights of seeing the children, causes significant stress to the worker. The survey undertaken by Bowers *et al.* (2018) had 68% of respondents claiming similar type of relationship issues with their partners. Their research finding is in line with the views of Langdon & Sawang (2017), that male construction workers are at their most depressive and anxious state when suffering poor relationship status. Langdon & Sawang (2017) also recommends that the wives of construction workers need further education on the industry which will allow them to understand the thought process of men in the construction industry and more importantly, console them when they feel stressed.

Financial issues

According to Milner & Law (2017), Milner, Niven & LaMontagne (2014) and Langdon & Sawang (2017), financial issues are linked to suicide in the Australian construction industry. Additionally, Langdon & Sawang (2017) inform that construction workers lose connection with their family as they work as much as possible to make ends meet: making considerable sacrifices working on weekends to make ends meet. These lost connections caused the employee to feel that their only obligation was to financially support the family. These findings accord with Milner, Niven & LaMontagne (2014) and their findings of personal issues being a major factor linked in male suicide in the Australian construction industry. Interesting fact on this is that there is good money to be earned in the industry (Australian Institute for Suicide Research and Prevention, 2006); however, there are many instances of poor financial management. Many construction industry workers are spending vast amount of their wage on alcohol and drugs, which then leads to financial strain on ongoing financial commitments such as mortgages and rent (Australian Institute for Suicide Research and Prevention, 2006). Additionally, many of the industries younger workers, particularly in the FIFO industry, are spending most of their salary on cars, boats and motorcycles; ultimately spiralling into debt (Pickles, 2015). Once the worker is in debt, they have no choice but to work longer hours to repay these debts (Milner & Law, 2017). Furthermore, many older, more experienced workers are getting frustrated at younger, less experienced workers who are getting paid the same remuneration. This has been shown to contribute to suicide when coupled with martial issues and feeling there is no one to talk to (Milner, Niven & LaMontagne, 2014).

Corcoran *et al.* (2015) concluded that five years of economic recession and austerity in Ireland had a significant negative impact on rates of suicide in men and on self-harm in both sexes. There was 57% increase in men's suicide in Ireland to recession and austerity between 2008 and 2012. Job instability is associated with episodic mental illness. When a person sees no way back from their financial difficulties they might become suicidal or attempt suicide. Mental health problems are also common in the workplace (MHFA, 2016). From an employer's perspective investing time and support to retain an experienced and skilled employee with a mental health problem is usually more cost-effective than recruiting and training a new person. Working with a qualified financial advisor can not only improve a person's financial decisions but also improve mental health (MHFA, n.d.). Addressing financial problems early on can reduce their impact on mental health. Trust, job security, and having supportive friends and family are all strongly linked with wellbeing (MHFA, 2015). Research has indicated that mental health issues – including depression, anxiety, and certain forms of psychosis – are three times more likely to occur when an individual is in debt (Campbell, 2016). However, mental disorders and suicides do not always correlate with personal financial loss. A number of recent studies have reported that, in Asian countries, mental disorder has been found in less than 50% of those who completed suicide (Pridmore & Reddy, 2012). One solution to employee's financial problems is employers to make available a suitable qualified financial adviser at low cost. Sound financial advice can possibly avoid one of the identified suicide risk factors. Financial advice helps the employee identify short, medium and long-term goals and develop strategies to achieve pre-determined financial goals (ASIC, n.d.).

Work-related stressors

As identified by Raynold (2017), there is a stigma associated with the Australian construction worker: a "bloke" dressed in hi-vis vests and steel capped boots; who works hard, has a laugh with his mates, and then goes home to his family. Being such a male dominated industry, it has identified that a lot of men do not know how to properly treat women as they have limited opportunities to interact outside of work; coupled with the fact that they are generally surrounded only by men for most of their working week (Australian Institute for Suicide Research and Prevention, 2006). The significance of this finding is that if there were more female participation in the construction industry, men would naturally feel more comfortable being around them outside of work; which in turn could have positively impacted on reducing issues such as domestic violence and divorce rates. Furthermore, it would lead to a much-needed cultural change in the industry (Skillen, 2018). It has been identified that men in the construction industry find it hard to open up to their co-workers and have one-on-one personal discussions; unless they have a strong personal relationship with someone they can trust. Again, this is associated with this unwanted stigma that the construction industry has (Raynold, 2017). They feel stressed that if they are open and honest to someone, that rumours will be spread, which will lead to a feeling of weakness. This type of feeling can lead to depression and ultimately suicide (Kamardeen & Sunindijo, 2017; Sunindijo & Kamardeen, 2017).

The construction industry is a fast-paced stressful environment (Langdon & Sawang, 2017). Work demands are high and there is an expectation from management that the worker must perform beyond expectation (Australian Institute for Suicide Research and Prevention, 2006). Again, not wanting to talk to someone due to feeling 'weak' has led to 35% of reported cases as being the primary reasoning behind the worker committing suicide (Broadbent & Papadopoulos, 2014), Construction is a market driven industry (Milner *et al.*, 2017), with workers often being contracted on a job-to-job basis only. Australian Institute for Suicide Research and Prevention (2006) informs that although the worker is employed on a full-time basis, there are still instances where they are only given short notice for termination. It has been discovered that there are instances where the employer has pleaded with the staff to continue to work on a project, then only to terminate them a few days later (Langdon & Sawang, 2017). Langdon & Sawang (2017) identifies that this type of stressor is also associated to male suicide in the Australian construction industry. Bullying is widespread in the construction industry; with apprentices reportedly being bullied by the most (Heaton, 2018). Older, more experienced workers see this as being a rite of passage to harden people up. Whilst many of the apprentices knew this was just a joke and a part of the industry, this type of treatment can be detrimental to a person's health (Broadbent & Papadopoulos, 2014). Workers who do not see this as a joke become increasingly insecure and do not know how to share their feelings with people; which often leads to mental illness and suicide (Broadbent & Papadopoulos, 2014).

In summary, personal, financial and work-related factors all play a role in suicide in the Australian construction industry. The unfortunate stigma associated with the worker is a key factor in them not wanting to speak up to discuss problems throughout their infancy stage. Additionally, research has showed that spouses of the construction worker do not fully comprehend the toll the industry has on the worker and how it affects their mental state. By doing literature review, we have identified a research gap to broadly cover the influencing factors attached to the suicide in Australian construction industry.

Research methodology

As mentioned earlier, higher suicide rate in Australian construction industry is obvious; but, influencing factors and reduced measures are to achieve through this study. The strategy to collect data is mainly designed on a holistic literature review; hence, deductive approach was selected focusing on both qualitative and quantitative data. A deductive approach is effective in situations when a hypothesis is developed based on existing theory and then designing the research strategy to test the hypothesis (Grote-Garcia & Loveless, 2011). Holistic literature review was designed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher *et al.*, 2015). Flow diagram shown in Figure 1 was adapted for this purpose based on one proposed by (Moher *et al.*, 2009). PRISMA was identified effective for the current research and therefore chosen due to its ability to capture evidence-based minimum set of items for reporting in systematic reviews and meta-analyses (Moher *et al.*, 2010).

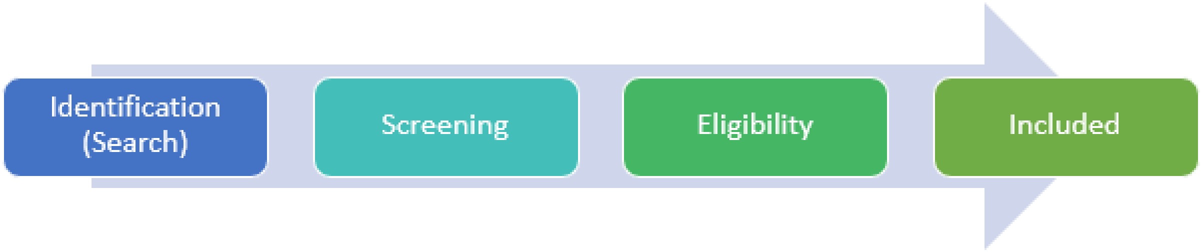


Figure 1: PRISMA bibliometric search flow diagram

The first step for the identification of targeted peer-reviewed journal articles utilised two databases/ literature collections including Web of Science and PubMed. The choice of Web of Science is mainly due to its reputation of comprehensive coverage for the study of science, technology and knowledge as recommended by Dr Brian Uzzi, Kellogg School of Management North-western University (Clarivate Analytics Company, n.d.). The enrichment of life science journals (National Centre for Biotechnology Information, n.d.) triggered to the choice of PubMed to address the cognitive aspect of the current research. A combination of keywords using Boolean Operators was used throughout the database search, which included: construction AND mental health; suicide AND construction AND Australia; Construction AND suicide AND stressors. The database search was also conducted using the term "intentional self-harm" with further refinement using the term "construction". The results were further screened according to timespan and language selection. Limited research on the given research focus (Andersen *et al.*, 2010; Milner, Niven & LaMontagne, 2014) cut the timespan only between 1985-2018, in retrospect of close to 35 years. Literature written in a foreign language was excluded and only articles that were written in English were included. Eligibility of search results was only concerned of journal articles. Articles were only included if they contained the key search terms in the abstract of the article for the last step of PRISMA. Accordingly, the study data on case studies, systematic reviews, meta-analyses and case-control studies. Due to specific suicidal data in the Australian construction industry being limited, sample size was not restricted; hence, preference was given even to research articles which dealt with smaller samples. Special consideration was given not to include data on 'attempt to commit suicide' or 'near misses'.

Data validity and reliability

The scope of the literature became more specific to the topic and the identification of some key authors (Dr Allision Milner, Professor Graham Martin, Mr Jorgen Gullestrop) in this research area became apparent when the data collection was progressing. This is mainly due to the valid approach by PRISMA that always capture mostly relevant and consistent data. In addition, data collected came across with the literature referring to the various Australian State's suicide registers (Andersen *et al.*, 2010; Heller, Hawgood & Leo, 2007). For example, Andersen *et al.* (2010) obtained specific suicide data from the QLD Suicide Register and information pertaining to the general Australian population from the Australian Bureau of Statistics (refer to Table 2). This is a clear indication that the information provided throughout this paper is based on statistical evidence already tested through valid research studies. Critically analysed data was extracted through credible sources including peer-reviewed journal articles, Australian Government websites, and non-for-profit organisations such as Mates in Construction and Lifeline; hence, the findings become credible and reliable. Furthermore, the cross-checking research process was utilised to check the reliability of the sources. For example, lliterature was obtained from scholars who have published multiple papers on the same research focus; Milner (Milner & Law, 2017; Milner, Niven & LaMontagne, 2014; Milner *et al.*, 2013).

Discussion

The findings revealed that the Australian construction industry is negatively impacted by the suicide of their workers triggering to loss of human resource resulting skills shortage and additional expenses of training and education. Data limitation on identifying suicide in construction industry indicates a huge research gap at both national and international level. It can be observed that among the literature, Heller, Hawgood & Leo (2007) and Andersen *et al.* (2010) have given a considerable effort to identify suicide pattern in Australian construction industry referring to reliable statistical data. However, these data now appear obsolete because they are corresponding to 2006 or before. This indicates a future research direction to further observe the suicide patterns of the modern construction industry whether they have been severe or not. Another gap in research in Australian context was none of the national research attempted to adopt a research like Järvholm & Stenberg (2002) which covered a big database of human to come across with the results. Even with the limited research, the current study could extract important factors that attribute to suicide in Australian construction industry. Work related stressors come first in this case (Gullestrup, Lequertier & Martin, 2011; Milner & Law, 2017; Milner *et al.*, 2017; Milner, Niven & LaMontagne, 2014; Milner *et al.*, 2013). Other than the work stressors, it was obvious other influencing factors come through the personal nature (Australian Institute for Suicide Research and Prevention, 2006). Personal nature was accounted to personal status and financial issues. Figure 2 summarise the findings of factors for the suicide in Australian construction industry.

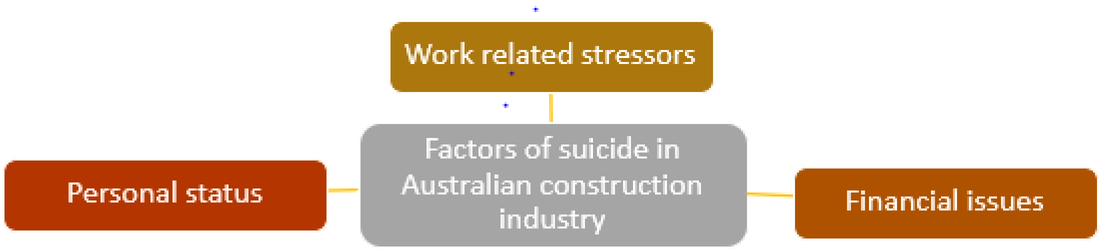


Figure 2: Factors of suicide in Australian construction industry

Strong marital status relationship showed a strong resistant to suicides whereas single and separated/ divorced relationships showed signs of becoming vulnerable to suicide or attempts (Milner, Niven & LaMontagne, 2014). FIFO workers have been given a special place in some literature identifying them as well more vulnerable to suicide (Bourke, 2018; Bowers *et al.*, 2018; Pickles, 2015). Although it is apparent that construction workers getting higher salaries, considerable of them are trapped with financial issues due to poor financial management. This has triggered them to no options but to work long hours for their employers to cover up debts and earn for survival, which indirectly creates opportunities to suicide (Langdon & Sawang, 2017; Milner & Law, 2017; Milner, Niven & LaMontagne, 2014). Although an Australian construction worker is fit in mental and health in appearance there is a hidden agenda of their feelings of work-related issues. Work related issues come in different forms including insecurity of job (Australian Institute for Suicide Research and Prevention, 2006; Langdon & Sawang, 2017), high work demands (Langdon & Sawang, 2017), bullying (Broadbent & Papadopoulos, 2014; Heaton, 2018). Not unveiling of these feelings to others, particularly to colleagues, has been always created problematic environment which ultimately leads to unfortunate suicides (Broadbent & Papadopoulos, 2014; Kamardeen & Sunindijo, 2017; Langdon & Sawang, 2017; Raynold, 2017; Sunindijo & Kamardeen, 2017).

Construction workers' mental health could be impacted by their working environment, an individual's social life as well as lifestyle and behaviour. Employees could be from varying socio-economic backgrounds. There are very few tested programs that address mental health and suicide in the construction industry. Mental health needs to be positively promoted in the construction industry as well as providing employees with relevant support. There needs to be early diagnosis, treatment and support to return to the workplace. There needs to be buy-in from the construction industry to provide strategies to reduce the suicide levels in the industry. This includes development of standards and procedures from the industry. The organisations could provide staff training and amend their policies to promote greater work life balance. The standards would need to be reviewed on a regular basis to see whether they are improving the suicide rates in the construction industry (Milner & Law, 2017). According to (Australian Institute for Suicide Research and Prevention, 2006), the goal for the construction industry would be to:

- reduce the rate of suicide in the construction industry
- improve work life balance;
- decrease depression and anxiety in construction workers
- improve working conditions in the construction industry.

To achieve the above, there would need to be an agreement within the industry on what can be practically changed in relation to policy, procedures and the culture. The industry would then be able to determine an approach to implement changes that would improve certain factors in the construction industry. The ultimate goal is for employees in the construction industry to have an improvement in their lives (Milner & Law, 2017). The key strategy that could be adopted to reduce the number of suicides include making employees aware of the Mates in Construction program. Mates in Construction is a charity organisation that is funded by various construction organisations, unions and the Federal Government. The key focus on Mates in Construction is suicide prevention. Mates in Construction offers community development programs on different construction sites. In addition, Mates in Construction provides employees with case managers to provide assistance (Gullestrup, Lequertier & Martin, 2011). Incolink provides a suicide prevention program to young employees that live in remote areas in Victoria. Incolink provides a redundancy payment fund, which has been established by unions and companies in the building industry in Victoria (Incolink, n.d.).

According to the Suicide in Queensland's Commercial and Construction Industry report, it has been recommended that there is awareness that suicide is an avoidable problem within the construction industry (Australian Institute for Suicide Research and Prevention, 2006). It is suggested that awareness is created by incorporating training into Blue Card training, or modules in TAFE and during an apprenticeship. Discussions should be held around the frequency of problems, which are associated with suicidal behaviour. These issues include depression, breakdown of marriage, drug and alcohol use etc. There should also be information about how to detect and respond to these problems. In addition, it is important that suicidal warning signs are incorporated into the training material. Mental Health sessions could be facilitated by construction companies to provide awareness to employees. There needs to be further information on how people can obtain help and where to get support (Australian Institute for Suicide Research and Prevention, 2006). Furthermore, there should be a holistic approach to mental health where employees are encouraged to prioritise their mental health. Employees should have access to an Employee Assistance Program, which offers a free and confidential counselling service for employees and their families. Other initiatives could include:

- Wellbeing programs including nutrition and meditation seminars.
- Resilience and Mental Health training.
- A dedicated site on the intranet for resources and tools on mental health.
- Compliance training in each organisation.
- Flexible working arrangements and helping to arrange family care if required.
- Providing leave for people impacted by domestic violence.
- Supporting team leaders to advocate for a mentally healthy workplace.

Whilst it is acknowledged that trying to implement all the above-mentioned initiatives might not be realistic, it is our belief that any mental health awareness initiatives being introduced are far better than none to reduce suicides in Australian construction industry.

Conclusion and future research

This paper has attempted to explore why the Australian construction industry has a higher suicide rate compared to Australia's general population. Two main objectives were targeted for this purpose: identifying critical factors for the issue and exploring strategies to reduce suicides in Australian construction industry. The research methodology was based on deductive approach and PRISMA strategy was applied for a more systematic literature review to collect data. After a thorough analysis, the study identified that personal factors, financial factors and work-related stressors contribute to such a high suicide rate in the Australian industry. Further discussion outlined that there should be a holistic approach to mental health where employees are encouraged to prioritise their mental health. It was evident that there were very few tested programs that address mental health and suicide in the construction industry. There was also a requirement that mental health needs to be positively promoted in the construction industry as well as providing employees with relevant support. Furthermore, there needs to be early diagnosis, treatment and support to workers to return to the workplace. There needs to be stringent actions on illegal work-related actions like bullying from the construction industry to provide strategies to reduce the suicide levels in the industry. The organisations could provide staff training and amend their policies to promote greater work life balance. Additionally, employees should have access to an Employee Assistance Program, which offers a free and confidential counselling service for employees and their families. Future research is imperative understanding the suicide pattern in Australian construction industry; hence, future research should be based on more human and applied research. Accordingly, first author of this paper is planning to conduct a PhD research further extending the research focus.

Acknowledgement

The authors convey their special thanks to all the reviewers for their comments and feedback to improve the quality of the paper.

References

Andersen, K, Hawgood, J, Klieve, H, Kõlves, K & De Leo, D, 2010, 'Suicide in selected occupations in Queensland: evidence from the State suicide register', *Australian New Zealand Journal of Psychiatry*, vol. 44, no. 3, pp. 243-9.

ASIC, n.d., *Financial advice*, viewed 13 September 2019, <https://www.moneysmart.gov.au/investing/financial-advice>.

Australian Building and Construction Commission, 2018, *2017-18 Annual Report*, Australian Building and Construction Commission, Australia, <https://www.abcc.gov.au/sites/g/files/net5466/f/abcc_annual_report_2017_18.pdf>.

Australian Bureau of Statistics, 2006, *3303.0 - Causes of Death, Australia, 2006*, viewed 05 September 2019, <https://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/145E222CF0CADBC0CA257410000FC26C>.

Australian Bureau of Statistics, 2019, *3303.0 - Causes of Death, Australia, 2017: Intentional self-harm, key characteristics*, <https://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/3303.0~2017~Main%20Features~Intentional%20self-harm,%20key%20characteristics~3>.

Australian Institute for Suicide Research and Prevention, 2006, *Suicide in Queensland's commercial building and construction industry: An investigation of factors associated with suicide and recommendations for the prevention of suicide*, Griffith University, Brisbane, Australia, <https://matesinconstruction.org.au/wp-content/uploads/2016/03/2006-MIC_AISRAP-Report.pdf>.

Australian Parliament House, 2011, *Suicide in Australia*, viewed 05 September 2019, <https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/FlagPost/2011/May/Suicide_in_Australia>.

Bourke, E, 2018, *Mental health distress more prevalent among FIFO workers than general community*, viewed 06 September 2019, <https://www.abc.net.au/news/2018-05-14/fifo-workers-suffer-more-mental-health-distress/9759232>.

Bowers, J, Lo, J, Miller, P, Mawren, D & Jones, B, 2018, 'Psychological distress in remote mining and construction workers in Australia', *Medical Journal of Australia*, vol. 208, no. 9, pp. 391-7.

Broadbent, R & Papadopoulos, T, 2014, 'Improving mental health and wellbeing for young men in the building and construction industry', *Journal of Child & Adolescent Mental Health*, vol. 26, no. 3, pp. 217-27.

Campbell, J, 2016, *Financial stress leads to symptoms of depression, PTSD* viewed 13 September 2019, <https://www.moneymanagement.org/blog/2016/05/financial-stress-leads-to-symptoms-of-depression>.

Clarivate Analytics Company, n.d., *Home-Web of Science Group*, viewed 4 September 2019, <https://clarivate.com/webofsciencegroup/?utm_source=false&utm_medium=false&utm_campaign=false>.

Corcoran, P, Griffin, E, Arensman, E, Fitzgerald, AP & Perry, IJ, 2015, 'Impact of the economic recession and subsequent austerity on suicide and self-harm in Ireland: An interrupted time series analysis', *Int J Epidemiol*, vol. 44, no. 3, pp. 969-77.

Grote-Garcia, SA & Loveless, D, 2011, 'Deductive Reasoning', *Encyclopedia of Child Behavior Development*, pp. 477-8.

Gullestrup, J, Lequertier, B & Martin, G, 2011, 'MATES in construction: impact of a multimodal, community-based program for suicide prevention in the construction industry', *International journal of environmental research and public health*, vol. 8, no. 11, pp. 4180-96.

Heaton, A, 2018, *Australia must eliminate bullying on construction sites*, viewed 6 September 2019, <https://sourceable.net/australia-must-eliminate-bullying-on-construction-sites/>.

Heller, TS, Hawgood, JL & Leo, DD, 2007, 'Correlates of suicide in building industry workers', *Archives of Suicide Research*, vol. 11, no. 1, pp. 105-17.

Incolink, n.d., *Incolink home page*, viewed 6 September 2019, <https://www.incolink.org.au>.

Järvholm, B & Stenberg, A, 2002, 'Suicide mortality among electricians in the Swedish construction industry', *Occupational and Environmental Medicine*, vol. 59, no. 3, pp. 199-200.

Kamardeen, I & Sunindijo, RY, 2017, 'Personal characteristics moderate work stress in construction professionals', *Journal of Construction Engineering Management*, vol. 143, no. 10, p. 04017072.

Kessler, RC, Barker, PR, Colpe, LJ, Epstein, JF, Gfroerer, JC, Hiripi, E, Howes, MJ, Normand, S-LT, Manderscheid, RW & Walters, EEJAogp, 2003, 'Screening for serious mental illness in the general population', vol. 60, no. 2, pp. 184-9.

Koskinen, O, Pukkila, K, Hakko, H, Tiihonen, J, Väisänen, E, Särkioja, T & Räsänen, P, 2002, 'Is occupation relevant in suicide?', *Journal of affective disorders*, vol. 70, pp. 197-203.

Langdon, RR & Sawang, S, 2017, 'Construction Workers' Well-Being: What Leads to Depression, Anxiety, and Stress?', *Journal of Construction Engineering Management*, vol. 144, no. 2, p. 04017100.

Lifeline Australia, n.d., *Statistics on suicide in Australia*, viewed 05 September 2019, <https://www.lifeline.org.au/about-lifeline/lifeline-information/statistics-on-suicide-in-australia>.

Liu, T & Waterbor, JW, 1994, 'Comparison of suicide rates among industrial groups', *American journal of industrial medicine*, vol. 25, no. 2, pp. 197-203.

Liu, T, Waterbor, JW, Roseman, J, Coombs, DW, Maetz, HM & Soong, S-J, 1994, 'Suicide in Alabama, 1980 to 1989', *Southern Medical Journal*, vol. 87, no. 1, pp. 10-6.

Meltzer, H, Griffiths, C, Brock, A, Rooney, C & Jenkins, R, 2008, 'Patterns of suicide by occupation in England and Wales: 2001–2005', *British Journal of Psychiatry*, vol. 193, no. 1, pp. 73-6.

MHFA, 2015, *Helping someone with mental health problems and financial difficulties: Guidelines for the support person*, Mental Health First Aid, <https://mhfa.com.au/sites/default/files/MHFA-financial-difficulties-support-person.pdf>.

MHFA, 2016, *Providing mental health first aid to a co-worker: Mental health first aid guidelines*, Mental Health First Aid, <https://mhfa.com.au/sites/default/files/mhfa_workplace_guidelines.pdf>.

MHFA, n.d., *Helping someone with mental health problems and financial difficulties: Guidelines for financial counsellors*, Mental Health First Aid, <https://mhfa.com.au/sites/default/files/MHFA-financial-difficulties-financial-counsellor.pdf>.

Milner, A & Law, P, 2017, *Summary report: Mental health in the construction industry*, University of Melbourne, Melbourne, <http://micaus.bpndw46jvgfycmdxu.maxcdn-edge.com/wp-content/uploads/2015/11/MIC-QLD-construction-industry-roundtable-report.pdf>.

Milner, A, Maheen, H, Currier, D & LaMontagne, AD, 2017, 'Male suicide among construction workers in Australia: a qualitative analysis of the major stressors precipitating death', *BMC Public Health*, vol. 17, no. 1, p. 584.

Milner, A, Niven, H & LaMontagne, A, 2014, 'Suicide by occupational skill level in the Australian construction industry: data from 2001 to 2010', *Australian New Zealand journal of public health*, vol. 38, no. 3, pp. 281-5.

Milner, A, Spittal, MJ, Pirkis, J & LaMontagne, AD, 2013, 'Suicide by occupation: systematic review and meta-analysis', *The British Journal of Psychiatry*, vol. 203, no. 6, pp. 409-16.

Moher, D, Liberati, A, Tetzlaff, J & Altman, DG, 2010, 'Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement', *International Journal of Surgery*, vol. 8, no. 5, pp. 336-41.

Moher, D, Liberati, A, Tetzlaff, J, Altman, DG & The, PG, 2009, 'Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement', *PLOS Medicine*, vol. 6, no. 7, pp. e1000097/1-6.

Moher, D, Shamseer, L, Clarke, M, Ghersi, D, Liberati, A, Petticrew, M, Shekelle, P & Stewart, LA, 2015, 'Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement', *Systematic reviews*, vol. 4, no. 1, pp. 1-9.

National Centre for Biotechnology Information, n.d., viewed 04 September 2019, <https://www.ncbi.nlm.nih.gov/pubmed>.

Our World in Data, 2015, *Suicide*, viewed 04 Spetember 2019, <https://ourworldindata.org/suicide#>.

Pickles, S, 2015, *Some FIFO workers pay high price for riches*, viewed 06 September 2019, <https://www.smh.com.au/national/some-fifo-workers-pay-high-price-for-riches-20150106-12ioki.html>.

Pridmore, S & Reddy, A, 2012, 'Financial loss and suicide', *The Malaysian Journal of Medical Sciences : MJMS*, vol. 19, no. 2, pp. 74-6.

Raynold, E, 2017, *Suicide disaster for Australia's most loveable tough guys*, news.com.au, <https://www.news.com.au/finance/work/at-work/suicide-disaster-for-australias-most-loveable-tough-guys/news-story/e76bb1112d16409e95ae24b7cc72eddf>.

Skillen, S, 2018, *Are women the untappable resource of the construction industry*, viewed 06 September 2019, <https://www.forsythesrecruitment.com.au/blog/women-untapped-resource-construction-industry/>.

Skills Australia, 2011, *Skills Australia submission to the House of Representatives Standing Committee on Regional Australia: Inquiry into the experience of fly-in, fly-out (FIFO) and drive-in, drive-out (DIDO) workers in regional Australia*, Skills Australia, Canberra, Australia

Sunindijo, RY & Kamardeen, I, 2017, 'Work stress is a threat to gender diversity in the construction industry', *Journal of Construction Engineering Management*, vol. 143, no. 10, p. 04017073.

The Chamber of Minerals and Energy of Western Australia, 2011, *Submission to the Standing Committee on Regional Australia's Inquiry into the Use 'Fly-In, Fly-Out' (FIFO) and 'Drive-In, Drive-Out' (DIDO) Workforce Practices in Regional Australia*, The Chamber of Minerals and Energy of Western Australia, Perth, Australia

World Health Organization, 2019, *Suicide*, viewed 04 September 2019, <https://www.who.int/news-room/fact-sheets/detail/suicide>.

A PROCESS MAP FOR SUPPLY CHAIN RELATIONSHIPS IN PREFABRICATED CONSTRUCTION

Ehsan Bakhtiarizadeh[1], Wajiha Shahzad[1], James Olabode Bamidele Rotimi[1]

[1]School of Built Environment, Massey University, Auckland, New Zealand

Abstract

Supply chain management (SCM) techniques are being applied to different industry sectors e.g. food production, pharmaceutical trades, and construction. Despite a handful of researches conducted on SCM in the construction industry, research with a focus on the prefabrication supply chain is limited, particularly where the major obstacles inhibiting the efficiency and effectiveness of prefabrication supply chain systems demand attention. Therefore, the current study provides an insight into supply chain integration in prefabrication. A review of relevant literature coupled with experiential learning is employed to map supply chain relationships and information flow in the prefabrication subsector of the construction industry in New Zealand. The objective is to establish inter-relationships of prefabrication supply chain partners, and investigate the impediments to achieving optimum benefits in SCM and any innovation opportunities. This study shows that any mechanisms that could eliminate intermediaries and distribute supply chain information more effectively, deserve attention. The use of unalterable information database in the supply chain could vividly accelerate business interactions and produce more transparent collaborations and trust among prefabrication projects partners.

Keywords: Prefabrication, Offsite fabrication, Information integration, Supply chain integration, Construction supply chain management, New Zealand

Introduction

Construction is one of the biggest industries in the world. In New Zealand, it made a contribution of 3.7% to the Gross Domestic Product (GDP) in the first quarter of 2019 (StatsNZ 2019). However, the industry is still suffering from many inherent issues including low productivity, poor quality of materials, lack of trust, lack of collaboration and information sharing among all the stakeholders (Li, Greenwood & Kassem 2019). Whilst the conventional type of construction is suffering from such issues, offsite manufacturing or prefabrication has been recognised for an effective solution to target these problems by reducing defects, lowering lifecycle time and costs, improving quality of final deliverables, and growing sustainability (Shahzad 2011). In New Zealand, the uptake of prefabrication is higher than other countries, with an estimated 32% uptake in 2015 compared to Australia 3%, UK 4%, Spain and France 5% (PrefabNZ 2015).

Business interactions is being accounted as a vital turning point for acquiring high benefits in supply systems (Nicholas & Edwards 2003). Effective flow of information and collaboration between project partners contribute to effective supply chain integration and trust (Bidabadi Zahra, Hosseinalipour, Hamidizadeh Mohammad & Mohebifar 2016). To meet these certain requirements a clear map of inter-relationships with respect to the flow of information must be established to provide all the construction stakeholders with an insight of prefabrication supply chain integration.

A study by Black, Akintoye and Fitzgerald (2000) indicates that integration of relationships, which is an effect of information integration, can bring improved performance and reduced conflicts in the construction supply chain. Hence, when information sharing is built explicitly among all involving parties, significant benefits including cost benefits, transparency, stakeholder’s satisfaction, trustworthy collaboration, and better quality products are obtained. Also, Cai, Jun and Yang (2010) advise that effective information sharing contributes to transparent relationships and improves trust and coordination.

However, there are a few barriers deterring the efficient supply chain management. Reluctance to adopt new technologies, low transparency and traceability, and lack of appropriate information technology are considered as some hurdles (Akintoye, McIntosh & Fitzgerald 2000; Harland, Caldwell, Powell & Zheng 2007). In addition, shortage of secure and tamper-proof block of information and knowledge precedents within the supply chain is considered as another hindrance (Penzes 2018). Therefore, the current paper provides a baseline for the prefabrication supply chain efficiency by establishing an information-based relationships map of prefabrication supply chain partners in New Zealand.

This study utilises literature review and empirical observations to investigate the existing status of prefabrication supply chain integration in New Zealand and to identify limitations to gaining a productive supply chain. Showing the arrows of relationships and information directions among supply chain stakeholders, findings reveal that there is a deficiency in having an appropriate platform for information storage when it comes to having integration and collaboration within the supply chain.

Literature review

Different synonyms that are interchangeably used; offsite manufacturing, offsite fabrication, pre-assembly, offsite construction, and prefabrication, all signify the process of building a component, a portion, or a complete structure of a bigger project remotely. Offsite fabrication is classified to five types including component-based (units and components such as precast beams and columns), panelised (such as precast floor or wall panels), modular (such as pods or modules), hybrid (combination of panelised and modular prefabrication) and complete building prefabrication (Shahzad 2016). Prefabrication is a potential remedy for traditional construction drawbacks and is perceived to be sociologically, economically and environmentally advantageous in regards to the reduction of waste and defects and promoting sustainability (Al-Ma'aitah ; Kaufmann & Remick 2009).

A study report published by BRANZ characterises prefabrication as the system and structure that facilitate the construction of a complete or a part of a building away from the final location (JC Burgess 2013). Prefabrication is envisaged as an innovative form of construction. Shahzad (2016) scrutinises the major benefits and impacts of prefabrication in New Zealand construction industry and states that this innovation has the potential to shorten the productivity problems arising during the use of conventional construction methods.

From environmental standpoint, prefabrication in the construction supply chain management (CSCM) reduces sustainability issues by minimising carbon footprint and waste (Afolabi, Ojelabi & Oyeyipo 2018; Kaufmann & Remick 2009). However, the construction industry, particularly the offsite fabrication is lagging behind in terms of supply chain practices and efficiency (Segerstedt Olofsson Anders & Bankvall Bygballe Dubois Jahre Lars Lena 2010; Shahzad 2016), and some factors that inhibit the uptake of offsite construction supply chain are identified as lack of trust, collaboration, and information integration among the partners in supply chain (PrefabNZ 2015; Shahzad 2011; Zhai, Reed & Mills 2013).

Impediments to an efficient offsite construction

Prefabrication is an innovative technology and supply chain management techniques for this innovation are tailored according to the project circumstances. The concept of prefabrication supply chain principally conforms to fundamental CSCM implications and therefore the barriers to efficient and effective prefabricated projects supply chains are mostly identified analogous to conventional or onsite projects. Some impediments to the effective supply chain in this sector have been diagnosed by various authors and are indicated in Table 1.

Among the factors shown in table 1, key constraints that inhibit the improvement of this innovative technology are:

- Reluctance to adopting innovation or information technology
- Transportation restrictions
- Low collaboration and trust
- Poor information integration

Information sharing and integration of systems require trust and coordination (Cheng, Law, Bjornsson, Jones & Sriram 2010). Poor information sharing results in lack of trust, and low level of trust among stakeholders leads to low collaboration and reluctance to adoption of innovation or technologies (Shahzad 2016). Having a safe and secure repository for retaining knowledge and information of supply chain exercises leads to a better supply chain integration and helps to maintain these information for future projects (Penzes 2018).

Information integration

Typical construction projects consist of 5 phases where several problems and complexities such as widely dispersed or decentralised information (that leads to wrong and defective products delivery) may arise (Behera, Mohanty & Prakash 2015). Although the transformation of traditional or onsite construction to the offsite construction improves the quality, customer satisfaction, efficiency, predictability, and sustainability of projects (Rahimian, Goulding, Akintoye & Kolo 2017), some deficiencies such as lack of effective information sharing barricade the productivity of it (Rahimian et al. 2017; Vrijhoef, Koskela & management 2000). Cheng et al. (2010) assert that since construction supply chains are highly dynamic and the structure of them are always susceptible to change, participants hesitate to work collaboratively to build enough trust and to share information efficiently.

Information that is exchanged within supply systems needs integration and management to provide the opportunity for fundamental improvement in clients and suppliers preferences and supply chain integration. Hatmoko and Scott (2010) note that CSCM is a system where suppliers, contractors, clients and all other parties work collaboratively to use information in order to carry out construction projects effectively and efficiently. Therefore, by devising a way to develop information integration, lots of bespoke issues pertinent to inefficiency in this industry would be minimised.

Information integration refers to the sharing of information among the supply chain partners and its main purpose is to achieve real-time transmission of information throughout the supply chain system (Prajogo & Olhager 2012). Integration of information, promises the logistics integration which refers to particular logistics practices and operational activities that coordinate the flow of materials from suppliers to customers (Stock, Greis & Kasarda 2000). Despite the fact that many researchers believe that information integration is necessary for an efficient supply chain management (Frohlich & Westbrook 2001; Patterson, Grimm, Corsi & Review 2003; Sahin & Robinson 2002; Samarasinghe, Tookey & Rotimi 2013), information exchange is not quite practically developed in CSCM due to the reluctance of stakeholders to using innovations and digital technologies (Cox & Ireland 2002; Fawcett, Magnan & Management 2002).

Information sharing in supply chain brings great enhancement in business collaboration and trust. As Yu (2001) explains, information sharing is an effective way of managing large supply chain systems. He elaborates that although decentralisation is an attribute of supply chain, uncertainties arise when information within supply chain is changed by one party and other parties remain unaware or get informed late (Yu 2001). This could generate a change in the delivery time of products to the site and an increase to the relative costs. Likewise, Čuš-Babič, Rebolj, Nekrep-Perc and Podbreznik (2014) demonstrate that data or information that is generated by multiple sources results in disintegration, scepticism and low level of communication efforts among parties.

Table 1: Impediments to an efficient and effective prefabrication supply chain management

Barriers as defined by different authors	(Behera et al. 2015)	(Blismas, Pendlebury, Gibb & Pasquire 2005)	(Akintoye et al. 2000)	(Jaillon & Poon 2010)	(Bidabadi Zahra et al. 2016)	(Blismas, Arif & Wakefield 2009)	(Harland et al. 2007)	(Shahzad, Mbachu & Management 2013)	(Shahzad 2016)	**(Čuš-Babič et al. 2014)**	(Gibb 1999)	(Rahimian et al. 2017)	(Gibb & Isack 2010)	(Prajogo & Olhager 2012)	(Zhai et al. 2013)	(Sutrisna & Goulding 2019)
Temporary and negative project-based viewpoint	*	*			*						*		*		*	
Lack of commitment of managers and experts		*	*		*			*	*						*	
Reluctance to adopting innovations and information technology		*		*	*	*		*	*		*	*			*	*
Vague regulations and strategic legislations			*			*		*	*			*			*	
Low transparency and traceability	*						*	*		*	*					
Decentralised or fragmented nature	*		*								*	*	*			
Low understanding of concepts			*					*	*			*			*	*
Low collaboration and partnership	*		*	*	*		*	*	*	*	*				*	
Lack of trust	*	*				*	*		*	*				*		
Poor information sharing or knowledge integration	*	*					*	*	*				*	*		*
Low data and information accuracy	*													*		*
Lack of sufficient suppliers		*						*	*		*		*		*	
Limited site storage		*				*		*	*						*	
Longer lead-time and lengthy design process		*		*					*		*	*			*	
Transportation constraints		*		*		*		*	*		*	*			*	
Inadequate risk management techniques																*

With effective flow of information and maintaining information in a safe platform without the concern of alteration, supply chain systems can achieve better integrity and performance. Adoption of a safe and secure platform for trading information, and creating a safe home for information to be deposited could effectively result in better decision making, collaboration, transparency and trust (O'brien & Marakas 2005).

Research method

This study investigates the supply chain integration issues in prefabrication sector, understands the status quo of relationships and information directions, and finds the corresponding solution for improving the innovation opportunities and enhancing supply chain integration in New Zealand. The paper adopts a qualitative research approach which can improve the description and explanation of real-world phenomena (Bradley, Curry & Devers 2007) and is a sort of research that extract findings from practical settings (Patton 2015). This method of research often involves collection of data from different sources (Nassaji 2015) and relies on observation to examine the situation and investigate the norm (Walliman 2017). Also, Creswell and Creswell (2017) describe that qualitative methods are the study of context and are based on observations where personal values can be brought into the study. As such, for this study;

1. First, a review of relevant literature is used to grasp a basic understanding of prefabrication technology. This step helped identify the key stakeholders involved in prefabrication supply chain and various stages of a project.
2. Second, based on empirical learnings and the understanding developed from literature, stakeholders inter-relationship within each stage with respect to the prevalent flow of information was identified
3. Finally, observation of information sharing processes among prefabrication supply chain partners was employed to map the information-based inter-relationship.

A similar approach of research was used by Kalian, Watson, Agbasi, Anumba and Gibb (2004) for process mapping the relationships associated with the flow of information within rainscreen cladding supply chain of UK construction industry, and also by Gray and Al-Bizri (2007) for modelling the supply of detailed fabrication and production information.

Findings and discussion

Construction projects often require integration between various entities in order to achieve a certain goal (Behera et al. 2015). Supply chain practices cannot be enhanced without an efficient integration and collaboration. Doran and Giannakis (2011) advise that to ensure that offsite practices can compete effectively with onsite practices and to overcome negative facets of prefabrication supply chain, there is a need to increase supply chain integration and relationships.

In order to model interconnectivity, there is a need for exploration of information flow and sharing process within the offsite supply chain. A review of literature has been employed to identify the stakeholders and prefabrication projects stages. Involved parties in an offsite construction supply chain are; statutory bodies, clients or customers, consultants, builders or developers, subcontractors, manufacturers, direct and indirect suppliers, and transporters or distributors (Behera et al. 2015; Chinyio & Olomolaiye 2009; Gibb 1999; Shahzad 2011; Smith ; Smyth & Pryke 2008).

According to Royal Institute of British Architects (RIBA) plan of work 2013, construction project phases comprise eight stages that form the building processes from inception of the project to handover and maintenance. Gibb (1999) clusters the construction of a two-storey office building (by modular construction approach) into 12 phases and compares that to its traditional approach. Using the RIBA plan of work as a default scheme and tailoring it for offsite construction, the proposed process map of this study entails 12 phases (Figure 1), and they are described as follows:

- **Strategic definition:** A generic assessment of the project from strategic standpoint as well as defining and briefing client's business and identifying core requirements of the project occur in this stage. Collaboration and information exchange between client and consultant take place at this stage.
- **Preparation & briefing:** The purpose of this stage is to define project objectives and scope, appraising sustainability, assigning project budget, undertaking feasibility studies, reviewing and exchanging project information, and carrying out risk assessment. Project briefing with regards to opportunities and constraints is initialised. Generic discussion regarding the suitability and feasibility study takes place, and information flows between client and consultant.
- **Concept design:** Concept design includes proposals for structural design and specifications, primary cost information, strategic information with respect to design programme, and finalization of project brief. Engineers and architects usually collaborate on the design phase (Behera et al. 2015). The flow of information in this stage is among statutory bodies, clients and consultants.
- **Developed design:** Developed design consists of updated and coordinated structural design, cost information, and project strategies. A number of design revisions or iterations might happen in this stage. Builders and subcontractors are informed of the holistic plans and design process in this stage and they are engaged from this stage to the post-project review phase (Vilasini, Neitzert, Rotimi & Windapo 2012). The flow of information is among statutory bodies, clients, consultants, builders, subcontractors, and direct suppliers.
- **Production planning:** This stage according to Behera et al. (2015) entails identification of required raw materials for manufacturing, determining the quantity of materials, price query and quotations from suppliers. Information streams among consultants, builders, manufacturers, and direct and indirect suppliers at this stage.
- **Technical design:** Technical design contains all architectural, structural, electrical and mechanical plans, drawings, proposals, and strategies. Indirect suppliers will get aware of the designated parts that need to be completed offsite. The information is exchanged here among statutory bodies, clients, consultants, builders, subcontractors, manufacturers, and direct and indirect suppliers.
- **Construction (site set-up and initialisation):** Initialisation comprises the development of construction programme, preparation of site, commencing the construction of foundation, and executing pre-requirements before the time that all prefabricated components or panels must be shipped to the site. A flawless collaboration is necessary among the involved parties at this stage as to prevent delays and reworks. The information flow is considered among statutory bodies, clients, consultants, builders, subcontractors, and direct suppliers.
- **Construction (offsite):** In this segment according to Behera et al. (2015) materials that are off-the-shelf and that need to be prefabricated are classified. Offsite manufacturing in accordance with construction programme and detailed design is developed and transportation planning is initialised (Kaufmann & Remick 2009). Information and data exchange in this section happens among statutory bodies, clients, consultants, builders, subcontractors, manufacturers, indirect suppliers, and distributors.
- **Construction (transportation and assembly on site):** Materials and components fabricated offsite are transported to the site for being erected. Efficient information sharing is essential for managing the interval time between the current shipment that is being erected and the next shipment, to have a smooth flow of transportation and to avoid warehouse surge. Information in this phase is shared among statutory bodies, clients, consultants, builders, subcontractors, manufacturers, and distributors.

- **Handover and Close out (pre-commissioning and commissioning):** The project is completed and can be handed over to the end user or client. All the terms and conditions of the contract has been met, and the surplus materials are stored to be used for future projects (Gibb 1999). Also, the collaboration and information sharing in this step is among statutory bodies, client, consultant, builder, and subcontractor.
- **In use and maintenance (guarantee period):** This phase encompasses post-occupancy and commissioning evaluation, performance monitoring, development planning, and as-built information updates. Interaction and information is updated among statutory bodies, client, consultant, and builder.
- **Demolition:** Project strategies defined at the beginning of the project should be in accordance with sustainability codes and standard, and must be implemented with respect to log-term impacts on the environment. With effective sustainability consideration in the context of projects a reduction in waste is achieved and the ability to dismantle the components for future use raises. Client or end user needs to inform statutory bodies in this case.

The customer–supplier relationship links the parties involved in a construction supply chain together and enhance the overall integrity (Love, Irani & Edwards 2004). Lack of communication and effective information integration leads to poor supply chain performance (Humphreys, Matthews & Kumaraswamy 2003). In case that supply chain integration deteriorates, project time encounters delays, cost will overrun, and quality will be exacerbated (Meng 2012). As it is depicted in Figure 1, the flow of information and interaction among different parties is complex and this may pose challenges to achieving effective collaboration and integration. The problem of inefficient offsite construction supply chain can be addressed by developing information integration and adopting advanced technologies as a solution.

Blockchain as a potential solution

Construction projects often require integration between various entities in order to achieve a certain goal (Behera et al. 2015). Supply chain practices cannot be enhanced without an efficient integration and collaboration. Doran and Giannakis (2011) advise that to ensure that offsite practices can compete effectively with onsite practices and to overcome negative facets of prefabrication supply chain, there is a need to increment supply chain integration and relationships. Thus, developing a framework for applying advanced technologies e.g. Distributed Ledger Technology (DLT) to control the information flow among entities provide all the construction practitioners with a better opportunity of increasing effectiveness and efficiency of supply chain.

Today, as organisations are moving toward e-commerce, where all the transactions are accomplished online, adoption of technology can substantially reduce bureaucracy and paperwork, improve communication and information sharing, enhance collaboration and trust among stakeholders , and reduce supply chain cycle time (Handfield & Bechtel 2002).

Key players / stages	statutory bodies (HSE, BCA, QA, Fire & rescue)	Client (building owner)	Consultant (Design team)	Builder (Developer)	Subcontractor	Manufacturer	Indirect supplier	Direct Supplier	Distributor
Strategic Definition (Inception, Briefing, Business case,...)		C	©						
Preparation & Brief (Develop project objectives, Budget, Limitations, Feasibilty study, sustainability plans,....)		C	©						
Concept Design (outline proposals and plans, cost and budget information, project strategies, site info,...)	O	C	©						
Developed Design (coordinated and updated design and proposals, strategies and....)	O	C	©	B	SC			DS	
Production Planning (coordinated and updated design and proposals, strategies and....)			©	B		M	IS	DS	
Technical Design (All plans and drawings, proposals and strategies according to the Design Responsibilities Matrix)	O	C	©	B	SC	M	IS	DS	
Construction (onsite preparation and initialising)	O	C	©	B	SC			DS	
Construction (Offsite)	O	C	©	B	SC	M	IS		D
Construction (transportation and assembly onsite)	O	C	©	B	SC	M			D
Handover and Close out (Pre-com and commissioning)	O	C	©	B	SC				
In use & Maintenance (post-occupancy and guarantee period)	O	C	©	B					
Demolition	O	C							

Figure 1: Relationship and information flow among prefabrication supply chain partners

Blockchain is a consensus-based ledger which facilitates transactions among its users by providing them with a secure and tamper-proof database. Blockchain originally was invented for transaction of crypto-currencies (e.g. Bitcoin) and it represents a network where various nodes perform transactions either publicly or privately. In public network, everyone is able to access the information of the ledger and in private network, people need to be granted access to engage (Li, Greenwood & Kassem 2018).

Blockchain technology operates through a decentralised peer-to-peer (P2P) network and; it is immutable or unalterable, it decrease dependency on intermediaries such as banks or insurance companies, it contains an algorithm and proof-of-work mechanism to validate transactions among all nodes (Zhao, Fan & Yan 2016). Information sharing with others are main concerns for most companies that provide intermediary services in industries (Lu & Xu 2017). As Penzes (2018) explains, Blockchain used in supply chain management provide all information and documentation accessible to all parties but impossible to falsify. Also, Zhao et al. (2016) advise that immutability of information in a chained block leads to trust and secure transaction. With this trust mechanisms arising from blockchain, supply chain partners are able to share their information or assets without the concerns of fraud.

One of the most dominant importance of blockchain in CSCM is that when all information and data are accumulated in blocks, it simplifies the traceability and helps clients or end-users to track back all processes to the provenance of products (Li et al. 2018). Therefore, by consolidating project information and integrating it into blockchain, efficiency of logistics, flow of information, transparency and trust would be highly improved and the dependency on intermediaries becomes less (Zhao et al. 2016). By adopting blockchain as a safe platform for transferring transactions and exchanging information, customers can also be assured of the quality of used materials (Lu & Xu 2017).

Conclusion

Supply chain management in the construction industry is considered as the network of activities that provide customers with economic values to the function of contract management, service and material procurement, delivery and facilities management (Love et al. 2004). Construction industry is very complex since many subcontractors and vendors are involved. Majority of the problems associated with conventional construction (socially, economically and environmentally) has been mitigated by the use of innovations such as prefabrication. Yet within this subsector, lack of information sharing which stems from unsecured integration of information results in low trust and transparency among entities. Also, Greta Gordon (2018) explain that New Zealand is experiencing low productivity, unsustainable materials, leaky buildings, and low quality components and products that are being used in the construction. This issue can be attributed to the lack of efficient supply chain integration in terms of ineffective information integration and low traceability function. Large number of parties engaged in supply systems normally work individually with low level of shared information which inhibits the supply chain integration and traceability of prefabricated products in New Zealand. In an integrated supply chain, information is shared securely and becomes available among the members without any change. This enhances supply chain visibility and avoids information delays and distortions (Cheng et al. 2010).

Blockchain technology (or distributed ledger technology) that ensures traceability, transparency, and security, is demonstrating potentials for mitigating supply chain management problems. With blockchain, information recorded in a shared ledger provides stakeholders with an auditable and secure platform which gives enough ability to track back the processes occurred in supplying a product all the way to the origin of materials. In addition, it streamlines transactions among users (peer-to-peer) by reducing the reliance on intermediaries in the network.

This paper represented an information-based relationships process map of prefabrication supply chain of New Zealand. Findings show that using blockchain technology contributes to the elimination of intermediaries and helps the effective diffusion of supply chain information. This technology also accelerates business interactions and produce more transparent collaborations among prefabrication projects partners. A review of relevant literature along with empirical observations were adopted in this study to identify the existing information integration of prefabrication supply chain in New Zealand. Also, limitations to gaining a productive supply chain were indicated. The paper concluded that there is a lack of trustworthy platform for information storage when it comes to having integrity within the supply chain and this issue can be addressed by adopting a digital shared ledger.

References

Afolabi, A, Ojelabi, RA & Oyeyipo, OJIJoCSCM 2018, 'An analysis of social media marketing of indigenous construction firms in Nigeria: A tool for sustainable growth', vol. 8, no. 2, pp. 60-72.

Akintoye, A, McIntosh, G & Fitzgerald, E 2000, 'A survey of supply chain collaboration and management in the UK construction industry', *European Journal of Purchasing & Supply Management*, vol. 6, no. 3, pp. 159-68.

Al-Ma'aitah, NJSCM 'Green supply chain management (GSCM) practices and their impact on performance: An insight from the Jordanian construction sector', vol. 8, no. 2, pp. 87-104.

Behera, P, Mohanty, RP & Prakash, A 2015, 'Understanding Construction Supply Chain Management', *Production Planning & Control*, vol. 26, no. 16, pp. 1332-50.

Bidabadi Zahra, T, Hosseinalipour, M, Hamidizadeh Mohammad, R & Mohebifar, A 2016, 'Supply chain collaboration within the Iranian construction industry', *Organization, Technology and Management in Construction: An International Journal*, no. 1, p. 1437.

Black, C, Akintoye, A & Fitzgerald, E 2000, 'An analysis of success factors and benefits of partnering in construction', *International Journal of Project Management*, vol. 18, no. 6, pp. 423-34.

Blismas, N, Arif, M & Wakefield, R 2009, 'Drivers, constraints and the future of offsite manufacture in Australia', *Construction Innovation*, vol. 9, no. 1, pp. 72-83.

Blismas, NG, Pendlebury, M, Gibb, A & Pasquire, C 2005, 'Constraints to the Use of Off-site Production on Construction Projects', *Architectural Engineering and Design Management*, vol. 1, no. 3, pp. 153-62.

Bradley, EH, Curry, LA & Devers, KJ 2007, 'Qualitative Data Analysis for Health Services Research: Developing Taxonomy, Themes, and Theory', vol. 42, no. 4, pp. 1758-72.

Cai, S, Jun, M & Yang, Z 2010, 'Implementing supply chain information integration in China: The role of institutional forces and trust⋆', vol. 28, no. 3, pp. 257-68.

Cheng, JCP, Law, KH, Bjornsson, H, Jones, A & Sriram, R 2010, 'A service oriented framework for construction supply chain integration', *Automation in Construction*, vol. 19, no. 2, pp. 245-60.

Chinyio, E & Olomolaiye, P 2009, *Construction stakeholder management*, John Wiley & Sons.

Cox, A & Ireland, P 2002, 'Managing construction supply chains: the common sense approach', *Engineering Construction & Architectural Management (Wiley-Blackwell)*, vol. 9, no. 5/6, pp. 409-18.

Creswell, JW & Creswell, JD 2017, *Research design: Qualitative, quantitative, and mixed methods approaches*, Sage publications.

Čuš-Babič, N, Rebolj, D, Nekrep-Perc, M & Podbreznik, P 2014, 'Supply-chain transparency within industrialized construction projects', *Computers in Industry*, vol. 65, no. 2, pp. 345-53.

Doran, D & Giannakis, M 2011, 'An examination of a modular supply chain: a construction sector perspective', *Supply Chain Management: An International Journal*, vol. 16, no. 4, pp. 260-70.

Fawcett, SE, Magnan, GMJIJoPD & Management, L 2002, 'The rhetoric and reality of supply chain integration', vol. 32, no. 5, pp. 339-61.

Frohlich, MT & Westbrook, R 2001, 'Arcs of integration: an international study of supply chain strategies', vol. 19, no. 2, pp. 185-200.

Gibb, A & Isack, F 2010, 'Re-engineering through pre-assembly: client expectations and drivers', *Building Research & Information*, vol. 31, no. 2, pp. 146-60.

Gibb, AG 1999, *Off-site fabrication: prefabrication, pre-assembly and modularisation*, John Wiley & Sons.

Gray, C & Al-Bizri, S 2007, 'Modelling Trade Contractor Information Production', *Architectural Engineering and Design Management*, vol. 3, no. 1, pp. 39-48.

Greta Gordon, MC 2018, *Building-quality issues: A literature review*, SR375.

Handfield, RB & Bechtel, C 2002, 'The role of trust and relationship structure in improving supply chain responsiveness', *Industrial Marketing Management*, vol. 31, no. 4, pp. 367-82.

Harland, CM, Caldwell, ND, Powell, P & Zheng, J 2007, 'Barriers to supply chain information integration: SMEs adrift of eLands', *Journal of Operations Management*, vol. 25, no. 6, pp. 1234-54.
Hatmoko, JUD & Scott, S 2010, 'Simulating the impact of supply chain management practice on the performance of medium-sized building projects', *Construction Management and Economics*, vol. 28, no. 1, pp. 35-49.
Humphreys, P, Matthews, J & Kumaraswamy, M 2003, 'Pre-construction project partnering: from adversarial to collaborative relationships', *Supply Chain Management: An International Journal*, vol. 8, no. 2, pp. 166-78.
Jaillon, L & Poon, CS 2010, 'Design issues of using prefabrication in Hong Kong building construction', *Construction Management and Economics*, vol. 28, no. 10, pp. 1025-42.
JC Burgess, NBaIp 2013, *Prefabrication impacts in the New Zealand construction industry*, SR279.
Kalian, A, Watson, A, Agbasi, E, Anumba, C & Gibb, AJBPMJ 2004, 'Modelling the building cladding attainment processes', vol. 10, no. 6, pp. 712-23.
Kaufmann, M & Remick, C 2009, *Prefab green*, Gibbs Smith.
Li, J, Greenwood, D & Kassem, M 2018, 'Blockchain in the built environment: analysing current applications and developing an emergent framework', in.
—— 2019, 'Blockchain in the built environment and construction industry: A systematic review, conceptual models and practical use cases', *Automation in Construction*, vol. 102, pp. 288-307.
Love, PE, Irani, Z & Edwards, DJJScmaij 2004, 'A seamless supply chain management model for construction', vol. 9, no. 1, pp. 43-56.
Lu, Q & Xu, X 2017, 'Adaptable Blockchain-Based Systems: A Case Study for Product Traceability', *IEEE Software*, vol. 34, no. 6, pp. 21-7.
Meng, X 2012, 'The effect of relationship management on project performance in construction', *International Journal of Project Management*, vol. 30, no. 2, pp. 188-98.
Nassaji, H 2015, *Qualitative and descriptive research: Data type versus data analysis*, Sage Publications Sage UK: London, England, 1362-1688.
Nicholas, J & Edwards, DJ 2003, 'A model to evaluate materials suppliers' and contractors' business interactions', *Construction Management & Economics*, vol. 21, no. 3, pp. 237-45.
O'brien, JA & Marakas, GM 2005, *Introduction to information systems*, vol. 13, McGraw-Hill/Irwin New York City, USA.
Patterson, KA, Grimm, CM, Corsi, TMJTRPEL & Review, T 2003, 'Adopting new technologies for supply chain management', vol. 39, no. 2, pp. 95-121.
Patton, MQ 2015, *Qualitative research & evaluation methods : integrating theory and practice*, Fourth edition edn, SAGE.
Penzes, B 2018, *Blockchain Technology in the Construction Industry*.
Prajogo, D & Olhager, J 2012, 'Supply chain integration and performance: The effects of long-term relationships, information technology and sharing, and logistics integration', *International Journal of Production Economics*, vol. 135, no. 1, pp. 514-22.
PrefabNZ 2015, *levers for prefabNZ*.
Rahimian, FP, Goulding, J, Akintoye, A & Kolo, S 2017, 'Review of Motivations, Success Factors, and Barriers to the Adoption of Offsite Manufacturing in Nigeria', *Procedia Engineering*, vol. 196, pp. 512-9.
Sahin, F & Robinson, EPJDs 2002, 'Flow coordination and information sharing in supply chains: review, implications, and directions for future research', vol. 33, no. 4, pp. 505-36.
Samarasinghe, A, Tookey, J & Rotimi, J 2013, 'Supply chain collaboration in New Zealand house construction'.
Segerstedt Olofsson Anders, T & Bankvall Bygballe Dubois Jahre Lars Lena, EAM 2010, 'Interdependence in supply chains and projects in construction', *Supply Chain Management: An International Journal*, no. 5, p. 385.
Shahzad, WM 2011, 'Offsite manufacturing as a means of improving productivity in New Zealand construction industry : key barriers to adoption and improvement measures : a research thesis submitted in fulfilment of the requirements for the degree of Masters of Construction Management at Massey University, Albany, New Zealand', Master of Construction Management (M.Con.Mgt.) thesis, Massey University.

—— 2016, ‘Comparative analysis of the productivity levels achieved through the use of panelised prefabrication technology with those of traditional building system : a thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy (PhD) in Construction, School of Engineering & Advanced Technology, Massey University, Albany, New Zealand’, Doctor of Philosophy (PhD) thesis, Massey University.

Shahzad, WM, Mbachu, JJIJoPO & Management 2013, ‘Prefabrication as an onsite productivity enhancer: analysis of impact levels of the underlying constraints and improvement measures in New Zealand construction industry’, vol. 5, no. 4, pp. 334-54.

Smith, RE ‘Off-site and modular construction explained’.

Smyth, H & Pryke, SJCRiC 2008, ‘Collaborative relationships in construction’, p. 245.

2019, *Gross domestic product overview for March 2019 quarter*, by StatsNZ, StatsNZ.

Stock, GN, Greis, NP & Kasarda, JD 2000, ‘Enterprise logistics and supply chain structure: the role of fit’, *Journal of Operations Management*, vol. 18, no. 5, pp. 531-47.

Sutrisna, M & Goulding, J 2019, ‘Managing information flow and design processes to reduce design risks in offsite construction projects’, *Engineering, Construction and Architectural Management*, vol. 26, no. 2, pp. 267-84.

Vilasini, N, Neitzert, T, Rotimi, J & Windapo, A 2012, ‘A framework for subcontractor integration in alliance contracts’, *International Journal of Construction Supply Chain Management*, vol. 2, no. 1, pp. 17-33.

Vrijhoef, R, Koskela, LJEjop & management, s 2000, ‘The four roles of supply chain management in construction’, vol. 6, no. 3-4, pp. 169-78.

Walliman, N 2017, *Research methods: The basics*, Routledge.

Yu, Z 2001, ‘Benefits of information sharing with supply chain partnerships’, *Industrial Management & Data Systems*, vol. 101, no. 3, pp. 114-21.

Zhai, X, Reed, R & Mills, A 2013, ‘Factors impeding the offsite production of housing construction in China: an investigation of current practice’, *Construction Management and Economics*, vol. 32, no. 1-2, pp. 40-52.

Zhao, JL, Fan, S & Yan, JJFI 2016, ‘Overview of business innovations and research opportunities in blockchain and introduction to the special issue’, vol. 2, no. 1, p. 28.

POSITION OF WOMEN IN AUSTRALIAN CONSTRUCTION INDUSTRY

Beatrix King[1], Pushpitha Kalutara[2], Darryl O'Brien[3], Ronald Webber[4], Stephen Poulter[5], Hayden Cassar[6]

[1]Built Environment, School of Engineering & Technology, CQUniversity, Brisbane, Australia

[2]Built Environment, School of Engineering & Technology, CQUniversity, North Rockhampton, Australia

[3]Technical and Regulation, Victorian Building Authority (VBA), Melbourne, Australia

[4] Built Environment, School of Engineering & Technology, CQUniversity, Mackay, Australia

[5]Built Environment, School of Engineering & Technology, CQUniversity, Sydney, Australia

[6]Built Environment, School of Engineering & Technology, CQUniversity, Wayville, Australia

Abstract

Australian Bureau of Statistics suggests that the construction industry is so integral to Australia that contributes a great proportion to the nations' GDP while generating the highest number of employment opportunities. However, there is a doubt whether a major recognition is given to the women in Australia in those employment opportunities; otherwise, knowingly undervalued by the industry. The current study attempts to find an answer through hypothesis validation which checks whether women's involvement of Australian construction industry has significantly increased in recent years referring to past 10 years. Research design will be based on the analysis of Australian Bureau of Statistics data and the findings of an extensive literature review. The study will also discuss the challenges, benefits and recommendations extending literature review and conducting an organisational review. The findings reveal the derived hypothesis is true and aftermath discussion suggests that it may be due to promotion of the industry and/or encouragement of women by support groups/ organizations. Research outcomes have a social importance; hence, Australian government agencies, construction organisations, professional bodies and other agencies can promote female workers entering Australian construction industry.

Keywords

Australian construction industry, Women in Australia, Employment opportunities, Hypothesis validation, Australian Bureau of Statistics data, Literature review, Organizational review

Introduction

Australia's population is growing by 1.6% every year, 38.6% is attributed to net overseas migration and 61.4% is attributed to natural increase/childbirth (Australian Bureau of Statistics, 2019a). With this increase every year, the population growth is a contributing factor in the rising demand for new structures in both residential and commercial spaces which makes the Australian construction industry strong and robust (Cartwright, 2018). This is showcased by the fact that Australian construction industry contributes $134.2 billion in 2015-16 financial year to the country's economy or approximately 8% to the gross domestic product making it the largest non-service related industry (Australian Bureau of Statistics, 2018b; Cartwright, 2018; Office of the Chief Economist, 2016). Not only higher contribution to GDP, but also the largest employment provider among all industries with whooping 1.1 million Australians (according to 2015-16 statistics) working within the construction industry (Australian Bureau of Statistics, 2019a; Cartwright, 2018; Office of the Chief Economist, 2016); however, Australian construction industry is regarded as the most male dominated sector in the country (Clarke *et al.*, 2012) creating more gender imbalance. First phase of the current study looks into the current statistics to understand the current pattern of women contribution to construction industry. The next phase will try identifying factors for that pattern.

The design of the methodology based on the development of a hypothesis and its validation will drive on to the research findings. The study analysed Australian Bureau of Statistics 10-year range data set from 2007-2008 financial year to 2017-2018 financial year corresponding to women employed in Australian construction industry. The analysed data validates that the trend of women employed in Australian construction industry is increasing. Knowing the pattern, the study conducted an organisational review and identified that several supporting schemes are currently in function in the form of grants, promotion and support groups. This raised why industry leaders are keen to help promote women in construction and what added benefits they will gain increasing women employment in construction industry. Understanding the traditional challenges and their negative influence on women employment in construction industry was another focus of the current research. Literature review was the prime strategy to answer all the questions after the pattern was identified. The findings led to the assumption that the increase pattern is due to the creation of more female focused organisations promoting equality and females in the construction industry. Research also identified that many challenges that women face working in the construction is directly correlated with the low female employment. Gender diversity and equality within the construction industry remains an important topic with more females entering the industry paving the way for younger female generations to enter into the construction industry and contribute their talents.

Research design

A deductive approach is effective in situations when a hypothesis is developed based on existing theory and then designing the research strategy to test the hypothesis (Grote-Garcia & Loveless, 2011). Several reports and scholarly materials have identified that the lack of gender equality in the Australian construction sector is a persistent problem (Clarke *et al.*, 2012; Galea *et al.*, 2015; Toohey, Colosimo & Boak, 2009). The problem triggered to develop the hypothesis of the current study which contemplates:

Women's involvement and employment in the Australian construction industry has significantly increased in recent years due to promotion of the industry and encouragement of women to further their career in the sector through support groups/ organisations.

Australian construction industry has the highest share of male employment of all 19 broad industries accounting for 88% of workforce compared with 54% across all industries (Department of Jobs and Small Business, 2018). Hence, reliable data is required for this study to be collated with such a large population of employment in the construction industry. Data was collected from the database of Australian Bureau of Statistics specifically referring to gender indicators (Australian Bureau of Statistics, 2018a). The Australian Bureau of Statistics database was purposefully chosen for data collection due to the data being reliable and updated until 2017-2018 financial year which is more current. Gender Indicators data includes data for many of Australia's industries including agriculture, mining, retail, transport and most importantly for this study's focus of construction industry. According to the database, Table 1 shows captured male and female population numbers working within construction industry from the financial year 2007-2008 to 2017-2018 financial year. Male population data was also extracted to verify still a large gender imbalance exists.

Table 1: Population of male and female workers in the construction industry

Financial year	Female population	Male population
2007-2008	114200	779800
2008-2009	114700	813700
2009-2010	114400	821400
2010-2011	113400	833700
2011-2012	113900	836800
2012-2013	113900	825500
2013-2014	116300	855600
2014-2015	115000	868400
2015-2016	118200	882200
2016-2017	126900	911000
2017-2018	132800	985900

Source: (Australian Bureau of Statistics, 2018a)

Figure 1 has captured the female population in comparison to the male population. More importantly, it tracks the pattern of the gap of gender imbalance. According to the figure, increase of overall male and female populations can be observed. Gap of gender imbalance has ups and downs; however, overall, it is also increasing.

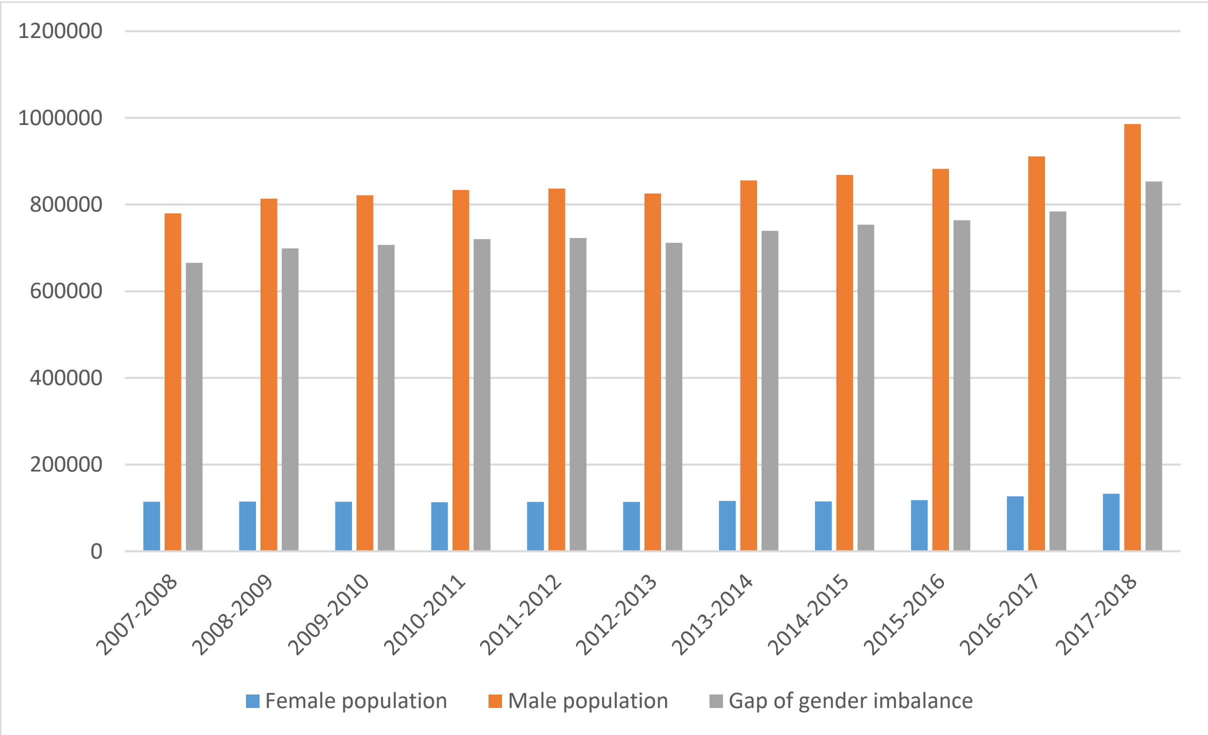


Figure 1: Pattern of male and female population in construction industry over the 10-year period

Although Figure 1 suggests an increase in female population over the 10-year period, due to the male population being 8 times the female population, the scale of the graph is not adequate enough to fully understand the population has been increasing. Figure 2 below shows the female population in isolation to better show the data. The data reflects the increase in population; however, there appears to be a plateau in population in the range of 2007 to 2008 and the range of 2009 to 2012 followed by a spike of population in 2013. There also appears to be a minor decrease in population in 2014 before quickly recovering in 2015 with a steady incline through to 2018. Overall, the figure suggests the female population growth as a steady increase.

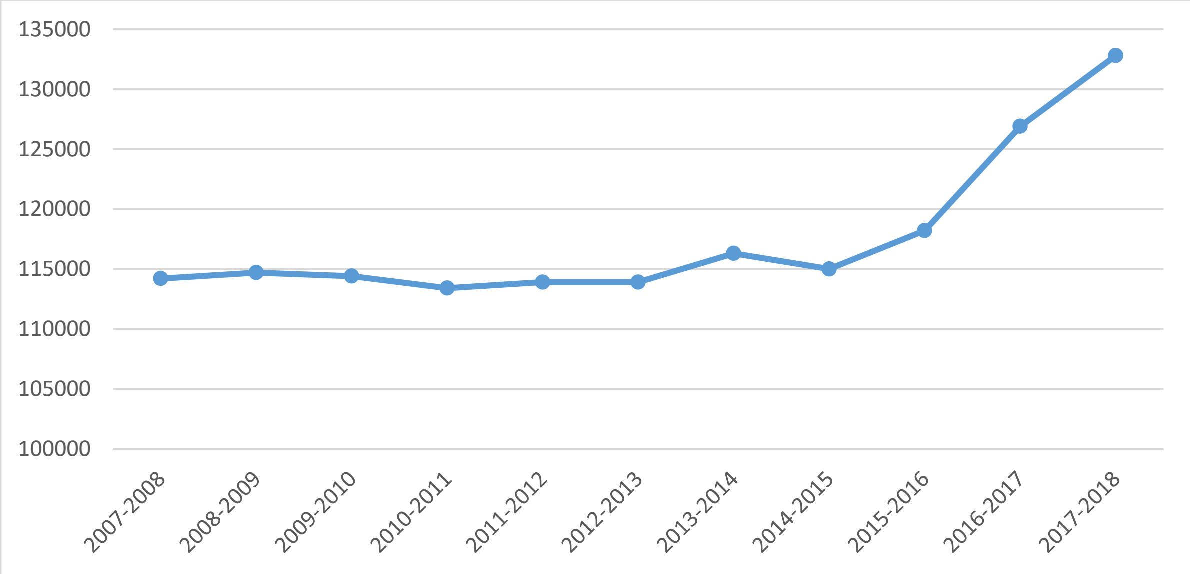


Figure 2: Pattern of female population in construction industry over the 10-year period

To further exemplify the population of the females working in the construction industry in 2007 to 2018, Figure 3 was plotted showing the changes between the years. As discussed above, there was a decrease in population in between first 2008 and 2009 and then 2009 and 2010 and lastly 2013 and 2014; however, throughout the remaining years (2014 to 2018), notable increase of female population is obvious.

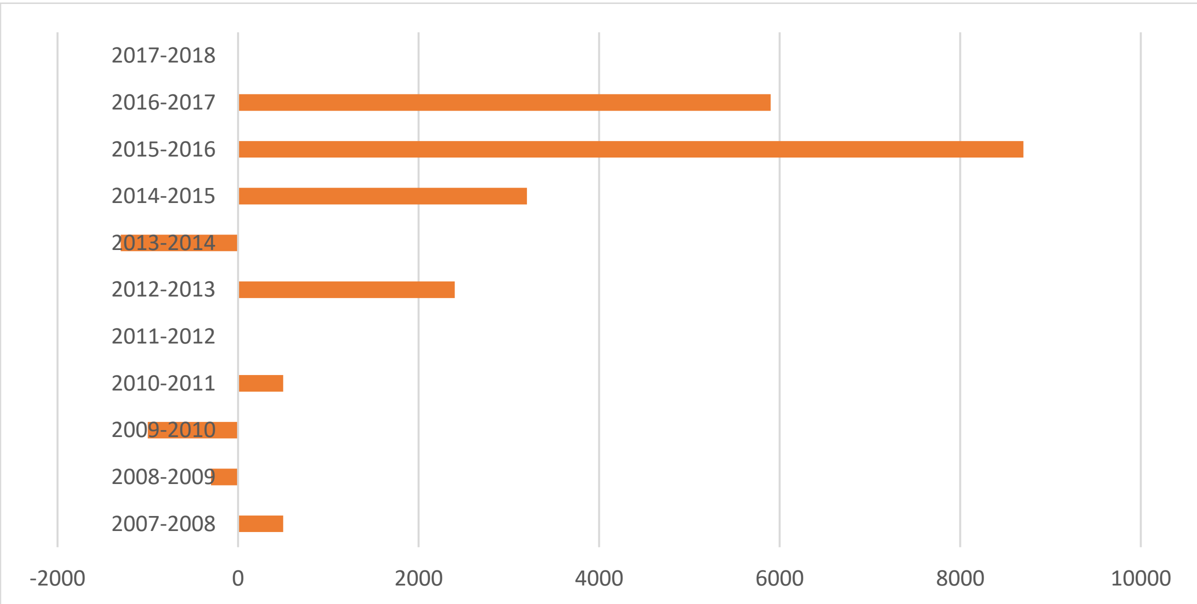


Figure 3: Change of female population in construction industry each year

Findings and discussion

The data collected from the Australian Bureau of Statistics 4125.0 Gender Indicators was able to show that the population of women within the construction industry from 2007 to 2018 has grown significantly. In 2007 the population was at its lowest in the 10-year study period with 114,200 women nationally working within the industry. By 2018 July the population had grown its highest in the 10-year period with 132,800 women, resulting in an increase of 18,600 or 14%. To fully understand the reason/s for the increase in female population over the past 10 years, it requires an investigation into the organisations and businesses who promote careers for women in the construction industry. The investigation should be amalgamated with looking at the benefits that women can bring to the industry as well as the challenges that may have contributed to the low populations in the first few years of the 10-year period. Identifying benefits and challenges can lead to further increase of female population engagement in Australian construction industry.

Promoting careers for women in the Australian construction industry

While it is easy to see there is low female population in the construction industry there are a number of steps that need to be made to help encourage women to pursue careers and promote the industry as a career prospect for anyone regardless of gender. Updating policies is often the first step, most companies will have ample room for improvement within their formal company policies. Ensuring all women within the company are afforded the ability to feel safe in the workplace; for example, enforcing a zero-tolerance policy to prevent harassment (Galea *et al.*, 2015). Galea *et al.* (2015) also suggests that allowances for maternity leave and work share practices to be offered; hence, expecting mothers feel as though they have options when taking leave after birth and starting part time work when they feel they are ready to come back to work. Policy changes ensuring no gender pay gaps within the company i.e. men and women at the same level being paid the same rate or salary, will work towards women feeling safe and valued (Smith, 2013; Stedman, 2018).

Construction sites are usually designed to facilitate men's requirements; hence, female workers and visitors face logistical and safety challenges (Employers, 2018). This is mainly due to the construction industry inherited with masculine culture such as bathrooms are not specially designed for females (Employers, 2018; Powell & Sang, 2013). Therefore allowances for female amenities must be provided on sites to promote female progression in construction industry (Employers, 2018). Furthermore, construction safety gear such as safety gloves and equipment like tools and heavy equipment are designed targeting men's bodies and sizes which are unsafe for women as they are too large and inefficient for women to use. Procurement of clothing and equipment for both male and female workers should be kept at the forefront of the procurement team when making purchasing decisions (Rosselle, 2018).

Professional female recruitment and encouragement will change the way the construction industry employees and promote women to further their careers (Rosselle, 2018). Recruiters may find that they will need to start thinking outside the box when it comes to the forms in which they look for candidates (Ellis, 2018). This might include giving presentations to industries that construction industry relies such as graphic designers or look for candidates within universities so that they are able to get a more even cross section of male and female perspective employees (Ellis, 2018). Internally, companies should also look to not overlook but promote women of applicable skills to higher positions to help encourage a diverse management team resulting GHD and AECOM both Australian engineering companies been awarded the Workplace Gender Equality Agency (WGEA) Employers of Choice for Gender Equality following their efforts to help achieve workplace equality (Cranenburgh, 2018). The formation of organisations solely for the encouragement of women will also help women form network connections and develop their skills making them more confident and better candidates for promoting their careers (Meg Munn, 2014; Wright, 2014). There are a number of national organisations such as the National Association of Women in Construction (NAWIC) and Women in Design and Construction (WIDAC) along with women's branches within the Master Builders, QBCC and other organisations which hold master classes, networking events and mentorships. Many of these organisations are relatively new forming in 2013-2015, the graphs show that this is the time that the population of women in the industry started to increase at a higher rate. The benefit of allowing women to connect with other women in the industry through networking and promoting women in the work place will continue to grow overtime with increases in female population as this is an ongoing issue (NAWIC, 2013).

Benefits of having women in the Australian construction industry

Encouraging women to working in the construction industry is an area with potentially tremendous room for growth (Women into Construction, n.d.). Women are very heavily represented in the clerical and administrative roles; however, they are grossly underrepresented in manual labour roles (Dainty, Green & Bagilhole, 2007; Dainty, Bagilhole & Neale, 2000). There is a strong evidence of shortages of skilled labourers such as electricians and mechanical ventilation contractors; hence, attracting women to these skilled trades could readily address the problem (Tyler, 2016). The construction industry often relies on workers who are efficient and problem solvers when issues arise on site and quickly need solving. Each project is unique and brings a new challenge; hence, a diverse team brings a variety of perspectives and backgrounds (Pulsinelli, 2011). Pulsinelli (2011) also stresses an increase of women in the industry means more viewpoints and different experience levels can be applied to a complex situation. It has been found through case study research that team performances are enhanced when women are involved in the workforce. The Harvard Business Review determined that not only is the team performances enhanced but the overall intelligence of teams was greater when women were incorporated into the teams (Tyler, 2016).

The companies are also said to perform better in financially in comparison to companies with homogenous gender profiles due to the better working teams. With diverse companies or groups comes a challenge to the status quo, expose and combat implicit bias and provide differing perspectives to existing problems (Employers, 2018). Diverse workplaces also pay big in public relations dividends with the reputation of the company increasing as the company drives innovation, improves decision making and delivers high quality results, in comparison to the less diverse competitors (Employers, 2018). Possibly the most important benefit of increasing the female population in the construction industry is to provide a career path to the up and coming generations of construction workers regardless of gender (Zitzman, n.d.). Many organisations have centred their aims to help encourage young people to join or participate in the construction industry. They try effective ways to reach out them communicating the value of construction careers before gender stereotypes or other cultural factors deter students from pursuing their interests in the construction industry (Employers, 2018). Current female leaders can encourage other women to pursue careers in the industry. This way, upcoming generation will realise construction industry is not a ‘boys club’; but, girls play a crucial role in future (Galea & Powell, 2018; Lingard & Lin, 2004; Zitzman, n.d.).

Challenges of women facing in the Australian construction industry

Non-gender inclusiveness in Australian construction industry has led to male dominated force which may be mostly due to male perception of women towards family responsibilities (Cassells, Gong & Duncan, 2011; Härtel *et al.*, 1999). The situation becomes worse when majority of male mangers of the construction industry perceive that childbearing age (maternity leave) is a waste considering questionable female employees’ future performance being productive (Lobel & Clair, 1992). According to May 2019 statistics, total females employed in the Australian construction industry were 147,000 and there were 10000 females under-employed among them (Australian Bureau of Statistics, 2019b). As a percentage it was 6.80%. Underemployment reflects the underutilisation of the productive capacity of the employed population (International Labour Organisation, n.d.). Elaborating the idea, the term under-employed refers to the situation where a person is working fewer hours when they are willing and available to work more. Furthermore, statistics show that despite the increase of women within the industry the number of women reaching top corporate management tiers has not increased (UNSW Australia, n.d.), in fact women leave the construction industry at a rate of almost 39% higher than men (APESMA, 2010). The National Association of Women in Construction or NAWIC studies have found that many of the challenges that women face in the construction industry are directly or indirectly related to gender bias (NAWIC, 2013). Accordingly, there are three major challenges that women face in the construction that undermine women’s recruitment, retention and progression in the construction industry.

- With most construction managers arriving on site at 6:30am and leaving after 6:30pm typically six days a week it can leave little time for picking up and dropping children at school and other household responsibilities (Lacaze-Duthiers, 2015). There is very little tolerance for part time or flexible work schedules due to the push to complete projects on time and within budget, often with little or no recognition by the clients on these work demands how they impact on the work force or gender equality (Galea & Powell, 2018).
- Nearly one third of women have reported that the fear of sexism has held them back from pursuing a senior role in the construction industry (Clark, 2017). Sexism or equality on the construction site can range from male only bathrooms at the site to women being lumped with more administrative tasks when they are far more qualified to do them or outdated attitudes (Frith, 2017).
- An even more alarming challenge women face on the construction site is safety, safety gear has long been made to tailor to the male physic which often triggers to be too large for women compromising the women's safety while wearing it (Unearth, n.d.).

Conclusion and future research

The research can conclude that the developed hypothesis was validated statistically that the female population is recently increasing in the Australian construction industry. Literature review into the reasons validates that the current increase is mainly due to the measures taken by the industry and government to promote female careers in the Australian construction industry. Measures strongly show the directions of systematic change that restricts the female inclusion such as: current policies, masculine environment at sites and recruitment process. Further literature review on the benefits and challenges has led to identifying the measures required further to promote female careers in future. Filling the shortage of skilled labour is one benefit due to more females in the construction industry. Gender diversity has positive evidence that the organisations function in greater productivity and better in financially which is another value proposition to engaging more women into Australian construction industry. Challenges are mainly correspond to family commitments/ responsibilities being bias on women towards responsibilities. Accordingly, women find uncomfortable being adjusted to the usual construction work daily routine, which creates them a number of household responsibility issues. Pushing for deadlines makes them into even worse situations by not offering part-time or flexible work schedules. Another major challenge women face in the construction industry is that the fear of sexism. This has created them holding back from pursuing for leadership roles or stagnating in the same area or even falling into do outdated attitudes. Safety is paramount in construction industry; however, women face challenges in safety of the construction industry due to unfit issues triggering with male-tailored safety gears.

It is obvious that heterogeneity lacks in the Australian construction in terms of gender diversity and equality. The research also suggests lack of literature or studies to recognise the heterogeneity of experiences among females working in the construction industry (Powell & Sang, 2013). As the current research identified, more research studies are required in future to explore sexuality, work-life balance, leadership, recruitment process, safety, masculine environment. Keeping the current study as a pilot study, the research group looks at a big picture of conducting future applied and human research to address the previous themes. The outcomes can be directed to document strategies to plan promoting female engagement in the Australian construction industry.

Acknowledgement

The authors convey their special thanks to all the reviewers for their comments and feedback to improve the quality of the paper.

References

APESMA, 2010, *Women in the professions: the State of Play 2009-2010*, The Association of Professional Engineers, Scientists and Managers, Melbourne, Australia, <http://www.professionalsaustralia.org.au/professional-women/wp-content/uploads/sites/48/2014/03/Womens-Survey-Report-web-2009-10.pdf>.

Australian Bureau of Statistics, 2018a, *4125.0 - Gender Indicators, Australia, Sep 2018*, viewed 11 September 2019, <4125.0 - Gender Indicators, Australia, Sep 2018>.

Australian Bureau of Statistics, 2018b, *5204.0 - Australian System of National Accounts, 2017-18*, viewed 11 September 2019, <https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/5204.02017-18?OpenDocument>.

Australian Bureau of Statistics, 2019a, *3101.0 - Australian Demographic Statistics, Dec 2018*, <https://www.abs.gov.au/AUSSTATS/abs@.nsf/mf/3101.0>.

Australian Bureau of Statistics, 2019b, *6291.0.55.003 - Labour Force, Australia, Detailed, Quarterly, May 2019*, viewed 11 September 2019, <https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/6291.0.55.003May%202019?OpenDocument>.

Cartwright, D, 2018, *10 Statistics defining the australian construction industry*, viewed 11 September 2019, <10 Statistics Defining the Australian Construction Industry>.

Cassells, R, Gong, C & Duncan, A 2011, *Race against time: How Australians spend their time*, AMP Limited, Sydney, Australia.

Clark, T, 2017, *Sexism 'holding back' up to third of women in construction*, viewed 13 September 2019, <https://www.constructionnews.co.uk/best-practice/sexism-holding-back-up-to-third-of-women-in-construction/10022050.article>.

Clarke, T, Nielsen, B, Nielsen, S, Klettner, A & Boersma, M, 2012, *2012 Australian Census of Women in Leadership*, Equal Opportunity for Women in the Workplace Agency, Sydney, Australia

Cranenburgh, N, 2018, *Top engineering firms recognised this year for better gender balance*, viewed 12 September 2019, <https://www.createdigital.org.au/top-engineering-firms-recognised-year-better-gender-balance/>.

Dainty, A, Green, S & Bagilhole, B 2007, *People and culture in construction: A reader*, Routledge, London.

Dainty, AR, Bagilhole, BM & Neale, RH, 2000, 'A grounded theory of women's career under-achievement in large UK construction companies', *Construction Management and Economics*, vol. 18, no. 2, pp. 239-50.

Department of Jobs and Small Business, 2018, *Australian jobs 2018*, Australian Government, <https://cica.org.au/wp-content/uploads/Australian-Jobs-2018.pdf>.

Ellis, G, 2018, *Level the jobsite: Why the world needs more women in construction (Infographic)*, viewed 12 September 2019, <https://blog.plangrid.com/2018/03/level-the-jobsite-why-the-world-needs-more-women-in-construction-infographic/>.

Employers, 2018, *Why we need more women in construction and trade jobs, and how to get them*, viewed 12 September 2019, <https://constructionjobs.com/blog/employers/why-we-need-more-women-in-construction-and-trade-jobs-and-how-to-get-them-there>.

Frith, B, 2017, *Construction must do more on sexism and gender inequality*, viewed 13 September 2019, <https://hrmagazine.co.uk/article-details/construction-must-do-more-on-sexism-and-gender-inequality>.

Galea, N & Powell, A, 2018, *Women in construction: government can do more to shake up the 'boys club'*, viewed 12 September 2019, <https://www.abc.net.au/news/2018-10-17/women-in-construction-goverment-can-do-more/10382932>.

Galea, N, Powell, A, Loosemore, M & Chappell, L, 2015, 'Designing robust and revisable policies for gender equality: lessons from the Australian construction industry', *Construction Management and Economics*, vol. 33, no. 5-6, pp. 375-89.

Grote-Garcia, SA & Loveless, D, 2011, 'Deductive Reasoning', *Encyclopedia of Child Behavior Development*, pp. 477-8.

Härtel, CE, Douthitt, SS, Härtel, G & Douthitt, SY, 1999, 'Equally qualified but unequally perceived: Openness to perceived dissimilarity as a predictor of race and sex discrimination in performance judgments', *Human Resource Development Quarterly*, vol. 10, no. 1, pp. 79-89.

International Labour Organisation, n.d., *Underemployment statistics*, viewed 13 September 2019, <http://www.ilo.org/global/statistics-and-databases/statistics-overview-and-topics/underemployment/lang--en/index.htm>.

Lacaze-Duthiers, PD, 2015, *5 Reasons for the lack of women In engineering*, 13 September, viewed 2019, <https://www.graebert.com/blog/general-news/5-reasons-lack-women-engineering/>.

Lingard, H & Lin, J, 2004, 'Career, family and work environment determinants of organizational commitment among women in the Australian construction industry', *Construction Management and Economics*, vol. 22, no. 4, pp. 409-20.

Lobel, SA & Clair, LS, 1992, 'Effects of family responsibilities, gender, and career identity salience on performance outcomes', *Academy of Management Journal*, vol. 35, no. 5, pp. 1057-69.

Meg Munn, M, 2014, *Building the future: women in construction*, The Smith Institute, <https://www.women-into-construction.org/wp-content/uploads/2019/08/building-the-future-women-in-construction.pdf>.

NAWIC, 2013, *What women want in a construction career*, The National Association of Women in Construction, <https://www.nawic.com.au/documents/NAWIC/15-04-13_national_nawic_discussion_paper.pdf>.

Office of the Chief Economist, 2016, *Australian industry report 2016*, Department of Industry, Innovation and Science, Canberra, Australia, <https://publications.industry.gov.au/publications/australianindustryreport/assets/Australian-Industry-Report-2016.pdf>.

Powell, A & Sang, KJ, 2013, 'Equality, diversity and inclusion in the construction industry', *Construction Management and Economics*, vol. 31, no. 8, pp. 795-801.

Pulsinelli, O, 2011, *Women provide unique perspective in construction industry*, viewed 12 September 2019, <https://www.mlive.com/business/west-michigan/2011/08/women_provide_unique_perspecti.html>.

Rosselle, E, 2018, *The time is now to inspire a new generation of women in construction*, viewed 12 September 2019, <https://www.autodesk.com/redshift/women-in-construction/>.

Smith, L, 2013, 'Trading in gender for women in trades: embodying hegemonic masculinity, femininity and being a gender hotrod', *Construction Management and Economics*, vol. 31, no. 8, pp. 861-73.

Stedman, M, 2018, *Supporting women in construction, engineeering and manufacturing*, viewed 12 September 2019, <https://www.engineering.com/JobArticles/ArticleID/15067/Supporting-Women-in-Construction-Engineering-and-Manufacturing.aspx>.

Toohey, T, Colosimo, D & Boak, A 2009, *Australia's hidden resource: The economic case for increasing female participation*, Goldman Sachs JBWere Investment Research Sydney, Australia.

Tyler, 2016, *Is it time for more women in the construction industry?*, viewed 12 September 2019, <https://esub.com/is-it-time-for-more-women-in-the-construction-industry/>.

Unearth, n.d., *Shattering the concrete ceiling: Gender diversity in construction*, viewed 13 September 2019, <https://unearthlabs.com/blog/construction-management/gender-diversity-in-construction/>.

UNSW Australia, n.d., *Demolishing gender structures*, UNSW Australia, <https://www.csi.edu.au/media/Construction_Booklet_FINAL2.pdf>.

Women into Construction, n.d., *History and vision*, viewed 12 September 2019, <https://www.women-into-construction.org/history-vision-women-into-construction/>.

Wright, T, 2014, *The women into construction project: an assessment of a model for increasing women's participation in construction*, Queen Mary University of London, London, UK

Zitzman, L, n.d., *Why the construction industry needs more women in leadership*, viewed 12 September 2019, <https://theundercoverrecruiter.com/construction-needs-more-women/>.

ANALYSING THE RELATIONSHIP BETWEEN CONSTRUCTION EMPLOYEES' MINDSET BEHAVIOUR AND PROJECT PERFORMANCE

De-Graft Owusu-Manu[1], Prosper Babon-Ayeng[2], Frank Ato Ghansah[3], Caleb Debrah[4], Frank Boateng[5] and David J. Edwards[6]

[1,2,3,4]Department of Construction Technology and Management/ Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

[5]School of Business and Management Studies, University of Mines and Technology, Tarkwa, Ghana

[6]Faculty of Technology Environment and Engineering; Birmingham City University, UK

Abstract

The purpose of the study is to analyse the relationship between an employee's mindset behaviour and project performance. Quantitative method was used, and a census and convenience sampling techniques were adopted to distribute and collect data at a response rate of 74.60% from employees in the construction industry in the Kumasi Metropolis. Responses were assessed based on the significance level of the employee's mindset behaviour on project performance using descriptive analysis, and the reliability of the scale was checked using Cronbach's Alpha Coefficient. Six mindset elements, namely; employee commitment, employee involvement, job satisfaction, employee lateness, employee theft, and employee absenteeism were selected to ascertain their significance level on Project Performance. The study affirmed that the positive effect of employees' job satisfaction, involvement and commitment to work leads to project performance. The study, therefore, contributed to knowledge by assessing the linkages between employees' mindset and project performance, and also to the existing body of knowledge to aid and guide researchers in the adoption of appropriate theoretical framework in conducting research on the relationship between employee's mindset behaviour and project performance. To recommend, further research should be done to develop a framework for managing the mindset behaviours of employees.

Keywords: behaviour, employee, mindset, organisation, project performance

Introduction

Increased employee performance indicates a significant objective for organisations in order to maintain their business success (Rusu et al. 2016). Modern trends in employee performance show that, in order to target increased employee performance, research should focus on employee performance assessment and on the influence of organisational context factors such as organisational objectives, organisational culture, employee motivation among others (Rusu et al. 2016). The mindset behaviour of an employee affects an employee's enthusism towards work, psychological presence and job commitment (Ali et al. 2010). Positive mindset behaviour of an employee would result in achieving increase in employee's performance (Heslin 2010). An employee would show positive mindset behaviour towards work, by the display of confidence, trust and job satisfaction by management. According to Mester et al. (2003) there are so many factors such as employee organisational commitment, job involvement and job satisfaction that affect the mindset behaviour of an employee towards work, but research study indicates that to a large extent the type of leadership style affects the mindset of an employee. In this contemporary era, management of organisations are consistently devising ways to generate employee's commitment towards work, empowering an employee would result in positive work attitudes leading to employee's commitment to work (Lok & Crawford 2001).

Previous study reveals that managerial practices influences not only employee motivation, but also employee behaviours. Therefore, the empowering practices of supervisors could influence the behaviours exhibited by an employee at work (Boudrias et al. 2009). Mindset is a mental framework that guides how people think, feel, and act in achievement contexts (Dweck 2006). Positive behavioural outcome of employees largely depends on the wider organisational culture and employees relationship with their management (Alfes et al. 2013). Employees who perceive the climate in their organisations to be supportive may be more likely to experience higher levels of positive mindset, which in turn positively influences their performance at work (Luthans et al. 2008). A project would be considered to have been successfully performed if it is executed meeting the objectives and goals as defined in the project plan (Frimpong et al. 2003).

There have being various studies such as, "Leadership style and its relation to employee attitudes and behaviour", by Mester et al. (2003) which try to identify the factors contributing to increase in performance of an employee, but employee attitudes and the inclusion of their opinions are very important in today's global and competitive environment in order to achieve maximum output from the employee (Magd et al. 2007). Parker & Griffin (2011) stated that extensive research is needed to explore the features of the working environment that may be relevant in directing and focusing the mindset behaviour of employees in positive ways. According to Brundin et al. (2008) employees' perception of how an organisation values them could be vital in influencing their mindset behaviour towards work. Mrazek et al. (2018) stated that paying more attention to employee mindset behaviour could lead to solving the pressing matters related to employee performance. Positive mindset behaviour of an employee towards work is paramount for an increase in the performance of an organisation (Brundin et al. 2008). Consequently, this calls for the need to conduct this study. Contrary to this, management need to consider employees'mindset behaviour as key to increase in performance of organisations (Offorbike et al. 2018). Mrazek et al. (2018) stated that paying more attention to employee mindset behaviour could lead to solving the pressing matters related to employee performance. These various studies conducted affirm the importance of considering employee's mindset behaviour on project performance, which necessitates the conduct of this study. Therefore, the objective of this study is to analyse the relationship between construction employees' mindset behaviour and project performance.

Literature review

Mindset is a mental framework that guides how people think, feel, and act in achievement contexts (Dweck 2006). According to Bagherian et al. (2009) mindset behaviours are generally positive or negative views about a person, place, thing or event. These views are often referred to as the mindset object. According to Ali et al. (2010) the concept of mindset behaviour influences an employee's psychological presence at work, enthusiam towards work and job commitment. There are so many factors that affect the mindset behaviour of an employee towards work, but research indicates that to a large extent the type of leadership style influences the mindset behaviour of an employee (Mester et al. 2003). Positive employee mindset behaviour would result in achieving increase in employee's performance (Heslin 2010).

Employee's Commitment Mindset

Research have shown that organisational commitment will lead to behavioural outcomes (Marhayani et al. 2019). Employees who are committed to their respective organisation are more likely not only to remain with the organisation but are also likely to exert more efforts on behalf of the organisation and work towards its success leading to increase in performance (Ali et al. 2010). Employee commitment can benefit organisations in several ways such as improve performance, and reduce absenteeism, thereby resulting in an increase in performance (Dockel et al. 2006). A committed employee is perceived to be one who stays with the organisation even in turbulent times, attends work regularly, protects company's assets and shares in the company's goals (Mester et al. 2003). According to Ali et al. (2010) studies have confirmed that, there are positive effects of employee commitment on organisational performance. Committed employees are considered as critical success factors for any organisation. Therefore, it is evident that for a sustained increase in project performance, employee commitment is an important factor. Literature reveals that highly committed employees are more satisfied with their work, perform at levels beyond expectation, are more motivated and experience higher levels of job involvement leading to an increase in the performance level of the organisation (Mester et al. 2003).

Employee's Job Satisfaction Mindset

The Hawthorne studies conducted in the 1930s makes researchers aware of the effects of employee attitudes on performance. Shortly after the Hawthorne studies, researchers began taking a critical look at the notion that a happy worker is a productive worker. No organisation can achieve its goals without satisfying the work force of the organisation. This therefore leads to the concept of employee job satisfaction been given a prominent place in many social science literatures (Pushpasiri & Ratnayaka 2018). Most of the earlier reviews of the literature suggested a positive relationship between job satisfaction and project performance. Job satisfaction depends on employees' perception and attitude towards their job and the environment where their job belongs. It is critical to the overall performance and profitability of the organisation as there is a strong correlation between job satisfaction and employee motivation as well as productivity (Dey et al. 2019). People who are happy with their jobs exhibit higher job performance (Judge et al. 2001). According to Pushpasiri and Ratnayaka (2018) the more satisfied an employee is the less turnover and absenteeism occurs. According to Chhikara & Nangia (2018) the failure to find a strong relationship between job satisfaction and performance is due to the narrow means often used to define job performance. Chhikara & Nangia (2018) argued that when performance is defined to include important behaviours not generally reflected in performance appraisals, such as organisational citizenship behaviours, its relationship with job satisfaction improves. Jackson & Schuler (2011) stated that if employees are not satisfied with their organisation, they tend to leave the organisation.

Employee's Engagement Mindset

Employee engagement or involvement refers to the degree to which one is cognitively preoccupied with, engaged in and concerned with one's present job (Mester, et al. 2003). Business units and organisations are almost twice as likely to be successful if they are above average in employee engagement. Employees who are engaged with their job and employer are more productive because they are motivated beyond personal factors. They are more focused and more motivated than their disengaged counterparts are. This means they work more efficiently and with the success of the organisation in mind (Gruman & Saks 2011). Research consistently shows that low levels of employee engagement are detrimental to performance. There is an assumption held by many scholars and managers that if employees are adequately informed about matters concerning them and are afforded the opportunity to make decisions relevant to their work, then there will be benefits for both the organisation and the individual (Shadur et al. 1999). According to Harter et al. (2002) not only does high employee engagement increase focus and efficiency, it decreases rates of absenteeism. Because engaged employees care about what they do, they recognise the importance of their effort in contributing to the success of the organisation. Research confirms that engagement lowers employees' intention to leave. According to Schaufeli et al. (2006) engaged employees work with dedication, vigor, and absorption. There is a trend showing that highly engaged employees work for organisations that had revenue growth at least one percentage point above the average for their industry, while the organisations of the most disengaged employees work for companies where revenue growth falls one or two percentage points below the average (Perrin, 2003). Various factors are known to cultivate employee engagement. These include fair and trustworthy leaders who show employees how their work makes a positive difference (Avolio et al. 2004), and a work environment in which employees are consulted, and appreciated (Harter 2008).

Employee's Theft Mindset

The most widely accepted definition of employee theft comes from Greenberg's (2002) study, which defines theft as the unauthorized taking, control, transfer of money or property that is perpetrated by an employee during occupational activity. The more dissatisfied the employee becomes with a workplace situation the more likely that employee would be inclined towards engaging in criminal behaviour such as theft (Schmidtke 2007). The more dissatisfied the employee becomes with a workplace situation the more likely that employee would be inclined towards engaging in criminal behaviour such as theft, which would lead to the retrogression of the performance of the organisation (Chen & Sandino 2012).

Kulas et al. (2007) argue that most of the concluded research which identifies why employees commit theft from the employer in the first place has nothing to do with the opportunity to steal, but more of a motivation to steal.

Employee's Absenteeism Mindset

Absenteeism is a habitual pattern of absence from a duty or obligation (Patton & Johns 2012).

The impact of absenteeism on firms or organisations is enormous, taking account of the costs associated with it (Carraher & Buckley 2008). A better understanding of the determinants of absenteeism can be valuable for organisations and policymakers (Stormer & Fahr 2013). The direct costs of sickness absence from work to employers include statutory sick pay, expense of covering absence with temporary staff and lost production. Indirect costs, such as low morale among staff covering for those absent because of sickness and lower customer satisfaction, are difficult to measure, while they also influence the overall levels of output (Leaker 2008). Employers should use a system of rewarding and recognition for employees because it has a vital effect in their job satisfaction and engagement which will lead to reduction of turnover and burnout among employees (Bayoumy 2019).

Employee's Lateness Mindset

According to Koslowsky (2000) lateness refers to the tendency of an employee to arrive at work after the scheduled starting time. According to Elicker et al. (2008) lateness is a behavioural outcome of certain organisational attitudes. Accordingly, the employee arriving late to work is consciously or unconsciously expressing negative feelings with the organisation. Bolton et al. (2010) found that employees who are never late to work have significantly higher levels of organisational commitment than employees who arrive late. For any organisation, lateness has both economic and psychological implications. If employees are part of a service-oriented organisation, their lateness may affect the quality or quantity of service offered, especially when fellow workers or consumers depend directly or indirectly on the latecomer's presence (Koslowsky 2000).

Research Methodology

This study uses the quantitative approach, which tend to relate to positivism and seek to gather factual data, to study the relationships between facts and how such facts and relationships accord with theories and the findings of any research executed previously. It is essential to ensure that the subject matter of investigation is both comprehended well by the researcher and is defined precisely, otherwise, the variables cannot be measured accurately and so, compromise the analyses and findings (Fellows & Liu 2015). The quantitative approach has been used in this study because it is necessary to have the absolute values of certain key issues during the research. For the purpose of this study, the population chosen consisted of formal employees of construction firms in Kumasi Metropolis. Census and Convenience sampling techniques have been used in the study. Convenience sampling describes the situation in which participants are included in a study only because they happen to be at the right place at the right time. Convenience sampling is a non-probability sampling technique, which involves a sample being drawn from a part of your population closer to you (Kothari 2004). The census approach was used to determine the appropriate sample size. The study made use of a population size of 72 comprising formal employees such as Quantity Surveyors, Site managers among others, of construction firms in the Kumasi Metropolis. The sample size for the survey after using the Kish formula using the population size was 42.

The questionnaire as a data collection instrument has been used in this study. A good questionnaire consists of questions that generate various types of information from respondents (Gall et al. 2003). The questionnaire consisted of two main parts; Part One and Part Two. Part one covered the demographic data of the respondent. According to Ahadzie (2007) the demographic data of the respondent is required to authenticate the credibility of the data collected. In the part two, the questionnaire was designed to seek information on the linkages between employee engagement or involvement, employee job satisfaction, employee organisational commitment and project performance. Primary data has been collected by means of questionnaires. Questionnaires were issued to the target group, who are formal employees of construction firms in the Kumasi Metropolis. Their responses were collected and analysed. Secondary data on the other hand was gotten from sources, which included reading and analysing already processed data from journals, and online libraries. The Likert scale rating was used in exploring the relationship between employee's mindset behaviour and project performance, respondents had to determine the significance level of some employee mindset behaviours on project performance by responding whether the variable is "Very significant" (1), "Significant" (2), "Moderately significant" (3), "Less significant" (4) or "Insignificant" (5) Data collected from the questionnaires was entered into an analysis package called Statistical Package for Social Sciences Windows Version 16 (SPSS). Tool of analysis used was the Descriptive Statistics to analyse the linkages between employee's mindset behaviour and project performance, and the reliability of the scale was checked using Cronbach's Alpha Coefficient.

Validity and Reliability of Scale Adopted

Fieldwork is very important as far as the reliability of data is concern (Patton 2002). With the view to ensuring quality research, the study embarked on some measures. Firstly, the researcher made sure that the right sources of data were selected. Because the study looked at analysing the relationship between the construction employees' behaviour and the project performance, data was collected from the formal workers of the construction industry in Kumasi. This ensured that the right data was gathered from the right sources that were very informative. Secondly, the study ensured that participants responded to the questionnaire at their own convenience. This is explained by the fact that there is the tendency for participants to give answers hurriedly if they are being interviewed out of their convenience. The questionnaires were delivered and picked as scheduled with the respondents. Finally, a Cronbach's alpha analysis was presented to measure the reliability of the scale before further analysis is done to give an in-depth understanding of the observed items used in the study. An alpha value of .70 or higher is acceptable as reliable, as a rule of thumb. From Table 1, the alpha value for analysing the six elements discovered to have significant effect on project performance was .894. This indicates that all the items reliably measured what they were intended to measure, and therefore, further analysis can be made.

Table 1: Cronbach's Alpha Analysis

Variables	No. of Items	Cronbach's Alpha
The selected Six elements (name: Six elements, namely; employee commitment mindset, employee involvement mindset, job satisfaction mindset, employee lateness mindset, employee theft mindset and employee absenteeism mindset)	6	.894

Source: Field survey, 2019

Data Analysis and Discussion of Results

Employee Commitment and Project Performance

In terms of respondents' contribution towards project performance due to their commitment level, it shows that 27 respondents representing 64% deemed it very significant, 10 representing 24% deemed it significant, 3 representing 7% deemed it moderately significantly, and 2 representing 5% deemed it less significant. Majority of the respondents affirm that commitment level leads to project performance. This confirms Konovsky & Cropanzano (1991) stance on employee commitment towards project performance. The authors uncovered a positive relationship between commitment and project performance.

Employee Involvement and Project Performance

When asked about respondents' involvement or engagement level in work related activities in the organisation that lead to project performance, it showed that 12 respondents representing 29% deemed it very significant, 27 representing 64% deemed it significant, 1 representing 2% deemed it moderately significant, and 2 representing 5% deemed it insignificant. Most of the respondents attested that employee involvement or engagement in work related activities of the organisation lead to project performance. This indicates that employees that are highly engaged are twice as likely to be performers. Employees who are engaged or involved in the activities of an organisation would exhibit positive mindset behaviour towards work, and this would consequently increase the performance of the employee in the organisation. Therefore, it is not abnormal that from the data analysis conducted, a very significant number of the respondents showed their involvement in the activities of the organisation,

Employee Job Satisfaction and Project Performance

With respect to whether the satisfaction respondents get from their work motivates them to contribute to project performance, it showed that 23 respondents representing 55% deemed it very significant, 16 representing 38% deemed it significant and 3 respondents representing 7% deemed it moderatelely significant. From the analysis of the data collected from the field, it can be deduced that, majority of the respondents deem the impact of job satisfaction on project performance very significant. According to Hagedorn (2000) when a worker feels a high level of achievement, intensely involved in the work place, appropriately compensated by recognition, responsibility, and good remuneration, job satisfaction is enhanced. Consequently, the enhancement of job satisfaction in an employee would create positive mindset behaviour towards work, which would aid increase the performance of an employee in an organisation. Therefore, this affirms the response from majority of the respondents who deem the impact of job satisfaction on employee mindset behaviour very significant.

Employee Absenteeism and Project Performance

The effects of absenteeism are difficult to quantify though various studies have attempted valuing it.

Productivity losses due to employee absence cost organisations millions of dollars each year (Mason & Griffin 2003). Although numerous dispositional, attitudinal, demographic, health, economic, and social factors have been linked with an individual's decision to attend work.

Data analysis shows that 23 respondents representong 55% deemed it very significant, 16 representing 38% deemed it significant, and 3 representing 7% deemed it moderately significant the relationship between employee’s absenteeism mindset behaviour and project performance . This clearly shows that respondents are aware of the negative effects of absenteeism on project performance. This corroborates with Dalton & Mesch (1991) view on the effect of employee absenteeism.

Employee Lateness and Project Performance

For an organisation, lateness has both economic and psychological implications. When productivity or output levels are affected, the efficiency of an organisation may be compromised (Koslowsky 2000). An employee's late arrival, particularly if the function performed at work is critical, may disrupt the production schedule of an organisation (Shahzad 2018). If employees are part of a service-oriented organisation, their lateness may affect the quality of service offered, especially when fellow workers or consumers depend directly or indirectly on the latecomer's presence. Koslowsky (2000) stated that employees who are never late to work have significantly higher levels of organisational commitment than employees who arrive late. Problems associated with lateness include compromised organisational efficiency. When asked whether employees are aware that lateness affects project performance, it showed that 22 respondents representong 52% deemed it very significant, 18 representing 43% deemed it significant, and 2 representing 5% deemed it insignificant. This clearly shows that the respondents are aware of the negative effects of lateness on project performance.

Employee Theft and Project Performance

Respondents were asked on the significance level of theft on project performance. It showed that 24 respondents representong 57% deemed it very significant, 16 representing 38% deemed it significant, and 2 representing 5% deemed it insignificant. This clearly shows that the respondents are aware of the negative effects of theft on project performance. This affirms Camara & Schneider (1994) position on employee theft who stated that employee theft is estimated to account for billions of dollars of loss globally each year, with employees accounting for more theft than customers.

Findings and Discussions

The study reveals that supervisors normally seek employees’ opinion on issues relating to work. This shows the level of involvement of employees in work related activities. This is an important aspect as it identifies the level at which supervisors ask for employees’ opinion and therefore the importance that managers place on them. The current level at which supervisor asks for employees’ opinion is in the right order. This affirms Boudrias et al. (2009) study that stated that employee engagement is integral to driving successful organisations. Engaged employees are satisfied and feel a sense of attachment to their job and the organisation. Therefore, this affirms the high significance level of impact employee engagement has on mindset behaviour as deduced from the study.

In addition, the study reveals that respondents deem the impact of job satisfaction on employee's mindset behaviour very significant. Both the employees and management confirm the existence of some motivation packages management has put in place in order to get employees satisfied with their job. This confirms a study conducted by Judge et al. (2001) who stated that, when employees are satisfied with their job, it creates positive mindset behaviour, and consequently leads to increase in their performance in the organisation. According to Dey et al. (2019) most of the earlier reviews of the literature suggested a positive relationship between job satisfaction and project performance. Employee job satisfaction is critical to the overall performance and profitability of the organisation as there is a strong correlation between job satisfaction and employee motivation as well as productivity. This affirms respondents view on the impact of employee job satisfaction and mindset behaviour to be very significant.

Furthermore, the study indicates that respondents deem the impact of job commitment on employee's mindset behaviour exhibited to be very significant. According to Ali et al. (2010) employees who are committed to their respective organisation are more likely not only to remain with the organisation but are also likely to exert more efforts on behalf of the organisation and work towards its success leading to increase in performance. Employee commitment can benefit organisations in a number of ways such as improve performance, and reduce absenteeism, thereby resulting in an increase in performance (Dockel et al. 2006). According to Ali et al. (2010) studies have confirmed that, there are positive effects of employee commitment on organisational performance. Committed employees are considered as critical success factors for any organisation. Therefore, it is evident that for a sustained increase in project performance, employee commitment is an important factor. Therefore, it can be deduced that a committed employee would possess positive mindset behaviour towards which would consequently aid increase the performance of an organisation.

From the study conducted, it indicates that majority of the respondents deem absenteeism, theft and lateness to significantly have a relationship with project performance. This corroborates with Dalton & Mesch (1991) view on the effect of employee absenteeism. The author stated that productivity losses due to employee absenteeism cost organisations millions of dollars each year

Conclusion

Organisations should put in place measures to ensure the motivation of employees for employees to exert positive mindset behaviours to gain performance. Motivation packages like involving employees in the decision making of the organisation, good compensation packages, good working conditions and equipment, opportunity for training and promotion should be in place in order to get the employees reflection of positive mindset behaviours and improved project performance. Further research should be done to develop a framework for managing the mindset behaviours of employees in order to aid increase their performance. Several limitations of the study have been identified. First, there was quite a small number of sample size used in the study. Future research should target a bigger sample size by extending the scope of the study to capture more geographical area. Second, the use of a single industry as the research target industry is a potential limitation on the generalisability of these results. In future research, attempts should be made to replicate these analyses in several different industries, but not only the construction industry. In summary, this study contributes to our knowledge of the linkage between employee's mindset behaviour and project performance. The study provides evidence of a significant relationship between employee's mindset behaviour and project performance. The results further indicate a significant relationship between employee engagement/involvement, employee job satisfaction, employee organisational commitment and the performance of a project. Therefore, it is in anticipation that this study will stimulate future research into the relationship between an employee's mindset behaviour and project performance.

References

Alfes, K., Shantz, A., Truss, C. & Soane, E. 2013, 'The link between perceived human resource management practices, engagement and employee behaviour: a moderated mediation model', *The International Journal of Human Resource Management*, 24(2), pp. 330-351.

Ali, A., Ahmad-Ur- Rehman, M., Haq, I.U., Jam, F.A., Ghafoor, M.B. & Azeem, M.U. 2010, 'Perceived organisational support and psychological empowerment', *European Journal of Social Sciences,* 17(2), pp. 186-192.

Ali, I., Rehman, K. U., Ali, S. I., Yousaf, J. & Zia, M. 2010, 'Corporate social responsibility influences, employee commitment and organsational performance', *African Jounal of Business Management* , 4(12), pp. 2796-2801.

Avolio, B. J. Gardner, W. L., Walumbwa, F. O., Luthans, F. & May, D. R. 2004, 'Unlocking the mask: A look at the process by which authentic leaders impact follower attitudes and behaviours', *The leadership quarterly* , 15(6), pp. 801-823.

Bagherian, R., Samah, B. A., Samah, A. A. & Ahmed, S. 2009, 'Factors Influencing Local People's Participation in Watershed Management Programs in Iran', *American-Eurasian Journal Agriculral and Environment Science*, 6(5), pp. 532-538.

Bayoumy, S. A. 2019, 'Relationship between Job characteristics and Work Engagement among Nursing Staff', *International Journal of Nursing Didactics*, 9(1), pp. 24-29.

Bolton, L. R., Becker, L. K. & Barber, L. K. 2010, 'Big five trait predictors of differential counterproductive work behaviour dimensions', *Personality and Individual Differences* , 49(5), pp. 537-541.

Boudrias, J. S., Gaudreau, P., Savoie, A. & Morin, A. J. 2009, 'Employee empowerment: From managerial practices to employees' behavioural empowerment', *Leadership and Organisation Development Journal,* 30(7), pp. 625-638.

Brundin, E., Patzelt , H. & Shepherd, D. A. 2008, 'Managers' emotional displays and employees' willingness to act entrepreneurially', *Journal of Business Venturing,* Volume 23, pp. 221-243.

Camara, W. J. & Schneider, D. L. 1994, 'Integrity tests: Facts and unresolved issues', 49(2), pp. 112-119.

Carraher, S. M. & Buckley, R. M. 2008, 'Attitudes towards benefits and behavioural intentions and their relationship to absenteeism, performance, and turnover among nurses', *Academy of Health Care Management Journal* , 4(2), pp. 89-109.

Chen, C. X. & Sandino, T. 2012, 'Can wages buy honesty? The relationship between relative wages and employee theft', *Journal of Accounting Research* , 50(4), pp. 967-1000.

Chhikara, D. & Nangia, R. 2018, 'The Relationship of High Performance HR Practices with the Job Satisfaction', *International Journal of Management, Technology And Engineering* , 8(12), pp. 5632-5642.

Dalton, D. R. & Mesch, D. J. 1991, 'On the extent and reduction of avoidable absenteeism: An assessment of absence policy provisions', *Journal of Applied Psychology*, 76(6), pp. 810-817.

Dey, T., Nafi, S. M., Miah, M. & Uddin, M. M. 2019, 'Analyzing the Extents of the Factors Influencial to the Level of Job Satisfaction: A Study on Bankers from Dhaka City's Private Commercial Banks', *International Journal of Science and Business* , 3(1), pp. 72-83.

Dockel, A., Johan, B. S. & Coetzee, M. 2006, 'The efect of retention factors on organisational commitment: an investigation of high technology employees', *Journal of Human Resource Management*, 4(2), pp. 20-28.

Dweck, C. S. 2006, Test your mindset. *Ballentine, New York.*

Elicker, J. D., Foust, M. S., O'Malley, A. L. & Levy, P. E. 2008, 'Employee lateness behaviour: The role of lateness climate and individual lateness attitude', *Human Performance,* 21(4), pp. 427-441.
Fellows, R. & Liu, A., 2015. *Research Methods for Construction.* 4th ed. West Sussex: John Wiley and Sons Ltd.
Frimpong, Y., Oluwoye, J. & Crawford, L. 2003, 'Causes of delay and cost overruns in construction of groundwater projects in developing countries; Ghana as a case study', *International Journal of Project Management,* pp. 321-326.
Gall, M. D., Borg, W. R. & Gall, J. P. 2003, Educational research: An introduction. *Longman Publishing.*
Greenberg, J. 2002, 'Who stole the money, and when? Individual and situational determinants of employee theft', *Organisational Behaviuour and Human Decision Processes,* 89(1), pp. 985-1003.
Gruman, J. A. & Saks, A. M. 2011, 'Performance management and employee engagement', *Human Resource Management Review,* Volume 21, pp. 123-136.
Hagedorn, L. S., 2000. Conceptualizing Faculty Job Satisfaction: Components, Theories, and Outcomes. *New directions for institutional research,* 2000(105), pp. 5-20.
Harter, J., 2008. Employee engagement: how great managing drives performance. *Positive psychology: Exploring the best in people* , Volume 4, pp. 99-110.
Harter, J. K., Schmidt, F. L. & Hayes, T. L. 2002, 'Business-unit-level relationship between employee satisfaction, employee engagement, and business outcomes: a meta-analysis', *Journal of applied psychology,* 87(2), p. 268.
Heslin, P. A. 2010, Mindsets and employee engagement: Theoretical linkages and practical interventions. In: S. L. Albrecht, ed. Sydney: Edward Elgar, pp. 218-226.
Jackson, S. E. & Schuler, R. S. 2011, Managing human resources. *South-Western Cengage Learning.*
Judge, T. A., Thoresen, C. J., Bono, J. E. & Patton, G. K. 2001, 'The job satisfaction-job performance relationship: A qualitative and quantitative review', *Psychological bulletin,* 127(3), p. 376.
Konovsky, M. A. & Cropanzano, R. 1991, 'Perceived Fairness of Employee Drug Testing as a Predictor of Employee Attitudes and Job Performance', *Journal of Applied Psychology,* 76(5), pp. 698-707.
Koslowsky, M. 2000, 'A New Perspective on Employee Lateness', *Applied psychology: an international review,* 49(3), pp. 390-407.
Kothari, C. R. 2004, *Research Methodology: Methods and Techniques.* 2nd ed. s.l.:New Age International Publishers.
Kulas, J. T., Mclnnerney, J. E., Demuth, R. L. F. & Jadwinski, V. 2007, 'Employee Satisfaction and Theft: Testing Climate Perceptions as a Mediator', *The Journal of Psychological Interdisciplinary Applied,* 141(4), pp. 389-402.
Leaker, D. 2008, Sickness absence from work in the UK. *Ecomomic and Labour Market Review,* 2(11), pp. 18-22.
Lok, P. & Crawford, J., 2001. "Antecedents of organizational commitment and the mediating role of job satisfaction". *Journal of Managerial Psychology*, 16(8), pp. 594-613.
Luthans, F., Norman, S. M., Avolio, B. J. & Avey, J. B. 2008, 'The Mediating Role of Psychological Capital in the Supportive Organisational climate: Employee Performance Relationship', *Journal of Organisational Behaviour,* 29(2), pp. 219-238.
Magd, H. A. E., Abdel, A. M. & Hamza, S. E. A. 2007, Organizational Excellence Journey: Critical Success Factors of Engineering firms in Saudi Arabia and United Arab Emirates.
Marhayani, Musnadi, S. & Ibrahim, M. 2019, 'Effect of competence and employee commitment to employee performance: job satisfaction as a mediator (study on watering office of aceh province)', *International Journal of Business Management and Economics Review,* 2(1), pp. 15-27.
Mason, C. M. & Griffin, M. A. 2003, 'Group absenteeism and positive affective: A longitudinal study', *Journal of Organizational Behaviour: The International Journal of Industrial, Occupational and Organizational Psychology and Behaviour,* 24(6), pp. 667-687.

Mester, C., Delene, V. & Roodt, G. 2003, 'Leadership style and its relation to employee attitudes and behaviour', *Journal of Industrial Psychology,* Volume 29(2), pp. 72-82.

Mrazek, A. J., Ihm, E.D., Molden, D.C., Mrazek, M.D., Zedelius, C.M. & Schooler, J.W. 2018, 'Expanding minds: Growth mindsets of self-regulation and the influences on effort and perseverance', *Journal of Experimental Social Psychology,* Volume 79, pp. 164-1180.

Offorbike, S. A., Nnadi, C. S. O. & Agu, J. C. 2018, 'Effect of Managing Employee Attitudes for Improved Performance of L.G.S.C., Enugu, Nigeria', *International journal of academic research in economics and management sciences,* 7(4), pp. 64-77.

Parker, S. K. & Griffin , M. 2011. Understanding active psychological states: Embedding engagement in a wider nomological net and closer attention to performance. *European Journal of Work and Organisational Psychology,* 20(1), pp. 60-67.

Patton, E. & Johns, G. 2012, Context and the social representation of absenteeism: Absence in the popular press and in academic research. *Human relations* , 65(2), pp. 217-240.

Patton, M. Q. 2002, *Qualitative evaluation and research methods.* s.l.:SAGE Publications.

Perrin, T. 2003, Working today: Understanding what drives employee engagement.

Pushpasiri, G. K. & Ratnayaka, R. M. 2018, 'Influence of Non-Financial Rewards on Employee Job Satisfaction: Private Banking Industry of Sri Lanka', *7th International Conference on Management and Economics,* 59(6).

Rusu, G., Avasilcai, S. & Hutu, C.-A. 2016, 'Organisational Context Factors Influencing Employee Performance Appraisal: A Research Framework', *13th International Symposium in Management,* Volume 221, pp. 57-65.

Schaufeli, W. B., Bakker, A. B. & Salanova, M. 2006, 'The measurement of work engagement with a short questionnaire: A cross-national study', *Educational and psychological measurement* , 66(4), pp. 701-716.

Schmidtke, J. M. 2007, 'The relationship between social norm consensus, percieved similarity, and observer reactions to coworker theft', *Human Resource Management Journal,* 46(4), pp. 561-582.

Shahzad, M. A. 2018, 'A study of casual relationship of job autonomy, social support and turnover intention', *Investigation Article,* 7(17), pp. 462-471.

Stormer, S. & Fahr, R. 2013, 'Individual determinants of work attendance: Evidence on the role of personality', *Applied Economics,* 45(19), pp. 2863-2875.

CASE STUDIES OF TRADITIONAL AND INNOVATIVE BUILDING APPROACHES FOR AGED CARE FACILITIES

Rami Mezher[1], Mary Hardie[1]

[1]School of Computing, Engineering and Mathematics, Western Sydney University, Sydney, Australia

Abstract

The construction industry has long been criticised as conservative and change-resistant. Despite this, recent years have seen an accelerating trend towards more sustainable processes, as well as, more efficient industrialised off-site construction. This paper explores case studies of innovations from one building company where two different approaches have been used to deliver an aged care residential development. Both projects happened at the same time, were of similar size and both were located in the Sydney metropolitan area. In one project, traditional brick and block construction systems were used, while the other introduced several technical innovations which included modular shoring of the excavations, prefabricated structural panels and preformed stairs. A scorecard system was developed to assess the social, economic and environmental impact of both projects. A measurable but modest performance improvement was observed in the project which took the innovative approach. Future study will broaden the scope of this kind of assessment to more cases and to different types of projects.

Keywords

Technical innovation; Offsite Construction Methods; Scorecard; Social, economic and environmental benefits.

Introduction

The construction industry is widely acknowledged for its dynamic role in a nation's economy, as well as, for its active contribution to Gross Domestic Product (GDP) (Nadim 2012). In addition, the construction industry has a high political, environmental and social profile due to its impact on the natural environment, employment rates and our built fabric (Ngowi et al. 2005). The prosperity, advancement and economic development of an economy generally can be shaped by its tendency for innovation. The application of superior solutions to meet new requirements and needs is a driver of economic prosperity. As a result, the construction sector is considered to be one of the most critical sectors of a national economy (Jones 2003). In particular, innovation involving Offsite Construction Methods (OSCM), is altering the way the construction sector operates by challenging productivity and efficiency levels in the traditional building sector. OSCM has been demonstrated to be capable of reducing cost and time while improving quality (Nadim 2012).

The term OSCM refers to the completion of elements of a construction project at a different location from where they will be installed permanently. OSCM is increasingly becoming the industry norm. This process involves the planning, design, fabrication and assembly in purpose-built offsite components which are shipped to the site for final assembly. The three main areas of potential benefits explored within this paper represent the aggregate of sustainable development. They are the social, economic and environmental benefits of technical innovation, forming the foundation of sustainability accounting.

Literature review

In 2008, Pichler defined innovation as being; the introduction of a process including the generation, development and implementation of new ideas and behaviour within a sector (Pichler 2008). Innovation, at heart, is an idea or a concept, that is fulfilled or delivered. Innovation can be an idea or concept that is driven by its result which when implemented works to improve efficiency (Vaughan 2013). Innovation within a firm is moulded by factors such as; culture, knowledge and management structure (Christensen 2006). Innovation can be generated due to a movement within an area, be it technological, scientific or financial. In order to be classified as an innovation, the new or enhanced item, procedure or system must be implemented and delivered (Hashi & Stojcic 2013). To be classified as an innovator, one must implement an idea and follow through on this idea to produce and implement change (Harris 2014). Over the past decades, technological innovation has changed the way we do things. Afuah (2003), defined technological innovation as the utilisation of knowledge concerning tools, processes, materials and techniques to create efficiency. Change and improved performance is a by-product of technological innovation. To be considered an established technological innovation, industry must accept the change as 'common-place', and in turn, the innovation must improve the performance of industry (Afuah 2003; Vaughan 2013).

A technological innovation that has more significant advantages, as well as, being less complicated will be integrated and adopted rapidly within society as compared to complicated technological innovation (Vaughan 2013). Such advantages and changes of technological innovation were described by one of the progenitors of innovation theory, Schumpeter (1934) as "creative destruction" as the old is replaced by the new. Moreover, Schumpeter further defined innovation as being either "radical" or "incremental, creating a hierarchy of change levels within society (OECD 2008). Tidd (2010) defined innovation as a linear development process, as well as, a life cycle phenomenon. This lifecycle starts with an invention through to the Research and Development (R&D) then through to diffusion which results in the implementation of that innovation (Tidd 2010). A chained lined method was introduced by Kline and Rosenberg (1986) which demonstrates the relationship between research, invention, innovation and the production which can be seen in figure 1 below.

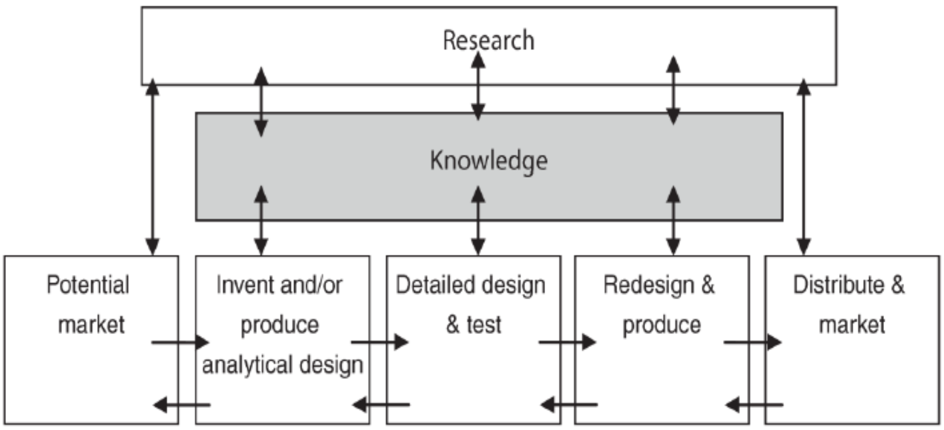


Figure. 1 - Innovation as a Life-cycle Phenomenon (Alessandro Maia 2015)

Implementation of technical innovation

One theory often used to explain the relatively slow development of construction innovations is that the industry is tailored to suit specific individual project requirements. Most projects are unique and largely non-repetitive which necessitates custom processes. Therefore, integrating innovation is a difficult task due to the unique nature of each project (Vaughan 2013). In addition, the construction industry by nature is often associated with high risks. Construction firms are conscious of the risk involved and often prefer to utilise traditional and previously tested methods. Innovative failure may entail high costs, hence the common decision to utilise traditional methods as opposed to innovative OSCM (Hobday 2000; Whitley 2006). Nevertheless, cost, time and quality are measures within the construction industry which have been demonstrated to be enhanced due to the implementation of technical innovation. However, this is now showing signs of change as evidenced by the industries move to OSCM. Lack of knowledge of the benefits of technical innovation may be another reason as to why the industry has a preference for not straying from traditional construction methods (Winter 2004).

Innovation can be hindered by many factors. Relationships between the builder, client and designer may hinder innovation (Gann 2000). According to Gann (2000), due to the lack of knowledge and complexity of OSCM, architects and designers may be reluctant to stray from traditional methods. The belief is that, with the implementation of technical innovation in construction projects, a lack of knowledge may devalue the relationship between the architect and the client. Thus, a conservative strategy minimises the amount of technical innovation specified on construction projects. Communication and trust are vital aspects required for technical innovation. Brachos et al. (2007) stated that knowledge transfer sometimes works against technical innovation within construction. The construction industry often lacks open communication and trust which in turns affects technical innovation. This lack of trust accounts for some of the risk aversion towards technical innovation in the construction industry (Brachos et al. 2007).

This lack of technical innovation within the construction industry has been researched extensively. According to Wandahl et al. (2011), technical innovation can be hindered due to the traditional framework of industry structure. This framework mandates independence between the parties (suppliers, manufacturers, architects) which causes a lack of communication, as a result reducing innovation rates (Wandahl et al. 2011). Van Egmond (2012) believes that technical innovation requires an open framework which allows parties to implement their internal innovation into construction projects which will enhance innovation. Furthermore, innovation is directly linked to sustainable development practice in a firm. Figure 2 below describes the components and strategies of sustainable development and its importance to enhance innovation within the construction sector.

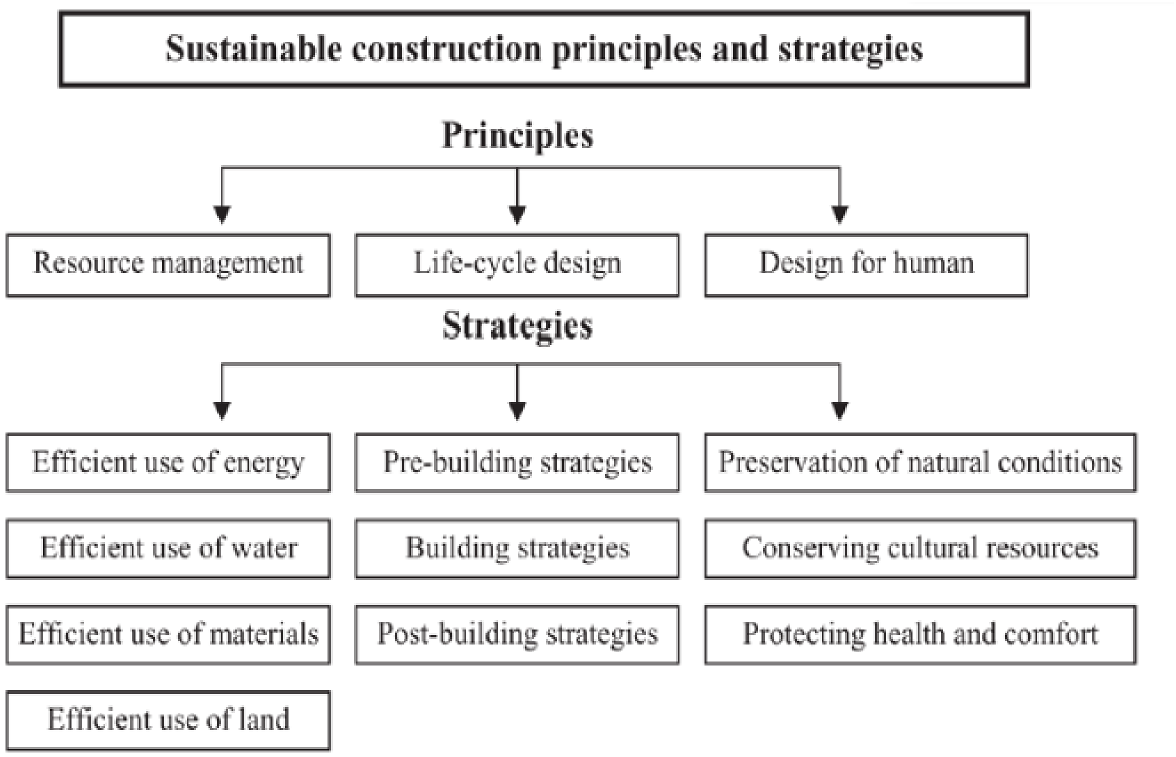


Figure 2 - Principles and Strategies for Sustainable Development (Sev 2009)

The built environment can play a significant toll on the natural environment. An innovation which improves the conservation of natural resources is a progression of its own. Table 1 below depicts several aspects of the effect of the construction industry on the natural environment.

Table 1 - The Effect of the Construction Industry on the Environment (Robins 2006)

	Environmental	**Social**	**Economic**
Raw material extraction and consumption, related resource depletion	*		*
Land use change, including clearing of existing flora	*	*	*
Energy use and associated emissions of greenhouse gases	*		*
Other indoor and outdoor emissions	*		*
Aesthetic degradation		*	
Water use and waste water generation	*		*
Increased transport needs depending on the site	*	*	*
Waste generation	*		*
Opportunities for corruption		*	*
Disruption of communities, including through inappropriate design and materials		*	*
Health risks on worksites and for building occupants		*	*

According to Robins (2006), the implementation of the "triple bottom line" accounting (TBL) is a useful measure of sustainable development within the construction industry. OSCM can be a form of sustainable development in which the above aspects are addressed. It has been stated that globalisation and macroeconomics play a vital role in a company's implementation of technical innovation (OECD 2008). Firms that compete in a global market tend to innovate more. Moreover, if performance standards replace higher tax rates, this will encourage innovation. Innovation rates are increased when market-based instruments are utilised. This is due to the higher return on the implementation of the innovation. A key driver behind technical innovation is the change of social perspectives regarding environmental aspects. This causes companies to innovate to keep up with their competitors. With the implementation of technical innovation in the construction sector, there is a possibility that production times and cost can be decreased, safety and quality can be increased. These factors can only be achieved once technical innovation are further implemented in the construction industry (Yudelson 2007).

Technical innovation through offsite and mechanised construction methods

Offsite Construction Methods (OSCM) involve the process of planning, designing, fabricating, transporting and assembling building elements for rapid site assembly (Jahn 1997). OSCM can include systems such as modular, panelised and componentized elements. OSCM is produced in a controlled factory environment, and up to 95% of the system can be constructed offsite ready for site installation (Chiheb 2017). The construction industry is facing increased demands to satisfy the "Triple P" (People, Planet and Profit). This demonstrates that the much of the construction industry desires to move towards sustainable development (Abbot, Jeong & Allen 2006; Sev 2009). As clients and developers are always looking for sound ways to improve the viability of projects, there has been a steadily increasing trend towards OSCM. OSCM is shaping the way the industry currently works, providing cost, time and quality advantages over the traditional form of construction (Jones 2003). Cost, time and quality are the primary focus of the modern construction industry delivery (Lawson 2014). The documented benefits of OSCM as compared to traditional methods can be summarised below (Chiheb 2017; Jahn 1997; Quale et al. 2012):

- Shorter construction schedules
- Predictability of cost is greater
- Reduction of waste
- Reduction of carbon emission
- Reduced site disturbance
- Increase in safety and security for labourers
- Labour productivity increased by 30%

In 2017, Chiheb undertook a study which focused on the success criteria of a construction project; time, cost, quality, safety and waste. This study was undertaken in the form of a survey, where clients were asked to vote on the reason as to why a client would utilise OSCM. The results showed time scoring the highest, followed by cost, quality, safety and waste respectively (Chiheb 2017). The results can be summarised in table 3.2 below.

Table 2- Success Criteria from a Clients' Perspective (Chiheb 2017)

Rank and outcome	**Votes**	**Comment**
Time-Saving	41%	41% of clients chose time as a priority as to why they would utilise offsite construction
Quality Improvement	28%	28% of clients chose quality as a priority as to why they would utilise offsite construction
Cost-Saving	17%	17% of clients chose cost as the number one reason as to using offsite construction
Safety	8%	8% of clients chose safety as a priority to utilise offsite construction
Waste Reduction	6%	6% of clients chose waste reduction as a priority to utilise offsite construction

Improved profits, safety, cost and quality have all been demonstrated as by-products of technical innovation (Gambatese & Hallowell 2011). OSCM is revolutionising the way the construction industry currently works, improving the quality, increases profits and stabilises the natural and built environment. The essence of technical innovation is categorised into three areas of sustainability. Social, economic and environmental benefits and values which will be considered in this research. The benefits of offsite construction will be considered from a social (safety and quality), economical (time and cost), and environmental (waste and productivity) perspective.

Social value of technical innovation

Social values can be difficult to quantify due to their largely subjective nature (Murphy & Topel 2007). Wood and Leighton (2010), described social values and benefits as being 'soft outcomes' due to their problematic nature to quantify. Social values and benefits take into consideration the welfare of the individual, the society and the community (Mulgan 2010; Wood & Leighton 2010). Commonly, social benefits are quantified by their improvement in the quality of life. Wellbeing, safety, quality, empowerment and happiness are all terms used to define social values. However, Mulgan (2010) defined social values as being non-material social factors such as that of morality and conformity. One's self-interest usually shapes the way we define the social benefit. Thus, the measure of social benefit is usually a personal opinion rather than reflecting the benefit of society as a whole.

Technical innovations such as OSCM play a crucial role in the construction industry by improving cost, time and quality of projects. Thus technical innovation is classified as an outcome of the social direction from within a society (Barman 2016). This can be seen by the better understanding of work safety and environmental issues in industry. Over recent years, humanity has acknowledged that natural resources are finite (Caputo 2011). The impact of the construction industry on the earth has become apparent. Table 3 below shows the effect that the built environment has on the natural environment.

Table 3 - *Effect of the Built Environment (Caputo 2011)*

Estimate of global resource used in building	
Resource	**%**
Energy	45 - 50
Water	50
Materials for buildings and roads	60
Agricultural land loss due to buildings	80
Timber products for construction	60 (90% of hardwoods)
Rainforest destruction	25 (indirect)
Estimate of global pollution that can be attributed to buildings	
Pollution	**%**
Air quality	23
Climate change gases	50
Drinking water pollution	40
Landfill waste	50
Ozone depletion	50

The social features of technical innovation have a direct relationship with its successful implementation within a society (OECD 2008). The consumer must demand a technical innovation, otherwise, the likelihood of success will decrease. Society's image of a technical innovation can make or break innovation. According to Gann (2000), social responsibilities have a distinct influence on technical innovation within the construction sector. Moreover, this is linked to the claim by Jones that innovative projects which improve the quality of life are required to meet society's needs (Jones 2003). Society's needs, expectations and responsibilities can enhance the development and utilisation of technical innovation. Yet as previously stated, technical innovation within the construction industry is slower than other industries due to the vast array of society's responsibilities and the difficulty in meeting them.

Francis (2005) stated that a technical innovation must contribute to the quality of the community in making the world a better place. Technical innovation such as that of OSCM and related mechanisation creates faster and safer construction sequences. An innovation may be shaped to suit society. This can be by the modification of a technical innovation towards a safer, cheaper, faster and better product or system. A social benefit is a by-product of a modified technical innovation in which the individual, as well as, society benefit from utilising the innovated product or system.

Economic value of technical innovation

From an economic perspective, innovation is most frequently associated with cost and time. OSCM can decrease the initial cost by up to 35% (Burwood & Jess 2005). The cost savings can be due to the more predictable nature of OSCM when compared to traditional construction. It is less likely to suffer from cost blowouts due to factors such as unpredictable weather. Cost and price factors can be measured in several ways (Ashworth & Perera 2015). Recent studies undertaken by Chiheb (2017) state that cost was the third most important factor from a clients' perspective. The standardised nature of offsite construction means that less labour is required onsite which leads to lower costs. Gibb and Isack (2003) stated that the cost savings of OSCM are indirect and relate to the entire life-cycle of the process. With the integration of offsite methods, fewer trades are required onsite which translates to cost savings. Moreover, the cost of administration will be minimised due to all trades working in a controlled environment. Lawson (2014) found that with the implementation of OSCM, 11-19% of the cost can be minimised and can be attributed to lower preliminaries, consultants' fees, snagging reduction and the speed of construction.

With the utilisation of OSCM, fewer activities are required on the critical path. In 2014, Lawson stated that with the integration of OSCM up to 50% of the construction programme could be minimised in relation to that activity which can be seen in figure 3.8 (Lawson 2014). In addition to this, recent surveys undertaken by Chiheb (2017) found that 41% of clients chose time and speed as their priority to utilise OSCM.

Environmental value of technical innovation

Over the past decade, environmental issues became increasingly important within the construction industry and environmental awareness have spread widely. Nowadays, organisations place more emphasis on sustainable development to meet society's demand. The Environmental Performance Index (EPI) ranks environmental performance on a national level. The environmental performance of nations can be seen in Figure 3 which shows the relationship between the sub-scores on the two policies (Environmental health and Ecosystem vitality) for 180 countries. Australia is currently ranked 21 of the 180 countries worldwide, raising awareness of environmental issues. Eco-innovation is a term which is widely accepted worldwide. It is defined as the development of a product or process which contributes to sustainable development to provide environmental improvements (Bossle et al. 2016; Mele & Russo-Spena 2015). Furthermore, Mi Sun (2017), described eco-innovation as being an innovation that results in the reduction of environmental risks, minimising resource consumption and the reduction of pollution. Nowadays, eco-innovation is often driven by regulations. However, the cost-savings and the environmental benefits arising from sustainable development have increased the demand for eco-innovation (Mi Sun et al. 2017; Mok, Han & Choi 2014; Rozkrut 2014).

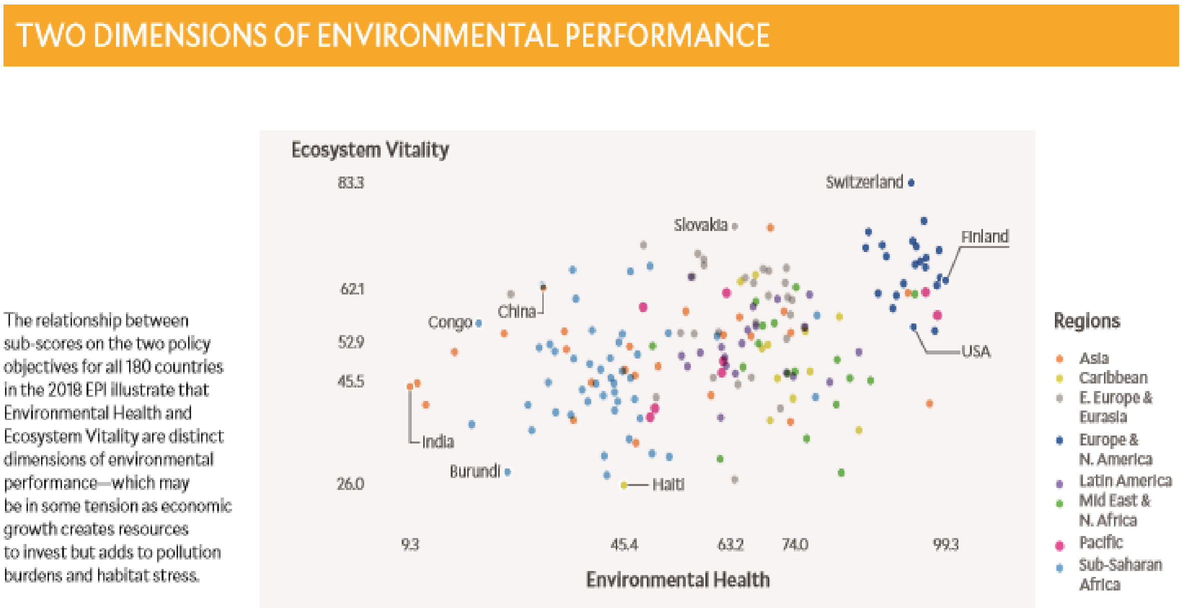


Figure 3 - Environmental Performance of Nations (CIESIN & YCELP 2018)

Technological advancements have had a significant impact on the increase of eco-innovation within the construction sector. Green growth statistics show an increase in sustainable patents namely; energy efficiency, renewable energy, air pollution and waste management (OECD 2008). OSCM has had a considerable influence on eco-innovation due to controlled factory environments. Also, the number of patents directly correlates to the technological advancement within a country. The construction industry contributes significantly to waste and greenhouse gas emissions which can be attributed to the resource intense nature of construction (Mok, Han & Choi 2014). Technological innovation is required within the construction industry to combat such issues. Therefore, innovation is required to minimise the built environment's effects on the natural environment. Currently, there is a considerable emphasis on environmental regulations. The Australian government plays a significant role in deploying these regulations within the construction sector, regulators have measured standards that target carbon emission, waste, energy, water and resource use within the construction sector. In order to foster environmental innovation, continual and stricter regulations are required (Horbach, Rammer & Rennings 2012). To promote environmental innovation, governments have established policies and incentives so that organisations can enhance economic development while protecting the environment equally (Zhou et al. 2013).

Clients today are increasingly requesting an eco-innovative project. The clients' primary concern is the products which will be utilised within the project. In addition to this, requirements such as material efficiency, reduced energy consumption, reduced waste and the elimination of harmful products are also sought for (Horbach, Rammer & Rennings 2012; Zhou et al. 2013). As a result, technical innovation within the construction sector has increased steadily and at a progressive rate in several fields (Yilmaz & Bakis 2015). The construction industry is a leading contributor to waste production within Australia.

The Australian National Waste Report showed that the construction industry produced more than 20 million tonnes of waste (Wardle, Cosson & Trinh 2016). This equates to nearly 33% of Australia's gross national waste generation. OSC provides a solution to such waste production, minimising waste by nearly 35%. The controlled nature of offsite construction allows minimal waste to be produced in the design phase. Figure 4 above describes the reduction of waste that can be achieved through the utilisation of various OSCM strategies, resulting in a total of 20-90% waste reduction depending on the system.

Table 4 - Reduction of Waste when using OSCM (Yilmaz & Bakis 2015)

Offsite method	Estimated Waste Reduction
Volumetric Systems	70-90%
Structural Insulated panels	50-60%
Precast Cladding	40-50%
Pods (Kitchen, Bath)	40-50%
Precast Floor Systems	30-40%
Timber Frame System	20-40%
Concrete Panel Systems	20-30%

Research and methodology

In determining an appropriate methodology, the logical data linkage and data analyses must be considered to answer the research questions posed. The primary objective is to ensure that the data collected allows the researcher to arrive at a result. The research design must consider the following;

- The research questions
- The data requirements
- The analysis method

Research questions

Through the undertaking of background research and preliminary literature review, the research aimed at answering the question 'What are the social, economic and environmental effects of Offsite Construction Methods (OSCM) and what effect do they have on a construction project?'. This research question was further broken down into the following sub-questions which were required to prove or disprove the hypothesis;

- What social benefits do OSCM have on construction projects? Are there any safety and quality benefits?
- What economic benefit do OSCM have on construction projects? Are there any cost and time benefits?
- What environmental benefit do OSCM have on construction projects? Are there any waste reduction benefits?

This study utilised a mixed method approach as it answers the research question, collects the required data and analyses this data to reach a conclusion. When human perception and behaviour becomes a focal point of research such as analysing the benefits, a mixed method approach would be preferably utilised (Hardie 2011). Triangulation can be carried out in a variety of methods such as; survey data, semi-structured interviews, observation and archival materials. It is a strategy aiming to provide a complete image of reality than what a single methodological approach may generate. This research through the use of a mixed method approach aimed to contribute to the understanding of the social, economic and environmental benefits arising through technical innovation in the realm of OSCM within the construction industry. A concurrent triangulation strategy allowed both a quantitative and qualitative data collection to be of equal value, which was necessary to provide consistency. The data collected for this research were collected between May 2018 – October 2018 inclusive taking form through academic references, trade literature, site visits, case studies, professional reports, documentation and observation.

Case studies

Case studies were utilised to enhance the knowledge of an individual, organisation, social and political phenomena (Hoskins 2013; Yin 2014). This method provides for an in-depth analysis of a product, process or a system innovation giving the reader an insight into the outcome of the study (Hoskins 2013). Furthermore, case studies provide an in-depth analysis of the innovation on a tested basis (Fellows 2015). Case studies collect material from multiple sources of information which therefore provides an in-depth picture of the social, economic and environmental benefit of technical innovation (Stake 1995). Case studies are generally representative exhibiting facets of the topic showing the range of alternatives (Yin 2014). Case studies function through theoretical generalisation, therefore forming a distinct style of research while merging an array of data collection methods (Fellows 2015; Stake 1995). Fellows (2015) stated that case studies following the scientific approach of a case study are of higher quality and reliability. Fellows (2015), further went on to describe the scientific approach as being the development of a clear research question, the utilisation of literature to formulate a hypothesis, definition of the methodology, a collection of the data and an analysis of the data to draw a conclusion. A scientific approach was utilised within this thesis.

Yin (2014) states that case studies can be in the form of single case studies or multiple case studies depending on the explanatory or descriptive nature of the research question. This research utilised multiple case studies as an in-depth analysis of the social, economic and environmental benefit of OSCM was required. The data collection for these case studies was through the comparison of an innovative project to a traditional project to draw a comparison and reach a conclusion.

Score card and data collection

Scorecards were utilised as a data collection tool (a blank scorecard example is given in Figure 3 below). Scorecards can be classified as taking a comparative or a non-comparative approach. Non-comparative involves the object being scaled independently of each item, while comparative scales involve the direct comparison of the stimuli. For this thesis, a Likert scale was utilised as this was the most common form of scaling within the construction industry and was viable to fulfil the research. Three separate case study innovations have been utilised to retrieve the data. Each case study will demonstrate the technical innovative category of a product, a process and a system. The case studies undertaken were subject to a scorecard approach to derive a standard set of social, economic and environmental criteria. Based on observed facts and through judgement made from the observation of the parties involved in the case studies, each case study was ranked according to the success criteria. A conclusion was drawn based on the observations and the results of the case studies. The results have been ranked in accordance with a quantitative approach. The total scores achieved per category demonstrates the most beneficial area of the innovation. The data (score) was analysed to draw conclusions. The scoring criteria were derived from the primary social, economic and environmental requirements and were scored from the perspective of the builder.

Social Value						
Project Information						
Score	1	2	3	4	5	
Social Benefit	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Overall Score
	*	*	*	*	*	
Acceptance of the innovation within society						
	Comment					
Improve social value and is it socially responsible						
Improved quality of life and quality of the project						
	Comment					
Does the innovation create change						
	Comment					
Does the innovation fit within society						
	Comment					
Does the innovation improve safety						
	Comment					
Is the innovation practical						
Is the innovation a better solution						
	Comment					
				Total		
				Possible Score		40
				Percentage		%

Figure 4 – Blank scorecard after Sev (2009)

Two building projects were studied. Both were built by the same head contractor in suburban Sydney in 2018. Both were Aged Care residential facilities. Project 1 was classified as the Innovative Project. Project 2 was considered to be a traditional project. The project details are shown in Table 4 overleaf. The cost, time and quality benefits were analysed and observations were made to compare the economic, environmental and social impact of three distinct innovations which were utilised on Project 1. The scorecards were prepared so that comparative judgements could be made. The first author completed the assessments by himself due to time constraints on the project.

Table 5 - Comparative Projects Under Study (Total Construction Pty Ltd 2018)

Comparative Projects		
	Project 1 – Innovative project	Project 2 – Traditional project
Project name	Toongabbie Residential Aged Care Facility	Beverly Park Aged Care Facility
Description	New 36 unit aged care facility – comprising 2 basement floors, commercial ground floor and 4 levels of independent living units	New 34 unit aged care facility – comprising 2 basement floors, and 2 levels of independent living units
Cost	\$16,388,000	\$18,145,000
Duration	381 days	436 days
GFA	5863 m^2	4992 m^2
GFA Rate (Gross)	\$2,787 / m^2	\$3,635 / m^2
Product innovation case study	Preformed stairs	Traditional in situ stairs
Process innovation case study	Modular hydraulic shoring	Ground anchors
System innovation case study	Prefabricated structural panels	Brick and block construction

Results

The scorecards demonstrated that there were significant benefits in the areas of safety, quality, cost, time and waste with the implementation of innovative construction processes. Safety was a significant benefit of the innovations utilised on Project 1. This was evident as minimal lost time injuries were experienced. Onsite quality procedures were minimised on Project 1 as such procedures were replaced with offsite quality control procedures. The cost benefits of innovative construction contributed largely to the success of the builder of Project 1. The cost comparison of the projects under study can be summarised in table 5 which shows a total saving of \$848 / m^2; this equates to 23% saving on the construction cost. Although these were not attributed solely to the chosen innovations studied, it shows the significance and potential cost benefits it provides on projects. Lawson (2014) stated that with the implementation of OSCM up to 50% of the construction programme could be minimised. As evident through the case studies, Toongabbie Aged Care Facility has a construction programme of 381 days, while Beverly Park Aged Care Facility has a construction programme of 436 days giving a total saving of 13%. Although this figure is not as large as predicted, when GFA is considered this demonstrates considerable benefit to the Project.

Table 6 – Scorecard results for innovative case study innovations

Innovative case study	Social	Economic	Environmental	Total /120
1. Preformed stairs	31	37	31	99
2. Modular shoring	37	34	33	104
3.Prefabricated panels	37	38	31	116

Conclusion and Limitations

The results attained from this research show that the industry is capable of the change required to meet sustainable development. There is, however, some reluctance when dealing with conservative clients and fixed expectations. The effect of technical innovation in the realm of OSCM can be seen in the case study analysis, where significant social, economic and environmental benefits were achieved with the implementation of OSCM on projects. The areas of improvement where social benefits (safety and quality), economic benefits (cost and time) and environmental benefits (waste). This demonstrates the effectiveness of OSCM over traditional construction methods within the limited context of the two projects that were studied.

The strength of OSCM was seen to be due to its demonstrated improvements in the three categories of technical innovation being; a product, a process and a system. The results showed that with the implementation of technical innovation all categories of technical innovation provided a significant improvement in sustainable development. OSCM through its benefits can work to improve the overall image of the construction industry in providing significant social, economic and environmental improvements. This is a study of two comparable projects. It does not purport to be a definitive study but rather a window into the relative readiness to change current practices.

Some theories related to the construction industry imply that the industry is at best lethargic in its adoption of technical innovation. With the implementation of OSCM, the five success criteria relate to construction projects being; cost, time, quality, safety and waste are an improvement. Thus, with the implementation of OSCM on projects this can work to improve the adoption of technical innovation in the industry. Through the study of the possible benefits of technical innovation in the realm of OSCM on projects it indicated that, contrary to the well-established theory, that technical innovation are implemented based solely on its economic benefits on construction projects. The results indicated that technical innovation had equal social, economic and environmental benefits. This can be seen as indicative of the changing social trends in its acceptance of a well-balanced innovation.

In addition to this, the results demonstrated that no one category strongly outweighed the other categories. Although the economic benefits scored the highest, the social benefits scored similar ratings followed by environmental benefits respectively. Demonstrating that with the implementation of technical innovation and OSCM, all facets of sustainable development are potentially improved.

Recommendations

Through conducting this research, it was seen that the construction industry needs to improve the implementation of technical innovation on projects. This can be done by understanding of the benefits that OSCM have on construction projects, as well as, the improvement of the implementation process. The possibilities of OSCM need to be further analysed and documented to provide insight into the social, economic and environmental benefits of such innovative methods. The understanding and knowledge gained through this analysis will encourage sustainable development through practice, therefore, benefiting the planet. The research demonstrated the need for further study into the area of OSCM and the social, economic and environmental benefits such methods portray.

Limitations

The methodological approach chosen for this thesis faced various limitations and constraints. Such limitations may influence the findings, as such the results serve as an initial study for future research in the line of study. Furthermore, the findings of this research should be taken as indicative rather than definitive. The scorecards were filled out by the primary researcher relying on project data available from the contractor. If time constraints had allowed, it would have been possible to have a series of experts fill out the scorecards and statistically examine the correspondences and variations.

This study aimed to investigate the possible social benefits; safety and quality, economic benefits; cost and time and environmental benefits; waste reduction of technical innovation in the realm of OSCM when implemented on projects. Through the study of literature and the undertaking of multiple case studies, it was found that strong social, economic and environmental benefits were achieved with the implementation of OSCM. Also, this was found across all areas of technical innovative categories of product, process and system innovation.

Based on the results, this study has given support to the hypothesis of that 'The implementation of technical innovations in the realm of Offsite Construction Methods will pave the way to attain the social, economic and environmental benefits'. Thus, future research within this field of study may include an overall analysis of the percentage of cost, time, quality, safety and waste improvements when OSCM are implemented on projects, this can be calculated through considering the lifecycle of the project. This may result in an improvement of the image of the construction industry, as currently, through literature, the perception is that the construction industry remains somewhat slow with its implementation of technical innovation.

References

Abbot, C, Jeong, K & Allen, S 2006, 'The economic motivation for innovation in small construction companies', *Construction Innovation*, vol. 6, no. 3, pp. 187-96.

Afuah, A 2003, *Innovation management : strategies, implementation and profits*, 2nd edn, Oxford University Press, New York.

Alessandro Maia, P 2015. Ideias Fundadoras - Stephen J. Kline, Nathan Rosenberg - An overview of innovation. *Revista Brasileira de Inovação*, vol. 14, no. 1, pp.9–48.

Ashworth, A & Perera, S 2015, *Cost studies of buildings*, 6th edn, Abingdon, Oxon : CRC Press, 2015.

Barman, E 2016, *Caring capitalism : the meaning and measure of social value*, New York : Cambridge University Press, 2016.

Bossle, B, Dutra, M, Vieira, M & Sauvée, L 2016, 'The drivers for adoption of eco-innovation', *Journal of Cleaner Production*, vol. 113, pp. 861-72.

Brachos, D, Kostopoulos, K, Eric Soderquist, K & Prastacos, G 2007, 'Knowledge effectiveness, social context and innovation', *Journal of Knowledge Management*, vol. 11, no. 5, pp. 31-44.

Burwood, S & Jess, P 2005, *Modern methods of construction: evolution or revolution?*, British Urban Regeneration Association (BURA) Steering and Development Forum.

Caputo, M 2011, 'Optimal control and resources', *IDEAS Working Paper Series from RePEc*.

Chiheb, Z 2017, 'Offsite construction ', *Architects; Journal*, vol. 244, no. 19, pp. 24-8.

Christensen, CM 2006, 'The Ongoing Process of Building a Theory of Disruption', *Journal of Product Innovation Management*, vol. 23, no. 1, pp. 39-55.

Center for International Earth Science Information Network (CIESIN) & Yale Center for Environmental Law & Policy (YCELP) 2018, *EPI results* Environmental Performance Index viewed 29 August 2019, <https://epi.envirocenter.yale.edu/epi-topline>.

Fellows, R 2015, *Research methods for construction*, 4th edn, New York : Wiley, 2015

Francis, L 2005, 'Innovation through management ', *Qualified Remodeler*, vol. 31, no. 7.

Gambatese, J & Hallowell, M 2011, 'Factors that influence the development and diffusion of technical innovations in the construction industry', *Construction Management and Economics*, vol. 29, no. 5, pp. 507-17.

Gann, D 2000, *Building innovation : complex constructs in a changing world*, T. Telford, London.

Gibb, A.G.F. & Isack, F., 2001. Client drivers for construction projects: implications for standardization. *Engineering Construction and Architectural Management*,vol. 8, no. 1, pp.46–58.

Hardie, M & Newell, G 2011, 'Factors influencing technical innovation in construction SMEs: an Australian perspective', *Engineering Construction & Architectural Management*, vol. 18, no. 6, pp. 618-36.

Harris, L 2014, *Idea engineering : Creative thinking and innovation*, New York : Momentum Press, 2014.

Hashi, I & Stojcic, N 2013, 'The impact of innovation activities on firm performance using a multi-stage model: Evidence from the community innovation survey 4', *Research Policy*, vol. 42, no. 2, pp. 353-66.

Hobday, M 2000, 'The project-based organisation: an ideal form for managing complex products and systems?', *Research Policy*, vol. 29, no. 7, pp. 871-93.

Horbach, J, Rammer, C & Rennings, K 2012, 'Determinants of eco-innovations by type of environmental impact: the role of regulatory push/pull, technology push and market pull', *Ecological economics*, vol. 78, pp. 112-22

Hoskins, S 2013, *Educational research: planning, conducting, and evaluating quantitative and qualitative research. 4th.Ed.*, Times Supplements Ltd.

Jahn, B 1997, *Offsite construction*, New York : McGraw-Hill, New York.

Jones, M 2003, *Managing innovation in construction*, London : Thomas Telford, London

Kline, SJ & Rosenberg, N 1986, 'An overview of innovation', in R Landau & N Rosenberg (eds), *The Positive Sum Strategy: Harnessing Technology for Economic Growth*, National Academy Press, Washington, D.C.

Lawson, M 2014, *Design in modular construction*, Boca Raton, Florida : CRC Press, 2014.

Mele, C & Russo-Spena, T 2015, 'Eco-innovation practices', *Journal of Organizational Change Management*, vol. 28, no. 1, pp. 4-25.

Mi Sun, P, Raimund, B, Ki Joo, H, Eun Kyung, J & Ji Hyung, J 2017, 'Eco-innovation indices as tools for measuring eco-innovation', *Sustainability*, vol. 9, no. 12, p. 2206.

Mok, K, Han, S & Choi, S 2014, 'The implementation of clean development mechanism (CDM) in the construction and built environment industry', *Energy policy*, vol. 65, pp. 512-23.

Mulgan, G 2010, 'Measuring social value', *Stanford Social Innovation Review*, vol. 8, no. 3, pp. 38-43.

Murphy, K & Topel, R 2007, 'Social value and the speed of innovation', *The American Economic Review*, vol. 97, no. 2, pp. 433-7.

Nadim, W 2012, *Modern methods of construction*.

Ngowi, A, Pienaar, E, Talukhaba, A & Mbachu, J 2005, 'The globalisation of the construction industry—a review', *Building and Environment*, vol. 40, no. 1, pp. 135-41.

Organisation for Economic Cooperation and Development (OECD) 2008, *Environmental policy, technological innovation and patents*, Paris : OECD, Paris.

Pichler, J 2008, *The theory of economic development* University of Zagreb, Faculty of Economics and Business, Zagreb.

Quale, J, Eckelman, M, Williams, K, Sloditskie, G & Zimmerman, J 2012, 'Construction matters', *Journal of Industrial Ecology*, vol. 16, no. 2, pp. 243-53.

Robins, F 2006, 'The challenge of TBL: a responsibility to whom?', *Business and Society Review*, vol. 111, no. 1, pp. 1-14.

Rozkrut, D 2014, 'Measuring eco-innovation: towards better policies to support green growth', *Folia Oeconomica Stetinensia*, vol. 14, no. 1, pp. 137-48.

Schumpeter, JA 1934, *The Theory of Economic Development*, Harvard University Press, Cambridge, Mass.

Sev, A 2009, 'How can the construction industry contribute to sustainable development? a conceptual framework', *Sustainable Development*, vol. 17, no. 3, pp. 161-73.

Stake, R 1995, *The art of case study research*, Thousand Oaks : Sage Publications, Thousand Oaks.

Tidd, J 2010, *Gaining momentum managing the diffusion of innovations*, London : Imperial College Press ; Singapore ; Hackensack, N.J. : Distributed by World Scientific Pub., London : Singapore ; Hackensack, N.J.

Van Egmond, E 2012, *Innovation, technology and knowledge transfer for sustainable construction*.

Vaughan, J 2013, *Technological innovation : perceptions and definitions*, 7th edn, Chicago, Illinois : American Library Association, 2013.

Wandahl, S, Jacobsen, A, Heidemann Lassen, A, Bolvig Poulsen, S & Sorensen, H 2011, 'User-driven innovation in a construction material supply network', *Construction Innovation*, vol. 11, no. 4, pp. 399-415.

Wardle, C, Cosson, K & Trinh, J 2016, *Australian national waste report 2016*, Randel Environmental Consulting Australia.

Whitley, R 2006, 'Project-based firms: new organizational form or variations on a theme?', *Industrial and Corporate Change*, vol. 15, no. 1, pp. 77-99.

Winter, J 2004, 'Why is construction so backward?', *Architectural Review*, vol. 216, no. 1289, pp. 96-.

Wood, C & Leighton, D 2010, 'Measuring social value: the gap between policy and practice', *Undercurrent*, no. 2, pp. 7-9.

Yılmaz, M & Bakış, A 2015, 'Sustainability in construction sector', *Procedia - Social and Behavioral Sciences*, vol. 195, pp. 2253-62.

Yin, R 2014, *Case study research : design and methods*, 5th edn, Thousand Oaks, California : SAGE, 2014.

Yudelson, J 2007, 'The keys to marketing green building', *Consulting-Specifying Engineer*, vol. 41, no. 5, pp. 29-33.

Zhou, Q, Mizunoya, T, Yabar, H, Higano, Y & Yang, W 2013, 'Comprehensive analysis of the environmental benefits of introducing technology innovation in the energy Sector: case study in Chongqing City, China', *Journal of Sustainable Development*, vol. 6, no. 8, pp. 71

ASSESSMENT OF DEFECTS AND DISPUTES IN RESIDENTIAL BUILDINGS

Vidal Paton-Cole[1]

[1] Melbourne School of Design, The University of Melbourne, Melbourne, Australia

Abstract

Residential buildings comprise of various forms that includes single detached houses, townhouses, multi-unit dwellings, block of apartments and multi-storey residential towers. Over the last two decades, Australian major cities have experienced significant population growth that has generated an increased demand for residential buildings inclusive of the various forms. Correspondingly, there has been an increase in the number of domestic building disputes. While current legislation, compliance and certification framework exists to regulate construction of residential buildings, defects in completed buildings continues to be a perennial problem. Recent cases of non-compliant building materials being utilised in many residential buildings in Australia is indicative of the lack of a working regulatory process for the importation and approval of materials before being incorporated into buildings. This paper presents assessment of protracted disputed cases and analyses of the underlying causes benchmarked against regulatory framework. To investigate and establish defects trend in low-rise residential buildings, the Victorian Civil and Administrative Tribunal (VCAT) database was used as a data source. This research shows that building defects can yield detrimental effects during the intended use of the building, leading to deterioration of constituent building elements if not detected early and subsequently affect the building value. It is thus evident that related construction defects and associated disputes could cause severe stress, depression and anxiety regardless whether pursued damages are recoverable or not. This research concludes that regulatory overhaul is required in the broader construction industry in Australia before the industry plunges into further crisis. Hence, regulations that directly or indirectly influencing building defects should be duly addressed to prevent continual recurrence of extensive latent defects.

Keywords

Defects, Disputes, Residential buildings, Regulations.

Introduction

In Australia, most people live in residential buildings that belongs to Classes 1 and 2 building classifications in accordance with the National Construction Code (ABCB 2010). Residential houses in subclass 1a includes typically standalone detached houses, as well as horizontally attached dwellings such as terrace houses or town houses with a fire resisting wall separating the horizontally attached houses. In subclass 1b, houses in this class includes boarding house, guest house or a hostel which must have less than twelve people cohabiting in it. Subsequently subclass 1b also incorporates four or more single houses used for short-term holiday stay and with all houses constructed on one allotment. Whereas, Class 2 buildings are apartment buildings which are typically multi-unit residential buildings where occupants live above and below each other. Each unit in an apartment building is considered by the National Construction Code as a "sole-occupancy unit". These two classes of houses are required to be designed and constructed in compliance with the National Construction Code (NCC) which is a "performance based document that contains the technical provisions for the design and construction of buildings and other structures, covering such matters as structure, fire resistance, access and egress, services and equipment, and energy efficiency as well as certain aspects of health and amenity" (ABCB 2010). In a nutshell, the National Construction Code thereby provides the framework for the inherently quality of work and materials needed for constructing various forms of residential buildings while ensuring that these buildings are fit for their intended purpose.

In recent past, quality standards in residential buildings has been an issue in the construction industry, influenced by construction and/or latent defects that undermines the performance requirements of these buildings. In Victoria (VIC) and New South Wales (NSW), residential buildings have been under the spotlight in recent times, resulting from the numerous complaints associated with defective building works but with limited research scope undertaken to date to understand the fundamental causes. Over the last few decades, to improve delivery and quality of new housing to homeowners in Victoria, there has been several legislative requirements, implemented with an underlining intent to minimize defects (Paton-Cole, VP & Gurmu, AT 2018) namely: House Builders Liability Act, 1972; House Contracts Guarantee Act, 1987; Domestic Building Contracts and Tribunal Act, 1995. Prior to these legislative frameworks, the state of Victoria trialled and discarded industry sponsored voluntary schemes and adopted the builder registration as the preferred method of improving quality in the construction of new houses (Georgiou 2010). As a means of improving quality and curbing defects, the 1995 Act (still current) requires home builders to be registered with the Victorian Building Authority and further provide a domestic building insurance to clients for building works more than $16,000.

Notwithstanding, despite the rigorous process governing residential building construction activities, there has been continual increase in complaints associated with defective works that often resulted in domestic building claims and some eventuate to construction dispute. As evident in the Victorian Managed Insurance Authority annual report (VMIA 2017), 1,068 Victorians were assisted during the financial year by the VMIA to rectify bad workmanship or finish building their homes, and in the process paid $179M to clients. The total number of building claims settled in the 2017-18 fiscal year significantly increased by 50% to 1,600. Subsequently, there has been corresponding increase in the number of domestic building disputes referred to the Victorian Civil and Administrative Tribunals (VCAT) in Victoria. In 2015-16 fiscal year, the Victorian Administrative and Civil Tribunal (VCAT) reportedly initiated 1,746 building and property cases, of which 1,328 were related to domestic buildings works (VCAT 2016). Generally, these complaints and building disputes resolution places a significant burden on all parties involved and could drag on for years, with low-level earners usually unable to cope with the implied legal cost. Due to the exorbitant related disputes associated with domestic buildings, to foster the Victorian Government's oversight of the residential building sector, the Domestic Building Dispute Resolution Victoria (DBDRV) was recently commissioned in 2017 to mediate disputes relating only to domestic buildings works. It is thus evident that there is an underlying problem that needs to be addressed, as the cost of remedying defects has serious economic consequences to both the builders and clients, which subsequently have an adverse effect on overall construction productivity.

The building construction industry

The construction industry is one of the largest contributors to Gross Domestic Product (GDP) in the Australian economy and was the second largest contributor during the 2015-16 financial year, accounting for 8.1 per cent of GDP while employing 1.1 million people that amounts to about 9 per cent of the national workforce. While the industry constitutes three primary sectors (including Engineering Construction, Residential Construction and Non-residential Construction), the residential construction sector represents a substantial part of the construction industry. The residential sector grew 10.6 per cent in 2015-16 (Economist 2016) in contrast to the other contributing sectors that were contracted resulting from the slowdown of the mining boom. This gives an indication of the significance of the residential building sector which comprise of various building forms that includes low-rise single detached houses, multi-unit dwellings, villa units and townhouse buildings. Across Australia, the construction trend exhibits a distinct national pattern, with continuing increase in residential construction activities in Victoria and New South Wales with declining activities across the other states. As reported by the Housing Industry Australia, out of the total residential dwelling approvals in 2016, almost 60% were in Victoria and NSW combined, with a similar trend projection for 2017 (HIA 2017, 2019). Thus, the residential construction cycle provides positive impact on economic growth and employment at both state and national levels.

Housing demand

Home ownership forms part of the Australian social and economic fabric. It is a dream of every Australian to one day own their own home and it would be unquestionable that a comfortable detached house with a backyard featuring huge freedom of space would top the list of preference for homeowners. However, due to the scarcity of land in close proximity to the major city centres in Australia, most homebuyers wanting a detached house would end up in a location further out from city centres and further from transport and other necessary amenities (Kelly & Donegan 2015). The easy access to available amenities, increasing demand and proximity to work in the Central Business District (CBD) have caused house prices to surge significantly over the years and have rendered houses located within a small radius (under 10 to 15 km) away from the city centre unaffordable. The increased demand for living within close proximity to the CBD particularly in Victoria and NSW has made vertical living in multi-storey residential buildings a popular trend and thus necessitating the extensive construction of significant number of apartment buildings. Data shows that the number of apartments constructed each year has tripled since 2009 while apartments now accounted for one-third of residential building approvals (Rosewall & Shoory 2017). As reported by the Australian Bureau of Statistics (ABS), approvals for apartment buildings is mostly contained in large cities with 90 per cent of apartment approvals in 2016 were in the three major cities of Sydney, Melbourne and Brisbane (ABS 2016). Majority of these apartments are generally built either within the CBD or in suburbs connected to the city centre, making it accessible to amenities and job opportunities.

However, for low to medium income earners, the location of affordable housing has moved significantly from the CBD to between 30-50 km radius of the city centre where newly subdivided block of lands are available particularly in Victoria and in New South Wales. Over the last decade, in a bid to ease the pressure of domestic housing availability and mitigate the shortage of new housing in the major cities of Victoria NSW and Queensland, numerous suburban developments have been undertaken in the outer metropolitan municipalities. Contributing factors influencing higher demand for detached housing also includes population growth, migration and the current low mortgage interest rates that has enhanced affordability.

The domino effect on construction quality

The increase in demand for residential buildings have resulted in a rapid construction process that too often resulted in the abysmal performance of newly constructed residential houses, arising from numerous defects that compromises the performance requirements. Eventually, builders and owners often become involved in issues related to defect damages in new homes. In a study undertaken to quantify the degree of defects being experienced in newly residential houses constructed in Victoria over a period of fifteen years between 1982 and 1997, it was reported that one in every eight houses reported defects with an estimated rectification cost of 4% of the contract value (Mills, Love & Williams 2009). Similarly, in another study recently concluded on new houses that were less than 5 years old or less, it was reported that out of 631 low-rise residential houses that were surveyed and constructed by registered builders, a mean of 3.38 defects per house was reported (Georgiou 2016). In a more recent research conducted, a study was undertaken to examine the impact of defects on multi-owned properties which consists of medium and higher density housing (Johnston & Reid 2019). Amongst the 212 building reports that were examined across three Australian states (New South Wales, Queensland and Victoria), it was reported that 85% of all the buildings had at least one defect across multiple locations. The most prevalent defect was related to building cladding with most of these being a consequence from water penetration.

In recent times, extremely poor performance of residential buildings particularly in Victoria and New South Wales have been under the spotlight and the residential building sector has been tarnished with poor construction quality. The most recent alarming case being the Opal Tower which is a 36 storeys residential tower containing 392 residential apartments with 3 levels of basements completed around August 2018. The residential tower exhibited poor performance through noticeable structural cracks in various areas of the building that has been occupied by the new owners for only four months. Six months later in June 2019, similar news was reported about the Mascot Towers in Sydney when significant structural cracks appeared on a basement wall. While this tower was completed around 2009, report by the Financial Review indicated that Strata minutes indicated that apartment owners have been battling with building defects since 2011 (Tan 2019). While Sydney has been plagued with structural defects in apartment buildings, similar residential towers in Melbourne have suffered fire damage as a result of combustible cladding used in the building envelope. These recent cases of non-compliant building materials being utilised in many residential buildings is indicative of the lack of a working regulatory process for the importation and approval of materials before being incorporated into buildings constructed in Australia's most populated cities.

While in any construction there are inherent defects due to the intricate process of construction, the extent to which defects has been reported in recent times is alarming (Georgiou 2010, 2016; Johnston & Reid 2019; Mills et al. 2009; Tan 2019). In a recent consumer survey, it was reported that nearly one in every three building consumers reported experiencing problem that occurred due to poor workmanship (VAGO 2015). This report further highlighted that these experiences of defects arising from poor building quality has profound impact on consumers while they try to resolve related defect matters with builders. This gives an indication of the possible psychological effects building defects have on homeowners. As builders do not normally have insurance policy in place to cover building defects during the statutory warranty period, cost arising from defects rectification is therefore an expense borne by the builder. With builders perceiving these rectification costs as cutting their profit margins while inflating their overheads, most builders often tend to evade from undertaking defects rectification and thereby leaving consumers/homeowners in a state of distress arising from poor quality of building works. Reworking of these construction activities does not only have financial implications such as cost overruns on construction projects but could also impact safety performance. Wanberg (2013) and others in their research suggested that when rework occurs during construction, there is an increasing propensity for safety incidents and/or accidents to occur (Wanberg et al. 2013). Research on reworking on construction activities suggested that reworking can adversely affect the performance and productivity of design and construction organisations (Love 2002), while these reworking activities could be very costly. Related research has also revealed that direct rework costs during construction could range from 2–5% of contract value (Alinaitwe et al. 2014; Love & Li 2000; Mills et al. 2009; Taggart, Koskela & Rooke 2014). With the significant contribution the construction industry makes to both the Victorian and Australian economies, it is evident that these numerous rectifications of construction defects will have an economic impact on both local and national economies with subsequent impact on construction productivity.

It is therefore evident that while defects may be associated with health and safety concerns of occupants, it also has significant economic ramifications. The cost of remedying defects could be costly with economic consequences to both the builder and owner which inversely affect productivity. The cost of undertaken reworking and replacing defective items could be an expensive process and influences the cost of insurance premiums which builders often filters down to homebuyers. Thus, curbing defects is not just beneficial to building efficient and more sustainable houses but will subsequently have invaluable economic benefits.

Review of construction defects

Defects in buildings can sometimes have a complicated interpretation. As defined by Georgiou et al. (1999) in their research, defect is defined as the shortcoming in the performance of a building element (Georgiou, Love & Smith 1999). Another research interchangeable used the terms error, fault, failure, defect, non-conformance, quality deviation, and failure of quality to describe the imperfections in buildings (Macarulla et al. 2012). Similar and synonymous terminologies have been used by other researchers to attribute defects in residential buildings (Assaf, Al-Hammad & Al-Shihah 1996; Atkinson 1999; Chew 2005; Mohd-Noor et al. 2016). Variances in adaptation of defects representation and interpretation in various studies could lead to inaccuracies in defects identification (Alencastro, Fuertes & de Wilde 2018).

In a research conducted about two decades ago, it was reported that human errors are the main sources of defects (Atkinson 1999). According to Olubodun and Mole (1999), the causative factor for defects could be categorised under design, construction, age, changing standards and vandalism(Olubodun & Mole 1999). Assaf et al. (1996) indicated that faulty design and construction are the two main causes of defects in buildings. Chew (2005) concluded that the sources of defects are related to deficiency in construction, design, material and maintenance practices. Mohd-Noor et al. (2016) found that usage factors such as impact damage or vandalism, change of use, and normal wear; environmental factors including artificial movement/vibration, natural movement/vibration and ageing, including construction factors which are related to material selection and workmanship were associated with some of the major causes of defects.

Georgiou et al. (1999) compared the defects in houses constructed by homeowners and registered builders and found no significant quality difference between the houses delivered by the two categories of builders. Georgiou (2010) further investigated building defects under two different Acts of the Parliament of Victoria, Australia and concluded that changes in legislation might not reduce the defects. Chong and Low (2005) studied the differences among the defects that occurred during construction and between two to six years after initial occupancy and found that the defects during both periods were very different (Chong & Low 2005). According to the research, some construction defects become latent defects, while some latent defects began to emerge. The study concluded that construction materials related defects could take time to develop and will usually appear during occupancy rather than during construction; similarly, any faults committed by the designers might not usually appear during the construction phase. Most construction defects are the result of poor workmanship and lack of protection, and as buildings aged, design, material, and maintenance defects became more apparent (Chong and Low 2005). Johnsson and Meiling (2009) compared the defects in industrialised housing and ordinary construction and found that industrialised buildings are better in terms of product quality (Johnsson & Meiling 2009).

Researchers estimated the cost of defects in construction using case studies of seven building projects (Josephson & Hammarlund 1999). Accordingly, the cost of defects was about 4.86% of production cost. Similar research on rectification cost established costs as 2–5% of contract value (Love & Li 2000; Mills et al. 2009)

Lo, Leung and Cui (2005) investigated defects in roof construction of medium-rise buildings in tropical climates and found that parapet wall failure led to tearing of waterproofing membrane. Forcada, Macarulla, Gangolells, et al. (2012) identified the post-handover defects in Spain, and the study revealed that the most common defects were derived from poor workmanship and were related to construction errors and omissions. The typical defects identified in the study were incorrect installation, appearance defects, and missing items or tasks mainly related to finishing. Similarly, Forcada, Macarulla and Love (2012) found that incomplete tile grouting and incorrect fixtures and fittings in toilets were the most frequent defects in residential buildings in Spain. Del Solar et al. (2015) studied defects in ceramic claddings and found that errors in piece layout, excessive visibility of joints, uneven surfacing and hollow zones were some of the major defects. According to Carretero-Ayuso, Moreno-Cansado and Cuerda-Correa (2015), fissures in walls and flooring, cracks in structural elements, and infiltration of humidity are some of the defects in residential buildings.

Research approach

In Victoria, a significant proportion of the building and construction disputes tendered to the Victorian Civil and Administrative Tribunal (VCAT) are mainly concerned with defects in buildings. In recent past, the enormous number of related construction defect cases received annually by VCAT was overwhelming and necessitate the establishment of the Domestic Building Dispute Resolution Victoria (DBDRV) in 2017, and was equipped with the authority to manage and resolve domestic building disputes. In order to investigate and establish the trends of the number of court cases related to defects in residential buildings, the Victorian Civil and Administrative Tribunal (VCAT) database was used as a data source. Where applicable, this was complement with additional data obtained from the appeals court database to supplemental review of cases considered in this research. The tribunal collects various evidence including independent expert witnesses and decides whether a particular complaint brought by the homeowner (the Plaintiff) is considered as a defect or not. If matters brought by homeowners goes in their favour, the builders (the defendant) would seek an appeal in the high courts which usually becomes a lengthy process. The tribunal cases from 2010 to 2017 were initially reviewed and analysed. The evaluation of cases was conducted with respect to the year of construction of the buildings, the suburbs in the Victorian state of Australia, and the year in which the case got a decision. To evaluate defects evolving to disputes, a case study approach was adopted. Four representative cases depicting very different characteristics were chosen from the VCAT database and the type of defects and decisions proffered by the tribunal qualitatively analysed.

Analyses of tribunal cases

For the timeframe of 2010 to 2017, a total of 662 cases were reviewed and analysed. Figure 1 below shows the distribution of disputes heard and decided by the Victorian Civil and Administrative Tribunal (VCAT) and directly related to defects occurrence in domestic residential buildings. The distribution of cases is represented as an index computed relative to 2010 taken as the base year. As depicted, the year 2017 has the highest index of 1.85 and the year 2011 has the lowest index value of 0.84.

Figure 1: Trajectory of defects' disputes in domestic buildings in Victoria (2010 – 2017)

The distribution shows an increasing trend of defects in domestic buildings over the period considered in this research. Fundamentally, it is evident that the significant population growth in Victoria that has necessitated increased demand for residential housing over the last decade have resulted in higher proportionate number of disputes. This has significantly impacted the image of building quality in the residential building sector and has affected consumer confidence. Previous study undertaken by the author (Paton-Cole, VP & Gurmu, A 2018) revealed that prior to 2010, there was significant spike in building defect complaints resulting from the collapse of the building insurance market. While this led to the birth of the Victoria Managed Insurance Authority (VMIA) instituted as the sole authority to regulate builders insurance for the construction of low-rise residential buildings, defect index in residential buildings have not been influenced during their existential period. This indicates that despite the government taking over of the insurance industry, the regulations governing construction of domestic housing are not adequate or not effectively implemented. Moreover, recent poor performance of multi-storey residential buildings around Australia most populated cities is indicative of the lack of a working regulatory process.

Review of case studies

Using the Victorian Civil and Administrative Tribunal (VCAT) database, four representative cases were selected and reviewed. Details of the cases reviewed are not mentioned herein due to compliance with research ethics. For simplicity, the cases are herein referred to as cases 1-4.

Case 1

This case involves the construction of a single storey brick veneer house in 2007 out in the Western suburbs for an agreed amount of about $225,000. The detached house was built on a waffle pod raft footings, expected to have being engineered in accordance with the applicable footing design standards. However, three months later, noticeable cracks appeared in various areas in the floor slab which the builder repaired. Following appearance of additional defects, the builder refused to undertake rectification works which led the owner to pursue the matter with VCAT. Summary of reported defects were as follows:

- Extensive cracks to floor slab in living room and master bedroom
- Subsequent cracks in floor area to en suite bathroom and kitchen
- Cracks on walls in family room
- Prominent noise in roof space during windy periods

VCAT review revealed significant amount or subsidence in the slab which then raised questions about the integrity of the geotechnical investigation. Assessment shows the soil class was correct classified. Photographic evidence documented by owner during construction proved sufficient to show that the builder did not include a spoon drain that was part of the footing design. This pictorial evidence was used to prove that the absence of an improper spoon drainage allowed water to pool next to the slab that initiated slab heaving. In addition, VCAT proceedings revealed that the builder failed to seal around the slab and thereby letting increased moisture content into the slab footprint. Considering expert and factual evidences, rectification costs ordered to be paid by the builder was over a quarter of the contract sum. Given the lengthy legal process, the builder's cost would have exceeded 50% of the contract value, which could have possibly been avoided had the builder complied with the approved drawings.

Case 2

This case involves the construction of two double storey townhouses in 2014 in the Eastern suburbs of Melbourne for a written contract of almost one million dollars that includes a liquidation clause of $500 per week. The builder was unable to complete the project on time with one townhouse completed about four months after practical completion. Prior to completion of the second townhouse, the owners asserted that the builder had repudiated the contract and thereby terminating the builders' contract. While it was reported that there were existing disputes between owners and builder, a legal proceeding was initiated by the builder at VCAT. Summary of the builders request included the following:

- Builder seeking relief on a "quantum meruit" basis or, in the alternative, sums allegedly due under the contract that included the amounts for variations made orally to the works

Upon review of the builder's application and based on expert evidence on the value of building works completed, VCAT determined and ordered the owners to pay the builder the "quantum meruit" of almost 68% the contract price, being value of work performed by the builder. As part of the decision, VCAT considered cost of rectification of defects to be incurred by the owners. Two years later after the practical completion date, the owners appealed to the Supreme Court on the basis that VCAT misunderstood the principles relating to valuation of work on a "quantum meruit" basis. However, by the end of the first quarter of 2018, the owner's appeal was dismissed. Considering the period before final settlement, a case of this nature would have been exhausting for both parties and otherwise very costly.

Case 3

The case presented here involves a dispute between four owners of various townhouses and the builder who constructed them. The four townhouses where completed by the builder in 2009 in the Northern suburbs of Melbourne and a number of defective works were found to be common to all the townhouses. The builder conceded responsibility for undertaking rectification works and entered a settlement agreement with the four owners with defective works to be completed within an agreed timeframe. However, over three years, the builder failed to undertake the rectification works. Summary of the most common defective works to be rectified included the following:

- Water leakage in balconies and exterior cladding had occurred in all four townhouses

Failure on the builder path left the owners with no option but to terminate the settlement agreement in 2012 and instead pursued proceedings with the VCAT. The builder argued that he's liable to fix defective works within a reasonable period and otherwise owes no obligation to owners. Upon examination of the evidences and expert witness testimonies by building consultants, it was conclude that the owners had given ample time to rectify the defects. In 2013, the tribunal assessed the owners' damages considering the costs incurred to engage an alternative builder to undertake the defective works with an average cost of about $30,000 awarded to each owner. Evidently, negligence of compliance during construction would have contributed to such defect manifesting itself typically across four different buildings. Dealing with the builder to rectify defective works over such a long period of time will no doubt be stressful for the owners that would have impacted the property value.

Case 4

Prior to the advent of private building surveyors, the relevant local councils were responsible for approving building plans and specification. This case depicts one a construction dispute during the aforementioned era. The owners and builder signed an agreement in 1987 to construct house up to "lock-up" stage. Six months later in 1988, both parties were in dispute about the quality workmanship. The Housing Industry Association (HIA) got involved and prepared a defect report following which an agreement between the owners and builder was agreed to undertake rectification works plus a deduction on the balance of the contract price owing to the builder by the owners. However, this did not solve the problem and while the local council issued the occupancy permit in 1988, the owners continually complained about the sub-standard completed work. Over a decade later, the owners submitted a number of claims to the Housing Guarantee Fund (which was the responsible insurance body at the time) but the claims were rejected. The complaints encompassed some major defects such as:

- Instability of the structure
- Water penetration damages with related claims to deficiency in both the sub- and super-structure

In rejecting the claims, the HGF asserted that the referred defect could not be the consequences of bad workmanship but rather a failure on the path of the owners to complete the building beyond the lock-up stage. Ultimately, the owners took the matter to court in 1993 claiming damages against the builder and the relevant local council. The owners alleged that the builder did not comply with the contractual plans and specs while the local council had been negligent in approving the plans and further giving approval of the foundations the council inspected in 1987. In consequence, in 1995, the owners were awarded costs plus interests against the builder for the following: defects rectification, general damages, inconvenience and distress and additionally costs against the relevant local council for rectification of footings. Evidence presented in this case reasonably depicts negligence and non-compliance with building regulation and code of practice. With the case dragged on for almost a decade, it would have costed a lot of money while mentally impacting all parties involved.

Conclusions

The research presented in this research has shown that there has been significant increase in the number of domestic building disputes arising from construction of low-rise residential buildings. With the substantial economic contribution of the residential building sector to the Victorian states' economy, it is evident that an underlying problem clouds current regulation and needs to be address. The cost of remedying defects does not only have serious economic consequences to all stakeholders but is also stressful, costly and time consuming when it evolves into construction disputes and thereby inflicting a negative effect on overall construction productivity. While absolutely eliminating defects occurrence in construction is practically not achievable due to the intricate process of construction itself, data examined in this research indicates the extent to which defects particularly in residential buildings has been reported in recent times is alarming. Review of selected typical cases of defects, builder's non-compliance contributes to construction and latent defects. This research concludes that current regulatory framework for quality management needs to be overhaul in order to enhance construction productivity and increase profitability. This is because defect cost arising from rectification work is normally an expense borne by the builder and cases of defects that escalates into construction dispute will wipe out profits resulting from exorbitant legal fees over a length period.

References

ABCB 2010, *National Construction Code Series 2019*, Australian Building Codes Board, Canberra , Australia.

ABS 2016, *Building Approvals Australia - 8731.0* Australian Bureau of Statistics, Canberra, Australia.

Alencastro, J, Fuertes, A & de Wilde, P 2018, 'The relationship between quality defects and the thermal performance of buildings', *Renewable and Sustainable Energy Reviews*, vol. 81, pp. 883-94.

Alinaitwe, HM, Rodrigues, MJ, Kakitahi, JM & Landin, A 2014, 'A comparison of construction related rework in Uganda and Mozambique', *Journal of Construction Project Management and Innovation*, vol. 4, no. 1, pp. 770-81.

Assaf, S, Al-Hammad, A-M & Al-Shihah, M 1996, 'Effects of faulty design and construction on building maintenance', *Journal of Performance of Constructed Facilities*, vol. 10, no. 4, pp. 171-4.

Atkinson, AR 1999, 'The role of human error in construction defects', *Structural Survey*, vol. 17, no. 4, pp. 231-6.

Carretero-Ayuso, MJ, Moreno-Cansado, A & Cuerda-Correa, EM 2015, 'Research and analysis on recurring anomalies in foundations and structures', *Journal of Performance of Constructed Facilities*, vol. 30, no. 3, p. 04015037.

Chew, M 2005, 'Defect analysis in wet areas of buildings', *Construction and Building Materials*, vol. 19, no. 3, pp. 165-73.

Chong, W-K & Low, S-P 2005, 'Assessment of defects at construction and occupancy stages', *Journal of Performance of Constructed Facilities*, vol. 19, no. 4, pp. 283-9.

Del Solar, P, Del Río, M, Villoria, P & Nadal, A 2015, 'Analysis of Recurrent Defects in the Execution of Ceramic-Coatings Cladding in Building Construction', *Journal of Construction Engineering and Management*, vol. 142, no. 4, p. 04015093.

Economist, OotC 2016, *Australian Industry Report*, Australian Government, Department of Industry, Innovation and Science, Canberra, ACT.

Forcada, N, Macarulla, M, Gangolells, M, Casals, M, Fuertes, A & Roca, X 2012, 'Posthandover housing defects: sources and origins', *Journal of Performance of Constructed Facilities*, vol. 27, no. 6, pp. 756-62.

Forcada, N, Macarulla, M & Love, PE 2012, 'Assessment of residential defects at post-handover', *Journal of Construction Engineering and Management*, vol. 139, no. 4, pp. 372-8.

Georgiou, J 2010, 'Verification of a building defect classification system for housing', *Structural Survey*, vol. 28, no. 5, pp. 370-83.

Georgiou, J 2016, 'Legislative control and the quality of housing in Victoria', PhD thesis, University of Melbourne.

Georgiou, J, Love, P & Smith, J 1999, ‘A comparison of defects in houses constructed by owners and registered builders in the Australian State of Victoria’, *Structural Survey*, vol. 17, no. 3, pp. 160-9.
HIA 2017, *Building Approvals: The Profile for Residential Building Approvals by Type and Geography*, Housing Industry Association, Australia.
HIA 2019, *Window into Housing 2019*, Housing Industry Association, Australia.
Johnsson, H & Meiling, JH 2009, ‘Defects in offsite construction: timber module prefabrication’, *Construction Management and Economics*, vol. 27, no. 7, pp. 667-81.
Johnston, N & Reid, S 2019, *An examination of building defects in multi-owned properties*, Deakin and Griffith Universities, Vic, Australia.
Josephson, P-E & Hammarlund, Y 1999, ‘The causes and costs of defects in construction: A study of seven building projects’, *Automation in Construction*, vol. 8, no. 6, pp. 681-7.
Kelly, J-F & Donegan, P 2015, *City Limits: Why Australia's cities are broken and how we can fix them*, Melbourne Univ. Publishing.
Lo, Y, Leung, W & Cui, H 2005, ‘Roof construction defects of medium-rise buildings in sub-tropical climates’, *Structural Survey*, vol. 23, no. 3, pp. 203-9.
Love, PE 2002, ‘Auditing the indirect consequences of rework in construction: a case based approach’, *Managerial auditing journal*, vol. 17, no. 3, pp. 138-46.
Love, PE & Li, H 2000, ‘Quantifying the causes and costs of rework in construction’, *Construction Management & Economics*, vol. 18, no. 4, pp. 479-90.
Macarulla, M, Forcada, N, Casals, M, Gangolells, M, Fuertes, A & Roca, X 2012, ‘Standardizing housing defects: classification, validation, and benefits’, *Journal of Construction Engineering and Management*, vol. 139, no. 8, pp. 968-76.
Mills, A, Love, PE & Williams, P 2009, ‘Defect costs in residential construction’, *Journal of Construction Engineering and Management*, vol. 135, no. 1, pp. 12-6.
Mohd-Noor, Z, Che-Ani, AI, Sulaiman, Z, Abd-Razak, MZ & Tawil, NM 2016, ‘Condition Monitoring Framework Based on the Cause of Mosque Physical Defects in Kuala Lumpur and Putrajaya’, *Journal of Performance of Constructed Facilities*, vol. 30, no. 5, p. 04016031.
Olubodun, F & Mole, T 1999, ‘Evaluation of defect influencing factors in public housing in the UK’, *Structural Survey*, vol. 17, no. 3, pp. 170-8.
Paton-Cole, VP & Gurmu, A 2018, ‘A review of defects in low-rise residential buildings in the Australian State of Victoria’, in *ICEC-PAQS 2018: Grassroots to Concrete Jungle: Dynamics in Built Environment*, pp. 1-9.
Paton-Cole, VP & Gurmu, AT 2018, ‘Review of domestic building acts for construction of low-rise residential buildings’, in *APNHR 2018: Smart and Sustainable Housing Futures: Proceedings of the Joint Conference of the Asia-Pacific Network for Housing Research and Australasian Housing Researchers*, pp. 160-9.
Rosewall, T & Shoory, M 2017, ‘Houses and apartments in Australia’, *RBA Bulletin, June*, pp. 1-11.
Taggart, M, Koskela, L & Rooke, J 2014, ‘The role of the supply chain in the elimination and reduction of construction rework and defects: an action research approach’, *Construction Management and Economics*, vol. 32, no. 7-8, pp. 829-42.
Tan, SL 2019, ‘Mascot Towers plagued with defects since
2011’, *The Australian Financial Review*.
VAGO 2015, *Victoria’s Consumer Protection Framework for Building Construction*, Victorian Auditor-General's Office, Melbourne, Victoria.
VCAT 2016, *VCAT 2015–16 Annual Report*, Melbourne: Victorian Civil and Administrative Tribunal.
VMIA 2017, *Annual report 2016–2017*, Victorian Managed Insurance Authority, Melbourne, VIC.
Wanberg, J, Harper, C, Hallowell, MR & Rajendran, S 2013, ‘Relationship between construction safety and quality performance’, *Journal of Construction Engineering and Management*, vol. 139, no. 10, p. 04013003.

VFM ASSESSMENT OF TRANSPORT PPPS: IMPLICATIONS FOR FUTURE IMPROVEMENT

Jianfeng Zhao[1], Henry J. Liu[1], Michael C.P. Sing[2], Xiaohua Jin[3], Richard Humphrey[1]

[1]Department of Architecture and Built Environment, Northumbria University, Newcastle upon Tyne, United Kingdom

[2]School of Architecture and Built Environment, The University of Newcastle, Callaghan, Australia

[3]School of Computing, Engineering and Mathematics, Western Sydney University, Kingswood, Australia

Abstract

Public-Private Partnerships (PPPs) have been adopted to deliver transport infrastructure assets worldwide, attributing to governments' increasingly limited fiscal budget. However, the key issue about whether PPPs can provide taxpayers with better value for money (V*f*M) is still under controversy. As an integral component of infrastructure procurement process, V*f*M assessment acts as an essential stage of governments' ex-ante evaluation for the use of PPPs. Despite this, relevant empirical research, especially within the context of transport infrastructure, has received limited attention. Against this backdrop, a total of 3 case studies of the Australian transport PPP projects has been undertaken and the SWOT analysis was conducted to examine the current practice in V*f*M assessment. The empirical evidence indicates that the approach being used by the Australian state governments for assessing V*f*M fails in addressing a critical perspective in terms of the improved service quality to be generated by private-sector entities. Based on this finding, a novel V*f*M-oriented decision-making model that is underpinned by the Dynamic Discrete Choice Model (DDCM) has been proposed. This paper contributes to the body of knowledge of PPPs V*f*M assessment and is significant for improving industry practice in decision making of procurement selection for transport assets.

Keywords

PPPs, Transport PPPs, V*f*M assessment, decision making, SWOT analysis, case study

Introduction

PPPs have been widely used to procure transport infrastructure due to the governments' limited budget (Reeves 2015; Penyalver, Turro & Williamson 2019). For example, $20 billion has been invested into PPPs since 2014 in New South Wales (NSW), Australia and more than 100 transport projects have been procured through the use of PPPs from 1980 to 2017 in Australia (NSW Treasury 2017; Department of Infrastructure and Regional Development 2017). Fundamentally, PPPs are considered as being a procurement method that can potentially generate such benefits as increased efficiency, competitive public services and risk sharing (McQuaid & Scherrer 2010; Appuhami, Perera & Perera 2011). However, they have been subjected to controversy, owing to a number of issues such as cost overruns, lengthy tendering and negotiation, inappropriate risk transfer and conflicting interests among stakeholders (Song et al. 2019). Therefore, V*f*M has been a critical criterion for governments to make a decision about whether or not PPPs can be adopted.

In this regard, the national guidelines of V*f*M assessment used for justifying the use of PPPs have been published in many developed countries such as Australia and the United Kingdom (UK) (HM Treasury 2006; Department of Infrastructure and Regional Development 2008). V*f*M in these documents is defined as "the optimum combination of whole-of-life costs and quality (fit for purpose) of the good or service to meet users' requirement". It is required that the Net Present Value (NPV) of a Public Sector Comparator (PSC) and that of a PPP option should be compared and whichever is lower is deemed favourable (Henjewele, Sun & Fewings 2012). Nonetheless, this approach is criticised as being vulnerable to manipulation, asymmetric comparison and incomplete evaluation (Murphy 2008; DeCorla-Souza & Farajian 2017; Opara 2018). Several studies have been conducted to identify the disadvantages of the PSC (Ng, Wong & Wong 2012; Decorla-Souza et al. 2017; Penyalver et al. 2019). But extant literature lacks empirical research to investigate how to improve current practice in V*f*M assessment of PPPs. Against this backdrop, this study aims to propose a novel V*f*M-oriented decision-making model by undertaking a case study of three Australian transport PPP projects and then a SWOT analysis for their V*f*M assessments.

Research on V*f*M assessment

V*f*M is a critical concept in the literature of infrastructure procurement. Yuan et al. (2009) identified a total of 15 process factors useful for measuring if PPPs are value for money. Moreover, Robinson and Scott (2009) contended that V*f*M is largely determined by the effectiveness of the asset's operational performance monitoring system. In addressing this, Liu et al. (2018) proposed a life-cycle performance prism to evaluate PPPs with the aim of ensuring value for money.

Essentially, V*f*M has been viewed as a terminology concerning life-cycle cost savings within the context of PPPs (e.g. Grimsey & Lewis 2005; Shaoul 2005; Morallos & Amekudzi 2008; Siemiatycki & Farooqi 2012 and Opara 2018). Consequently, V*f*M assessment is essential for the decision making of infrastructure projects to identify an appropriate procurement method.

Case study: Current practice in V*f*M assessment in Australia

Case study has been applied in this paper as it is acknowledged as being an approach suitable for all stages of a research program, such as the generation of new knowledge (Flyvbjerg 2006). In order to propose a new model, a total of 3 transport projects based in NSW have been selected to conduct the case study, including the Cross City Tunnel (CCT), Lane Cove Tunnel (LCT) and North West Rail Link (NWRL).

Case background

The Cross City Tunnel (CCT) project incorporates a 2.1km twin-tunnel toll road, which links Darling Harbour of Sydney CBD to Rushcutters Bay, NSW. It is under a 33-year DBFOM (design-build-finance-operate-maintain) contract that is up to a value of AU$680 million, running from December 2002 to December 2035. The CCT project is being operated by a private entity (Transurban) and engaged with a series of public-sector parties such as Minister for Roads, Treasury and NSW Roads and Marine Services (RMS) (project client). Similarly, the Lane Cove Tunnel (LCT) is a project based in NSW and is under the DBFOM contract (i.e. contract value AU$1.1 billion) valid from December 2003 to January 2037. The LCT is a 3.6km-long motorway in twin tunnels connecting Epping Road Bridge crossing to Gore Hill Freeway, Artarmon. This project is also being operated by Transurban with a partnership of such public-sector organisations as NSW Minister for Roads, Rail Corporation and RMS (project client). In addition to CCT and LCT, another NSW-based project being studied in this paper is the Sydney North West Rail Link (NWRL), where the relevant contract is associated with a total value of AU$3.7 billion and a term from September 2014 and April 2034. The NWRL is approximately 15.5 kilometres, which connects Cudgegong Road, Rouse Hill and Chatswood, and it incorporates a total of eight new stations. This project encompasses three major contracts, including a: (1) D&C (design and construct) contract of the tunnel and station civil works package that has been awarded to the Thiess, John Holland and Dragados Joint Venture; (2) D&C contract of the surface and viaduct civil works package to be delivered by Impregilo Salini Joint Venture; and (3) PPP contract between the Transport for NSW (public authority) and NRT Pty Ltd for the operations, trains and systems package.

Current V*f*M assessment practice

During the decision-making stage of procurement selection, the three PPP projects introduced above had undergone a V*f*M assessment that was performed by the NSW state government. As stated in the 'Summaries of Contract Change' of the CCT projects, the NSW RMS's V*f*M assessment was primarily relying on (NSW Government, 2008, p.4):

> … a 'comparative value' assessment against a PSC – a hypothetical, risk-adjusted estimate of the net present cost of delivering the project, to the same level and standard of service, using the most efficient likely form of delivery able to be financed by the public sector …

Essentially, the 'Updated Summary of Contracts' of the LCT has a statement that is same as above, indicating that the project's V*f*M assessment in terms of the decision making of selection of procurement method relating to PPPs is a cost-focused comparison depending on the PSC. A detailed statement (shown as below) about the V*f*M assessment can be identified in the footnote of the LCT contract summary (NSW Government, 2010, p.8).

> .. For a 'public sector comparator' based on the most efficient likely form of delivery of the Lane Cove Tunnel project able to be financed by the public sector, the estimated net present value of the normalised risk-adjusted financial cost of the project to the RMS, using 10 September 2003 interest rates, was $193.2 million. In contrast, the delivery of the project by the private sector, in accordance with the rights, obligations and risk allocations described in this report, was expected to result in a significant net financial benefit to the RMS, with the financial costs of the project to the RMS being outweighed by a substantive transfer of risks to the private sector.

In the NWRL project, which is a more recent project passing the financial close in September 2014, the relevant V*f*M assessment also relied on the PSC. The official 'Contract Summary' of the NWRL has statements presented as follows (Transport NSW, 2014, pp.12-13).

> … the 'Public Sector Comparator' (PSC) provides a hypothetical estimate of the risk adjusted cost of the project if it (i.e. NWRL) were to be designed, built and operated by the State. To develop the estimate, the PSC was based on a reference project developed by the State, consistent with the Specified Performance Requirements …

> … the present value of the OTS PPP was evaluated using a discount rate that included a systematic risk premium of 1.40%, in accordance with NSW Treasury policies on the assessment of complying proposals …

To provide more detailed information, Table 2 summarises the PSC-based V*f*M assessment of the NWRL project. It can be noted that the NSW state government's decision making for applying PPPs to the NWRL project was based on 'financial benefit'.

Table 1: PSC-based VfM Assessment of the NWRL project

Cost Category	*PSC (NPC $m)*	*PPP (NPC $m)*	*Cost Savings (NPC $m)*	*Cost Savings (%)*
D&C cost	*2,911.9*	*2,893.7*	*(-18.2)*	*(0.5%)*
O&M cost	*1,178.1*	*872.7*	*(-305.4)*	*(8.1%)*
Total costs	*4090.0*	*3,766.4*	*(-323.6)*	*(8.6%)*
Transferred risk	*488.8*	*Include above*	-	-
Total NPC	*4,578.8*	*3,766.4*	*(-812.4)*	*(21.6%)*

(Source: Transport for NSW, 2014)

SWOT analysis

It can be identified from the case study above that the method being applied for V*f*M assessment of the three NSW-based transport PPP projects were primarily focused on cost savings to be yielded from an involvement of private-sector entities. Essentially, this kind of assessment is dominating in 17 out of 22 countries according to a survey that was conducted by Leigland (2018). To further interpret current V*f*M assessment practice, the SWOT analysis for the PSC is conducted for the purpose of identifying implications for future improvements.

Strengths

S_1 – Benefits measuring: Governments embarking on PPPs need to demonstrate their potential benefits as they represent the interest of the public (Broadbent & Laughlin 2004). The qualitative aspect of the PSC has addressed service quality, regional development, time saving and environmental and intergenerational impacts, and taken into account tariff level, cost effectiveness, financial attractiveness, public support and transparent procurement process (Ng et al. 2012; Almarri & Boussabaine 2017; Penyalver et al. 2019). By contrast, the quantitative side of the PSC has alleviated the tight wallet of public sectors (Cheung, Chan & Kajewski 2009). For example, an average saving of 15% for roads and 2-4% for schools and hospitals respectively has been revealed (Opara 2018).

S_2 – Choices making: The primary objective of the PSC is to facilitate the decision making of governments in terms of what is an appropriate procurement method (Gopalkrishna & Karnam 2015). In this regard, it draws a comparison between the NPV of PPP life-cycle cost or shadow bidding price (SBP) and that of a PSC, and whichever is lower is postulated to be the 'winner' (Zwalf, Hodge & Alam 2017; Kweun, Wheeler & Gifford 2018). Therefore, the PSC has been widely adopted worldwide.

S_3 – Less complex and more specialised: Compared with massive information and hypotheses required in cost-benefit analysis, a simple spreadsheet is sufficient to instigate explicit result of PSC (OECD 2008). Furthermore, the PSC is a binomial targeting at the selection between PPPs and conventional public sector procurement (PSP), making it more specialized and pinpoint (Dewulf, Blanken & Bult-Spiering 2012; Leigland 2018). Occasionally, in a procurement market where competition is weak and/or dynamic assessment is needed (SBP and actual bidding price) (Mols 2010), the PSC can still function well and the statistics used for indicating whether the proposed projects are V*f*M are easy to compile and to be understood by key stakeholders (OECD 2008; Ren et al. 2019).

Weaknesses

W_1 – Asymmetric comparison: First, the PSC is a hypothetical scenario where governments are in charge of financing, building and asset operations (Connolly, Martin & Wall 2008). It is thus meaningless in comparing the hypothetical with an actual bidding of PPP (Gopalkrishna & Karnam 2015). Second, although it's a comparison between the PSC and SBP where pricing is an estimate value before actual bidding, there is disparity in the use of different discount rate (Zwalf et al. 2017). For example, governments may prefer a social discount rate in the PSC, while private-sector consortia request the weighted average cost of capital (Decorla-Souza et al. 2016; Zwalf et al. 2017). Third, project is assumed to be risk-free in conventional PSP while risks can be transferred to private sectors in PPPs. In fact, the risks and corresponding costs in conventional PSP are underwritten by taxpayers and those in PPPs are offset through private sector's reasonable profit or governments' compensation over time (Murphy 2008). Put it simply, it is unclear who pays the cost. Therefore, Murphy (2008) concluded that comparison benchmark is false and should be substituted by the net benefit rather than cost.

W_2 – Contentious discount rate: Central to the calculation of the PSC is the selection of a reasonable discount rate (Zwalf et al. 2017), which is however criticised as being 'contentious' (Quiggin 2004; Peng et al 2014). For instance, in the UK, the discount rate of the PSC was initially assigned to 7% and then was decreased to 6% and 3.5% eventually (Hodgson & Corrigan, 2005). This change incurs the underestimate of PPPs and overstate of the PSC, which are beneficial to private sector but generate risk to government (Opara et al. 2017).

W_3 – Subjective assumptions and inaccurate estimate: An assumption in the PSC is that PPPs can provide better services than the PSP, utilising same or less resources (cost and time). However, many PPPs have experienced time and budget overruns, poor performance and even contract termination (Vining & Boardman 2014). For example, Blanc-Brude, Goldsmith and Välilä (2009) proved that PPPs are more expensive than conventional PSP by 24% in European road projects. Moreover, another core aspect in the PSC is risk transfer (Ball & King 2006). But, risk transfer can be unsuccessful, as relevant risk quantification and analysis are inaccurate (Aldrete, Bujanda & Valdez 2012). Cases have been reported that disproportioned risk transferred to private sector has led to the decrease of ridership and poor service quality in transport projects (Siemiatycki and Friedman, 2012; Mouraviev and Kakabadse, 2014). Moreover, a series of other issues have be identified, including the lack of (1) sustainability; (2) social benefits; and (3) transaction costs (Patil & Laishram 2016; DeCorla-Souza & Farajian 2017; Opara & Rouse 2019), causing the invalidity of the PSC.

Opportunities

O_1 – Prosperous market: The demand for building new infrastructure and rehabilitating aging assets is increasing (Sing, Love & Liu 2019). More than £600 billion has been spent to different infrastructure sectors in the UK since 2018, involving transport, hospitals and schools (HM Treasury 2018). In the era of new public management, expectations from the public are relating to high-quality services, improved government accountability and performance (Opara & Rouse 2019). With this, government's concern has been changed to seeking an economic, effective and efficient procurement approach (McKevitt & Davis 2016). Thus, it is anticipated that the PSC will be ameliorated and harnessed for decision making.

O_2 – Scientific and technique stimulus: Due to the irreplaceable position, significant efforts have been made to improve V*f*M assessment in infrastructure procurement (Tsamboulas, Verma & Moraiti 2013; Jasiukevicius & Vasiliauskaite 2018). These cover the establishment of a qualitative assessment framework, discount rate selection, data exchange and risk pricing (Ng et al. 2012; Zwalf et al. 2017; Makovšek & Moszoro 2018; Ren et al. 2019). Although debate about V*f*M assessment has not been diminished, such aforementioned actions will further stimulate the development of other techniques, such as the simulation of all benefits of transport projects, to supplement the PSC.

Threats

T_1 – Ideological bias and manipulation: An critical principle of choosing an appropriate procurement method is that no predetermined preference should exist (Eadie, Millar & Toner 2013). Essentially, PPPs are more preferred than conventional PSP under certain ideological bias (Loxley 2012). For example, guarantees and subsidies are promised to attract private sectors in order to enable PPPs to be the 'only game in town' (Reeves 2011; Bayliss & Van Waeyenberge 2018). The PSC under this situation is forced to be more expensive than PPPs, and this can easily be realised by manipulating calculation in the spreadsheet (Hodgson & Corrigan 2005; Wall & Connolly 2009; Whiteside 2019). The bias and manipulation may be the corollary of the constrained budget and desire to keep investment off balance sheet, and they tarnish V*f*M assessment and result in the sacrifice of social welfare(Vining & Boardman 2014; Opara et al. 2017).

T_2 – Opaque information: There is a concern that information about how V*f*M is assessed by the governments is unavailable to the public in some regions/countries, e.g., Alberta, Canada, Ireland and Belgium (Reeves 2015; Opara *et al.* 2017; Willems *et al* 2017). The aftermath of opaque information is binary. First, infrastructure investment will fall short of scrutiny and the above discussed manipulation will become a 'new normal' (Reeves 2015). Second, there is a risk that project or corporate bankruptcy and chaos may happen (Whiteside 2019). A solution proffered by Opara (2018) is disclosing the components of the PSC before the contract is signed.

A novel V*f*M-oriented decision-making model

According to the analysis results, it is obvious that the current V*f*M assessment within the context of transport infrastructure procurement focuses primarily on cost comparison and does not address the relationship between two critical aspects that are related to key stakeholders' expectations (e.g. client and asset end-users), i.e., improved service quality and enhanced asset usage (after introducing private sector into the asset procurement), which have been identified as critical in transport (Department for Transport, 2017; Liu *et al.*, 2018). As a result, there is a need for developing a new method to supplement extant V*f*M assessment for the decision making of PPP option.

V*f*M in terms of government's selection for an appropriate procurement method for transport infrastructure is referred to as a concept with regard to maximizing values to taxpayers by: (1) saving costs from public money and/or (2) enhancing asset service to better satisfy the public's transport demand (i.e. an improved functionality) throughout the project's dynamic life-cycle (Macário, Ribeiro & Costa 2015). This definition enables an ideal environment to apply the Dynamic Discrete Choice Model (DDCM), which is developed from the Random Utility Maximization (RUM) theory and is helpful for an 'economic agent' to efficiently make a proper choice that is capable of maximizing the value to satisfy relevant key stakeholders over change of time (McFadden 1977).

Mathematically, DDCM can be represented as Equation (1) below:

$$V\left(x_{n0}\right)=\max_{\{d_{nt}\}_{t=1}^{T}} E\left(\sum_{t'=t}^{T}\sum_{i=1}^{J}\beta^{t'-t}\left(d_{nt}=i\right)U_{nit}\left(x_{nt},\varepsilon_{nit}\right)\right) \quad \textit{Equation 1}$$

where x_{nt} represents state variables, x_{n0} is the agent's initial condition; d_{nt} is n' decision from among *J* discrete alternatives; U_{nit} stands for the flow utility; and *T* denotes the time horizon. As this is a choice between PPPs and conventional PSP, a binomial logit decision-making model derived from Equation (1) can be developed to modelling the choice of the use of PPPs in terms of the private sector's contribution to asset usage through an improved service quality.

$$u_{ijt}=\mathrm{Logit}(\frac{\mathrm{P}_{ijt}}{1-\mathrm{P}_{ijt}})=\alpha+\alpha_1^{x_{ijt}^o}x_{ijt}^o+\zeta_{ijt} \quad \textit{Equation 2}$$

where u_{ijt} denotes the utility government i can gain from the decision j (j=1, PPPs are favoured; j=0, traditional procurement method may be better) at time t; P stands for probability; α is a constant; $\alpha_1^{x_{ijt}^o}$ is the coefficient that indicates functionality x_{ijt}^o's impact on u_{ijt}; and ζ_{ijt} is a random vector depending on i, j, t, indicating the impacts of unobservable dynamic issues on the economic agent's decision making.

To further develop Equation (2), x_{jt}^o can be expanded by introducing an 'impact factor' (x_o) and an initial traffic volume (VOL_{kqm}) (i.e. Traffic volume has been widely used in practice as a proximity variable to forecast asset usage (i.e. transport demand) (Department for Transport, 2017) to estimate the relationship between private-sector-provided service and asset usage (traffic volume). x_o is simulated through a process of adapting the Bayesian Networks (BN) (which is demonstrated below) with an input variable of service quality (x_s). In other words, x_{ijt}^o in Equation (2) is a variable comprising: (1) service quality (x_s); (2) transport demand represented by traffic volume (VOL_{kqm}); and (3) an impact factor (x_o) mathematically representing the causal relationship between x_s and VOL_{kqm}. The service quality (x_s) can be viewed as end-user satisfaction, which has been acknowledged as being an important key performance indicator of the service provided by transport systems (Mouwen 2015; Yuan, Ji, Guo & Skibniewski 2018).

The BN-based modelling in this study is developed with an assumption proposed by (Sun, Zhang & Yu 2006), who assumed that factors determining the observed volume are independent of each other. Therefore, let (s, o) be a partition of the node indices of the BN, so that it converts to disjointed subsets, and then let (x_s, x_o) be a partition of the corresponding variables. Accordingly, the marginal probability of x_s can be written as:

$$p(x_s) = \sum_{x_o} p(x_s, x_o) \qquad \textit{Equation 3}$$

Consequently, the conditional probability $p(x_o|x_s)$ derived from BN can be reformulated as:

$$p(x_o \mid x_s) = \frac{p(x_o, x_s)}{p(x_s)} = \frac{p(x_o, x_s)}{\sum_{x_o} p(x_s, x_o)} \qquad \textit{Equation 4}$$

With a reference to the Gaussian mixture model (Sun et al. 2006) and a lemma proved in Rao (1973), Equation (4) can be further represented as below.

$$p(x_o \mid x_s) = \sum_{l=1}^{M} \beta_l G(x_o; \mu_{lo|s}, \textstyle\sum_{lo|s}) \qquad \textit{Equation 5}$$

where $G(x_o; \mu_{lo|s}, \sum_{lo|s})$ is a multidimensional normal density function with mean $\mu_{lo|s}$ and covariance matrix $\sum_{lo|s}$;

$$\beta_l = \frac{\alpha_l G(x_s; \mu_{ls}, \sum_{lss})}{\sum_{j=1}^{M} \alpha_j G(x_s; \mu_{js}, \sum_{jss})}$$

$$\mu_{lo|s} = \mu_{lo} - \textstyle\sum_{los} \sum_{lss}^{-1} (\mu_{ls} - x_s)$$

$$\textstyle\sum_{lo|s} = \sum_{loo} - \sum_{los} \sum_{lss}^{-1} \sum_{lso} \qquad \textit{Equation 6}$$

And, an optimal forecasting of x_o after the calculation of minimum mean square error equals to:

$$x_o = E(x_o \mid x_s) = \int x_o p(x_o \mid x_s) dx_o$$

$$= \sum_{l=1}^{M} \beta_l \int x_o G(x_o; \mu_{lo|s}, \textstyle\sum_{lo|s}) dx_o = \sum_{l=1}^{M} \beta_l \mu_{lo|s} \qquad \textit{Equation 7}$$

Finally, x_o is integrated into the annual average daily traffic AADT forecasting method (US Department of Transportation, 2018) to forecast x_{ijt}^{o}, being represented as:

$$x_{jt2}^{o} = \frac{1}{12} \sum_{m=1}^{12} \left[\frac{1}{7} \sum_{q=1}^{7} \left(\frac{1}{n_{qm}} \sum_{k=1}^{n_{qm}} VOL_{kqm} \right) \right] \left(1 \pm \sum_{l=1}^{M} \beta_l \mu_{lo|s}\right) \qquad \textit{Equation 8}$$

where VOL_{kqm} is the daily volume for k^{th} occurrence of the q^{th} day (1 to 7) of week within the m^{th} month (1 to 12); k is occurrences of day q in month m for which traffic data are available; and n_{qm} is number of occurrences of day q in month m for which traffic data is available.

To integrate the elements presented from Equations (3) to (8) into Equation (2), a decision-making model therefore can be finalized as Equation (9) below:

$$u_{ijt} = \mathrm{Logit}\left(\frac{\mathrm{P}_{ijt}}{1-\mathrm{P}_{ijt}}\right) = \alpha + \alpha_1^{x_{ijt}^{o}} \frac{1}{12} \sum_{m=1}^{12} \left[\frac{1}{7} \sum_{q=1}^{7} \left(\frac{1}{n_{qm}} \sum_{k=1}^{n_{qm}} VOL_{kqm} \right) \right] \left(1 \pm \sum_{l=1}^{M} \beta_l \mu_{lo|s}\right) + \zeta_{ijt} \qquad \textit{Equation 9}$$

The final decision of an ‘economic agent’ (i.e., a public authority embarking on PPPs) is based on the result to be generated from Equation (9). In alignment with the RUM theory, if there exit l and m (l and $m \in j$), the phenomenon represented as Equation (10) will be enabled and then an alternative procurement method l is estimated to be more effective than the other option.

$$\mathrm{D}_{ijt} = \mathrm{P}(u_{ilt} > u_{imt}, \forall l \neq m) \qquad \textit{Equation 10}$$

Conclusion

PPPs have been an integral strategy of governments’ procurement of transport infrastructure worldwide. V*f*M assessment, as a critical stage of the development process of PPPs, plays a decisive role in ensuring future success of the projects. However, relevant empirical research into this field is limited, particularly within the context of transport infrastructure. Thus, this paper has undertaken a total of three case studies of the Australian transport PPPs followed by a SWOT analysis for current practice in V*f*M assessment.

Empirical evidence has demonstrated that existing V*f*M assessment concentrates only on the comparison between the NPV of PSC and that of PPPs. The salient features of transportation, such as service quality and traffic volume, are neglected. The results of the SWOT analysis further indicate that the PSC is unable to provide a comprehensive evaluation (W_3) and is subjected to asymmetric comparison (W_1) and inaccurate discount rate (W_2). In addition, the PSC can easily be manipulated to be preference of PPPs (T_1) and the information about how V*f*M assessment is undertaken is not transparent to the public (T_2). Therefore, it is imperative that new models should be developed to address them and to supplement the use of the PSC.

Based on the case study and SWOT, a new V*f*M-oriented decision-making model is proposed, encompassing the components of service quality, traffic demand and an impact factor that represents their causal relationship (O_2). This model can be used to supplement current V*f*M assessment (S_1-S_3) and shed light on improvement of future practice in PPPs. Future research will be focused on testing the feasibility of the developed model.

References

Aldrete, R, Bujanda, A & Valdez, GA. 2012, *Valuing public-sector revenue risk exposure in transportation public–private partnerships*, Article, https://www.scopus.com/inward/record.uri?eid=2-s2.0-84988515235&doi=10.3141%2f2297-11&partnerID=40&md5=afa3b3033905adb91b14cdee4184432c.

Almarri, K & Boussabaine, H. 2017, 'The Influence of Critical Success Factors on Value for Money Viability Analysis in Public–Private Partnership Projects', *Project Management Journal*, vol. 48, pp. 93-106.

Appuhami, R, Perera, S & Perera, H. 2011, 'Coercive policy diffusion in a developing country: The case of public-private partnerships in Sri Lanka', *Journal of Contemporary Asia*, vol. 41, no. 3, pp. 431-51.

Ball, R & King, D. 2006, 'The private finance initiative in local government', *Economic Affairs*, vol. 26, no. 1, pp. 36-40.

Bayliss, K & Van Waeyenberge, E. 2018, 'Unpacking the Public Private Partnership Revival', *Journal of Development Studies*, vol. 54, no. 4, pp. 577-93.

Blanc-Brude, F, Goldsmith, H & Välilä, T. 2009, 'A comparison of construction contract prices for traditionally procured roads and public-private partnerships', *Review of Industrial Organization*, vol. 35, no. 1-2, pp. 19-40.

Broadbent, J & Laughlin, R. 2004, 'Striving for Excellence in Public Service Delivery: Experiences from an Analysis of the Private Finance Initiative', *Public Policy and Administration*, vol. 19, no. 4, pp. 82-99.

Cheung, E, Chan, APC & Kajewski, S. 2009, 'Enhancing value for money in public private partnership projects: Findings from a survey conducted in Hong Kong and Australia compared to findings from previous research in the UK', *Journal of Financial Management of Property and Construction*, vol. 14, no. 1, pp. 7-20.

Connolly, C, Martin, G & Wall, A. 2008, 'Education,education, education: The third way and PFI', *Public Administration*, vol. 86, no. 4, pp. 951-68.

DeCorla-Souza, P & Farajian, M. 2017, *Evaluation of a nontraditional approach to fund, finance, and manage metropolitan freeways*, Article, https://www.scopus.com/inward/record.uri?eid=2-s2.0-85033782866&doi=10.3141%2f2670-05&partnerID=40&md5=8aa955344f08867f86c1f9b3cab3062d.

Decorla-Souza, P, Lee, DB, Sullivan, M & Timothy, D. 2017, 'A Benefit-Cost Analysis Framework for Evaluation of Highway Public-Private Partnership Projects', in *Advances in Public-Private Partnerships - Proceedings of the 2nd International Conference on Public-Private Partnerships*, pp. 257-74.

Decorla-Souza, P., Ham, M. & Timothy, D. 2016, Illustration of a framework for benefit-cost evaluation of highway concession proposals. *Transportation Research Record*, 2597, pp. 52-59.

Department for Transport. 2017, '*Value for money framework*', available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/630704/value-for-money-framework.pdf (29 May 2019).

Department of Infrastructure and Regional Development. 2008, '*National Public Private Partnership Guidelines-Volume 4: Public Sector Comparator Guidance*', Available at: https://www.infrastructure.gov.au/infrastructure/ngpd/files/Volume-4-PSC-Guidance-Dec-2008-FA.pdf (Accessed: 12-2018).

Department of Infrastructure and Regional Development. 2017, '*Infrastructure and Transport PPPs and Privatisation in Australia*', Available at: https://www.bitre.gov.au/publications/2017/files/is_093.pdf (Accessed: 12-2018).

Dewulf, G, Blanken, A & Bult-Spiering, M. 2012, *Strategic Issues in Public-Private Partnerships: Second Edition*, Strategic Issues in Public-Private Partnerships: Second Edition.

Eadie, R, Millar, P & Toner, L. 2013, 'Public private partnerships, reevaluating value for money', *International Journal of Procurement Management*, vol. 6, no. 2, pp. 152-69.

Flyvbjerg, B. 2006, 'Five Misunderstandings About Case-Study Research', *Qualitative Inquiry*, vol. 12, no. 2, pp. 219-45.

Gopalkrishna, N & Karnam, G. 2015, 'Performance Analysis of National Highways Public Private Partnerships in India', *Public Works Management and Policy*, vol. 20, no. 3, pp. 264-85.

Grimsey, D & Lewis, MK. 2005, 'Are Public Private Partnerships value for money?', *Accounting Forum*, vol. 29, no. 4, pp. 345-78.

Heckman J. 1981, *Statistical models for discrete panel data. InStructural analysis of Discrete Data with Econometric Applications*, Manski C, McFadden D (eds). MIT Press, USA.

Henjewele, C, Sun, M & Fewings, P. 2012, 'Analysis of factors affecting value for money in UK PFI projects', *Journal of Financial Management of Property and Construction*, vol. 17, no. 1, pp. 9-28.

HM Treasury. 2018, '*National infrastructure and construction pipeline 2018*'. Available at: https://www.gov.uk/government/publications/national-infrastructure-and-construction-pipeline-2018 (Accessed: 26-11-2018).

Hodgson, M & Corrigan, K. 2005, 'To privatize or not?', *Canadian Consulting Engineer*, vol. 46, no. 1, pp. 26-33.

Jasiukevicius, L & Vasiliauskaite, A 2018, ‘The assessment of public-private partnership’s possibilities to optimize investments in public infrastructure’, *Engineering Economics*, vol. 29, no. 1, pp. 32-45.
Kweun, JY, Wheeler, PK & Gifford, JL. 2018, ‘Evaluating highway public-private partnerships: Evidence from U.S. value for money studies’, *Transport Policy*, vol. 62, pp. 12-20.
Leigland, J. 2018, ‘Public-private partnerships in developing countries: The emerging evidence-based critique’, *World Bank Research Observer*, vol. 33, no. 1, pp. 103-34.
Liu, HJ, Love, PED, Smith, J, Sing, MCP & Matthews, J. 2018, ‘Evaluation of public–private partnerships: A life-cycle Performance Prism for ensuring value for money’, *Environment and Planning C: Politics and Space*, vol. 36, no. 6, pp. 1133-53.
Loxley, J. 2012, ‘Public-private partnerships after the global financial crisis: Ideology trumping economic reality’, *Studies in Political Economy*, no. 89, pp. 7-38.
Macário, R, Ribeiro, J & Costa, JD. 2015, ‘Understanding pitfalls in the application of PPPs in transport infrastructure in Portugal’, *Transport Policy*, vol. 41, pp. 90-9.
Makovšek, D & Moszoro, M. 2018, ‘Risk pricing inefficiency in public–private partnerships*’, *Transport Reviews*, vol. 38, no. 3, pp. 298-321.
McFadden, D. 1977, *Modelling the Choice of Residential Location*, Cowles Foundation for Research in Economics, Yale University.
McKevitt, D & Davis, P. 2016, ‘Value for money: a broken piñata?’, *Public Money and Management*, vol. 36, no. 4, pp. 257-64.
McQuaid, RW & Scherrer, W. 2010, ‘Changing reasons for public-private partnerships (PPPs)’, *Public Money and Management*, vol. 30, no. 1, pp. 27-34.
Mols, F. 2010, ‘Harnessing market competition in PPP procurement: The importance of periodically taking a strategic view’, *Australian Journal of Public Administration*, vol. 69, no. 2, pp. 229-44.
Morallos, D & Amekudzi, A. 2008, ‘The State of the Practice of Value for Money Analysis in Comparing Public Private Partnerships to Traditional Procurements’, *Public Works Management & Policy*, vol. 13 pp. 114-25.
Mouraviev, N & Kakabadse, NK. 2014, ‘Risk allocation in a public-private partnership: A case study of construction and operation of kindergartens in Kazakhstan’, *Journal of Risk Research*, vol. 17, no. 5, pp. 621-40.
Mouwen, A. 2015, ‘Drivers of customer satisfaction with public transport services’, *Transportation Research Part A: Policy and Practice*, vol. 78, pp. 1-20.
Murphy, TJ. 2008, ‘The case for public-private partnerships in infrastructure’, *Canadian Public Administration*, vol. 51, no. 1, pp. 99-126.
NSW Government. 2008, '*Cross City Tunnel: Summary of contracts*', available at: http://nswtreasury.prod.acquia-sites.com/sites/default/files/2017-02/Cross_City_Tunnel_co ntracts_summary_2008_update_lowres.pdf (20 May 2019).
NSW Government. 2010, '*Lane Cove Tunnel: Updated summary of contracts'*, Available at: http://nswtreasury.prod.acquia-sites.com/sites/default/files/2017-02/Lane_Cove_Tunnel_contracts_summary_09August2010.pdf (20 May 2019).
NSW Treasury. 2017, ‘*NSW PPP Guidelines 2017 Official Launch*’, https://www.treasury.nsw.gov.au/sites/default/files/201707/NSW%20PPP%20Guidelines%202017%20Official%20Launch%20Presentation%20-24%20July%202017.pdf (Accessed: 24-7-2017).
Ng, ST, Wong, YMW & Wong, JMW. 2012, ‘Factors influencing the success of PPP at feasibility stage - A tripartite comparison study in Hong Kong’, *Habitat International*, vol. 36, no. 4, pp. 423-32.
OECD. 2008, *Public-private partnerships: In pursuit of risk sharing and value for money*, vol. 9789264046733, Public-Private Partnerships: In Pursuit of Risk Sharing and Value for Money.
Opara, M. 2018, ‘Value for Money and Risk Relationships in Public-Private Partnerships: Evaluating Program-based Evidence’, *Australian Accounting Review*, vol. 28, no. 3, pp. 391-404.
Opara, M, Elloumi, F, Okafor, O & Warsame, H. 2017, ‘Effects of the institutional environment on public-private partnership (P3) projects: Evidence from Canada’, *Accounting Forum*, vol. 41, no. 2, pp. 77-95.
Opara, M & Rouse, P. 2019, ‘The perceived efficacy of public-private partnerships: A study from Canada’, *Critical Perspectives on Accounting*, vol. 58, pp. 77-99.
Patil, NA & Laishram, BS. 2016, ‘Sustainability of Indian PPP procurement process: Development of strategies for enhancement’, *Built Environment Project and Asset Management*, vol. 6, no. 5, pp. 491-507.
Peng, W, Cui, Q.B., Lu, Y & Huang, L. 2014, 'Achieving value for money: An analytic review of studies on Public Private Partnerships', *The 2014 Construction Research Congress: Construction in a Global Network proceedings*, Geogria Institute of Technology, America, pp. 1189-1198.
Penyalver, D, Turro, M & Williamson, JB. 2019, ‘Measuring the value for money of transport infrastructure procurement; an intergenerational approach’, *Transportation Research Part a-Policy and Practice*, vol. 119, pp. 238-54.

Queiroz, C. 2007, *Public-private partnerships in highways in transition economies recent experience and future prospects*, Article, https://www.scopus.com/inward/record.uri?eid=2-s2.0-38349118259&doi=10.3141%2f1996-05&partnerID=40&md5=2167ee4234d487b84eae261dd01a1158.

Quiggin, J. 2004, 'Risk, PPPs AND THE Public Sector Comparator', *Australian Accounting Review*, vol. 14, no. 33, pp. 51-61.

Rao, C.R. 1973, *Linear statistical inference and its applications*. Wily, USA.

US Department of Transportation. 2018, 'Traffic data: Computation method', available at: https://www.fhwa.dot.gov/policyinformation/pubs/pl18027_traffic_data_pocket_guide.pdf (20 May 2019).

Reeves, E. 2011, 'The only game in town: Public private partnerships in the Irish water services sector', *Economic and Social Review*, vol. 42, no. 1, pp. 95-111.

Reeves, E. 2015, 'A Review of the PPP Experience in Ireland: Lessons for Comparative Policy Analysis', *Journal of Comparative Policy Analysis: Research and Practice*, vol. 17, no. 5, pp. 467-80.

Ren, GQ, Li, HJ, Ding, R, Zhang, JS, Boje, CL & Zhang, WS. 2019, 'Developing an information exchange scheme concerning value for money assessment in Public-Private Partnerships', *Journal of Building Engineering*, vol. 25.

Robinson, HS & Scott, J. 2009, 'Service delivery and performance monitoring in PFI/PPP projects', *Construction Management and Economics*, vol. 27, no. 2, pp. 181-97.

Shaoul, J. 2005, 'A critical financial analysis of the Private Finance Initiative: selecting a financing method or allocating economic wealth?', *Critical Perspectives on Accounting*, vol. 16, no. 4, pp. 441-71.

Siemiatycki, M & Farooqi, N. 2012, 'Value for Money and Risk in Public–Private Partnerships', *Journal of the American Planning Association*, vol. 78, no. 3, pp. 286-99.

Siemiatycki, M & Friedman, J. 2012, 'The Trade-Offs of Transferring Demand Risk on Urban Transit Public-Private Partnerships', *Public Works Management and Policy*, vol. 17, no. 3, pp. 283-302.

Sing, MCP, Love, PED & Liu, HJ. 2019, 'Rehabilitation of existing building stock: A system dynamics model to support policy development', *Cities*, vol. 87, pp. 142-52.

Song, J, Li, Y, Feng, Z & Wang, H. 2019, 'Cluster Analysis of the Intellectual Structure of PPP Research', *Journal of Management in Engineering*, vol. 35, no. 1.

Sun, S, Zhang, C & Yu, G. 2006, 'A Bayesian Network Approach to Traffic Flow Forecasting', *IEEE Transactions on Intelligent Transportation Systems*, vol. 7, no. 1, pp. 124-32.

Transport for NSW. 2014, 'Contract summary: Operations trains and systems, Public Private Partnership contract', available at: http://nswtreasury.prod.acquia-sites.com/sites/default/files/2017-02/NWRL_OTS_PPP_Contract_Summary_Dec_2014.pdf (20 May 2019).

Tsamboulas, D, Verma, A & Moraiti, P. 2013, 'Transport infrastructure provision and operations: Why should governments choose private–public partnership?', *Research in Transportation Economics*, vol. 38, no. 1, pp. 122-7.

Vining, AR & Boardman, AE. 2014, 'Self-interest springs eternal: Political economy reasons why public-private partnerships do not work as well as expected', *CESifo DICE Report*, vol. 12, no. 3, pp. 17-23.

Walder, JH & Amenta, TL. 2004, 'Financing new infrastructures: Public/private partnerships and private finance initiatives', in *Moving People, Goods, and Information in the 21st Century: The Cutting-Edge Infrastructures of Networked Cities*, vol. 9780203642962, pp. 88-110.

Wall, A & Connolly, C. 2009, 'The private finance initiative: An evolving research agenda?', *Public Management Review*, vol. 11, no. 5, pp. 707-24.

Whiteside, H. 2019, 'Public-private partnerships: market development through management reform', *Review of International Political Economy*.

Willems, T, Verhoest, K, Voets, J, Coppens, T, Van Dooren, W & Van den Hurk, M. 2017, 'Ten Lessons from Ten Years PPP Experience in Belgium', *Australian Journal of Public Administration*, vol. 76, no. 3, pp. 316-29.

Yuan, J, Ji, W, Guo, J & Skibniewski, MJ. 2018, 'Simulation-based dynamic adjustments of prices and subsidies for transportation PPP projects based on stakeholders' satisfaction', *Transportation*.

Yuan, J, Zeng, AY, Skibniewski, MJ & Li, Q. 2009, 'Selection of performance objectives and key performance indicators in public–private partnership projects to achieve value for money', *Construction Management and Economics*, vol. 27, no. 3, pp. 253-70.

Zwalf, S, Hodge, G & Alam, Q. 2017, 'Choose Your Own Adventure: Finding a Suitable Discount Rate for Evaluating Value for Money in Public–Private Partnership Proposals*', *Australian Journal of Public Administration*, vol. 76, no. 3, pp. 301-15.

STUDENT PERCEPTIONS OF PROJECT MANAGEMENT: POSTGRADUATE EDUCATION IN AN AUSTRALIAN UNIVERSITY

Shirley Boon[1], Samer Skaik[1]

[1]School of Engineering and Technology, Central Queensland University, Melbourne, Australia

Abstract

There is a mounting literature advocating the need to educate and train project management professionals in order to meet the evolving complexities in projects. It is imperative, therefore, to continually examine the extent to which PM education is effective in equipping students with the requisite knowledge and skills in preparation to enter the PM workforce. This study adopts a case study approach to examine perceptions of postgraduate students about their completed graduate diploma in PM which is offered at an Australian university. The findings of the study revealed that students are generally satisfied with their learning experience in the selected course. The findings suggest that the course learning outcome that has mostly been attained by graduates is the ability to apply soft skills in managing projects and activities. Three areas for improvement were identified for further improvement: firstly, designing more assessment tasks with a primary focus on practical and technical aspects; secondly, selecting teaching staff who have a mixture of academic and industry experience; and finally inviting more industry guest lectures to share their real-world PM experience. The study contributes to the existing literature about good practices in PM in tertiary education.

Keywords

Course learning outcomes, higher education, PM education, student satisfaction.

Introduction

There is a gap between the university education of Project Management (PM) and the ‘real’ industry needs (Ramazani & Zergeas, 2014). To close the gap, many universities started to offer PM courses that are more relevant to cater for the increased demand of competent project managers (Pant & Baroudi 2008). A successful PM course is one that could adequately equip students with certain knowledge and skills for career advancement and to boost their confidence in breaking into the PM space. In this context of the ever-growing demand and competition amongst global universities to attract international students, it is therefore critical for universities to offer courses or programmes of the highest possible quality to attract students who endeavour to keep their competitive advantage (Lebcir et al. 2008).

There is a growing phenomenon that PM courses are now part of the curriculum of most business schools at all levels and there is evidence of increasing efforts to elevate PM education towards a more applied academic, interdisciplinary and theoretically-grounded field beyond the perceived technical nature (Cicmil & Gaggiotti 2018). As such, it was suggested that higher education institutions are to engage actively with their key stakeholders and to develop courses that meet the needs of both employers and students and advance the existing body of PM knowledge (Bredillet et al. 2013).

This study will specifically look into the satisfaction of students towards the core learning outcomes of a completed Graduate Diploma of PM course as well as the course design and its alignment with international standards. Further, strategic recommendations for improvement will be explored through analysing students' feedback as this study is focusing on the students' perspectives towards the course. The course learning outcomes will be used as benchmark of the quality. Satisfaction of students will be measured based on their confidence about attainment of the course learning outcomes.

Literature Review

The growth of PM

Today, projects can be observed in almost all industries. Organisations are increasingly using 'projects' to achieve their strategic goals (McKevitt, Carbery, & Lyons 2017). In the modern workplace, operating an enterprise is an amalgamation of different 'projects', such as corporate renewal, capability integration, and leadership capacity development. Leaders in complex organisations usually oversee project-based activities from the outset to the end (Berggren & Söderlund 2008). Educational institutions and training providers have been attempting to meet this rapidly growing demand. PM is an essential part of the curriculum of various programmes within higher education institutions, as it has been integrated particularly in business, engineering, and technology programs (Ramazani & Zergeas 2015). Similarly, Umpleby & Anbari (2004) commented that PM techniques are increasingly applied in today's global knowledge society, resulting in high demand for skilled practitioners, which fuels the need for training programs, professional certification and academic degrees in the area of PM. Academia is currently facing increasing demands in the design and delivery of their degree programs (Reid et al. 2012). In other words, there is now an increasing trend of knowledge generation and application-based problem-solving to meeting customer needs globally.

The gap between education and the reality of PM

Although the investment and expenses spent on PM education are substantial, the failure rate of projects is still relatively high. According to the Chaos report released by Standish Group (2015), which included an analysis of 50,000 global projects, only 44% of projects were completed on budget and 40% on time. Vavpotič et al. (2015) and Vrhovec (2016) also found that 18% projects have failed, and 43% projects completed way over budget and schedule.

The problem of project failures is still so significant despite all undertaken research and improvements in PM tools, techniques and processes. This also signifies that despite the growing popularity of this profession, the current PM education has failed to prepare future project managers to competently handle the complexities of the 'real' project environments (Córdoba & Piki 2012). In most projects, the expected performance of project management practitioners was below expectations (Ramazani & Zergeas 2015).

According to Soldano (2000), the goal of increasing productivity could not be reached due to the reason that tools and techniques imparted and taught through PM training are not being applied in the project environment. It also indicates that the present PM education did not adequately develop students to face the 'real world' and to deal with 'wicked problems' (Winter et al. 2006). Projects should focus on achieving an outcome not just by producing an output. A congressional investigation determined that between 80% and 95% of project failures are a result of either human or miscommunication (which is still human) issues (Pellerin 2009, as cited in Cooke-Davies 2011). People can clearly be seen as a critical component in the difference between 'complicated' and 'complex' projects. Furthermore, history has shown that irrespective of how those projects have been labelled, their success or failure is due to the behaviour of the people within the teams, as well as how they are managed and led.

Bridging the gap

High-quality PM education and effective training are central to project success and it is vital for organisational competitiveness, as this is one of the main reasons that PM graduates of universities have been in high demand across industries (Ramazani & Zergeas 2014). Thomas and Mengel (2008) suggested that there is a need for PM educators to re-evaluate and rediscover the appropriate approaches to educate and train future project managers given the rising challenges and uncertainties in project environment. Hence, it is inevitable for PM education to train and equip students with the necessary skills and knowledge in order for them to competently handle project complexities. In order to overcome challenges in PM education, there is a need for fresh approaches (Córdoba & Piki 2012). Exposure of students to case studies from the real world as they develop and apply PM knowledge and techniques as well as learning from each other are all essential parts of the learning experience. The strategy to expose PM students in dealing with ‘real' project situations through effective catered learning environments has been used as an essential method for them to reflect on their attitudes and skills towards projects to promote more adequate, discerning and professional responses to the complexities of PM practice. This same strategy also seeks to go beyond technical procedures to bring a balance between reflection and action in PM education (Thomas & Mengel 2008).

PM education in Australia

Universities are building bigger and bigger lecture halls and thousands of higher education institution around the globe are responding to the ever-increasing demands for quality education (Council of Higher Education, 2014). Australia is now one of the key destinations for higher education and is attracting students from all around the world. The complex and dynamic nature of PM in Australia has opened new doors of opportunities. The higher education institutions are now more enthusiastic to engage with their key stakeholders actively and to develop courses that meet the needs of employers and students and advance the existing knowledge and research in PM (Bredillet et al. 2013). They strive to offer quality educational experience that helps improve the employability rate of their graduates.

Until the time of writing, a careful google search revealed that there are approximately 30 higher education institutes in Australia offering postgraduate PM courses; namely, graduate certificate, graduate diploma and master of PM. Having said that, there are only two universities offer undergraduate programmes in project management, namely RMIT and Sydney universities. This is justified considering that there is a unanimous view that PM discipline is considered complementary and prior qualifications in certain professions and/or sufficient industry experience are essential for those who are willing to advance their managerial competences.

Colleges and universities are under pressure from a variety of stakeholders to demonstrate evidence-based, authentic assessment results (Richardson et al. 2012). Overall graduate education has been going through changes whereby universities are more compelled to find more innovative approaches to instruction and course delivery to stay competitive. More and more energy is now being invested in ensuring quality education and learning outcomes as higher education systems continue to expand. There is a need for a change in learning and teaching to ensure that courses achieved standards of quality (Coates 2016). Turner & Huemann (2000) cited various scholars who suggested that “the development of competence in a trade or profession requires the individual to gain a mixture of knowledge, skills, attitudes, and behaviors to be able to deliver consistent and desirable results”. Knowledge will be gained from a mixture of formal education and experience whilst the skills, attitudes and behaviors will be gained through the experiential application of the knowledge.

Quality of PM courses

Universities around the world strive to have their degrees accredited by professional bodies as an indicator of quality and excellence. Course evaluation is the most effective way to determine a program's performance and the improvements it needs, which makes the evaluation crucial to the program's success and accreditation (Imam & Tasadduq 2012). According to Zerby and Joiner (2005), accreditation is being pursued globally with the rise of popularity in formal education programs, and at the same time, it is a key strategic goal for each country to internationalise its academic programs. Additionally, specialised accreditation of certain degrees, which aim to train graduates to be proficient in specialised skill sets in particular fields such as PM, have become standard requirements for the recognition of a specific discipline as a profession (Zerby & Joiner 2005).

Most of international higher education institutions offering PM degrees usually seek accreditation from the Global Accreditation Centre (GAC) established by Project Management Institute in 2001. As noted by GAC, the key mission of accreditation process "is a collaboration with colleges, universities and other educational institutions to encourage appropriate education and career development within the field of PM" (PMI 2017). GAC's work, in evaluating both undergraduate and graduate degree programs with an aim to prepare graduates for the PM profession, reflects its objective to attain and uphold academic excellence in PM education programs (Zerby & Joiner 2005).

The activities of a PM course or degree must meet the requirements, standards, and qualifications of GAC. According to the latest PMI-GAC accreditation handbook, programs should offer activities that lead to the achievement of students in three key areas for learning outcomes which address accepted skills, competencies and knowledge found within the management of projects discipline and documented in professional standards as follows:

1) Technical Expertise: This refers to PM that meets project needs within limitations based on professional guidelines and standards.

2) Professional Behavior: This refers to ethical and culturally aware stakeholder engagement, communication, leadership, and teamwork.

3) Strategic Awareness: This refers to contextual awareness and knowledge of strategic and operational drivers required to inform decisions and deliver sustained competitive advantage.

Course learning outcomes

In the recent few years, educational learning outcomes have gained much attention, discussed not only in peer-reviewed literature, but also in national and international conferences, as a way of measuring the knowledge and skills that students take away from a program or course of study. Learning outcomes can be applied at three different levels: institutional, national and international levels. Firstly, at a higher education institutional level, it is used to assess a course unit or module, or a course or program. Secondly, at a national level, it can be applied in qualifications frameworks and systems for quality assurance. Thirdly, at an international level, it is used for transparency purposes and for wider recognition (Adam 2004). Learning outcome is defined as the expectations of what students should know and can do after the completion of their course of study (Rahman & Abdullah, 2013). They also focus on the measurable development of students, including cognitive, behavioural and attitudinal, as they engage in a learning experience. At the end of a learning activity, students are expected to demonstrate the acquirement of certain knowledge, skills, and attitudes – these are the learning outcomes (Adam 2004; Ashiem et al. 2007).

The Course Learning Outcomes (CLOs) of specific courses are designed specifically based on the course content and what students are expected to attain upon completion of the course. CLOs should be distinct, not overlapping with each other, and should target certain course-related skill levels (Felder & Brent 2004).

As such, CLOs and outcomes-based approaches are instrumental in the design of curriculum, teaching, learning, assessment and quality assurance. Their role in higher education approaches of the twenty-first century, as well as the re-evaluation of the fundamentals of teaching and assessment, is likely to be imperative (Adam 2004).

Course learning outcomes (CLO) provide students with the ‘connection’ and ‘common understanding’ which have been identified as essential elements to increase PM higher education quality through successful course activities of transferring knowledge into practice (Bechkam et al. 2017). Therefore, it is always worthwhile for PM educators to evaluate the quality of courses by measuring the level of students’ satisfaction and attainment of the course learning outcomes. That would trigger the extent by which a university was able to meet the industry demands of competent project managers and to produce world-class graduates to meet the competitive career demand of PM in the ‘real-world.'

Students’ satisfaction with their university education

Machado et al. (2011) asserted that it is a global challenge to meet the needs of students in order to retain them. There is breadth of research on the factors that contribute to the students’ satisfaction and retention. In order to ensure students’ satisfaction and for the betterment of education, curriculum and pedagogy have been revised according to assessment and evaluation, which is becoming an essential process in academic programs (Biney et al. 2008). Identifying and meeting the needs of students have become the focus of higher education institutions (Deshields et al. 2005). In developed countries, especially, studies conducted at the higher education level revealed that students’ satisfaction with regards to university’s education services can be affected by various factors (Butt & Rehman, 2010).

According to Aldridge and Rowley (1998), from the perspective of students, their success in learning is affected by the quality of education. In other words, students’ level of satisfaction or dissatisfaction can contribute greatly to their success or failure in learning. It is necessary, therefore, that universities evaluate students’ level of satisfaction, bringing them more in line with what is deemed good quality services (Herdlein & Zurner 2015). As such, it is imperative to examine the level of student satisfaction towards the course by measuring the extent that students have attained the course learning outcomes. By using the course learning outcomes as a benchmark, the university will be able to evaluate the course quality and gain insight for further improvement.

Methodology

For this study, the Graduate Diploma in PM course offered at an Australian university was selected as a case study to measure the level of student’s attainment of CLOs and explore the opportunities for further improvement of PM education. Attainment of course learning outcomes as a benchmark of students’ satisfaction has also been used by other similar studies (Lawrence 2018). The case study method is a creative alternative to the traditional methods because it focuses on the participant’s perspective as the primary focus of the process (Yin 1994). As stated by Yin (1994), the case study approach is a “systematic inquiry into an event or a set of related events which aim to describe and explain the phenomenon of interest”. This approach has been proven effective as a research method to explore and evaluate the success of various university programs and has widely been used to evaluate, compare and analyse various programs within a university (Centeio et al 2017; Gholami & Qurbanzada 2016; Ghanbari 2014; Stolar 2016; Pearce 2012). This approach comprises of the descriptive statistics, exploratory as well as explanatory techniques (Sekaran & Bougie 2015; Hayes et al 2013). Two main sources of information were used in this study, including publicly available information in the university website and a short survey.

Results and analysis

Publicly available information

As mentioned in its website, the PM graduate diploma degree at the selected university aims to provide students with great educational experiences and to equip them with competent knowledge and skills through case studies, research and coursework. The advertised course overview implies that enroled students should have a basic requisite knowledge in PM as it aims to "extend" student's understanding of PM by developing a deep foundation knowledge. However, the admission criteria allow students who completed a bachelor's degree in any discipline with no industry experience to enrol in the course. This would mean that the requisite knowledge could have been obtained as part of the undergraduate studies. This assumption may stand when it comes to engineering, business and ICT undergraduate programmes whereby PM related units are usually embedded within such programmes as mentioned in the literature.

The university website also mentions that postgraduate PM courses have been designed to develop graduates who will be eligible for membership with the Project Management Institute (PMI). As such, all the unit materials have been aligned with the PMI global standards and core bodies of knowledge. At the time of conducting this research, the course consisted of seven core units and one elective unit that must be completed within one year if a student enroled on a full-time basis. Students may enrol in this course directly and acquire the graduate diploma qualification as an independent degree or as an interim award upon completion of the first year of the parent Master of PM Course. The graduate diploma degree has seven explicit learning outcomes. Graduates of this course should have attained the following learning outcomes:

CLO (1) Describe the PM principles and their application throughout the project lifecycle.
CLO (2) Articulate innovative solutions and measures to address PM problems.
CLO (3) Develop PM documentation tailored to a specific PM context.
CLO (4) Apply suitable decision-making processes for unfamiliar project contexts.
CLO (5) Employ contemporary PM knowledge and skills to projects with different complexities.
CLO (6) Engage appropriate soft skills in managing activities and stakeholders.
CLO (7) Address ethical issues within a project context and ensuring continuous improvement.

An analysis was conducted based on an initial literature review to map the seven CLOs against the PMI-GAC Key Focus Areas to examine the level of alignment between the course learning outcomes and the PMI standards as detailed in Table 1.

Table 1. Mapping of CLOs with PMI-GAC Focus Areas

CLO no.	PMI-GAC 4th Edition Key Focus Areas (Key Competencies)		
	Technical Expertise	Professional Behavior	Strategic Awareness
1	√		
2	√		
3	√		
4		√	√
5	√		
6		√	
7		√	√

The mapping was performed according to the understanding of the authors of the course learning outcomes and the key competencies required by PMI-GAC. Based on this mapping, it is apparent that the selected course was designed with the aim to meet the PMI-GAC requirements and standards. Examining the learning outcomes of each of the seven core units comprising this course as to whether or not they are also aligned with the three areas of focus is important to shape a full picture about the detailed level of alignment, but this exercise is beyond the scope of this paper.

The short survey

The short survey was disseminated to students during May 2018 whereby a convenience sampling was used to collect data from 35 respondents. At that time, the entire population of students who completed all units of the graduate diploma course was approximately 145 students. Although the sample is a bit small, it exceeds the minimum sample number of 30 responses in order to be sufficient to perform a statistical analysis (Peterson 1988).

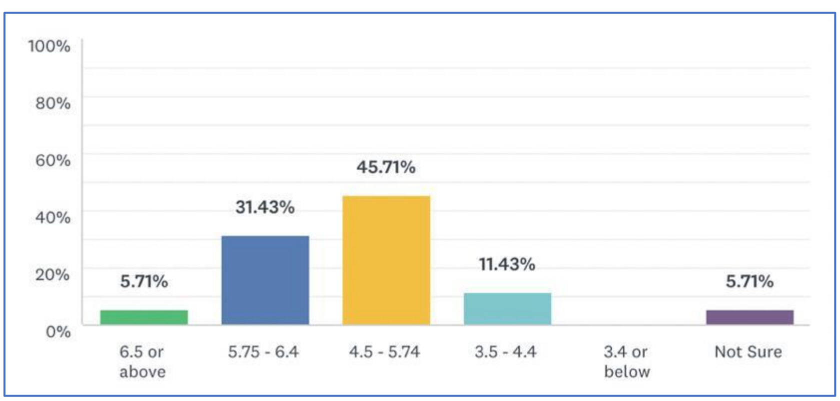
A pilot study has been conducted prior to the dissemination of the mass survey and the survey instrument was further refined and improved accordingly. Afterwards, an online survey questionnaire form was designed using *SurveyMonkey* and the survey link was broadcasted and emailed to target students who completed the graduate diploma of PM in the selected university whether as an interim or exist award. A total of 145 emails were sent and a total of 35 responses have been received signifying a total of 24% response rate.

Participant's backgrounds

The participants were asked to specify their level of academic achievements in terms of the grade point average (GPA) scores. Reponses are illustrated in figure 1. Amongst the participants, there was a total of 13 who scored a minimum GPA of 5.75 signifying high achieving students. 16 students scored a GPA between 4.5 to 5.74 signifying average students. Four students scored a GPA of 4.4 or less signifying low achieving students. Two students were unsure of their GPA. This distribution indicates a fair representation of students with diverse abilities in the survey which would reduce any bias in the collected data.

There is a total of 10 students who have more than three years of working experience, 12 students with 'one to three' years of working experience and 7 students with less than one year of work or no experience at all. This supports the given earlier assumption that students can enrol in the course without any industry experience.

Figure 1 Participant's academic achievements in terms of GPA scores



Students' attainment of Course Learning Outcomes

The survey results from the 5-point Likert scale were analysed using descriptive statistical techniques to measure the frequencies of each scale to determine the participants' satisfaction level towards each course learning outcome (CLO). The percentage of each scale was calculated to draw an overall conclusion. There is a total of seven CLOs that were evaluated in the survey.

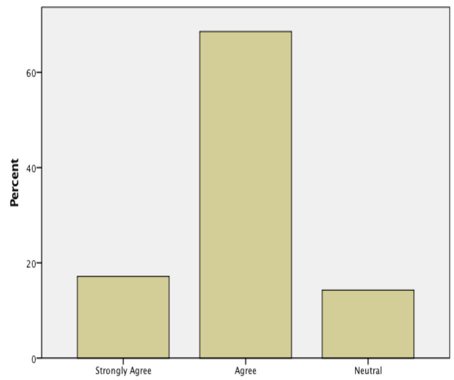


Figure 2. Students' Satisfaction Percentage Towards CLO1

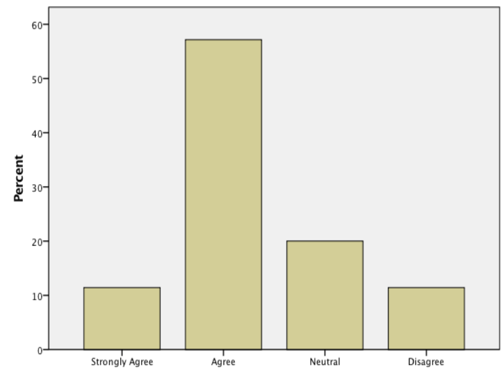


Figure 3. Students' Satisfaction towards Percentage CLO2

Figure 2 indicates that most students (85.7%) have agreed and/or strongly agreed that they have successfully attained CLO 1 - Describe the PM principles and their application throughout the project lifecycle- while there were five students (14.3%) who were unsure about their attainment of this CLO.

Figure 3 shows that a total of 24 students (68.5%) have successfully attained CLO 2 - Articulate innovative solutions and measures to address PM problems- while there were 4 students (11.4%) who were not satisfied. The rest of the students (20%) were neutral about this. Similar analysis was done for all other CLOs and the summary of this analysis is tabulated in Table 2.

Students were also asked to rate their overall satisfaction with the attainment of CLOs of the selected course. As illustrated in figure 4, a total of 26 students (74.3%) are satisfied with the PM course and somehow feeling confident to be project managers. However, there are eight students (22.9%) who are unsure if they are confident to be project manager. This result indicates that majority of students are satisfied with the course but there is room for improvement to raise the satisfaction level based on student's feedback.

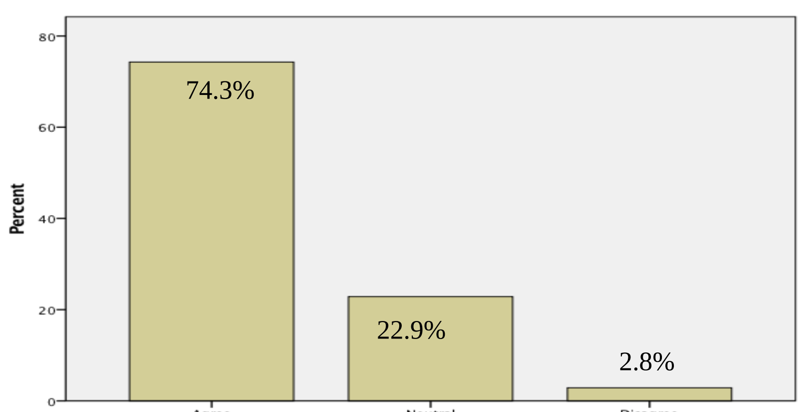


Figure 4. Students overall satisfaction towards the selected PM course

The Relative Importance Index (RII) statistical formula was used to calculate the RII value of each of the three Areas of Focus addressed by PMI-GAC. This tool is useful to rank the Area of Focus that that were mostly attained by students. The higher the value of RII, the higher level of satisfaction towards a particular area of focus. The use of the RII formula for the calculation is based on the responses rating against each of the given options as follows: (RII) = $5\ n_5 + 4\ n_4 + 3\ n_3 + 2\ n_2 + 1\ n_1 / 5\ n$

The five- point scale ranging from 1 to 5 is the rating weight to be selected by the respondent for each option, where "5" is the highest weight and "1" is the lowest weight. In addition, "n_5" refers to the number of respondents who selected the highest weight; "n_1" refers to the number of respondents who selected the lowest weight and 'n' refers to the total number of respondents.

These 'Areas of Focus' are set to be essential as guidelines for the design of course learning outcomes of PM courses. Based on the results, "Professional Behaviour" was rated as the highest attained area by students while 'Technical expertise' was the lowest as shown in Table 2.

Table 2. Students' Satisfaction Towards Key Competencies

Focus Area	Rank	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Total respondents	RII
Professional behavior	**1**	8	21	6	0	0	35	**0.811**
Strategic awareness	**2**	2	22	9	2	0	35	**0.737**
Technical expertise	**3**	0	24	7	3	1	35	**0.709**

The (RII) was also calculated the level of student satisfaction with the attainment of each core learning outcome as demonstrated in Table 3.

Table 3. Relative Importance Index (RII) of Students' Satisfaction towards course learning outcomes

CLO	Rank	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Total respondents (N)	RII
6- Engage appropriate soft skills in managing activities and stakeholders	**1**	7	25	3	0	0	35	**0.823**
1- Describe the PM principles and their application throughout the project lifecycle	**2**	6	24	5	0	0	35	**0.806**
4- Apply suitable decision-making processes for unfamiliar project contexts	**3**	4	26	4	1	0	35	**0.789**
7- Address ethical issues within a project context and ensuring continuous improvement	**4**	5	22	6	2	0	35	**0.771**
5- Employ contemporary PM knowledge and skills to projects with different complexities	**5**	4	22	7	2	0	35	**0.760**
3- Develop PM documentation tailored to a specific PM context	**6**	4	17	14	0	0	35	**0.743**
2- Articulate innovative solutions and measures to address PM problems	**7**	4	20	7	4	0	35	**0.737**

The CLO that has been most attained by students is CLO 6 (RII value of 0.823) which indicates that students are most confident in employing appropriate soft skills in managing activities and stakeholders. Based on the mapping of course learning outcomes with the PMI-GAC Key Focus Areas, this refers to the Key

Competency or Focus Area 2 (Professional Behaviour). This was found consistent with the result shown in Table 1 in which Professional Behaviour has been ranked the highest in terms of student level of attainment.

The least attained course learning outcome is CLO 2 (RII value of 0.737) which refers to the ability to develop innovative solutions and processes to address PM problems. This result is not surprising because the skills and knowledge needed to formulate and develop innovative ideas and solutions to solve wicked problems in PM are often developed through accumulative and real experiences in the 'field'. In addition, this result was also affirmed by the previous question whereby (Technical Expertise) was ranked as the least attained by students as shown in Table 1.

The participants were also asked to identify which unit in the PM course that that was most helpful in building PM knowledge and skills. Students were also asked to provide comments on their choice. By using frequency analysis, results show that the 'PM research proposal' unit got the highest frequency among all the course units. The participants identified a few aspects in the unit to justify their choice and mainly emphasised on learning simple steps in conducting research to resolve certain problems. The findings are interesting because they reveal that students have gained practical skills in research and critical thinking that help them find solutions to given problems.

Analysis of students' qualitative feedback

Students were also invited to provide qualitative comments via an open-ended question regarding areas for further improvement. The qualitative data collected from the survey have been thematically analysed and categorised to find the top four most common issues raised by students that provide insights and opportunities for further improvement, as follows:

1. Recruit PM academics who are still 'in touch' and not entirely disconnected from the industry so that the academics are able to continuously provide fresh and current insights and knowledge from the 'real' project world to the PM students.
2. Assessment design should focus more on practical aspects to polish technical skills such as getting the opportunity to manage real projects as part of the coursework.
3. More guest lecturers from the industry to be invited in all units to share their experiences with students
4. Effective internship arrangement should be introduced in the course and be aligned with student background and expertise.

Discussion and Conclusion

This study aimed to examine perceptions of PM students, who completed a graduate diploma course within an Australian university, about their education experience. The study measured students' satisfaction towards the PM course through their attainment of course learning outcomes and explored opportunities for further improvement. The analysis revealed that 'practical' experience was found lacking from student's perspectives. It seems that students expect more practical and hands-on learning from the course which has also been reflected in the results of students' qualitative feedback. This finding is consistent with literature that indicates that students mostly expect to be trained with practical and effective PM tools as well as soft skills and strategies for personal resilience that can immediately be applied in practice (Cicmil and Gaggiotti 2018). One way to resolve this would be to create more opportunities for students to handle real projects through industry placement or PM simulation by providing dynamic case studies of projects that would require interim actions from students depending on given inputs and scenarios. The survey participants have also addressed the importance of having effective internship arrangement within the course. According to Chen, Shen & Gosling (2018), internships are very useful in terms of the possible experiential learning activities to enhance employability and they stand to be an effective approach to bridge the gap between education and employment demands.

The findings provide insights that should attract the attention of universities, in order to increase the level of students' satisfaction and enhance the learning experience of the PM students. The improvements needed include designing course assessments towards a more practical learning outcome that focuses on the technical aspects. Another area of improvement is to hire more qualified and experienced lecturers and host more industry guest lectures to share experiences from the real-world. This is somewhat consistent with recent research urging universities to increase emphasis on critical thinking (82% agreement), complex problem solving (81%), written and oral communication (80%), and on the application of knowledge and skills in real world settings (78%) because employees are now expected to demonstrate both acquisitions of knowledge and its application (Garnjost & Brown, 2018).

Overall, the findings revealed that students are generally satisfied with their learning experience in the selected course. The findings also suggest that the course learning outcome that has been attained most by graduates is the ability to apply soft skills in managing projects and activities. Three areas for improvement were identified for further improvement: firstly, designing more assessment tasks focusing on hands-on practical and technical aspects; secondly, selecting teaching staff who have a mixture of academic and industry experience; and finally inviting more industry guest lectures to share their real-world PM experiences. The study revealed that students find it more beneficial and effective to manage simple 'real' projects as part of coursework, through collaboration with the industry and have this integrated into the curriculum. It is also imperative for universities to embrace co-creation practices where students, academics and industry experts are involved in designing and further refining the PM courses in order to ensure practicality and relevance of the course to the evolving industry requirements. This study has its own limitations as it was based on a single case study which may not be sufficient to represent a true picture of the status of PM tertiary education in Australia.

References

Adam, S 2004, 'Using learning outcomes: A consideration of the nature, role, application and implications for European education of employing 'learning outcomes' at the local, national and international levels', *United Kingdom Bologna Seminar,* 1-2 July 2004, Heriot-Watt University (Edinburgh Conference Centre), Edinburgh.

Ashiem, C, Gowan, A, & Reichgelt, H 2007. 'Establishing an assessment process for a computing program', *Information Systems Education Journal,* vol. 5, no. 1, pp. 23-25.

Beckham, R, Riedford, K & Hall, M 2017, 'Course mapping: expectations visualized', *The Journal for Nurse Practitioners*, vol. 13, no. 10, pp. e471-e476.

Berggren, C & Söderlund, J 2008, 'Rethinking project management education: Social twists and knowledge co-production', *International Journal of Project Management*, vol. 26, no. 3, pp. 286-296.

Bernard, HR 2002, *Research methods in anthropology: Qualitative and quantitative approaches,* 3rd edn, Alta Mira Press, Walnut Creek, CA.

Biney, P, Kommalapati, R, Gyamerah, M, Annamalai, A, Obiomon, P, Ketkar, M, Sarker, N, Iyengar, R & Peng, X 2008, 'Development of performance criteria for assessing program outcomes in engineering, engineering technology and computer science programs', *Proceedings of the American Society of Engineering Education Annual Conference & Exposition*, Pittsburgh, PA, pp. 13.434.1-13.434.13, viewed 9 June 2018, https://peer.asee.org/3793

Bredillet, CN, Conboy, K, Davidson, P & Walker, D 2013, 'The getting of wisdom: the future of PM university education in Australia', *International Journal of Project Management*, vol. 31, no. 8, pp. 1072-1088.

Butt, BZ & Rehman, K 2010, 'A study examining the students satisfaction in higher education', *Procedia-Social and Behavioral Sciences*, vol. 2, no. 2, pp. 5446-5450.

Council on Higher Education, 2014, *Framework for Institutional Quality Enhancement in the Second Period of Quality Assurance*, viewed 27 Aug 2018, http://www.che.ac.za/sites/default/files/publications/QEP%20Framework%20Feb%202014.pdf

Centeio, EE & McCaughtry, N 2017, 'Implementing comprehensive school physical activity programs: a Wayne State University case study', *Journal of Physical Education, Recreation & Dance,* vol. 88, no. 1, pp. 42–49.

Chen, TL, Shen, CC & Gosling, M 2018, 'Does employability increase with internship satisfaction? Enhanced employability and internship satisfaction in a hospitality program', Journal of Hospitality, Leisure, Sport & Tourism Education, vol. 22, pp. 88-99.

Cicmil, S & Gaggiotti, H 2018, 'Responsible forms of PM education: Theoretical plurality and reflective pedagogies', *International Journal of Project Management*, vol. 36, no. 1, pp. 208-218.

Coates, H 2016, Assessing student learning outcomes internationally: Insights and frontiers, *Assessment & Evaluation in Higher Education*, vol. 41, no. 5, pp. 662-676.

Cooke-Davies, T. 2011, Aspects of complexity: *Managing projects in a complex world*. Project Management Institute.

Córdoba, J & Piki, A 2012, 'Facilitating PM education through groups as systems', *International Journal of Project Management*, vol. 30, no. 1, pp. 83-93.

Garnjost, P & Brown, SM 2018, 'Undergraduate business students' perceptions of learning outcomes in problem based and faculty centered courses', *The International Journal of Management Education*, vol. 16, no. 1, pp. 121-130.

Ghanbari, S 2014, Integration of the arts in STEM: a collective case study of two interdisciplinary university programs, doctoral thesis, University of California, San Diego, ProQuest Dissertations Publishing.

Herdlein, R and Zurner, E 2015, 'Student satisfaction, needs, and learning outcomes: a case study approach at a European university', *SAGE Open*, vol. 5, no. 2, p. 2158244015580373.

Imam, M & Tasadduq, I 2012, 'Evaluating the satisfaction of ABET student outcomes from course learning outcomes through a software implementation', *International Journal of Quality Assurance in Engineering and Technology Education (IJQAETE)*, vol. 2, no. 3, pp. 21-33.

Lawrence, JM 2018, 'A case study comparing student satisfaction and attainment of course outcomes when passive and active pedagogical approaches were used to teach global logistics to industrial distribution and logistics students', *ASEE Southeastern Section Conference,* 4-6 March, American Society for Engineering Education.

Lebcir, RM, Wells, H & Bond, A 2008, 'Factors affecting academic performance of international students in PM courses: a case study from a British Post 92 University', *International Journal of Project Management*, vol. 26, no. 3, pp. 268-274.

McKevitt, D, Carbery, R & Lyons, A 2017, 'A profession but not a career? Work identity and career satisfaction in PM', *International Journal of Project Management*, vol. 35, no. 8, pp. 1673-1682.

Pant, I & Baroudi, B 2008, 'PM education: the human skills imperative', *International Journal of Project Management*, vol. 26, no. 2, pp. 124-128.

Pearce, C 2012, 'The accommodation of international students in university mentor programs: a case study from Curtin University', *Journal of the Australian and New Zealand Student Services Association*, vol. 40, pp. 29–37.

Peterson, R.A 1988, *Marketing research*. Business Publications, Incorporated.

Project Management Institute (PMI) 2017, *Global Accreditation Center*, viewed 16 September 2018, https://www.pmi.org/global-accreditation-center

Rahman, NA & Abdullah, SR 2013, 'Assessment tool of course learning outcomes for mechanical design of process equipment', *Procedia - Social and Behavioral Sciences,* vol. 102, ppl 116-121.

Ramazani, J & Jergeas, G 2015, 'Project managers and the journey from good to great: the benefits of investment in PM training and education', *International Journal of Project Management*, vol. 33, no. 1, pp. 41-52.

Ramsden, P 2005, 'Using research on student learning to enhance educational quality', *Deliberations*, viewed 7 June 2018, www.londonmet.ac.uk/deliverations/ocsld-publications/isltpramsden.cfm

Richardson, TM, Watkins, D & Field, S 2012, *The use of the electronic portfolio in evaluating and assessing the efficacy of graduate PM education*, paper presented at PMI Research and Education Conference, 16-18 July, viewed 9 June 2018, https://www.pmi.org/learning/library/electronic-portfolio-evaluating-assessing-efficacy-6356

Sekaran, U & Bougie, R 2015, *Research methods for business*, 6th edn, Wiley, Chichester.

Soldano, D 2000, *A new model for PM education*, Paper presented at Project Management Institute Annual Seminars & Symposium, Houston, TX, Project Management Institute, Newtown Square, PA.

Standish group 2015, Chaos report, viewed 9 August 2019, https://www.standishgroup.com/sample_research_files/CHAOSReport2015-Final.pdf

Stolar, M 2016, *A Case Study of Pennsylvania's University Programs for Students With Intellectual Disabilities*, Indiana University of Pennsylvania.

Thomas, J & Mengel, T 2008, 'Preparing project managers to deal with complexity – advanced PM education', *International Journal of Project Management*, vol. 26, no. 3, pp. 304-315.

Treece, EW & Treece, JW 1982, *Elements of research in nursing*, 3rd edn, Mosby, St. Louis, MO.

Turner, JR & Huemann, M 2000, Formal education in PM: current and future trends, paper presented at Project Management Institute Annual Seminars & Symposium, 7 September, viewed 9 June 2018, https://www.pmi.org/learning/library/formal-education-project-management-trends-476

Umpleby, SA & Anbari, FT 2004, Improving global PM education, paper presented at PMI Global Congress 2004—EMEA, 19-21 April, viewed 9 June 2018, https://www.pmi.org/learning/library/improving-global-project-management-education-8422

Winter, M, Smith, C, Morris, P & Cicmil, S 2006, 'Directions for future research in PM: the main findings of a UK government-funded research network'. *International Journal of Project Management*, vol. 24, pp. 638–649.

Yin, RK 1994, *Case study research: Design and methods,* 2nd edn, Sage Publications, Newbury Park, CA.

Zerby, J. P. & Joiner, J. C. (2005). *An overview of PMI's degree accreditation programme and other trends in PM degree programmes globally and within the EMEA region*. Paper presented at PMI® Global Congress 2005—EMEA, Edinburgh, Scotland. Newtown Square, PA: Project Management Institute.

EFFECTIVENESS OF PROJECT SCHEDULING TRAINING IN INFRASTRUCTURE ROAD PROJECTS IN QUEENSLAND

Christopher Burgess[1], Samer Skaik[1]

[1]School of Engineering and Technology, Central Queensland University, Australia

Abstract

A project schedule is the output of detailed planning that represents specifically how the project will be delivered to achieve the desired outcome. The benefits of project scheduling can be enhanced through training. The current literature suggests that training comes in many different forms, with varying levels of effectiveness and outcomes for participants. Training is one of the most universally used techniques to promote increased knowledge and capability amongst employees. Research indicates that a lack of training is a major contributor to project practitioners running additional software systems in parallel. This study aims to identify current training practices for project managers in the area of project scheduling and examine the impact of current training practices in road infrastructure projects in Queensland. An online survey was sent to 151 managers, who were directly involved in project delivery and/or management of road infrastructure works in Queensland. 77 participants responded to the survey with a response rate of 51%. The results of this study indicate that the current training methodology and delivery approach is working. The findings suggest that training methodology and delivery approach can be improved to better engage with participants and increase project outcomes, when measured in the long term. The key performance indicator of return on revenue used in the survey indicates that 79.22% of all projects have a higher than 5% return which appears to be acceptable. The results contained herein are a launching platform for further research into project scheduling, the training methods, and the impacts on the road infrastructure industry.

Keywords

Project management, project scheduling, road infrastructure, RoadTek, training

Introduction

Project management software packages are increasingly being used by organisations to manage and control project delivery (Pellerin et al. 2013). For the purpose of this paper, references to project management software specifically refer to project management scheduling software. The majority of such software packages require a significant monetary investment to purchase (Pellerin et al. 2013) in addition to ongoing training and support. With this in mind, training providers have seized the opportunity to capitalise on project management software training delivery. Training comes in many different forms with varying levels of effectiveness (McCarty and Skibniewski, 2017). The Project Management Body of Knowledge describes project scheduling as '*a detailed plan that represents how and when the project will deliver the products, services, and results defined in the project scope and serves as a tool for communication, managing stakeholder's expectations, and as a basis for performance reporting'* (PMI, 2017).

Project scheduling is considered the most significant activity undertaken after project approval has been granted (Kerzner, 2013). It is considered to be one of four critical aspects of successful project delivery (Varajao, et al., 2014). Project management scheduling software has the ability to assist project personnel in planning, organising, monitoring, and controlling activities contained within the projects. Further, it provides the ability to create logical relationships, identify gaps, and is a visual aid for presenting project progress to project stakeholders (PMI, 2017). The Project Management Institute

(PMI) recognises that project schedules are fundamental to project management methodologies, yet not enough focus is applied (PMI, 2018). The PMI Scheduling Professional (PMI-SP) certification was developed to bridge this gap. Project managers and project teams are increasingly globalised and operating virtually with increased focus on project deliverables. One vital component for project success in this environment is effective management of resources, activities, dependencies, and ultimately the project outcomes or deliverables (PMI, 2018). Many studies (i.e. Raymond and Bergeron 2008, Pellerin et al. 2013 and Nasseri, Widen, and Aulin 2016) suggest that improved scheduling and general utilisation of project management software reduce project failure rates, improve performance when measured against predetermined key performance indicators (KPIs) and can lead to increases in productivity and efficiency. In recent times, there have been multiple studies (i.e. White and Fortune 2002 and Pellerin et al. 2013) that have addressed the relationships between project management software and in some cases project scheduling software utilisation and project outcomes.

Relevant studies on the impacts that the training delivery method has on project outcomes are rare with the road infrastructure industry. Pellerin et al. (2013) analyse the impacts that the software packages have on the performance of engineering projects, however they lack quality data around how the software was implemented, what training the project managers were provided and the method in which the training was delivered. Pellerin et al. (2013) also address the impacts to project delivery by understanding the relationship between software utilisation measured in hours and project performance measured as a cost performance index (CPI). A study conducted by White et al. (2002) shows that 64% of respondents in their study used project management scheduling software on a daily basis. The increase in utilisation of project management software has piqued the interest of many researchers in recent times. For example, McCarty et al. (2017) investigate the correlation between the software toolset training and the project outcomes across multiple disciplines including Aerospace, Automotive, Construction, Energy, Government, Healthcare, Manufacturing and Pharmaceutical. While McCarty et al. (2017) have some respondents from a construction setting, no studies to date have specifically focused on scheduling within the road infrastructure industry.

This study provides a unique perspective on the road infrastructure industry, the training provided to project managers, and the delivery method in which the training is undertaken are analysed and compared. Carrillo, Ruikar, and Fuller (2013) describe a lack of understanding of technologies and software systems as a key factor in limiting the successful outcomes from the implementation of project management software. This may result in ad hoc use, and may add little value to project delivery (Carrillo, Ruikar, & Fuller, 2013).

While the basic concepts of project planning and scheduling appear to be sufficiently discussed in project management literature, there is a dearth of research that specifically addresses the individual components that make up planning and scheduling. It is now apparent that there is a need for the road infrastructure industry to address each of the key components individually to evaluate and improve the project planning and scheduling phases of project delivery. This study aims to answer two research question:

1) What are the current training practices for project managers in the area of project scheduling?

2) How are the current training practices affecting project outcomes?

Literature review

Current training practices

Training is one of the most universally used techniques in promoting increased knowledge and capability amongst employees (McCarty et al. 2017). Delivery methods for training vary across industries, however, they commonly include: face-to-face, online or web-based, mentoring/coaching, lunch & learn, conference attendance, and in some cases blended approaches. McCarty et al. (2017) find these approaches to have varying levels of success. The face-to-face sessions involve participants attending a classroom style lecture. Online or web-based training has spiked in recent years due to its cost-effective nature and convenience (McCarty et al. 2017). This involves participants engaging with online resources and often working in their own time to complete the required learning. Mentoring and coaching style approaches involve individuals being coupled with a more experienced co-worker or consultant to pass on experience and learnings in similar scenarios. It is worth noting that coaching and mentoring are not the same and do differ slightly. 'Lunch & Learn' style sessions are relatively new and provide a more sociable experience of relatively short duration for attendees. Conference attendance requires staff to be taken offline to attend. McCarty et al. (2017) find the relevant cost to be highest amongst the training delivery methods.

Observations made by Pellerin et al. (2013) indicate that a lack of training is a major contributor to project practitioners running software systems in parallel. Ironically, over the past fifteen years, significant changes in project management literature have come in the area of project scheduling (Pinto, 2002). Techniques like the Program Evaluation and Review Technique (PERT) and the Critical Path Method (CPM) have been widely embraced within project management circles from the late 1950s (Pinto, 2002). Further, Pinto (2002) describes a number of new developments, techniques, and research studies that make it critical for project professionals to keep up to date with their discipline. Furthermore, Nasseri et al. (2016) suggest this could be attributed to a lack of understanding given that the fundamentals taught in project management literature reflect the traditional Gantt Chart style approach.

A study by McCarty et al. (2017) into the impact of the project management information systems (PMIS) training indicates that only 596 of the 911 people surveyed indicate that they had received beneficial project management software training within the previous twelve months via any of the examined training methods. The remaining 315 participants claim to have received no training at all. Training delivered via a 'lunch and learn' session is determined to have the greatest efficiency outcome, followed by coaching/mentoring, web-based training, and then conference participation in fourth (McCarty et al. 2017). While web-based training is a popular way of delivering training due to its cost effective nature, it was reported as having the largest participant pool. Practitioners who receive classroom training achieve 3.73 hours of training more than the next closest delivery method (McCarty et al. 2017). With the popularity of web-based or other desktop based training on the rise, McCarty et al. (2017) indicate that employers and organisations should be cautious about what they want to achieve and realise that the short term gain by reduced cost could have long term impacts on project outcomes that could wind up costing more money over time.

Costs for project management software training, as indicated by McCarty et al. (2017), indicate that for an accumulated 80 hours of training, cost ranges between $1,700 and $3,100. This is a significant investment from employers, senior managers and organisational leaders. The findings from analysis of the survey results from McCarty et al. (2017) indicate that practitioners experience statistically significant differences of outcomes depending on the delivery method of the software training provided. The greatest beneficial impact is generated by classroom training, followed by coaching/mentoring, conferences attendance, and then web-based training in fourth place. To objectively measure and evaluate the appropriate cost for project management software training, it is nearly impossible (McCarty et al. 2017). McCarty et al. (2017) assert that the complexities of the individual's experience, education, computer literacy, and workplace efficiencies are all factored into how successful the training outcomes were.

Contrary to the findings from McCarty et al. (2017) and others within the construction industry, Mallonee et al. (2018) find in a medical setting that participants, regardless of the training method (e.g. online or in-person), demonstrates high levels of knowledge gain. Further, Mallonee et al. (2018) indicate that the training method had no effect on a participant's readiness to implement the content of the training. However, the in-person attendees indicate significantly higher levels of satisfaction with the training compared with their online counterparts (Mallonee et al. 2018).

Project scheduling devices

In the construction industry, the utilisation of mobile smart devices is on the increase (Sattineni and Schmidt 2015). Given the rise of smart devices within all industries, software manufactures have increased software functionality and distribution (Sattineni et al. 2015). No longer are project managers and other project staff confined to a desktop computer using Microsoft Excel to perform project scheduling.

Results from research by Sattineni et al. (2015) conclude that the use of mobile smart devices is on the rise and is enabling project personnel to make informed decisions, stay connected, and improve quality assurance like never before. The use of mobile devices within the construction industry have obvious advantages. Furthermore, the increase in utilisation smart devices and project management software within the construction industry will necessarily boost up the demand of construction specific software with increased functionality. Project scheduling devices are only as good as the individuals or teams that feed information into them. Pinto (2002) states that project scheduling is dramatically influenced by human behaviours, suggesting that project team members routinely pad their estimates up to 200%.

Implementation

According to a study by Sattineni et al. (2015), employees who had used mobile devices within a construction project raised more negatives to their use on site. The primary concern raised in this study was for worker safety, by concerns over distraction and inattention to construction activities that could jeopardise safety if not completed with one's full attention. Although more negatives where listed, the study indicates that the benefits appear to outweigh the negatives. Some of the benefits to having smart devices on construction sites were: viewing and sharing documents; email; improved productivity; paperless processes; and increased access to name a few. Pellerin et al. (2013) suggest that in order to maximise the use of project management software that sufficient training should be undertaken, and further, adequate planning and monitoring controls should be applied throughout the project to achieve or exceed the KPI's.

Some key implications for organisations looking to implement new project management software into their workplaces were observed in a research conducted by Kagan, Naumova, and Vilman (2016). In their research, it is found that after the period of transition and implementation of the new project management software, a competent team can have their earning capacity reduced by as much as 60% of the previous baseline. After the implementation is finalised, the earning capacity of the same team can be up to 20% higher than the original baseline. This would indicate that an organisation may have to endure short term pain, to gain in the long run. Furthermore, the changeover between softwares will often result in temporary increases in individuals' workload, potentially meet employee resistance, and it may be unclear to the employees why the change of software is required.

These more sophisticated project scheduling tools come with some disadvantages, such as higher financial demands, potential training and implementation for current staff (Kagan et al. 2016). These disadvantages may result in poor utilisation, hindering the implementation and therefore effectiveness of project scheduling software.

While the concepts described by PMI (2018) are adequately discussed and documented, there are relatively low numbers of studies that detail the enablers and barriers to successful project scheduling (Nasseri et al. 2016). Furthermore, Nasseri et al. (2016) highlight that significant work should be put in during the planning phase of the project. They also find that this decreased the workload throughout the project execution and reduce rework.

Tangible improvements to project outcomes

The project planning and utilisation of project management scheduling software has a strong connection with project success. This has been found in many studies (McCarty et al. 2017; Nasseri et al. 2016; Pellerin et al. 2013; and Sattineni et al. 2015). According to Pellerin et al. (2013), the team was able to use real project data from 21 engineering project to amongst other things, establish a correlation between the quantity (in hours) use of project management software's and the overall project CPI rating. Sattineni et al. (2015) find that while the majority of participants experienced some improved productivities, and communications the study also noted that not enough time or focus was provided to the training of staff required to use smart devices and therefore may have contributed to a lack of utilisation. Nasseri et al. (2016) provide project managers, individuals and organisations with a framework for utilising a taxonomy which can be used when considering project complexity, planning and scheduling methods as inputs. They also conclude that if project managers or projects schedulers focus on the more significant elements and prioritise their planning and execution, the chances of project success will increase.

Method

An online survey was used to gather quantitative data from the Department of Transport and Main Roads (DTMR) in Queensland. DTMR employs more than 10,000 employees spread across the State delivering front line services such as customer service, marine operations, and road infrastructure projects. RoadTek is a commercial business within DTMR and was selected as a convenient organisation to disseminate the survey to its project managers. RoadTek provides a range of road infrastructure solutions and services including: civil construction and maintenance; bridge construction and maintenance; traffic electrical services; road marking; and emergency response.

RoadTek allowed access to their project managers, who are regularly engaged in road infrastructure projects. Furthermore, RoadTek has implemented and currently operates under a well-defined project management methodology based on the Project Management Body of Knowledge. RoadTek's Highway 21 (intranet webpage) houses the project management methodology, as well as all supporting documentation, templates, guidance, and subject matter experts contact details. Within Highway 21, Primavera P6 has its own webpage where there is detailed description of how Primavera benefits RoadTek at a strategic level and enables effective and efficient project scheduling. RoadTek's adoption of Primavera P6 provides the business with the visibility of project timeframes, resource requirements, progress and performance that it requires to effectively manage the various programs of works.

All participants that undertook the survey, were employed by RoadTek at the time of collecting data. RoadTek employs 1183 full time equivalents. 151 employees were identified using purposive sampling based on their title containing 'manager or coordinator' as detailed on the establishment list. Participants were expected to have a broad level of experience, both with project management software and road construction. Whilst all the participants work for RoadTek, RoadTek delivers many key road construction and infrastructure projects including: i) Road construction and maintenance; ii) Bridge construction and maintenance; iii) Electrical infrastructure installation and maintenance; and iv) Road delineation and furniture. Although RoadTek operations are limited to within Queensland, RoadTek is a culturally inclusive workplace with employees from a variety of cultures both from within Australia and internationally.

Of the 151 employees invited to undertake the survey, 77 responded corresponding to a response rate of 51%. Participants were contacted via email which provided a web link to undertake the survey. Initial contact was made on the 20th August 2018. The initial email was sent out by the Occupational Group Leader for Construction and Maintenance Management, with a follow up reminder email sent out on the 28th August 2018 by the Occupational Group Leader. The survey was available to RoadTek staff from the 20th to the 30th of August 2018.

Result and analysis

Participant Background

41 of the 77 participants (53%) were current project managers within the road infrastructure delivery. 92% of participants (71 of 77) have worked in the road infrastructure industry for greater than five (5) years. 33 of those participants (43%) were involved for a period between five (5) and fifteen (15) years, with only 6% of participants (5 of 77) who have been involved in the road infrastructure industry for less than five years. Only four (4) of the survey participants indicated that they had never used project scheduling software. 47% of participants (36 of 77) indicated they have been using project management scheduling software for a period ranging between 5 and 15 years. The respondents indicated that they

had a moderate ability to schedule projects using project management scheduling software prior to undertaking any training.

Time spent on scheduling

To establish the level of effort expended by project managers in scheduling their projects, participants were asked to rank '*How much time do you spend (on average) per week scheduling projects?'* Participants were given the choice of five (5) indications, from less than two (2) hours, to over fifteen (15) hours. Of the 77 participants, 72% of participants (56 of 77) indicated that they spend less than five (5) hours per week scheduling their projects. None of the survey participants indicated they spend more than fifteen (15) hours per week scheduling their projects.

Most recent training experience

Survey participants were asked '*When did you last receive Project Management Scheduling training?'* Participants were asked to indicate from one of five (5) choices from those being trained within six (6) months, to never having been trained at all. As illustrated in Figure 1, 69% of participants indicated it had been over twelve (12) months since they last received project management scheduling training. Only ten (10) of the respondents (7.7%) indicated that they had never received project management scheduling training. Of the ten (10) respondents who indicated never having received training, four (4) of whom had a role title of project coordinator.

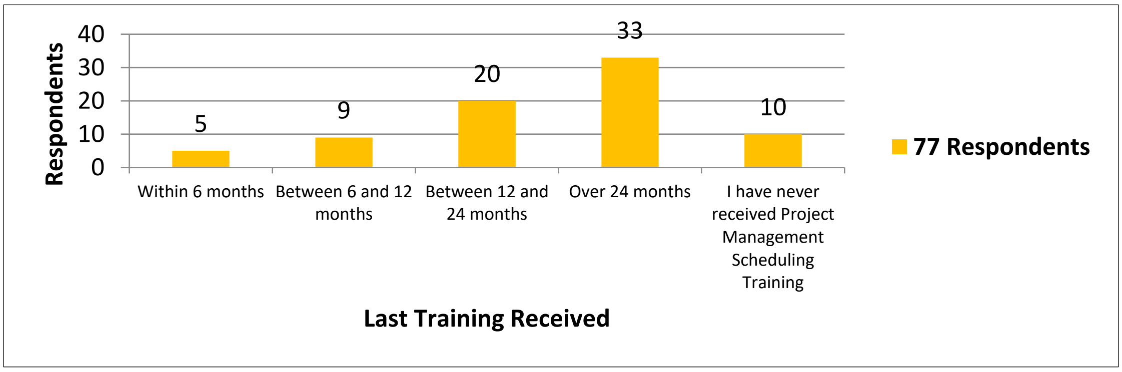


Figure 1. Most recent project management scheduling training

Training delivery method

To establish how RoadTek is facilitating the training of their project managers in project scheduling software, participants were asked '*How was your most recent project management scheduling training delivered?'* Training delivered to project managers within RoadTek is heavily skewed towards the 'face to face' and web-based delivery methods scoring 37 (48%) and 18 (23%) respectively as illustrated in Figure 2. Of the ten (10) participants that indicated they have never received project management scheduling training as detailed in Figure 1, four (4) of those participants skipped this question. Interestingly, only 2 participants had received face to face training in the previous 6 months. 32 of the participants (42%) indicated that they last received face to face training over 12 months ago.

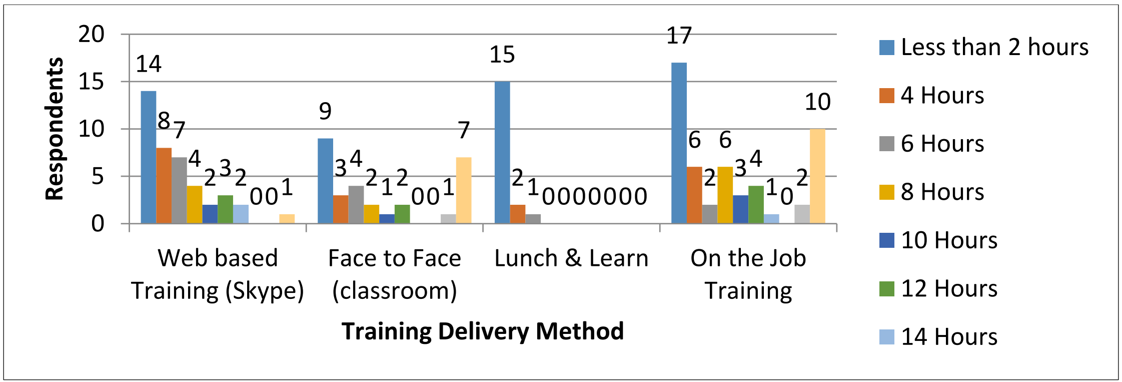


Figure 2. Hours spent on each training method in the past 12 months.

Figure 2 indicates that participants undertook significant amounts on the job training and web-based training in the past twelve (12) months. The duration of this training on average was indicated at less than two (2) hours. Five (5) survey participants did not respond to this question.

Capability after receiving training

To assess the participant's capability after the training was completed, they were asked '*After undertaking project management scheduling software training, I would classify my ability to schedule projects as…*'. 59 survey participants (77%) indicated an improvement of moderate or greater (See figure 3 for the breakdown of this number). Two (2) participants chose not to answer this question in the survey.

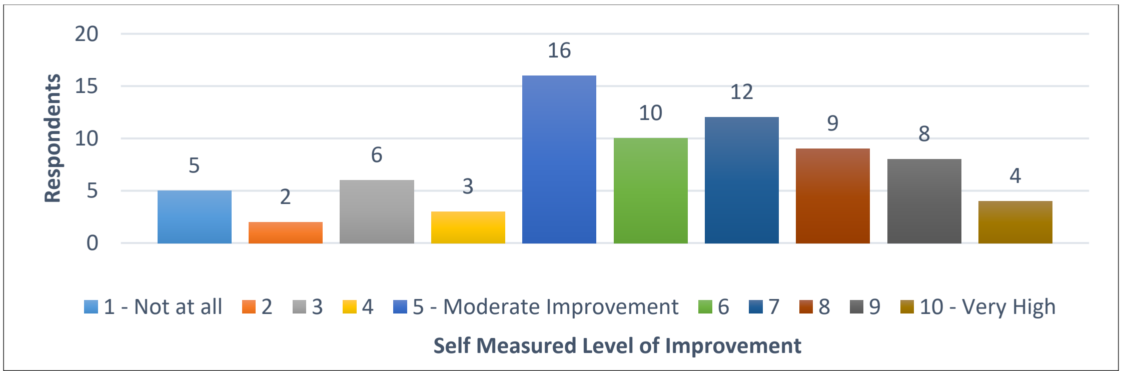


Figure 3. Capability after receiving training.

Return on revenue

Return on revenue is a common predetermined key performance indicator (KPI) that project success and project manager's performance are measured against. It is easily determined with a simple calculation of overall revenue minus overall expenses, and then expressed in many cases as a percentage. Participants were asked '*on average what was the Return on Revenue, expressed as a percentage on your projects over the past 2 years?'* 60% of participants (46 of 77) recorded a 5.00 to 9.99% return of revenue (Figure 4), while 10% (8 of 77) respondents were unsure of the average results over the past two (2) years. Of some concern for RoadTek, are the eight (8) people who were unsure of the return on revenue that their projects performed at over the past two years.

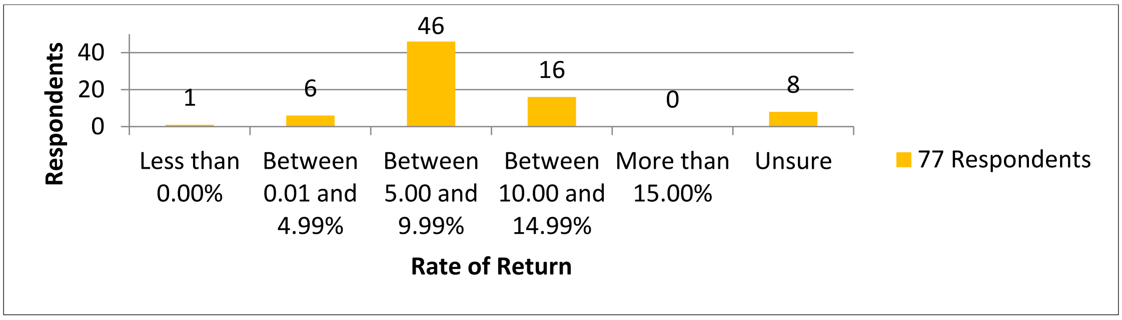


Figure 4. Average Return on Revenue over the past two years.

Position based analysis

Survey participants were asked to select their current role within the department in one of the demographic questions. The results from that question were then combined with the results from another question asking participants to express the average 'Return on Revenue' over the previous two years. In the demographic question, those participants that selected the Senior Project Manager, Principal Project Manager, Construction Manager, and Operations Managers positions form part of the senior leadership team within each operations unit. These positions are at the top of the hierarchy, with primary responsibility of delivering a program of work.

Further, the participants that selected Project Manager, Project Engineer, and Delivery Managers form the middle layer of management within the each operations unit. These positions report to either the Senior Project Manager, Construction Manager, or Operations Managers. These positions are in direct control of road infrastructure projects and provide the linkage between senior management and the field based road construction crews.

A combined total of 71 responses were recorded against the positions compared in this analysis. Of the remaining six participants, five indicated they were Project Coordinators and one participant skipped this questions. The Project Coordinator was excluded from this analysis as their position works across many different projects, with no direct control over project scheduling and project outcomes in RoadTek's reporting structure.

The results as in figure 5 indicated that 26% Senior Leadership group returned on average 10.00 to 14.99% over the past two years in comparison to the Project Manager's group which was on 18%. A similar result was observed with 69% of the Senior Leadership group indicating an average return of 5.00 to 9.99%, in comparison to the Project Manager's group with only 52% indicating the same rate of return.

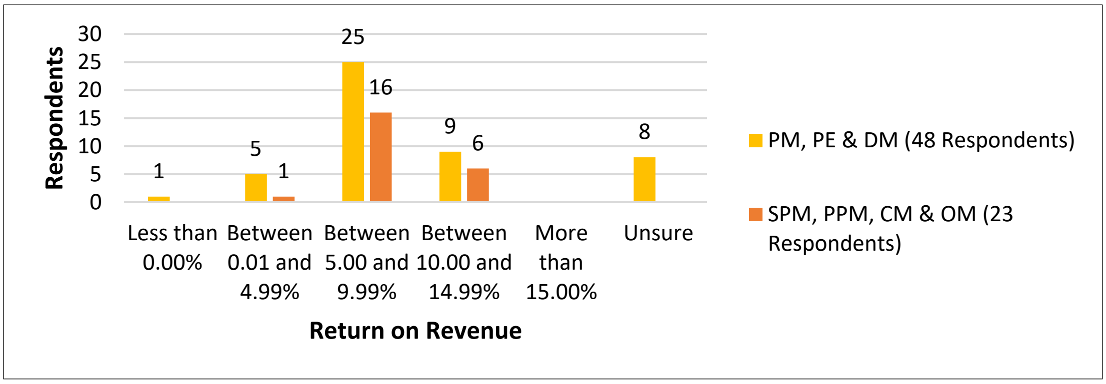


Figure 5. Position Based Analysis of Position Title and Return on Revenue.

Most recent training experience compared with the return on revenue

In this analysis, the results from another question: "*When did you last receive Project Management Scheduling Training" were compared* with the previous question where participants were asked to express the average Return on Revenue over the previous two years. 73 responses were totalled in this comparison, with four (4) participants indicating they had not received any training. The results illustrated in figure 6 indicated that 62% of the 'Face to Face' learning group indicated a 5 to 9.99% average return, where 61% of the Web-based training group indicated the same result.

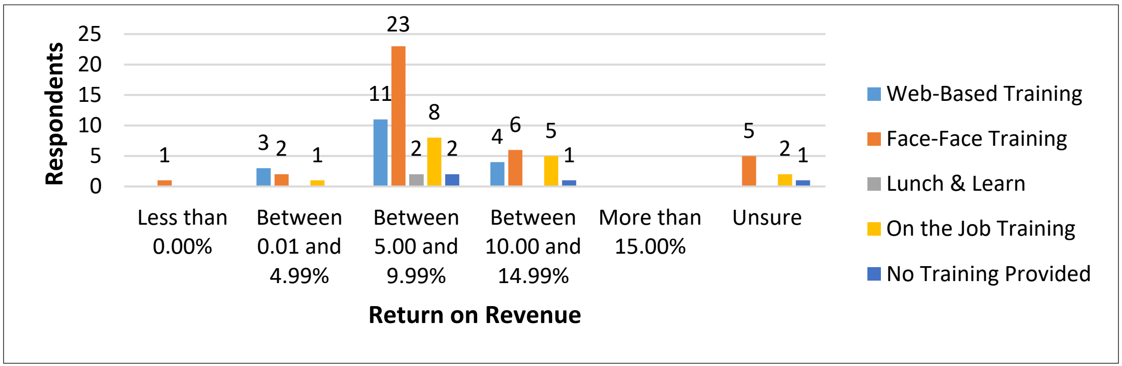


Figure 6. Most Recent Training Delivery Method Compared with ROR

Timing of the last training received compared with return on revenue.

A further comparison was carried out to analyse the relationship between timing of the last training received and return on revenue. 48% of respondents (see figure 7) indicated a return on revenue of between 5 and 9.99% after receiving their last training in project management scheduling software over twelve (12) months ago. In contrast, of the eight participants who indicated they had never received any project management scheduling training, four participants indicated returns of 5.00 to 9.99% and the remaining four participants indicated returns of 10.00 to 14.99%. Thus, 33% of the participants who indicated a return of 10.00 to 14.99% had not received any project management scheduling training.

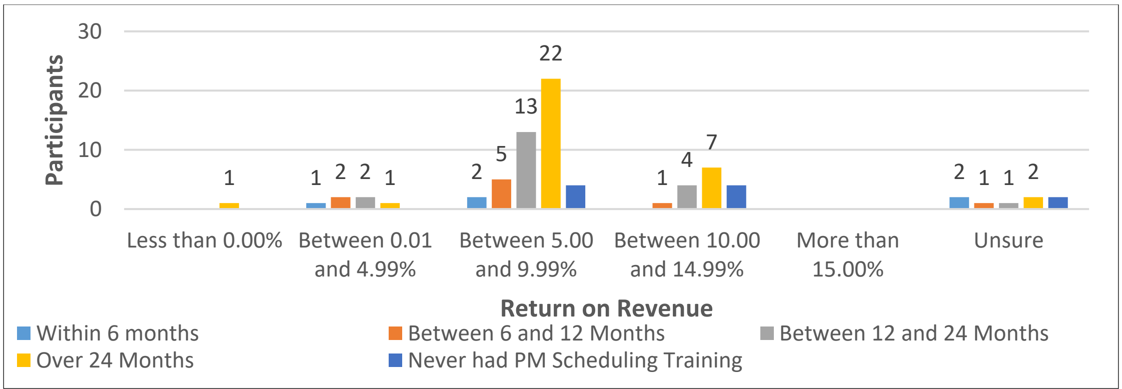


Figure 7. Timing of Last Training Compared with RoR

Most recent training compared with hours spent on scheduling.

Figure 8 shows the comparison between most recent training and hours spent on scheduling. Participants were asked: '*How much time do you spend on average per week scheduling projects?'* Their answers were compared with the answers of another question asking *'When did you last receive project management scheduling training?'* 71% of the participants (22 of 31) that indicated they spend less than 2 hours per week scheduling projects received training over 12 months prior.

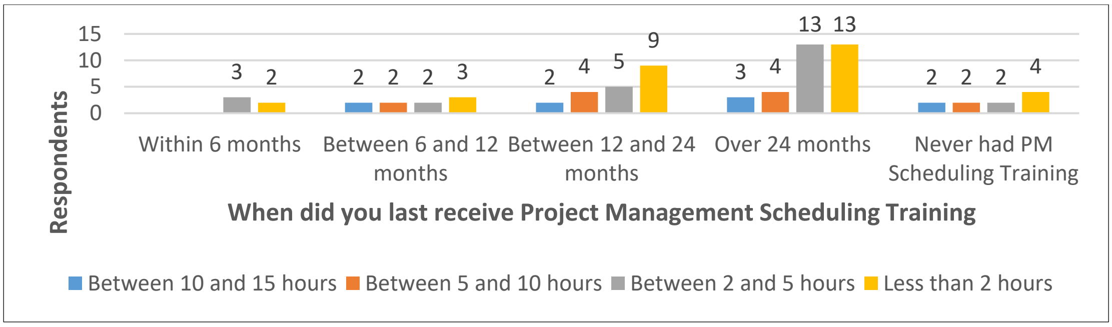


Figure 8. Most Recent Training Compared with Hours Spent Scheduling.

Discussion

RoadTek's training delivery method over the past 12 to 24 months has almost been completed in a web-based environment. Only 5% (4 of 77) of the respondents indicated they received face to face training within the past 12 months and all 18 of the respondents who received web-based training indicated that the training occurred in the last 24 months. Web-based training delivery has been a trend within organisations since 1999 as shown by Sitzman et. al (2006). Training using the web-based approach, has made RoadTek along with many other organisations rethink their training delivery strategy. The Primavera P6 training was originally delivered 'face to face' in a single full day (8 hour) training session; now the web-based training is completed in two (2), three (3) hour session to maintain engagement. A full day of 'face to face' training may not be enjoyable, but it is tolerable. A web-based full day session may be unbearable to most of participants which is consistent with the finding of Sitzman et al. (2006) that participants lost interest in the training material using a web-based training method within the first four (4) to six (6) hours. RoadTek has made a significant monetary investment in Primavera P6, and the training. Since January 2018, RoadTek has trained 35 employees with only 8 of these being 'face to fac'e (figure 6), primarily due to the convenience being that they were located in the same place as the trainers. RoadTek currently delivers Primavera P6 training on a monthly basis, with two 3 hours sessions scheduled two months in advance.

McCarty et al. (2017) found that the greatest efficiency came from a 'Lunch and Learn' training delivery method. The 'Lunch and Learn' model is something that has not been utilised formally by RoadTek, although two (2) survey participants indicated receiving a formal 'Lunch and Learn' style training. However, the results indicate that 23% (18 of 77) of participants were involved in a 'Lunch and Learn' style session. As there has been no formal sessions arranged for a 'Lunch and Learn' style format (RoadTek, 2018), this indicates that it may be done in a peer-to-peer environment, and in an informal manner.

As organisations move towards a web-based approach to training for the obvious cost savings reasons (Sitzman et al. 2006), organisations like RoadTek would need to rethink their approach to training delivery. While the online delivery method streamlines the delivery, employees can engage with the material directly from their work site, office, or home (McCarty et al. 2017). In the same survey by McCarty et al. (2017), the online delivery was found to be amongst the lowest performing training delivery method. However, Sitzman et al. (2006) found that for procedural knowledge, the knowing of how to, a web-based delivery method was equally as effective as its 'face to face' counterpart. Ongoing training and support are provided via a web-based skype phone call system with RoadTek's Operational Service Delivery team fielding over 1,000 calls since January 2018 from project staff in relation to Primavera P6 (RoadTek, 2018).

As described by McCarty et al. (2017), it is nearly impossible to objectively measure the appropriate costs for project management software training; however the training is critical to project success as discussed by Kostalova et al. (2015). Recent training (within 12 months) was provided to only 18.18% (14 of 77) of respondents. This result was significantly less than the results stated by McCarty et al. (2017) in their study with 65.42% of participants indicating they had received meaningful PMIS training within the previous 12 months. On the contrary to the research of McCarty et al. (2017), the results of the survey indicate no decline in the quality of the outcomes when the training delivery methods are compared (see Figure 6).

Coinciding with RoadTek's change to a web-based training approach was also a downturn in its internal training budgets. RoadTek has found itself at the centre of turbulent times over the past decade and has cut costs from many different areas of the business, one of which being training. As indicated by Jewson et al. (2014), more emphasis is now put on the who, what, where, when and how of the training methodology. A training budget of $1,500 per person is allowed in the annual budgeting process. This seems significant on the surface, however given the quantity and rising cost of mandatory safety, environmental, and quality training required to maintain our accreditations, the budget does not stretch far.

Figure 5 details on average how much time RoadTek project staff spend scheduling their projects. 73% of participants (56 of 77) indicated that they spent less than five (5) hours scheduling projects on average per week. Results from Pellerin et al. (2013) indicated a direct correlation between software utilisation and the reported CPI score. However, Pellerin et al. (2013) found that of more significance statistically was the intensity of use. Data collection to measure the intensity of use was not part of the scope of this paper. Pellerin et al. (2013) recommended that high levels of system utilisation are implemented to maintain good performance, however, at some point (to be determined by the organisation) increased software utilisation will provide no further benefits to project outcomes.

The key performance indicator of return on revenue used in the survey indicates that 79.22% of all projects have a higher than 5.00% return which appears to be acceptable. However, when compared to the construction industry, this appears to be on the lower end of the spectrum, with the average construction project returning 15.9% gross return for the first two quarters of 2018 (CSI, 2018). The data contained herewith provide no clear correlation between the project return on revenue, and the time spent scheduling, training delivery method or the amount of hours spent training (Figures 6, 7, 8). This is in contrast to McCarty et al. (2017) who indicated a positive correlation between the number of training hours received and the impact of the training on project outcomes, regardless of the delivery method. With this in mind, to optimise training outcomes, RoadTek could investigate including mandatory refresher training courses for all project staff directly involved in project scheduling. This is supported by findings of McCarty et al. (2017) and Mullaly and Thomas (2009) who suggest that individuals, who build a stronger foundational base with training, provide proficiencies and create increased organisational value.

This research indicates a slight improvement in project outcomes, measured as a CPI if included in the senior leadership team (see Figure 5). McCarty et al. (2017) suggested that this is attributable to their level of experience and fluency with the software systems. There are two specific reasons of difference to disagree with this proposition. Firstly, the data collected in this research indicate no statistical difference in the experience of the senior leadership group when compared to the project management group. Secondly, fluency in the use of software is irrelevant to an individual's given level of technical experience in that field (Mallonee et al. 2018). In this research, there was no clear connections between the training provided, the training delivery method, the timing of the last training and the return on revenue.

Conclusion, limitation and further research

This study aimed to identify current training practices for project managers in the area of project scheduling and examine the impact of current training practices in the context of road infrastructure projects in Queensland. Overall, the results of this study indicate that the current training methodology and delivery approach is working. The findings suggest that RoadTek could improve their training methodology and delivery approach to better engage with participants and increase project outcomes, when measured in the long term. The key performance indicator of return on revenue used in the survey indicates that 79.22% of all projects have a higher than 5.00% return which appears to be acceptable. The results provide no clear correlation between the project return on revenue, and the time spent scheduling, training delivery method or the amount of hours spent training.

This has some obvious limitations in this study. Firstly, as the sample group of participants is limited to RoadTek, it lacks variety across the road infrastructure industry and focuses on a singular government operated business. This does not provide a good representation of the civil construction road infrastructure industry. Secondly, the sample size of 77 is relatively small when compared to the wider road infrastructure industry within Queensland. Thirdly, the electronic survey is self-reported, and due to time constraints on project deliverables there is insufficient time to track participants training and correlations to tangible outcomes in the future. Finally, the sample group operates with a single project scheduling software system (Primavera P6). This is not indicative of the norms in the construction industry.

With the above being said, this research does provide insight into the scheduling systems training provided to Project Managers and measure its effects on project outcomes. Further, it provides a starting point for future more detailed analysis using a larger sample group from both the private and public sectors. Although the data set is relatively small, and with limitations across the wider industry, the study does present an exhaustive exploration of project scheduling training provided to project managers within the road infrastructure industry and measures its effects on project outcomes expressed as a CPI. This study identified numerous avenues for further research and potential business improvement opportunities with regards to project scheduling training delivered in RoadTek for the road infrastructure industry. To further support the road infrastructure industry, it is proposed that three (3) future research topics are investigated hoping to better understand the effectiveness of the training and where 'real project' efficiencies can be gained:

1) the correlation between the amount of time scheduling and the projects outcome;
2) investigation into a tangible measurement for user acceptance and satisfaction compared with project based outcomes, based on the training delivery method; and
3) a detailed skills assessment prior to, and then six months after the training.

References

Carrillo, P., Ruikar, K., & Fuller, P. (2013). 'When will we learn? Improving lessons learned practice in construction'. *International Journal of Project Management,* vol. 31, pp. 567-578.

Jewson, N., Felstead, A., & Green, F. (2014). 'Training in the public sector in a period of austerity: the case of the UK'. *Journal of Education and Work,* vol. 28, no. 3, pp. 228-249.

Kerzner, H. (2013). 'Project Management: A Systems Approach to Planning, Scheduling, and Controlling'. *John Wiley & Sons Inc.,* Hoboken, New Jersey.

Kostalova, J., Tetrevova, L., & Svedik, A. (2015). 'Support of Project Management Methods by Project Management Information Systems'. *Procedia – Social and Behavioural Sciences,* vol. 210, pp. 96-104.

Mallonee, S., Phillips, J., Holloway, K., & Riggs, D. (2018). 'Training providers in the Use of Evidence-Based Treatments: A Comparison of In-Person and Online Delivery Modes'. *Psychology Learning & Teaching,* vol. 17, no. 1, pp. 61-72.

McCarty, A., & Skibniewski, M. (2017). 'The Impact of PMIS Training: Patterns of Benefit Realization in Project Management Information Systems Training'. *Journal of Engineering, Project, and Production Management,* vol. 7, no. 1, pp. 2-13.

Mullaly, T., & Thomas, J. L. (2009). 'Exploring the Dynamics of Value and Fit: Insights from Project Management. *Journal of Project Management,* vol. 40, no. 1, pp 124-135.

Nasseri, H. A. A., Widen, K., & Aulin, R. (2016). 'A taxonomy of planning and scheduling methods to support their more efficient use in construction project management'. *Journal of Engineering, Design and Technology,* vol. 14, no. 3, pp. 580-601.

Pinto, J. K. (2002). 'Powerful forces have affected the practice of R&D project management in the past decade. Here's a review of the most fundamental ones'. *Industrial Research Institute,* vol. March – April, pp. 22-37.

Pellerin, R., Perrier, N., Guillot, X., & Leger, P. (2013). 'Project Characteristics, project management software utilisation and project performance: An impact analysis based on real project data'. *Procedia Technology,* vol. 9, 2013, pp. 857-866.

Project Management Institute Inc (PMI) (2017). ‘A Guide to the Project Management Body of Knowledge (PMBOK guide)’, 6th edn, Project Management Institute Inc, Newtown Square, Pennsylvania.
Project Management Institute Inc (PMI) (2018). PMI Scheduling Professional (PMI-SP)®, viewed 25th August 2018, https://www.pmi.org/certifications/types/scheduling-sp
Raymond, L., & Bergeron, F. (2008). ‘Project management information systems: An empirical study of their impact on project managers and project success’. *International journal of Project Management,* vol. 26, no.2, pp. 213-220.
RoadTek. (2018). System Support Data 2018.
Sourced internally from Operational Service Delivery, Brisbane, Australia.
Sattineni, A., & Schmidt, T. (2015). ‘Implementation of mobile devices on jobsites in the construction industry’. *Procedia Engineering,* vol. 123, pp. 488-495.
Sitzman, T., Kraiger, K., Stewart, D., & Wisher, R. (2006). ‘The comparative effectiveness of web-based and classroom instruction: A meta-analysis’. *Personnel Psychology,* vol. 59, pp. 623-664.
Varajao, J., Dominguez, C., Ribeiro, P., & Paiva, A. (2014). ‘Critical success aspects in project management: Similarities and differences between the construction and the software industry’. *Tehnicki vjesnik*, vol. 21, no. 3, pp. 583-589.
White, D., & Fortune, J. (2002). ‘Current practice in project management – an empirical study’.*International Journal of Project Management*, vol. 20, pp. 1-11.

A SYSTEMATIC APPROACH TO GROUP-BASED ASSESSMENT IN PROJECT MANAGEMENT EDUCATION: CQUNIVERSITY CASE STUDY

Samer Skaik[1], Roksana Jahan Tumpa[1]

[1]School of Engineering and Technology, Central Queensland University, Melbourne, Australia

[2] School of Engineering and Technology, Central Queensland University, Sydney, Australia

---

Abstract

Group-based assessments have long been adopted as a means to develop interpersonal and leadership skills of project management students and reduce marking workload. The authentic design of group-based assessments plays a vital role to embrace cooperative learning and polish student's teamwork abilities. However, the traditional means of crafting group assessments do not only increase the vulnerability of students to academic misconduct but also jeopardise the development of teamwork and communication skills which are key attributes of project management graduates. The paper aims to examine the effectiveness of an appropriately designed group-based assessment on the learning of project management students. The paper starts by reviewing the good practices in designing effective group-based assessments. The paper then selects a case study of a postgraduate project management unit at CQUniversity to examine how the assessment design was implemented and its impact on students' learning. Multiple sources of information were used in this case including publicly available information, the unstructured observation of the unit developer and anonymous students' feedback. The paper concludes that implementing the group-based assessment, as informed by scholarly work, requires more time and efforts from the teaching team in terms of close faculty coordination, providing timely information, forming groups, providing personalised feedback to each group, marking the staged submissions and responding to students' enquiries in class and via emails. However, that is considered a little price to pay compared to the benefits and positive effects on student's experience and attainment of learning outcomes. The demonstrated assessment design may stand as a useful and reliable framework for educators who use or develop authentic group-based assessments in any discipline.

Keywords

Academic misconduct, assessment design, employability, group assessment, project management.

Introduction

Collaborative learning has long been considered as an effective means of learning style where students form a group to achieve a common target. In the group work, team members depend on each other to perform tasks and share the credit of success and hold the responsibility of failure (Chen & Kuo 2019). There is a growing evidence that indicates the performance of teamwork outweighs the achievement of an individual (Chen & Kuo 2019). Although many studies prove that collaborative learning performs outstandingly in sharing knowledge and facilitating teamwork, a few studies have addressed the difficult aspects of the group work (Moreno, Ovalle & Vicari 2012).

There are many factors which determine the outcomes of group assessments in the tertiary education. Such factors include skills, abilities of team members, gender, cultural background, ethnicity of group members (Smith & Spindle 2007). Moreno, Ovalle and Vicari (2012) mention Group formation is one of the crucial factors. However, Hilton and Phillips (2010) argue saying group achievement does not depend on the group formation process. On the other hand, if groups are not managed effectively, the consequences can be negative including unfair marks distribution, free-riding, wastage of time, disappointment towards group-based assessments (Maiden & Perry 2011).

This paper aims to examine the effectiveness of an appropriately designed group-based assessment on students' learning. The paper starts by demonstrating the theoretical framework underpinning the good practices in designing group-based assessment as identified in previous scholarly works. The paper then selects and analyses a case study to examine how the group-based assessment, informed by scholarly work, was implemented in PM tertiary education and the extent of its success in addressing the raised concerns, especially developing students' soft skills, motivating them to learn and deterring them from engaging in academic misconduct activities.

Graduate attributes of PM students

In recent years, not only do employers expect graduates to demonstrate technical or hard skills, but also employees need to exhibit a range of competences. A study conducted by Osmani, Weerakkody and Hindi (2017) reveal that tertiary education and institutions should design their curriculum in a way that assists students develop some skills which are expected of graduates when they enter the job market. Os-sanchez et al. (2017) emphasise on providing PM graduates with trainings for both types of competences. A wide range of literature indicates that the competence of project managers can be categorised in two broad types: hard and soft skills (Edum-Fotwe & McCaffer 2000).

Over 50 types of human and hard skills have been identified in a normative study (Osmani, Weerakkody & Hindi 2017). However, when these skills are investigated against job industry, they can be classified into 10 core categories. Employers seek these 10 fundamental themes from the delegates. These skills include communication, team working, problem solving, use of information & communication technology, creativity, interpersonal characteristics, leadership, self-management, critical thinking, time management, and research skills (Osmani, Weerakkody & Hindi 2017).

Multiple educational institutions and organisations have set their own graduate attributes. Regardless of the structure and geographical location, the primary focus of all organisations and universities is to grow graduates with soft skills as while recruiting employers are not willing to compromise soft skills of graduates over technical skills (Finch et al. 2013). According to CQUniversity graduate attributes published in 2019, the attributes of postgraduate students are knowledge, communication, cognitive, creative and critical skills, self-management, ethical and professional responsibility and leadership traits. Graduates with a good control over communication skills are considered competitive in the ever-demanding employment market (Finch et al. 2013).

Group-based assessments – a tool to improve interpersonal skills in PM

PM discipline is facing many challenges worldwide. One of those challenges is that educational institutions are not adequately preparing graduates to face complex scenarios in the real project environment (Winter et al. 2006). Organisations previously tended to focus on the technical skills of graduates which are tightly inclined to the three constraints of PM: time, cost and quality (Atkinson 1999). However, employers now not only expect employees to demonstrate a set of technical skills, but also want them to show a range of soft skills such as communication skills, interpersonal skills and leadership traits (Brown & Bowen 2009). Employers believe universities are not paying much attention to the development of non-technical skills (Hassall et al. 2005).

As employers are focusing on having graduates with personal transferable skills (PTS) along with their technical skills, over the past two decades, most of the disciplines at different universities across the world have emphasised on group activities (Wosnitza & Volet 2014). Furthermore, in order to develop both technical and non-technical skills in graduates, higher education has started focusing on the inclusion of groupwork in the curriculum (Cooley et al. 2014). According to Chen and Kuo (2019), both students and teachers benefit from team activities. Students can incorporate social and logical expertise in them by participating in team work. On the other hand, when educational institutions deal with an astronomical number of students and having a limited finance, teachers consider group-based assessments as an effective means of evaluating students (Cumming 2010).

Group formation - a challenge to group assessments

Although groupwork has been considered as sharing knowledge and collaborative learning, unsuccessful outcomes may be the results of teamwork. The collaborative learning does not happen simply putting some students in a group (Cooley et al. 2014). It has been a difficult and time-taking task for instructors (Ounnas, Davis & Millard 2009). Wosnitza and Volet (2014) agree saying it is a challenging and frustrating task for both students and facilitators.

Hilton and Phillips (2010) recommend teachers to decide the methods of group formation. According to them, the team development could either be a random selection or a systematic approach. Random selection, student selection and teacher selection are most commonly used team formation methods (Hilton & Phillips 2010). Lambic et al. (2018) and Sadeghi and Kardan (2015) discourage student-selected group formation method as close friends are not sincere in the context of education and learning in the team and they are not task oriented. The outcomes of the assessment are pessimistic due to multiple reasons and the work quality is compromised at the expense of exchanging mutual benefits (Lambic et al. 2018). Hence, giving students the discretion to form a group will threaten the main purpose of introducing group-based assessments in higher education which are building team work and communication skills. Lambic et al. (2018) and Sadeghi and Kardan (2015) emphasise close friends are not sincere in the context of education and learning in the team. Hence, students can achieve outstanding outcomes if the groups are not established on the foundation of prior relationships (Lei, Kuestermeyer & Westmeyer 2010). This can be achieved if the groups are formed by teachers.

Teachers form groups depending on students' ability and their previous academic achievements. The formation of this type of group is challenging if the teachers do not have any background information about the students (Chen & Kuo 2019). Chen and Kuo (2019) state that groups formed by this approach is subjective since the factors considered while forming groups vary from teacher to teacher. According to Kelly (2009), while organising groups, teachers carefully make a balanced mixture of low, average and high learning skill set students, so, mediocre peers can learn from prodigy.

Groups organised by teachers present stability in the team which is a key attribute of productive groups. The teams formed by facilitators experience satisfactory outcomes. Purposeful assignment is applicable or beneficial where the task requires a range of skills and diverse capabilities (Kelton 2019). However, teams selected by teachers has some drawbacks. Students feel forced to work with a group of unknown people (Kelly 2009). The group maker has to be mindful of the factors. Prior academic achievement, individuals' learning styles and personality types may not be enough factors to be considered in a particular situation to get the best outcomes of the groups (Kelton 2019). According to Lei, Kuestermeyer, and Westmeyer (2010), there are six elements for consideration in group forming: ethical background, gender, acquittance, skills, level of motivation and sources.

Forming groups with students from different parts of the world is a cumbersome task given the fact that students differ in culture and ethnicity (Kelly 2009). Kimmel and Volet (2009) assert that diverse groups perform better and stimulate cognitive, interpersonal skills and better management control in comparison to non-diverse groups in a small group size. Because of a myriad of ideas and suggestions, culturally diverse teams are more productive than homogenous group (Kimmel & Volet 2009). Kelly (2009) and Kimmel and Volet (2009) suggest that, although groups with diverse ethnicity demonstrate lower performance than homogenously formed groups in the beginning week of the group formation, diverse groups perform equally as homogenous groups lately. It is probably due to the fact that students from different culture and ethnicity take time to achieve an optimum level of behavioural integration. One way to foster a quicker harmonisation between the diversified team members formed by teachers is the use of a group charter.

Effects of a group charter on team collaboration

A group charter is a written and dynamic document which discusses how the group will operate to accomplish a task. Team members can change charters depending on the scope of the work. The content of group charters may differ from assignment to assignment (Sverdrup & Schei 2015). Aaron, McDowell and Herdman (2014) claim that a group charter should stress on schedules of meetings, decision-making processes, methods of communication and conflict handling process. A group charter includes presence, absence and delay of members, strong and weak sides of every member, obstacles, and sanction issues (Cox & Bobrowski 2003).

Sverdrup and Schei (2015) mention that in the initial phase of group formation, team members should discuss the type of tasks needed to be completed and their contribution level to the work. Then, expectation in terms of quality and effort should be discussed. Teams should not limit this discussion in the primary stages of charter formation, it can be amended at any stage of the group work such as in scheduled meetings. It is also recommended to store them in a written form (Sverdrup & Schei 2015).

Mathieu and Rapp (2009) prove in their longitudinal study that teams with a developed group charter perform exceptionally as a whole. Sverdrup, Schei and Tjolsen (2017) examine that an advanced performance and better adaption to unforeseen situation are noticed in teams with a group charter than groups without one. Aaron, McDowell and Herdman (2014) argue that a group charter is an essential tool to increase productivity, team cohesion, communication skills and performance of the team members.

Progressive group assessment design

Although assessments facilitate learning, it may have some negative aspects due to the assessment design. Sometimes, instead of providing students with a deep understanding, it may render superficial learning. This is because the way the assessments are designed may have an impact on students' learning. One way to make assessments more authentic is to introduce progressive assessments. In a progressive arrangement, assessments spread out throughout the term instead of a long end-of-term submission or examination. This approach provides students with an opportunity to work on their mistakes depending on the teachers' feedback (Saint et. al 2015). Progressive approach motivates students and eliminates the tendency of "Why bother, I am going to fail anyway" altogether (Saint et al. 2015). Brown and Knight (2012) highlighted saying incremental feedback are provided in a staged assessment method instead of getting feedback at the end where students fail to get an opportunity to work on their mistakes. Saint et al. (2015) and Brown and Knight (2012) agree stating that student should get an opportunity to compensate their poor performance by getting staged feedback. A similar strategy was adopted in the United Kingdom by Evans, Zeun and Stanier (2014) which significantly improved students' performance and engagement.

When it comes to getting feedback incrementally and improving the performance in subsequent submissions, feedback provided by teachers is not out of concern. Constructive feedback is also an important factor to be considered in order to improve students' performance (McKevitt 2016). Pokorny and Pickford (2010) mention students prefer constructive feedback on their drafts in order to bring enough and required changes to the final submission.

Oral defence of groupwork

Although oral assessment as a part of examination process has been quite common in the UK and New Zealand, it is completely absent from the Australian education system (Kiley et al. 2018). The practice of oral component has been prevalent in health profession for a prolonged time (Salamonson et al. 2016; Hashim et al. 2015). This is because students can reflect their critical thinking capability, problem-solving competence and knowledge about the subject matter as students are presented with a set of standardised unknown questions (Roberts 2013).

Students are assessed on their interpersonal skills and analytical expertise at the same time when it comes to participating in oral defence (Shenwai & Patil 2013). In addition to that, oral defence is an opportunity where students demonstrate their depth of knowledge about the work they submit (Shenwai & Patil 2013). Huxham, Campbell and Westwood (2012) assert that this face-to-face communication between students and teachers renders an opportunity to oral examination committee to measure students' capabilities. Salamonson et al. (2016) claim that students are able to manifest their comprehensive learning and contextual knowledge which cannot be expressed through customary examination setting. Their research exhibit that students are satisfied with oral component as a part of assessment process. Thomas, Raynor and McKinnon (2014) have echoed the positivity of oral examination.

Oral examination has been found to be a tool to reduce academic misconduct in universities. This method has been introduced as a mode of verifying the originality of students' work and enhancing their oral presentation skills (Thomas, Raynor & McKinnon 2014). Incalculable and unforeseen questions are asked by examiners or teachers which prepare students for getting in-depth knowledge. As a result, students go into details instead of depending on a stereotyped learning. In many modern universities in Italy, a 5-minute short viva has been set as the final requirement (Wooldridge 2005). Moreover, academic integrity can also be maintained through oral assessments as students need to exhibit their learning by themselves (Davis & Karunathilake 2005). Norton, Scantlebury and Dickins (1999) believe this way of arrangement will be appreciated by students as it stimulates academic molarity and robust learning. Furthermore, many students in the study the study of Thomas, Raynor and McKinnon (2014) reported that oral defence provides them with the opportunity to learn from others' perspective which they might not have come across otherwise.

Group Self and Peer Assessment (SPA)

Mounting research suggests that self and peer assessment process has been recognised as a means of enhancing students' learning, inculcating personal transferable skills in them, thus preparing graduates as better workforce for the competitive job market (Adachi, Tai & Dawson (2018). A study conducted by Jin (2012) demonstrates that self/peer evaluation is a unique method of determining coordination and group members' contribution to the group work.

Group member self-assessment

Self-assessment is an approach to reviewing one's own work and instil self-regulatory behaviour in them. Adachi, Tai and Dawson (2018) assert that students make judgement of their work and provide feedback against set criteria. The self-evaluation process helps develop multiple personal transferable skills such as communication, cognitive, critical thinking and collaboration (Adachi, Tai & Dawson 2018; Reinholz 2016). Boud and Soler (2016) emphasise that these soft skills are often expected of students when they enter job market. That is the reason, universities include these human skills in graduate learning outcome and graduate attributes. Needless to say, self-assessments help develop their transferable skills, thus preparing them to be better workforce. Kearney (2013) divulges that students are being disengaged from active learning because of traditional assessment design. He conceptualised a framework called Authentic assessment for sustainable learning (AASL) and Authentic self- and peer-assessment for learning (ASPAL) in order to bring collaboration in group work, involve in the assessment development and assess their own work.

Group peer assessment

Planas-Llado et al. (2018) and Dingel and Wei (2014) argue that peer evaluation is helpful to gauge the contribution of each member, social loafing and free-riders. Apart from the benefits provided by the inclusion of peer evaluation in the group-based assessments, these techniques also reduce the risk of academic misconducts cases which is a common issue across all disciplines (Simpson & Clifton 2016).

Although there are a wide range of benefits achieved by students, the comprehensive level of feedback provided by a novice is under question due to reliability, accuracy, the degree of students' understanding about the expectation and quality (Potter et al. 2017; Sridharan, Tai & Boud 2019; Sprague, Wilson & Mckenzie 2019). Sprague, Wilson and Mckenzie (2019) notice the variation of feedback in their study depending on level of students. Students with high expertise are able to distinguish between high, moderate and low quality of work and rate according, whereas the low ability students are either reluctant or incapable. Sridharan, Tai and Boud (2019) claim that peers tend to be biased when the scores are added to the final grades. They do not genuinely judge their peers, especially non-contributing students if their feedback affects their academic results.

Technology available for managing group work

Team work can be effectual if collaboration can be cultivated in the group work. There are a number of PM tools available to manage the team in the context of group projects. One of those tools is Asana. Asana is a PM tool designed to bring collaboration and help team track, organise and manage more efficiently. Asana is an effective tool to keep track of work and achieve good outcomes (Asana 2016). Asana developed by Dustin Moskovitz (the co-founder of Facebook) is a web-based software to check how team members are making progress on the project. Asana is not only available on desktops, but also obtainable on iOS and Android (Keiser 2014). This tool eliminates the use of email and brings all necessary features into one software (Abramova, Pires & Bernardino 2016).

Based on a survey participated by Asana Premium customers exhibits that Asana has made team members 1.45 times more efficient. 65% customers reported that Asana has reduced the time consumed on status meetings and email (Asana 2016). Customers using Asana delineate that Asana enhances responsibility among team members, communication, makes team goals clear and meet deadlines as team members will be notified with the deadlines in an advance (Abramova, Pires & Bernardino 2016). Asana helps make a chat with team members, taking notes and file sharing is much easier in Asana as it can work along with Dropbox, one of the commonly used methods of file sharing (Abramova, Pires & Bernardino 2016; Keiser 2014).

Methodology

In conducting this research, the case study strategy was found appropriate to achieve the research aim. The case study attempts to explain a phenomenon in the real-life context from a wide perspective (Taylor & Thomas-Gregory 2015). According to Merriam 2009; Stake 1995; Yin 2014, case study is defined as an approach which focuses on a phenomenon, a variable or a set of variables, or a case happening in the defined time and place context. The phenomenon or case can be a person, an organisation or a group of people. While other qualitative research approaches seek to answer the 'what' of a phenomenon, a case study approach seeks to define 'why' or 'how' a phenomenon works (Polit & Beck 2008). One of the aims of using case study approach is to answer the research question based on the experiences and viewpoints of participants (Castillo-Montoya 2016). A case study approach has widely been implemented as a research methodology in higher education because of its effective and reliability of the results (Stewart, Speldewinde & Ford 2018; Kumar 2015; Scott et al. 2012; Strong & Watts 2005).

This research focuses on 'how' to enhance students' interpersonal skills and diminish their vulnerability to academic misconduct through group-based assessments. The case study design allows collecting data over a period of time and investigating the problem in the real-life context (Yin 2014). This research has used a single case which is appropriate under certain circumstances such as when the case is (a) to test any theory, (b) a unique case, (c) a revelatory case which was inaccessible before and (d) a longitudinal case (Yin 2014). As far as this research is concerned, it is a unique case which presents a systematic approach where group-based assessment has been used to enhance students' interpersonal abilities and minimise students' vulnerability to academic misconduct. A postgraduate unit "Research in Project Management - PPMP20015" within Master of Project Management (MPM) course was selected as a case study. In that unit, a novel approach for group-based assessment was introduced hoping to enhance students' learning experience. Multiple sources of information were used in this study including publicly available information, the unstructured observation of the unit developer and anonymous students' feedback.

The MPM Course is offered by CQUniversity Australia over four metropolitan campuses in addition to online delivery. The course is developed to be completed over two years. The vast majority of students enroled in this course are international students, predominantly from the Asian sub-continent. The first student cohort enroled in the course in term 1, 2016 and since then the course has witnessed an exponential grown in enrolment numbers. Since its inception and until the time of writing, more than 4000 students have enroled or completed the course with the majority of students based in Melbourne and Sydney campuses. The "Research in project management" unit is a core unit within the MPM course offered in the second term of students' study plan. Around 250 students were enroled in the unit in the last two terms. The unit is delivered via 2 hours semi-flipped lectures and 1.5 hours tutorials in computer labs. Tutorial class size is capped at 22 students in order to provide more personalised support to each student. The unit is designed to equip students with essential knowledge and skills associated with developing research proposals in the context of PM discipline. In doing so, students are expected to demonstrate PM competences in planning their research projects. The unit has five unit learning outcomes as follows:

1. Apply PM processes, tools and techniques in articulating, designing and planning for the execution of a research project
2. Develop and employ ethical practices that consider social, cultural and legal responsibilities of researchers
3. Conduct a literature search to identify a problem that warrants research within the PM context
4. Select appropriate research approaches, methods and skills for solving the research problem
5. Prepare a research proposal with necessary components that describe an organised, coherent and convincing statement of the research intent, significance and strategies to conduct the research.

Rationale for the change

When the unit was offered in the first two terms in 2017, it did not include the first learning outcome, listed above, relating to application of PM. In term 1, 2018, the unit was completely redeveloped, and the first learning outcome was introduced as part of a major course restructuring and improvement initiated by the first author. The new learning outcome aimed to make this unit more interesting, engaging and rewarding to students who used to perceive any research method unit as too boring and theoretical.

Originally, students were assessed via two individual assessments: a critical review report (20%) and a research proposal (80%). However, this assessment design was not effective enough in terms of stimulating students to genuinely engage with the assessment task and diminishing their vulnerability to academic misconduct, namely contract cheating. In addition, students missed the opportunity to reinforce their understanding of PM by polishing their learnt concepts and acquired skills in their planning and presentation of their research project proposals in a group setting. Furthermore, the enrolment numbers of students were expected to drastically increase from 86 students in term 1, 2018 to 246 students in term 2, 2018 onwards as a result of the course restructuring as well as its popularity. This means that more cost-effective assessment design would be needed from an operational perspective. Those reasons triggered a holistic review and revision to the assessment design, unit delivery and learning materials that took place during the second terms in 2018. This case study only examines the assessment design relating to group work that was introduced in this unit.

The new assessment design

The new assessment design has evolved and improved over three terms between July 2018 and July 2019 where continuous improvement took place after each term in response to the students' performance and feedback received from students and teaching team. The main objectives of revising the assessment design were to i) stimulate unmotivated students to engage in the learning process and be deterred from engaging in academic misconduct; ii) produce a resilient assessment design that improves student experience and attainment of learning outcomes (see Skaik & Borg 2018) and iii) reduce the marking load. The unit includes two main assessments: 1) critical review report 20% and 2) research proposal 80%. The two assessments are fully personalised; and a novel tool to generate unique research topics is made available to each student in week 1 of the term. The first assessment is undertaken individually as before while the second one was changed to be undertaken in a group setting. In the first assessment, students prepare a critical report around the chosen topic by reviewing relevant scholarly articles in order to build a basic knowledge. The design of the second group assessment is meant to be a challenging project-based assessment that requires each group to ultimately develop a fully detailed research proposal. The assessment includes the following graded stages:

1. Part 2A, 10%: Outline proposal and group presentations (week 7)
2. Part 2B, 20%: Draft research proposal and oral examinations (week 9)
3. Part 2C, 40%: Final research proposal (week 12)
4. Part 2D, 10%: Group member performance evaluation (week 12)

The approach for designing the group assessment consists of five integrated aspects: 1) semi-random group forming 2) development of a group charter, 3) breaking down the main assessment into progressive submissions 4) inclusion of oral presentation & defence and 5) group self and peer evaluation. The assessment design requires students to follow a systematic and progressive approach in order to develop and orally present & defend their group research proposals. The sequential submission process requires students to progressively complete each part of the assessment, many of which are undertaken during the tutorials. By doing so, some complexities are created, as opposed to individual assessment, to challenge group members and mimic the context of real projects.

Group forming

As advocated in the literature, the cornerstone of an effective group-based assessment in the context of PM education is the group forming process that should be given the utmost attention of the educators to be fit for purpose. In this unit, the group assessment is designed to be completed by a semi-randomly formed group of 3-5 students. In forming the groups, the unit coordinator or a delegate takes into consideration the diversity in GPA (as a main factor) in addition to ethnicity and gender (as secondary factors) to achieve some balance in the formed groups. The semi-random allocation largely prevents students with previous relationship to work together in order to minimise the possibility of collusion. The GPA criteria ensure a fairer and more balanced allocation of students across groups whereas high achievers would support low achievers.

As a good practice, groups are formed during the tutorial timing in week 5. Depending on the number of required groups in each class, the unit coordinator or a delegate creates initial equal categories based on their GPA prior to going to class. Then, during tutorials, one member of each category is assigned a unique group. During group forming and based on the tutor's developed knowledge of students' background in the first four weeks, the tutor assigns students considering the ethnicity factor to mitigate vulnerability to collusion. The tutor also ensures that at least two female students are put together in any group in response to an earlier feedback that a sole female in a group feels marginalised and singled out.

Each group member must enrol in their group online by the given deadline. The group must select its group leader (who is not necessarily the one with the highest GPA). Then the group negotiates its own group rules by completing a supplied group charter template during tutorials. The group charter template and relevant handouts are adapted from a book authored by Stein and Hurd (2000). Afterwards, each group discusses and prioritises the project ideas of research projects that were completed as part of the first assessment in order to decide upon the group research topic. Each group must meet on a regular basis and keep a record of group minutes of meetings until the end of the term. All group communications must ideally be conducted through Asana and a privately configured group forum in Moodle (e.g. CQuniversity learning management system). If a group decides to use an external platform, each member must keep a full record of all exchanged communications throughout the term for scrutiny by the faculty. Each group is also required to give a second opportunity to dysfunctional members before reporting them to the respective faculty.

The oral assessment parts

The two oral assessment items are embedded in the assessment to make it more authentic with the aim to not only develop communication skills but also verify that each group member has made a genuine attempt to complete the work and attainted the learning outcomes. Each group member is required to present part of the outline proposal submitted in week 7, to the class during tutorials in week 8 followed by a Q&A session. This graded activity is anticipated to be quite useful and engaging for groups where they learn from each other as well as give and receive timely feedback on the proposal outlines. The feedback will then be incorporated in the draft detailed proposal.

Following the submission of the draft detailed proposal in week 9, each group is required to attend ‘one to one’ interview with the respective tutor during the tutorial in week 10. For interviews, each group is required to bring and make available, all previous digital archives of group communications and earlier versions of drafts. Each group member is expected to explain the content of any part of the draft proposal. The tutor firstly investigates the available records to verify the level of genuine contribution of each group member in undertaking the work. The tutor then asks questions to each group member around the development of the draft detailed research proposal to verify the level of contribution in the project, identify any error or misunderstanding, detect misconceptions and probe the depth of understanding of the assessment task. Each member then receives an individual mark based on the quality of submitted work and performance during the interview. Each group receives constructive feedback on the draft submission, and it is made compulsory to incorporate the given feedback in preparing the final submission.

Group member performance evaluation

Evaluation of group members is the fourth and last deliverable of the assignment. In week 12, students receive an email from the Unit Coordinator inviting them to respond to a compulsory survey by a given deadline. The survey is designed online via a customised platform developed by the university which is synchronised with the unit Moodle site, so, students and group listing can be retrieved automatically. The designed survey for this unit includes five Likert scale rating questions and one open-ended question. The survey aims to evaluate the performance of each group member from various aspects. The following 5-point Likert’s scale questions are used in the survey:

1. This group member is competitive
2. Did work accurately and completely
3. The work contributed by the member is their own work
4. Contributed their fair share of the work
5. Contributed positively to group discussions

Students are required to self-rate their performance and rate each member of their group against the given criteria. To ensure the objectivity of the evaluation, students are informed that the unit coordinator may request groups with suspicious evaluations to provide further evidence.

The efficacy of the introduced assessment design

As observed by the first author who developed and coordinated the unit, the introduced group-based assessment had a positive impact on students' learning experience. Students showed a greater level of ownership, autonomy, commitment and engagement with the unit learning materials and weekly activities. No single academic misconduct case, on the basis of contract cheating or collusion, was reported in the unit after this intervention based on the data from two consecutive terms. The majority of groups met the expectations by undertaking the group assessment as a real project, managing activities using Asana and engaging with stakeholders in an impressive manner. The tutor's commitment was a critical success factor in achieving the objectives of the new assessment design.

In the unit evaluation, many students acknowledged the efforts in the unit development, delivery and assessment design. They also acknowledged the continuous support and guidance from their teaching team that facilitated their learning. Some students considered the new assessment design as the best aspect of the unit being stimulating and challenging. One student said: "*this is the only unit which makes the student very busy throughout the semester and also it helps us to take challenges in each assessment*." A second one noted: *Overall, every assessment task inspired me to learn and give chance to improve your level in research. Each task was well organised and stimulated my interest in the research."* A third one stated: "*I think it encourages everyone to study. Not every was doing good job in assignments previously but due to strict criteria, everyone started getting serious. Even I started thinking about my future through this course. I learned a lot through this course*".

However, some students were concerned about the significant weight of the group assessment (e.g. 80 out of 100 of the overall marks). The assessment requirements were a bit overwhelming and stressful for some students. Two possible factors may have contributed to this: firstly, students felt they were under full scrutiny by their respective tutors in undertaking their group work; secondly, it was the first time for students to undertake a group-based assessment in such systematic manner. One student looked at the overwhelming experience from a positive lens by stating: "*The best thing about this unit is that you have a lot of things to do which is good because due to this you always keep in touch with your unit, and it improves your learning skills*". This view was supported by another student who stated: "*The course was well laid out. The information that was provided, whilst there was a lot and could be overwhelming, it was required for the course and was beneficial and will be useful for future studies*." A third student found the extra load is confined to the group leader only by saying: "*There is a huge amount of burden given to the leader in the second part of assessments, but I understand the goal of the unit which is very close to real life situation. I just hope that this unit will give lesser pressure to future students of this unit."*

Many students commended the way how the groups were formed which resulted in a good mix. Students mentioned that this has encouraged them to get involved in undertaking the assessment. However, students showed divisive views regarding the GPA criterion for group forming. The concerns seem to be mainly raised by high achieving students who found it a bit frustrating to be given a mark almost levelled with other group members who did not put enough efforts. One student said: "*I understand the purpose for this assessment is to get an experience of managing and handling teams. But not everyone in the group care about good marks. The person who cares ends up putting in all efforts."*

Some students found the decomposition of the assessment task into consecutive sub-tasks very helpful. Creating a dummy deadline for students to complete the work in stages helped students to stay organised and improve the ultimate output. The sequential assessment was quite effective in deterring student procrastination. That also enabled tutors to timely track students' progress throughout the term and flag vulnerable students or groups who may need further support. One student said: "*The best aspect is that I have never seen the pattern of assignments like this, it was something beyond my imagination. It means that the way of doing assignments was easy not to hard*". Another student gave a similar comment by saying: "*My best aspect of this unit is assigned tasks, which is well designed and helped to improve in the step by step process*." Students asserted the importance of the timely feedback received on each part to improve subsequent parts. This seems to be a critical success factor in consecutive assessments. A student noted: "*the assignment structure like 2A 2B 2C which where progressive helps us in getting feedback from the professor, that helped a lot in improving the assignment.".*

As observed, embedding oral assessments was quite effective in stimulating, most of (if not all) students to take an active role in undertaking the group work. Some students conveyed that the mere existence of the oral assessments forced low achieving students to put genuine extra efforts in undertaking the assigned tasks and understanding the work developed by other group members in preparation of oral assessments. Oral presentations were also effective in improving the future work of groups by learning from each other and benefiting from the strength of presented works in improving their future work. However, it was observed that some tutors have not engaged enough in reviewing the drafts and preparing appropriate questions before conducting oral examinations.

In terms of self and peer assessment survey, some students found it to be the best part they experienced in the unit. The majority of students provided reasonable rating and comments about their team members as well as themselves. However, it was noted that many students were reluctant to provide low rating to their peers (e.g. less than 3 of 5) despite the fact their comments justified such low rating on the basis of lack of contribution or poor-quality work. This finding emphasises the importance of including the open-ended question in the survey as it was quite helpful in understanding the rationale of given rating and moderating the survey results accordingly.

In terms of PM competencies, students realised the value created by undertaking the group-based assessment tasks in improving the interaction with others, maximining their learning and polishing their soft skills. One student said: "*The best aspects of unit for me was being in the part of group which was really helpful, caring and supportive…my team was like a family. From this unit I think I have built my time management skills*." Another one said: "*I have learnt new tools and techniques that can be used in project management that helps to develop my skills*". A third student said: "*The best thing of this unit is that it makes us work in team with responsibility, and how to manage the team*". Furthermore, students liked the introduction of Asana as a team management tool and the creation of private forums in Moodle for group communications. However, a few students pointed that those interactive tools were not practical and a bit overwhelming, claiming that they had to engage with them just to get marks.

Conclusion

Traditional approaches to group-based assessment in PM education deprive students from many opportunities in improving their soft skills and be better prepared to join the workforce. This paper aims to examine the effectiveness of adopting a systematic approach to group-based assessment in PM tertiary education. To achieve this aim, the paper demonstrated and analysed a case study where the group-based assessment was designed based on good practices in a postgraduate unit offered within Master of Project Management at CQUniversity. As a critical success factor, the group assessment should be a project-based or problem-based assessment. The case study adopts a project-based group assessment. In designing such group assessment, five integrated aspects were considered: 1) semi-random group forming 2) development of a group charter, 3) breaking down the main assessment into progressive submissions 4) inclusion of oral presentation & defence and 5) group self and peer evaluation. The assessment design aimed to not only develop the interpersonal abilities of PM students but also stimulate them to engage genuinely and positively in undertaking the assessments in order to minimise students' vulnerability to contract cheating or collusion. The findings from the unit evaluation and teaching observations of the unit under study indicated that the assessment design had an obvious positive impact on students' learning and motivation levels. The findings revealed that managing the introduced group-based assessment required commitment and active engagement from the teaching team in terms of providing adequate information, forming groups, providing regular feedback to each group, marking the staged submissions and responding to students' enquiries in class and via emails. However, that was considered a little price to pay compared to the benefits and effect of the introduced systematic approach on students' experience and attainment of learning outcomes as demonstrated in the paper. The tested approach may stand as a useful and reliable framework for educators who intend to use or enhance group-based assessments in any discipline.

References

Aaron, J.R., McDowell, W.C. & Herdman, A.O. 2014, ‘The effects of a team charter on student team behaviors’, *Journal of Education for Business*, vol. 89, no. 2, pp. 90-97.

Abramova, V., Pires, F. & Bernardino, J. 2016, ‘Open Source vs Proprietary Project Management Tools’, *New Advances in Information Systems and Technologies,* vol. 1, no. 3, pp. 177-186.

Adachi, C., Tai, J.H.M. & Dawson, P. 2018, ‘Academics’ perceptions of the benefits and challenges of self and peer assessment in higher education’, *Assessment & Evaluation in Higher Education,* vol. 43, no. 2, pp. 294-306.

Asana. n. d, *Asana guide,* viewed 19 August 2019, https://asana.com/guide/resources/info-sheets/why-asana

Atkinson, R. 1999, ‘Project management: cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria’, *International Journal of Project Management*, vol. 17, no. 6, pp. 337–342.

Boud, D. & Soler, R. 2016, ‘Sustainable assessment revisited’, *Assessment & Evaluation in Higher Education,* vol. 41, no. 3, pp. 400-413.

Brown, M. & Bowen, T. 2009, *Project Steering Meeting*, M. Alam, Manchester.

Brown, S. & Knight, P. 2012, *Assessing learners in higher education,* Routledge.

Castillo-Montoya, M. 2016, ‘Preparing for interview research: The interview protocol refinement framework’, *The Qualitative Report*, vol. 21, no. 5, pp. 811-831.

Chen, C.M. & Kuo, C.H. 2019, 'An optimized group formation scheme to promote collaborative problem-beased learning’, *Computer & Education*, vol. 113, pp. 94-115.

Cooley, S.J., Cumming, J., Holland, MJ.G. & Burns, V.E. 2014, ‘Developing the Model for Optimal Learning and Transfer (MOLT) following an evaluation of outdoor group work skills programmes', *European Journal of Training and Developement*, vol. 39, no. 2, pp. 104-121.

Cox, P.L., Bobrowski, P.E. & Maher, L. 2003, ‘Teaching First-Year Business Students to Summarize: Abstract Writing Assignment’, *Business Communication Quarterly,* vol. 66, no. 4, pp. 36–49.

Cumming, J. 2010, ‘Student-initiated group management strategies for more effective and enjoyable group work experiences’, *Journal of Hospitality, Leisure, Sports and Tourism Education,* vol. 9, no. 2, pp. 31–45.

Davis, M.H. & Karunathilake, I. 2005, ‘The place of the oral examination in today's assessment systems’, *Medical Teacher*, vol. 27, no. 4, pp. 294–297.

Dingel, M. & Wei, W. 2014, ‘Influences on peer evaluation in a group project: an exploration of leadership’, *Assessment & Evaluation in Higher Education*, vol. 39, no. 6, pp. 729-742.

Edum-Fotwe, F.T. & McCaffer, R. 2000, ‘Developing project management competency: perspectives from the construction industry’, *International Journal of Project Management*, vol. 18, no. 2, pp. 111-124.

Evans, D.J.R., Zeun, P. & Stanier, R.A. 2014, ‘Motivating student learning using a formative assessment journey’, *Journal of Anatomy* , vol. 224, no. 3, pp. 296–303.

Finch, D.J., Hamilton, L.K., Baldwin, R. & Zehner, M. 2013, ‘An exploratory study of actors affecting undergraduate employability’, *Education & Training,* vol. 55, no. 7, pp. 681-704.

Hashim, R., Aisha, A., Zuhra, F., Salman, H. & Salman, A. 2015, ‘Structured viva as an assessment tool: perceptions of undergraduate medical students’, *Pakistan Armed Forces Medical Journal*, vol. 6, no. 1, pp. 141-144.

Hassall, T., Joyce, J., Arquero, M., Jose, L., Donoso, A. & Jose, A. 2005, ‘Priorities for the development of vocational skills in management accountants: A European perspective’, *Accounting Forum*, vol. 29, no. 4, pp. 379–394.

Hilton, S. & Phillips, F. 2010, 'Instructor-ssigned and Student-selected groups: a view from inside’, *Accounting Education*, vol. 25, no. 1, pp. 15-33.

Huxham, M., Campbell, F. & Westwood, J. 2012, ‘Oral versus written assessments: a test of student performance and attitudes’, *Assessment & Evaluation in Higher Education*, vol. 37, no. 1, pp. 125–136.

Jin, X.H. 2012, ‘A comparative study of effectiveness of peer assessment of individuals’ contributions to group projects in undergraduate construction management core units’, *Assessment & Evaluation in Higher Education*, vol. 37, no. 5, pp. 577-589.

Kearney, S. 2013, ‘Improving engagement: the use of ‘Authentic self-and peer-assessment for learning to enhance the student learning experience’, *Assessment & Evaluation in Higher Education*, vol. 38, no. 7, pp. 875-891.

Keiser, B E. 2014, ‘Tools will keep us together: collaboration for library teams’, *Online Searcher*, vol. 38, no. 1, pp. 52–57.

Kelly, P. 2009, ‘Group work and multicultural management education,’ *Journal of Teaching In International Business*, vol. 20, no. 1, pp. 80-102.

Kelton, A. 2019, ‘Formation and Composition of Students Groups as a Teaching Methodology’, *ProQuest Dissertations and Theses.*

Kiley, M., Holbrook, A., Lovat, T., Fairbairn, H., Starfield, S. & Paltridge, B. 2018, ‘An oral component in PhD examination in Australia: Issues and considerations’, *Australian Universities' Review*, vol. The 60, no. 1, p. 25.

Kimmel, K. & Volet, S. 2009, ‘Significance of context in university students' (meta)cognitions related to group work: a multi-layered, multi-dimensional and cultural appraoch’, *Learning and Instruction*, vol. 20, no. 6, pp. 449-464.

Kumar, M.N. 2015, ‘Improving Student Satisfaction Improves Learning: A Case Study in the Scholarship of Teaching’, *Proceedings of the 26th Annual Conference of the Australasian Association for Engineering Education (AAEE2015), Blended Design and Project Based Learning: A Future for Engineering Education*, Geelong, Victoria, Australia, pp. 6-9.

Lambic, D., Lazovic, B., Djenic, A. & Maric, M. 2018, ‘A novel metaheuristic approach for collaborative learning group formation’, *Journal of Computer Assisted learning*, vol. 34, no. 6, pp. 907-916.

Lei, S.A., Kuestermeyer, B.N. & Westmeyer, K.A. 2010, ‘Group composition affecting student interaction and achievement: instructors’ perspective’, *Journal of Instructional Psychology*, vol. 37, no. 4, pp. 317-327.

Maiden, B. & Perry, B. 2011, ‘Dealing with free-riders in assessed group work: results from a study at a UK university’, *Assessment & Evaluation in Higher Education*, vol. 36, no. 4, pp. 451–464.

Mathieu, J.E. & Rapp, T.L. 2009, ‘Laying the foundation for sucessful team performance trajectories: the roles of team charters and performance strategies’, *Journal of Applied Psychology*, vol. 94, no. 1, pp. 90-103.

Merriam, S.B. 2009, *Qualitative research: A guide to design and implementation*, CA: Jossey- Bass, San Francisco.

McKevitt, C.T. 2016, 'Engaging students with self-assessment and tutor feedback to improve performnace and support assessment capacity’, *Journal of University Teaching & Learning Practice*, vol. 13, no. 1, pp. 2.

Moreno, J., Ovalle, D.A. & Vicari, R.M. 2012, ‘A genetic algorithm approach for group formation in collaborative learning considering multiple student characteristics’, *Computers & Education*, vol. 58, no. 1, pp. 560-569.

Norton, L.S., Scantlebury, E. & Dickins, T.E. 1999, ‘Helping undergraduates to become more effective learners -an evaluation of two learning interventions’, *Innovations in Education and Training International*, vol. 36, no. 4, pp. 273–284.

Osmani, M., Weerakkody, V., Hindi, N. 2017, ‘Graduate attributes in higher education: examining academics’ perception in the Middle east’, *Journal of Education for Business*, vol. 92, no. 2, pp. 53-64.

Os- sanchez, L.B., Ortiz-Marcos, I., Rodriguez-Riveero, R. & Juan-Ruiz, J. 2016, ‘Project management training: an integrated approach for strengthening the soft skills of engineering students’, *International Journal of Engineering Education*, vol. 33, no. 6, pp. 1912-1926.

Ounnas, A., Davis, H.C. & Millard, D.E. 2009, ‘A framework for semantic group formation in education', *Educational Technology & Society*, vol. 12, no. 4, pp. 43-55.

Planas-Llado, A., Feliu, L., Castro, F., Fraguell, R.M., Arbat, G., Pujol, Sunol, J.J. & Daunis-i- Estadella, P. 2018, ‘Using peer assessment to evaluate teamwork from a multidisciplinary perspective’, *Assessment & Evaluation in Higher Education*, vol. 43, no. 1, pp. 14-30.

Pokorny, H. & Pickford, P. 2010, 'Complexity, cues and relationships: student perceptions of feedback’, *Active Learning in Higher Education*, vol. 11, no. 1, pp. 21–30.

Polit, D.F. and Beck, C.T., 2008, *Nursing research: Generating and assessing evidence for nursing practice*, Lippincott Williams & Wilkins.

Potter, T., Englund, L., Charbonneau, J., MacLean, M.T., Newell, J. & Roll, I. 2017, ‘ComPAIR: a new online tool using adaptive comparative judgement to support learning with peer feedback’, *Teachning and Learning Inquiry*, vol. 5, no. 2, pp. 89-113.

Reinholz, D. 2016, 'The The assessment cycle: a model for learning through peer assessment', *Assessment & Evaluation in Higher Education*, vol. 41, no. 2, pp. 301-315.

Roberts, D. 2013, ‘The clinical viva: an assessment of clinical thinking’, *Nurse Education Today*, vol. 33, no. 4, pp. 402–406.

Sadeghi, H. & Kardan, A.A. 2015, ‘A novel justice-based linear model for optimal learner group formation in computer-supported collaborative learning environments’, *Computers in Human Behavior*, vol. 48, pp. 436-447.

Saint, D.A., Horton, D., Yool, A. & Elliott, A. 2015, ‘A progressive assessment strategy improves student learning and perceived course quality in underguate phusiology’, *Advances in Physiologu Education*, vol. 39, no. 3, pp. 218–222.

Salamonson, Y., Metcalfe, L., Alexandrou, E., Cotton, A.H., Mcnally, S., Murphy, J. & Frost, S.A. 2016, ‘Measuring final-year nursing students’ satisfaction with the viva assessment’, *Nurse Education in Practice*, vol. 16, no.1, pp. 91-96.

Scott, G. W., Goulder, R., Wheeler, P., Scott, L. S., Tobin, M. L., & Marsham, S. 2012, ‘The Value of Fieldwork in Life and Environmental Sciences in the Context of Higher Education: A Case Study in Learning about Biodiversity’, Journal of Science Education and Technology, vol. 21, pp. 11-21.

Shenwai, M.R. & Patil, K.B. 2013, ‘Introduction of structured oral examination as a novel assessment tool to first year medical students in physiology’, *Journal of clinical and diagnostic research: JCDR*, vol. *7*, no. 11, p. 2544.

Simpson, G. & Clifton, J. 2016, ‘Assessing postgraduate student perceptions and measures of learning in a peer review feedback process’, *Assessment Evaluation in Higher Education*, vol. 41, no. 4, pp. 501-514.

Skaik, S. & Borg, J. 2018, ‘Towards deterring contract cheating: Stimulating students' motivation through authentic assessment design,’ *In 29th Australasian Association for Engineering Education (*AAEE) *Conference*, p. 640.

Smith, J. L. & Spindle, R.M. 2007, ‘The impact of group formation in a cooperative learning environment’, *Journal of Accounting Education*, vol. 25, no. 4, pp.153-167.

Sprague, M., Wilson, K.F. & McKenzie, K.S. 2019, ‘Evaluating the quality of peer and self evaluations as measures of student contributions to group projects’, *Higher Education Research & Development*, pp. 1–14.

Sridharan, B., Tai, J. & Boud, D. 2019, ‘Does the use of summative peer assessment in collaborative group work inhibit good judgement?’, *Higher Education*, vol. 77, no. 5, pp. 853–870.

Stake, R.E. 1995, *The art of case study research*. Thousand Oaks, CA: Sage.

Stein, R.F. and Hurd, S., 2000. *Using Student Teams in the Classroom: A Faculty Guide*. Anker Publishing Company, Inc., 176 Ballville Road, PO Box 249, Bolton, MA 01740-0249.

Stewart, B., Speldewinde, P. & Ford, B. 2018, ‘Influence of improved teaching practices on student satisfaction ratings for two undergraduate units at an Australian university’, *Assessment & Evaluation in Higher Education*, vol. 43, no. 4, pp. 598-611.

Strong, T. & Watts, T. 2005. ‘Improving Outcomes by Improving Student Satisfaction: A Case Study of a Small Accounting Program’, *5th Annual Hawaii International Conference on Business 2005 Conference Proceedings*, pp.2873-2888.

Sverdrup, T.E. & Schei, V. 2015, ‘Cut Me Some Slack: The psychology contracts as a foundation for understaniding team charters’, *The Journal of Applied Behavioral Science*, vol. 51, no. 4, pp. 451-478.

Sverdrup, T.E., Schei, V. & Tjolsen, O.A. 2017, ‘Expecting the unexpected: using team charters to handle disruptions and facilitate team performance’, *American Psychological Association*, vol. 21, no. 1, pp. 53-59.

Taylor, R. & Thomas-Gregory, A. 2015, ‘Case study research’, *Nursing Standard*, vol. 29, no. 41, pp. 36-40.

Thomas, J., Raynor, M. & Mckinnon, M. 2014, ‘Academic integrity and oral examination: an Arabian Gulf perspective’, *Innovations in Education and Teaching International*, vol. 51, no. 5, pp. 533–543.

Winter, M., Smith, C., Morris, P., Cicmil, S. 2006, 'Directions for future research in project management: The main findings of a UK government-funded research network', *International Journal of Project Management*, vol. 24, no. 8, pp. 638–649.

Wooldridge, A. 2005, *The brains business: A survey of higher education*, Economist Newspaper.

Wosnitza, M. & Volet, S. 2014, 'Trajectories of change in university students’ general views of group work following one single group assignment: significance of instructional context and aspects of experience', *European Journal of Psychology and Education*, vol. 29, no. 1, pp. 101-105.

Yin, R.K. 2014, *Case study research: Design and methods (5th ed.)* Thousand Oaks, CA: Sage.

CRITICAL SUCCESS FACTORS OF PUBLIC PRIVATE PARTNERSHIPS (PPPs) IN NEW ZEALAND

Nasir Rasheed[1], Cresencio Angob Tejano Jr[1], Wajiha Shahzad[1], James Olabode Rotimi[1]

[1]School of Built Environment, Massey University, Auckland, New Zealand

Abstract

Funding modern day projects in the face of declining public reserve pools has influenced the scale of infrastructure provision. Public private partnership (PPP) emerged as an effective solution for delivering infrastructure in many countries. However, not all projects have been reported successful. Literature suggests that an understanding of critical success factors (CSFs) is imperative to achieving project goals/successes, hence CSFs for PPPs has generated research interests worldwide. However, there is little to no research in this area in New Zealand. To address this gap, this study established a rank-order of CSFs, which could improve the delivery of future PPP projects in New Zealand. 27 CSFs were identified from the review of literature and presented to PPP practitioners, to capture their perceptions in New Zealand. The questionnaire survey was essentially Likert scaled. Findings revealed that "approval and negotiation process", "innovation and project complexity", "client's brief", "project's technical feasibility" and "strong private consortium" are five top ranked factors. In future, as more responses are collected, factor analysis technique will be used to explore the grouping of these factors to enable valuable deductions. The results of the study can assist stakeholders in policy formulation and investment related decision-making.

Keywords: Public private partnerships, Mean value analysis, Critical success factors, Infrastructure

Introduction

Infrastructure demand is on the rise with the ever-growing urban population worldwide (Mcnichol, Cooper & Sturmy 2015). Governments are struggling to keep up with such high level of investments in infrastructure. Hence, innovative procurement methods, which involve the private sector, have become a necessity to remedy this situation. One such method is public private partnerships, which helps public sector to achieve its goal of infrastructure provision by tapping into resources of private sector. Moreover, it provides private sector an opportunity to capitalize on its investment. PPP is a popular choice for project delivery and has grown in the recent years with a key reason being the unprecedented lack of economic growth all over the world (Kleimeier & Versteeg 2010).

PPP has been utilized to deliver transport, telecommunication and energy sector projects for infrastructure expansion in numerous cases (Carnis & Yuliawati 2013). A key reason behind increasing popularity of PPPs worldwide is the execution of numerous successful projects (Hodge & Greve 2007). It has been used to achieve value for money with the help of private sector involvement in countries like China, UK, Malaysia and Australia (Chou & Pramudawardhani 2015).

In past, provision, improvement and operation of general infrastructure was achieved using public finances. However, after the rise of PPP more recently, public sector is using private sector's expertise to provide infrastructure (Iossa & Martimort 2015; Bwanali & Rwelamila 2017). Private sector is normally engaged through the use of concession contracts for a pre-determined period of time (Ross & Yan 2015).

The incentive for application of PPP lies primarily in its ability to allocate different risks to the project parties (Sastoque et al. 2016). However, if not managed properly, these risks can result in project failure as well. For this reason, PPP is not considered suitable for projects having high amounts of uncertainty and insecurity of cash flows (Blanc-Brude & Makovsek 2013). It is rarely used for research and development activities, product launching and other possible risk heavy endeavours. So, projects having manageable risks and well-established operating methodologies are ideal candidates for PPP application (Grimsey & Lewis 2007). These risks can be related to different project stages such as conception, planning, construction and operation.

New Zealand government showed its interest in pursuing PPP option for infrastructure development in 2009. Infrastructure Transaction Unit (ITU) was established to streamline the process for PPP implementation (Liu & Wilkinson, 2011). PPP policy published by the government highlighted its intentions to prefer PPP over traditional methods of delivery provided they deliver value for money (Treasury New Zealand 2015). National Infrastructure Plan issued in 2010, stressed Government's priorities for infrastructure and its willingness to use PPPs across sectors. Mayoral position paper on PPPs, published in 2013, identified PPPs as a viable procurement strategy in New Zealand.

Hobsonville schools project was the first project procured through "Design, Build, Finance and Maintain (DBFM)" modality of PPP under a concession contract of 25 years in 2012. Since then, ten new social infrastructure project, including schools and prisons, have been launched and executed, most of which are in operation stage. Furthermore, two road infrastructure projects are in their construction stage (Treasury New Zealand 2018).

With the increasing popularity of PPPs internationally, a number of areas related to PPP have been researched upon. A considerable attention has been paid to research domains relevant to relationship management, government regulation and guarantees, procurement and legal issues within PPPs (Osei-Kyei & Chan 2015). A research trend established by Zhang et al. (2016) by systematically reviewing PPP literature in Chinese and international journals revealed PPP success factors as a promising area for research. Ke et al. (2009) also stressed the importance of this area in his study, which established seven major areas for PPP research. It is evident from such indicators that research interest in this area will only grow, as PPPs are continuously being applied in other markets around the world.

Al-Saadi & Abdou (2016) suggests that critical success factors are considered vital for successful implementation of PPP projects. Various research methods such as interviews, questionnaires and case studies have been used in the past to investigate these CSFs in numerous countries. However, there is little known about these CSFs in countries such as New Zealand which have just began to adopt PPPs. This study aims to address this gap by conducting an investigation into the factors critical for success of PPP projects in New Zealand perspective.

To achieve this goal, this study followed a three-step approach. In the first step, 27 CSFs were identified by reviewing PPP literature. A 5-point Likert scale questionnaire survey was conducted in the second step, which gathered the opinions of PPP practitioners working in New Zealand concerning the importance of the identified factors. In the last step, mean score of factors was used to ranked them which indicated their relevant importance. The top five factors were selected for discussion.

Literature Review

According to Sehgal & Dubey (2019) CSFs are those particular features and activities of a project, which result in its favourable result when followed in execution of the project. The concept of CSFs has been around since the 1970s (Osei-Kyei & Chan 2015). Its application in numerous areas such as information systems, business services and manufacturing industry has been observed as a managerial tool (Li et al. 2005). Jefferies (2006) argued that these factors have a positive influence on the outcome of the project if managed periodically.

Since the early 1990s, several researchers have applied this idea of CSFs to formulate and understand PPP policy and guidelines (Zhang et al. 2016). A lot of research has been undertaken to identify CSFs in countries such as UK, Australia, China, Singapore, Malaysia, Nigeria and Ghana (Li et al. 2005; Jefferies et al. 2002; Jefferies 2006; Qiao et al. 2001; Chan et al. 2010; Hwang et al. 2013, Ismail, 2013; Olusola et al. 2012). A range of areas of PPPs from different sectors consisting of various project models within PPP has been explored in these studies. Some of these sectors for which CSFs have been explored by researchers include transportation, power, telecommunication and housing.

Qiao et al. (2001) identified and analysed 27 CSFs of BOT projects in China against different stages of the project. They argued that "stable political and economic situation" needs to be given importance in the evaluation phase of the project. Moreover, factors such as "technical solutions" for tendering stage, "reasonable risk allocation" for award phase, "competent project team" for construction phase and "management control" for operation phase of the project were identified to be important. Similarly, Zhao et al. (2010) investigated 31 success factors for Chinese PPP power projects that were delivered using the "build own transfer (BOT)" mode by reviewing relevant literature and carrying out interview with experts.

A recent study by Yang et al. (2017), followed a similar approach in exploring the CSFs for BOT projects in China. Their findings reveal that "reasonable risk allocation", "government support and guarantee", "a strong project consortium" and "project technical feasibility" are top ranked important CSFs for BOT project in China.

On the other hand, despite the unique characteristics of PPP projects several studies have also engaged this concept of CSFs for PPP infrastructure projects in general, without specifying sector or project type (Ismail 2013; Chan et al. 2010).

Li et al. (2005) identified 18 CSFs for PPP/PFI projects in the UK construction industry and examined their relative importance using a questionnaire survey. Mean analysis of these factors found "appropriate risk allocation", "strong private consortium" and "available financial market" to be the most crucial factors. Similarly, for an Australian sports stadium project, Jefferies et al. (2002) identified and examined 15 CSFs, which was delivered using the "build operate own transfer (BOOT)" mode of PPP. "Technical innovation", "efficient approval process", "solid consortium" and "good resource management" were found to be the most significant CSFs. The findings suggest that the negotiation process plays a key role in project success.

Following Li et al. (2005) 18-CSF list, Chan et al. (2010) explored this concept in People's Republic of China. An empirical questionnaire survey instrument was employed to solicit the views of Chinese PPP experts. They employed factor analysis technique to group these factors into clusters which are, "macroeconomic stability", "shared responsibility between public and private sectors", "transparency in procurement", "stability in political and social atmosphere" and "informed government". They further concluded that the factor group "stable macroeconomic environment" is very critical due to rapidly changing global financial situation. Ismail (2013) also adopted the same methodology to study these CSFs in Malaysian PPP projects.

Following the New Zealand government's decision to pursue PPP as a procurement model, Liu and Wilkinson (2011) investigated the barriers and drivers for its adaptation in New Zealand's perspective. They used semi-structured interviews with PPP experts to investigate these issues. Some of the drivers in their findings are also the key critical success factors highlighted in a number of international critical success factors studies, namely, better risk allocation and whole of life cost savings.

Asquith et al. (2015) studied the effect of political influence on PPP health sector project in New Zealand. They conducted an exploratory study to identify the critical success factors for partnerships contracts in the health sector. Their findings suggest that clear contractual relationships, commitment and trust play key roles in determining the success of these partnerships. Furthermore, private sector respondents showed their concern about reforms in the political process, which dictates their decisions about entering into these partnerships.

Although several previous studies address CSFs related to PPP in international literature, studies focusing this area in New Zealand’s context remain sparse. Moreover, due to distinctive characteristics of PPP to a country require a study on CSFs specifically for PPP in that country. Hence, this present study fills the gap by investigating the CSFs for implementation of PPP in New Zealand. The factors noted above from the most prominent studies have been extracted into 27 CSFs, as shown in Table 1.

Table 1: List of CSFs identified from literature

Critical Success Factors	References								Total
	1	2	3	4	5	6	7	8	
Appropriate risk allocation	*	*	*	*	*	*	*	*	8
Strong private consortium	*	*	*	*	*	*	*	*	8
Favourable legal framework	*	*		*	*	*	*	*	7
Transparency in procurement	*	*	*	*	*	*		*	7
Political support	*	*	*	*		*	*		6
Strong and committed public authority	*			*	*	*	*	*	6
Risk sharing	*			*	*	*	*		5
Adequate financial market	*		*	*		*	*		5
Stable macroeconomic conditions	*			*		*	*	*	5
Credible cost benefit analysis	*			*		*	*	*	5
Social support	*		*	*		*		*	5
Government guarantees	*		*	*		*		*	5
Commitment and responsibility	*	*		*		*			4
Sound economic policy	*			*		*		*	4
Shared authority	*				*	*		*	4
Sound governance	*		*			*		*	4
Multipurpose project targets	*			*		*		*	4
Competitive procurement	*		*			*			3
Project's technical feasibility	*		*					*	3
Client's brief		*	*						2
Innovation/Project complexity							*		2
Approval and negotiation process		*							1
Environmental impact		*							1
Community support		*							1
Business diversification			*						1
Credit rating of investors		*							1
Availability of suitable financier		*							1

References: 1 = (Li et al. 2005); 2 = (Jefferies 2006); 3 = (Chan et al. 2010); 4 = (Ismail 2013); 5 = (Hwang et al. 2013); 6 = (Chou & Pramudawardhani 2015); 7 = (Al-Saadi & Abdou 2016); 8 = (Yang et al. 2017)

Research Methodology

The critical success factors were identified from existing literature. These factors have received recognition from a number of researchers in their studies as showcased in Table 1. Moreover, the respondents were requested to list any significant factor in the survey, which might have been missed during the review of literature. The research data for the current study was derived from the 27 CSFs identified from literature, using a five-point Likert scale questionnaire survey. Many other studies have utilized similar kind of scale in the area of construction management (Li et al. 2005; Chan et al. 2010; Ismail, 2013; Yang et al. 2017).

The survey measured the opinions of PPP professionals from public and private sectors in New Zealand regarding CSFs for PPPs. The complete questionnaire comprised two parts. The first part contained questions about the respondents' individual profiles and the second part surveyed the respondent's level of agreement against each of the identified CSFs. Questionnaire was pre-tested with the help of three academic and PPP professionals, before the start of data collection. Their proposed changes were incorporated in the questionnaire to help the respondents understand questions better.

The questionnaire survey was administered through Survey Monkey in July 2019 among New Zealand practitioners with involvement in PPP projects. Convenience sampling method was adopted to gather responses. Initial set of respondents were approached from an on-going PPP project. Considering the level of experience of these individuals in PPP scene, it was expected that they had connections with other potential respondents also, hence, some of the them were asked to distribute the survey form link to their peers as well.

The data was analysed using mean value analysis (MVA) and based on calculated mean scores, ranking of CSFs was generated. This method has been used by several studies in the past to analyse similar kind of data (Ismail 2013; Hwang et al. 2013). MVA is considered an acceptable method for ranking factors; however, it does not take into account interdependency of factors (Chou & Pramudawardhani 2015). Cronbach's alpha using SPSS was calculated to check the reliability of the data. Cronbach's Alpha value was 0.966 suggesting high reliability of the data.

Findings and Discussion

It was anticipated that some respondents might not be familiar with all the success factors identified from literature. To remove any bias from the data obtained from the survey respondents, an additional 'no idea' option for each question was included. Moreover, to safeguard the quality of the data, 11 responses were excluded from the analysis for their incompleteness.

Basic information gathered from the first section of questionnaire is presented in Table 2. Most of the respondents belong to the private sector. Efforts are being made to get more responses from the public sector at this ongoing data collection stage. Out of the total 33 valid responses, 29 belong to the private sector. About half of the private sector respondents have gained their PPP experience working with the main contractor.

Only 15% of the respondents have PPP work experience of more than 15 years. This could be due to the relatively new nature of PPPs in New Zealand. In addition, 35% of the respondents have also worked on PPP project outside New Zealand.

Table 2: Basic information of survey participants

Item	Type	Frequency	Percentage (%)
Public	Central government	2	6
	Local government	2	6
Private	Main contractor	16	48
	Consultant	2	6
	Subcontractor	6	18
	Others	5	15
			100
Position	Project Director	3	9
	Construction Manager	2	6
	Project Manger	9	27
	Project Engineer	2	6
	Quantity Surveyor	3	9
	Planning Engineer	2	6
	Others (Supervisor, Contract administrator, Area manager etc.)	12	36
			100
Experience	upto 5 years	19	58
	5-10 years	6	18
	11-15 years	3	9
	Over 15 years	5	15
			100
Country	New Zealand	21	64
	Australia	3	9
	UK	3	9
	Ireland	2	6
	Others	4	12
			100

Ranking of Critical Success Factors (CSFs)

Mean value analysis of the survey responses for the identified CSFs is used to rank factors in order of their importance. Mean scores for these factors range from 4.03 to 3.06 as shown in Table 3. The results indicate that only one factor is above the mean score of 4 and all of the remaining factors lie in the mean value range of 3 to 4.

The top five important factors based on respondent’s perception are approval and negotiation process, innovation based on complexity of the project, client’s brief, project’s technical feasibility and strong private consortium. A brief discussion of these factors is provided in the following paragraphs.

Table 3: Mean scores of CSFs

Rank	CSFs	Mean Score
1	Approval and Negotiation Process	4.03
2	Innovation/Project Complexity	3.94
3	Client's Brief	3.91
4	Project's Technical Feasibility	3.82
5	Strong Private Consortium	3.82
6	Sound governance	3.76
7	Appropriate Risk Allocation	3.74
8	Credible cost benefit analysis	3.74
9	Competitive Procurement	3.74
10	Transparency in procurement	3.74
11	Strong and committed public authority	3.74
12	Sound Economic Policy	3.68
13	Environmental Impact	3.65
14	Risk Sharing	3.65
15	Commitment and Responsibility of Public and Private Sectors	3.62
16	Availability of Suitable Financier	3.56
17	Multipurpose project targets	3.56
18	Community Support	3.53
19	Political Support	3.53
20	Shared Authority between Public and Private Sectors	3.47
21	Favourable Legal Framework	3.41
22	Social Support	3.35
23	Government Guarantees	3.29
24	Adequate Financial Market	3.26
25	Credit Rating of Investors	3.26
26	Business Diversification	3.21
27	Macroeconomic stability	3.06

Approval and negotiation process is identified as the most important factor for success of PPP projects in New Zealand. PPP tend to have a complex approval and negotiation process (Li et al. 2005). Jefferies (2006) identified this factor to be crucial for success in his case study of Australian Super Dome project. He argued that it can help identify key issues to be resolved at the early stage.

Innovation and project complexity is perceived as the second most important CSF by the study participants. Solving complex project issues through the use of innovative methods is one of the strong suits of private sector. It is one of the key reasons for private sector involvement in provision of public infrastructure as public sector often lacks the use of inventive techniques (Cheung and Chan 2010). As most of the respondents at this stage of the study belong to private sector, the second rank of this sector is somewhat justified.

Client's brief, with a mean value of 3.91 is the third most important CSF in New Zealand's perspective. A client's brief helps in clear communication of public sector requirements which play a vital role in the success of PPPs (Cheung et al. 2012).

Project's technical feasibility and strong private consortium are ranked fourth/fifth by the participating respondents with mean values of 3.82. These factors have received considerable attention from PPP practitioners in other countries as well. Li et al. (2005) in his study for PPP CSFs for UK construction industry ranked project's technical feasibility at sixth position. Strong private consortium on the other hand was identified as the top ranked factor in the same study.

Project company's ability to effectively handle the technical aspects play an important role in winning the contract. An effective feasibility report should address the technical problem associated to the project (Chan et al. 2010). Moreover, a strong private consortium helps the private sector participants to take advantage of each other's strengths. This helps them deal with the relevant project risks in a cooperative manner which is essential for achieving project objectives (Verweij et al. 2019).

Surprisingly, the success factor 'Macroeconomic stability' has not gotten much attention from the respondents and ranks last in the table above. In Chan et al. (2010) ranking of CSFs it was ranked fourth. Li et al 2005 also emphasized the importance of favourable economic condition for successful execution of PPP projects. New Zealand enjoys a stable economy (OECD 2019), which is one of the potential reasons for this factor's low importance in respondents' point of view.

Conclusion

PPP has emerged as an innovative way of procuring public infrastructure projects. Private sector expertise and finances are used for provision of a project or service under long term contracts. These long-term contracts and complex arrangements can cause many issues during this process. Success of the project is dependent on many factors which if managed properly can lead to positive results.

This study examined the relevant critical success factors of PPP in New Zealand and ranked them in order of their importance. The findings show that all factors have a mean score of more than 3 which indicate that they were somewhat significant in PPP practitioners' views. Some of the top ranked factors are approval and negotiation process, innovation and project complexity, client's brief, project's technical feasibility and strong private consortium.

In future, as more responses are collected from public and private sector participants, factor analysis technique will yield useful factor groupings. Moreover, a comparison between the perceptions of public and private sector parties can generate some useful insights.

There are some limitation to this study. Firstly, the CSFs are collected from the literature in general and from international PPP experience in other countries, some of which might not reflect a true representation of New Zealand. Secondly, all of the identified CSFs may not apply to all the PPP projects due to their generic nature. A project specific context, such as PPPs in social or road infrastructure, may be investigated in future. Lastly, similar studies can be conducted using a different research instrument such as case study or interviews to highlight the opinions of the practitioners.

References

Al-saadi, R. & Abdou, A. 2016. Factors critical for the success of public–private partnerships in UAE infrastructure projects: experts' perception. *International Journal of Construction Management,* 16**,** 234-248.

Asquith, A., Brunton, M. & Robinson, D. 2015. Political Influence on Public–Private Partnerships in the Public Health Sector in New Zealand. *International Journal of Public Administration,* 38**,** 179-188.

Blanc-Brude, F. & Makovsek, D. 2013. Construction risk in infrastructure project finance. *Research, EDHEC Risk Institute, February*.

Bwanali, S. & Rwelamila, P. D. 2017. Public Private Partnerships: A possible alternative for delivery of infrastructure projects in Africa. *International Journal of Construction Supply Chain Management* 7(3), 93-109.

Carnis, L. & Yuliawati, E. 2013. Nusantara: Between sky and earth could the PPP be the solution for Indonesian airport infrastructures? *Case Studies on Transport Policy,* 1**,** 18-26.

Chan, A. P., Lam, P. T., Chan, D. W., Cheung, E. & Ke, Y. 2010. Critical success factors for PPPs in infrastructure developments: Chinese perspective. *Journal of Construction Engineering and Management,* 136**,** 484-494.

Cheung, E. & Chan, A. P. 2010. Evaluation model for assessing the suitability of public-private partnership projects. *Journal of management in engineering,* 27**,** 80-89.

Cheung, E., Chan, A. P. & Kajewski, S. 2012. Factors contributing to successful public private partnership projects: Comparing Hong Kong with Australia and the United Kingdom. *Journal of Facilities Management,* 10**,** 45-58.

Chou, J.-S. & Pramudawardhani, D. 2015. Cross-country comparisons of key drivers, critical success factors and risk allocation for public-private partnership projects. *International Journal of Project Management*, 33**,** 1136-1150.

EY. 2013. Mayoral Position Paper on Public Private Partnerships. Available: http://media.nzherald.co.nz/webcontent/document/pdf/201348/PPPStudyForAttachmen1.pdf.

Grimsey, D. & Lewis, M. 2007. Public private partnerships: The worldwide revolution in infrastructure provision and project finance, Edward Elgar Publishing.

Hodge, G. A. & Greve, C. 2007. Public–private partnerships: an international performance review. *Public administration review,* 67**,** 545-558.

Hwang, B.-G., Zhao, X. & Gay, M. J. S. 2013. Public private partnership projects in Singapore: Factors, critical risks and preferred risk allocation from the perspective of contractors. *International Journal of Project Management,* 31**,** 424-433.

Iossa, E. & Martimort, D. 2015. The simple microeconomics of public-private partnerships. *Journal of Public Economic Theory,* 17**,** 4-48.

Ismail, S. 2013. Critical success factors of public private partnership (PPP) implementation in Malaysia. *Asia-Pacific Journal of Business Administration,* 5**,** 6-19.

Jefferies, M. 2006. Critical success factors of public private sector partnerships: A case study of the Sydney SuperDome. *Engineering, Construction and Architectural Management,* 13**,** 451-462.

Jefferies, M., Gameson, R. & Rowlinson, S. 2002. Critical success factors of the BOOT procurement system: reflections from the Stadium Australia case study. *Engineering, Construction and Architectural Management,* 9**,** 352-361.

Ke, Y., Wang, S., Chan, A. P. & Cheung, E. 2009. Research trend of public-private partnership in construction journals. *Journal of Construction Engineering and Management,* 135**,** 1076-1086.

Li, B., Akintoye, A., Edwards, P. J. & Hardcastle, C. 2005. Critical success factors for PPP/PFI projects in the UK construction industry. *Construction management and economics,* 23**,** 459-471.

Liu, T. & Wilkinson, S. 2011. Adopting innovative procurement techniques: obstacles and drivers for adopting public private partnerships in New Zealand. *Construction Innovation,* 11**,** 452-469.

Mcnichol, D., Cooper, M. W. & Sturmy, T. 2015. Construction Goes Global: Infrastructure and Project Delivery Across Borders. AIG.

Ng, A. & Loosemore, M. 2007. Risk allocation in the private provision of public infrastructure. *International Journal of Project Management,* 25**,** 66-76.

OECD. 2019. Economic survey of New Zealand [Online]. Available: http://www.oecd.org/economy/new-zealand-economic-snapshot/ [Accessed].

Olusola, B. S., Opawole, A. & Emmanuel Akinsiku, O. 2012. Critical success factors in public-private partnership (PPP) on infrastructure delivery in Nigeria. *Journal of facilities management,* 10**,** 212-225.

Osei-Kyei, R. & Chan, A. P. 2015. Review of studies on the Critical Success Factors for Public–Private Partnership (PPP) projects from 1990 to 2013. *International Journal of Project Management,* 33**,** 1335-1346.

Qiao, L., Wang, S. Q., Tiong, R. L. & Chan, T.-S. 2001. Framework for critical success factors of BOT projects in China. *The Journal of Structured Finance,* 7**,** 53-61.

Ross, T. W. & Yan, J. 2015. Comparing public–private partnerships and traditional public procurement: Efficiency vs. flexibility. *Journal of Comparative Policy Analysis: Research and Practice,* 17**,** 448-466.

Sastoque, L. M., Arboleda, C. A. & Ponz, J. L. 2016. A proposal for risk allocation in social infrastructure projects applying PPP in Colombia. *Procedia Engineering,* 145**,** 1354-1361.

Sehgal, R. & Dubey, A. M. 2019. Identification of critical success factors for public–private partnership projects. *Journal of Public Affairs***,** e1956.
Treasury New Zealand 2015. The New Zealand PPP Model and Policy: Setting the Scene. Available: https://treasury.govt.nz/sites/default/files/2015-10/ppp-public-model-and-policy-sep15.pdf
Treasury New Zealand. 2018. Public Private Partnership Projects [Online]. Available: https://treasury.govt.nz/information-and-services/nz-economy/infrastructure/nz-infrastructure-commission/infrastructure-transactions-unit/public-private-partnerships/projects [Accessed 2019].
Verweij, S., Loomans, O. & Leendertse, W. 2019. The Role of the Public Partner in Innovation in Transport Infrastructure PPPs: A Qualitative Comparative Analysis of Nine Dutch DBFM Projects. *Public Works Management & Policy***,** 1087724X19847215.
Yang, J., Nisar, T. M. & Prabhakar, G. P. 2017. Critical success factors for build–operate–transfer (BOT) projects in China. *The Irish Journal of Management,* 36**,** 147-161.
Zhang, S., Chan, A. P., Feng, Y., Duan, H. & Ke, Y. 2016. Critical review on PPP Research–A search from the Chinese and International Journals. *International Journal of Project Management,* 34**,** 597-612.
Zhao, Z.-Y., Zuo, J., Zillante, G. & Wang, X.-W. 2010. Critical success factors for BOT electric power projects in China: Thermal power versus wind power. *Renewable Energy,* 35**,** 1283-1291.

PERSPECTIVE: SUSTAINABLE SOLUTION TO THE CONSEQUENCE OF THE MINING INDUSTRY RECYCLING MINING WASTE MATERIALS TO LIGHTWEIGHT GREEN BUILDING MATERIALS

Boon K. Ng[1], Ee Ling Yong[2], Farzaneh Tahmoorian[1], Hana Speering[3] and Ronald Webber[1]

[1]School of Engineering & Technology, Central Queensland University, Mackay, QLD 4740, Australia

[2]Department of Water and Environmental Engineering, School of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia

[3]School of Medicine, University of Wollongong, Wollongong, NSW 2522, Australia

Abstract

Australia is noted for its promotion to make the environment greener in order to improve sustainability. However, the reliance on mining export has been questionable in relation to environmental contaminants in Australia, due to the mining activities. Mining wastes, by-products of mining activities, possess the potential for environmental hazards. This is especially detrimental when no other disposal solution other than landfill is deemed viable to contain the waste materials. This is due to leaching of its heavy metal contents into the soil, resulting in potent contamination of agricultural soil as well as underground water. Sludge is one of the mining waste products. The historical handling method for its disposal is landfill or staging ground. Since the last decades, remediation of mining wastes has been enforced by legislation. That is to say, there has been no solution deemed sustainable as toxic chemicals including arsenic, mercury, chromium, and cadmium are all present in the waste, can contaminate both soil and drinking water. In the worst-case scenario, apart from soil contamination, there is the potential for human suffering through the shutting down of vital human organs and the central nervous system due to these contaminants being ingested. A recent technology, in converting marine clay into lightweight green building materials, has been proven as a prominent alternative use for contaminated soil. This study is to critically review the feasibility of using this technology to address the environmental landfill problems via converting the environmentally hazardous mining waste (sludge), to other waste materials to lightweight aggregates. These aggregate materials can further be utilized for various value-added green building applications, including lightweight partition wall, thermal insulative panel, and lightweight brick. This paper aims to evaluate, review, comment and provide perspective based on the previous research studies, accessing its viability and transferability as fundamental before carrying out the research activity.

Keywords

Mining waste, sludge, coal bottom ash, acid mine drainage, lightweight aggregate, green building material

Mining wastes

In any mining activity, mineral waste is the by-product resulted from these three phases, namely mining, minerals processing, and metallurgical process. During these processes, any inefficiency in each phase is likely to result in a mineral loss to waste rock, tailings, sludge, slag, leached ore as well as mine wastewater, illustrated in Figure 1. There are substantial quantities of heavy metal species present in the wastewater resulting in ecological contamination of agricultural soil as well as underground water (Lèbre et al., 2017). Lottermoser *et al.* (Lottermoser, 2011) reported a comprehensive discussion on types of mining wastes and their sources.

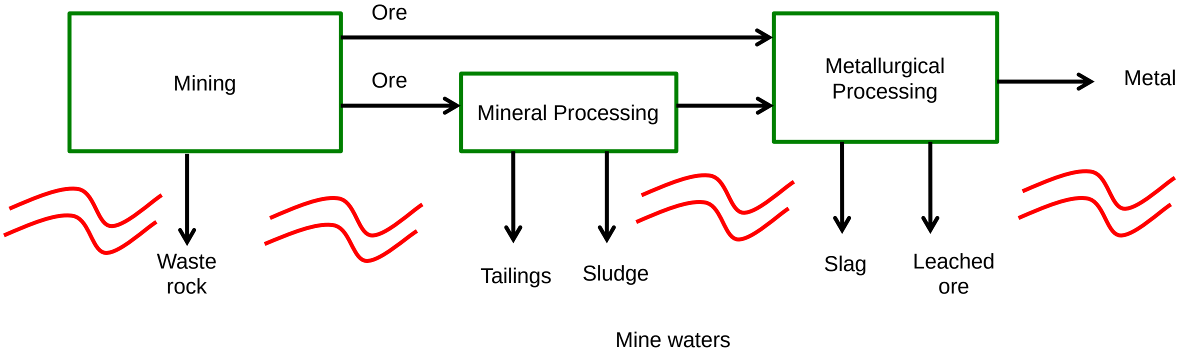


Figure 1 Origins of mineralised waste

Environmental contamination by mining waste and acid mine drainage

Uncontrolled mining activities have led to the production of high levels of hazardous wastes worldwide (Ashley et al., 2003, Ashley et al., 2004, Bhattacharya et al., 2006, Jung, 2008, Lèbre et al., 2017, Modabberi et al., 2013). These wastes are typically associated with a high proportion of acid-generating sulfide minerals; and toxic metals and metalloids including As, Sb, Cu, Pb, Cd, Zn, Hg, Ag, Sn, Fe, Al, Mn, Tl, U, Th and W (Ashley et al., 2003, Ashley et al., 2004, Bhattacharya et al., 2006, Jung, 2008, Lèbre et al., 2017, Modabberi et al., 2013). These contaminants present in tailings and sludge will cause a major ecological disruption to the aquatic and terrestrial system via erosion, dispersal, leaching and atmospheric transportation (Anawar et al., 2011, Anawar, 2015, Paktunc et al., 2003). Furthermore, landfill (Anawar, 2015, Juillot et al., 1999), pedogenesis (Anawar, 2015, Courtin-Nomade et al., 2005), chemical weathering and formation of sulfide derivatives and Fe, Mn and Al oxyhydroxide derivatives have resulted in acid mine drainage (AMD, see Figure 2) within the locality, such as the mine site, neighboring residential and/or agricultural communities and marine ecology (Anawar, 2015, Bhattacharya et al., 2006, Luptakova et al., 2012). It is evident that the mining activities have detrimental impacts exert on environmental degradation, water, and soil contamination and loss of biodiversity. In short, mining activities possess major health risks to residents living within the community, probable extinction of animal, plant and marine species due to biotoxicity. In the worst-case scenario, apart from soil contamination, there is a potential for human suffering through the shutting down of vital human organs and the central nervous system (Anawar, 2015, Hamilton, 2000, Zhuang et al., 2009).

Figure 2 Illustration of pollution caused by AMD: (A) AMD effluents, (B) blooms of secondary efflorescent minerals in Morocco (A and B are reproduced from Ref. ((Khalil et al., 2014), copyright 2014), (C and D) AMD in South Africa (reproduced from Ref. (Clay et al., 2013), copyright 2013 Deloitte & Touche), (E) Cyanide leach, (F) Sulphide deposits in Canada generated by mining (E and F, reproduced from Ref. (Burtnyski, 2007), copyright 2014),, (G) Stream affected by AMD in the United States reproduced with permission from Ref. (Schaider and Hauri, 2009) copyright 2009, (H) AMD originated from gold mining in South Africa at Hippo Dam of the Krugersdorp Game Reserve. (reproduced from Ref. (Kefeni et al., 2017), copyright 2011)

Remediation technologies to address the mining waste and acid mine drainage

Reliance on landfill as a disposal option is unsustainable, a framework of remediation and rehabilitation has been specifically legislated to protect the environment, land and water resources. These applications, originally developed jointly by academia, governments and industry, are to alleviate the AMD and its environmental impacts from various mining wastes through comprehensively understanding the chemistry. Four remediation applications (Anawar, 2015) that have been found useful are discussed briefly as follows.

Carrier microencapsulation via the suppression of pyrite oxidation

This application is found to be effective even in acidic pH range and the presence of Fe oxidising microorganisms. This application relies on iron phosphate/silicate coating on the pyrite surface to inhibit O_2 diffusion, pyrite oxidation, and AMD production. In addition, career microencapsulation is employed to serve as a protective coating on pyrite surface to suppress pyrite oxidation (Anawar, 2015, Evangelou, 2001, Satur et al., 2007, Thakur Jha et al., 2012).

Use of biochar for phytostabilization

This application relies on the innovative technology by developing biomass-derived biochar to enhance the growth of plant species and revegetation within the areas as well as phytostabilization of mining wastes. Biochar addition plays a pivotal role in neutralising the land via soil pH, organic matter, nutrient retention, cation exchange, and water-holding capacity. The secondary role of biochar addition is to reduce the bioavailability and toxicity of heavy metal contents. In short, the use of biochar addition leads to a rebalancing of pH via neutralisation of acidity and reduction of heavy metal contents, there reduces the AMD build up rate (Fellet et al., 2011, Jain et al., 2014, Kim et al., 2014).

Store-release covers

This application is currently the most widely used method to remediate the mining wastes at present. This method constitutes four-layered of soil fractions (topsoil-moisture retention-barrier-subsoil). The topsoil is to plant native grass for stabilising and alleviating soil erosion. The moisture retention layer is made of clay/silt materials while the barrier uses capillary break materials. These two layers are integrated to isolate the rainwater from mining wastes which are submerged at the bottom layer (subsoil), to suppress the oxidation of sulfide derivatives and leaching of heavy metal contents and AMD into the neighbourhoods. In authors' opinion, this is a just refined option of landfill disposal for mining wastes without addressing the environmental issues in entirety (Alvarenga et al., 2009, Eamus et al., 2013, Valente et al., 2012).

Integrated remediation system consisting of wetland treatment and microbial populations

This application incorporates a joint system relying on both wetland treatment and microbial populations. This remediation method is cost-effective and efficient in pH rebalancing, buffering AMD and suppression of heavy metal contents and sulfide derivatives, via physical, chemical and biological processes (Gazea et al., 1996, Sheoran and Sheoran, 2006).

Perspectives from experts

Of all remediation applications, most of the options are not cost-effective and therefore not viable when profitability is the only concern. Some applications are cheap and therefore sustainable, but the scarcity of water and climate change means that the desired outcome using these options will be grossly limited.

For this reasoning, there has been no cost-effective and method-efficient for the treatment of AMD. Few research studies (Abrosimova et al., 2015, Parviainen et al., 2014, Wei et al., 2014) have therefore reported that prevention and prediction are the best practices for easing the AMD problems without providing any other specific concrete solutions.

Kefeni *et al.* (Kefeni et al., 2017) provided their future perspective for future research directions in need of a quick solution in easing the AMD problems. The authors proposed that, instead of focussing on remediation of AMD, research studies should be shifted to the recovery and reuse of resources from AMD and mining wastes. The authors also outlined the needs to take into consideration to provide further benefits as well as alleviate environmental pollution (Kefeni et al., 2017).

In this paper, the authors evaluate the viability of converting mining wastes to useful products (sludge, tailings from iron ore production and bottom ash from coal industry) from its various waste spoils to value-added materials like lightweight aggregates. Moreover, these aggregate materials can further be utilized for various value-added green building applications, including lightweight partition wall, thermal insulative panel, and lightweight brick. This research direction will not only provide a prominent alternative to environmental problems but also provide additional benefits, as concluded by Kefeni *et al.* (Kefeni et al., 2017). When considering Australia is supporting sustainable urbanisation, the demand for recycled green lightweight building materials is immensely high and therefore this research direction will serve as an attractive solution to address the AMD problems.

Green building materials

Green building materials are conventionally produced from waste materials having the ability of energy conservation. They emerge as an alternative primarily due to environmental sustainability and non-renewable resource depletion. Apart from these benefits the importance of this application can be extended to environmental responsibility, resource efficiency as well as the promotion of positive corporate reputation in sustainability (Tan and Xu, 2016, Ng et al., 2015).

Currently, some commercially available green building materials are made of foam glass and ceramic materials. Although these green building materials are lightweight resource-efficient, possess low thermal conductivity (energy conservation), high thermal stability and high fire resistance (safety); the cost of manufacture is deemed ineffective due to the substantial cost of the raw materials. Waste materials are not used in high proportion during manufacture because of the sophisticated and costly sorting process of recycling glass and ceramics (Ng et al., 2015, Tan and Xu, 2016).

Lightweight aggregate (LWA), being one of the green building materials, has gained popularity in the construction industry as LWAs possess the properties of being lightweight, low thermal conductivity and low water absorption from sintering process. LWA can then be extended to various applications, such as lightweight brick, insulative panel, partition wall and etc. The applications of LWA is significant in sky-rise building structure where the weight of the building becomes critical and the use of LWA is an attractive option in overcoming the issue. A report carried out by the UK (Waste and Resources Action Program) concluded that employment of lightweight green building materials has resulted in a significant reduction in energy consumption of the buildings (González-Corrochano et al., 2014, Lee et al., 2019, Ng et al., 2015).

Lightweight Aggregate (LWA)

LWA (shown in Figure 3) is conventionally produced by vitrifying clay or shale to a temperature where the expansion or bloating of the materials can happen. LWA is not only lightweight but also highly useful of its superior noise abatement, fire resistance, insulation and geotechnical properties (Weinecke and Faulkner, 2002).

Ideal LWA is resilient in compressive strength and lower density material which is typically used in precast concrete to; 1) reduce the load in high-rise building, 2) reduce the total weight of concrete blocks, 3) reduce the building material cost, and 4) increase worker productivity and/or building progress (Ng et al., 2015, Weinecke and Faulkner, 2002, Lee et al., 2019).

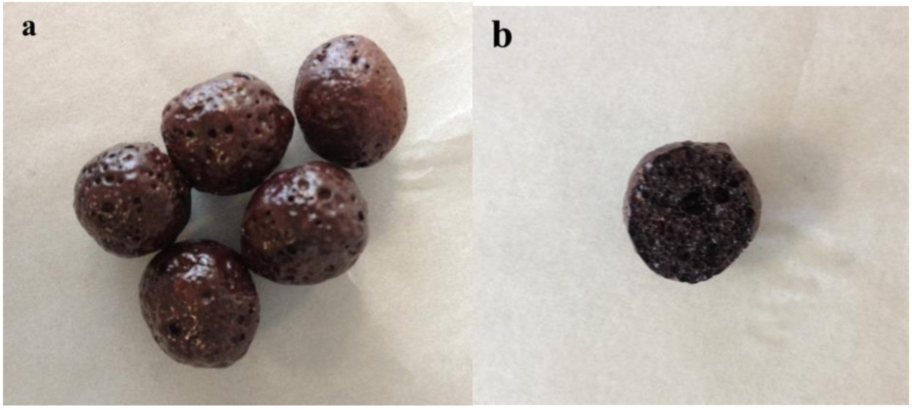


Figure 3 The pictures of the (a) LWAs; (b) cross-section of the lightweight aggregate

What types of waste materials will be an advantage to sources?

Formation of LWA relies on the use of a material with a high loss on ignition (LOI), such as high-carbon fly ash, to minimise the density of the aggregate material. During the vitrification, the LOI material is vaporised resulting in a porous structure with lower density. Waste materials that are suitable to be used for bloating are fly ash, bottom ash, contaminated river-bottom solids and washings from igneous rock washing. (Primary material) (Ng et al., 2015, Weinecke and Faulkner, 2002)

Secondary waste material, sludge, consisting of large water content, is usually present in the aggregate-making process to lower the process energy requirement. The sludge with high LOI ability has the ability to enhance the porosity in the product by increasing porosity resulting in a lower density. Typically, sludge makes up approximately 30% of the dry weight of an aggregate mixture. The main limitation of sludge usage is the water content present in the sludge. In previous research, the purpose of the solar drying process was to reduce the water content economically to approximately 40-45% of its dry weight. Solar drying can be utilised in the future research study for dehydration without relying on heating devices. On the other hand, tailings, typically contain a large amount of waste solids, can also be used as an alternative to reduce the water content present in sludge without drying (Ng et al., 2015, Weinecke and Faulkner, 2002).

The bloating process can be complemented by using foaming and/or fluxing agents or waste materials to accomplish bloating of a material. A list of major chemical agents that are required for the bloating process is illustrated in Figure 4, Riley's diagram (Ng et al., 2015). Waste glass has a good source of silica which serves as a good fluxing agent. Addition of foaming, fluxing agents and additives usually constitutes no more than 10% of the dry weight of the aggregate mixture. Apparently, density is one of the most important parameters to evaluate the quality of LWA. Normally, the lower density of LWA can result in lower thermal conductivity and lower building dead load. During the sintering process, the LOI material becomes soft and semifluid. When sintering hits, a critical temperature, the foaming agents swell up the aggregate mixture and the primary material (LOI) vaporizes, resulting in entrapment of gas molecules in the mixture which bloats up the structural integrity of LWA and generates closed cellular structures. Addition of fluxing agent, silica and metal oxide as well as vitrification are to build up the compressive strength, most importantly, to lock-in and stabilize the heavy metal contents within the closed pore structures (González-Corrochano et al., 2014, Lee et al., 2019, Ng et al., 2015, Weinecke and Faulkner, 2002, Tan and Xu, 2016, Kastiukas et al., 2016).

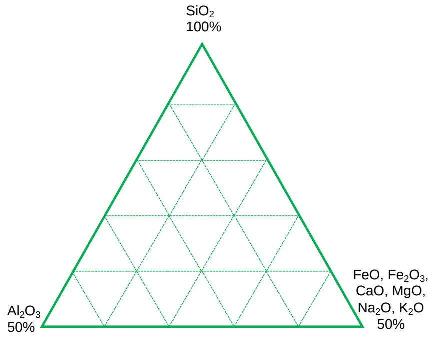


Figure 4 Riley's ternary diagram (Ng et al., 2015)

Preparation of lightweight aggregate

Formation of LWA involves multiple steps, as shown in Figure 5 (Ng et al., 2015). Waste materials (such as sludge, coal bottom ash, and waste glass) are to be the major raw materials, accounting for over 90% of the aggregate mixture. Firstly, optimal ratios of solid wastes are to be weighed and mixed evenly. Following that, appropriate amounts of foaming and fluxing agents (silicon carbide, sodium silicate, calcium silicate and/or aluminum silicate) and additives (CaCO3, borax or sodium dihydrogen phosphate) are to be added into the waste mixture. Next step is to ball-mill the mixture to properly mix and grind the materials into a fine mixture followed by glomerating into 1-cm semi-spherical balls, aggregate materials. These aggregate balls will be vitrified where the sintering requires a gradual increase in temperature rather than a rapid change in thermal condition as this will cause breakages in the aggregate materials, resulting in the release of gas molecules instead of entrapment. During the sintering process, the aggregate materials bloat and create closed cellular structures within pores as a result of vaporization of LOI contents and foaming agent, resulting in low density. Also, during the sintering process, the fluxing agent and additives integrate into the aggregate mixture to constitute the structural integrity, i.e. resultant compressive strength, low water absorption, and low thermal conductivity. Once the sintering process is complete, the aggregate materials are to be cooled down naturally in the furnace where LWA can be obtained when the materials reach room temperature.

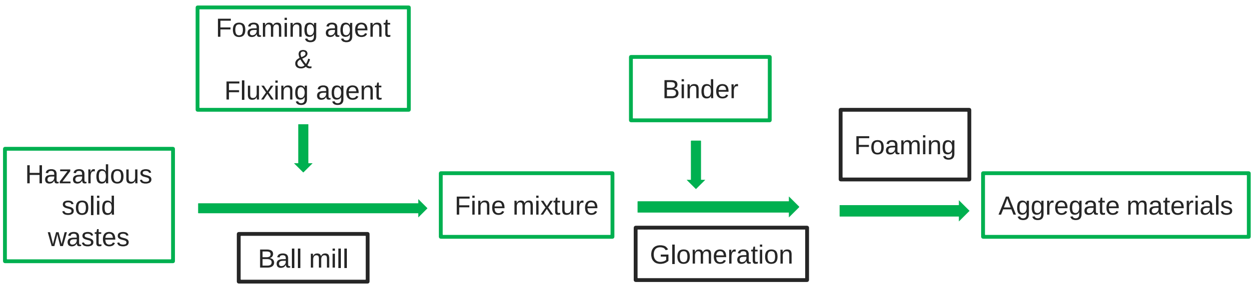


Figure 5 Schematic of the production of lightweight aggregate materials

Feasibility

The feasibility study assesses the viability of converting mining wastes, such as sludge, tailings and coal bottom ash, to LWAs. This section is to evaluate the use of waste materials, and foaming and fluxing agents.

A recent technology (Ng et al., 2015, Tan and Xu, 2016), for converting marine clay into lightweight green building materials, has been proven as a prominent alternative use for contaminated soil. This application uses over 95% of waste materials consisting of marine clay, incineration bottom ash and waste glass in the conversion to aggregate materials. It is therefore highly promising due to high usage in waste materials. The usage of marine clay is to create the porous nature resulting in low density and high porosity for the aggregate materials. Primary waste materials to be used for replacing marine clay are, sludge and tailings (by-products of mining wastes) as they constitute similar properties. Sludge possesses high water content whilst tailings have high solid contents, therefore the mixture of sludge and tailings will be a good replacement for marine clay.

Second waste material, coal bottom ash (Lee et al., 2019), is to replace incineration bottom ash due to their similar chemical properties in bloating to optimise the density and porosity. The utilisation of waste glass remains unchanged in this plan.

From Riley's ternary diagram (Figure 4), the hypothesis is that the chemical composition of the waste materials requires an adequate amount of quantity for foaming and fluxing agents and additives in order to produce quality lightweight aggregate. The chemical compositions of sludge, tailings and coal bottom ash can be characterised by elemental analysis (EI), powder X-ray diffraction (PXRD) for solid wastes; and ion chromatography (IC) for heavy metal contents in sludge. The chemical analyses enable us to determine the amount of silicate derivatives required in the sintering process. Foaming (metal oxides) and fluxing (silicate derivatives) agents are required to optimise sintering temperature for energy consumption, this is to reduce the melting point of the mixture of sludge/tailings.

In summary, the feasibility of using the recently developed application to convert sludge, tailings, coal bottom ash and waste glass into lightweight aggregates is therefore deemed highly probable where the empirical approach is required for optimisation to accomplish optimal conditions. The ideal sintering condition for bloating is detailed as follows (Ng et al., 2015):

1. Low sintering temperature and short holding time (energy consumption, cost-effective and time-efficient);
2. Low density (<1.5 g/cm^3);
3. High porosity (>80%);
4. Low water adsorption (<10%);
5. High usage of solid waste (>95%).

Characterisation of lightweight aggregate

A number of properties tests are required to characterise the properties of the LWA and briefly discussed here (Kastiukas et al., 2016, Lee et al., 2019, Ng et al., 2015, Australian Standard 1289).

- Loss on ignition and carbon contents: Efficiency of LOI contents and remaining carbon contents in LWA can be determined by EI and PXRD;
- Bloating index (%): Bloating index in % can be measured through the measurement of LWA (before and after) in cm followed by converting into %;
- Density of LWA: Density of LWA can be determined via the displacement of water in given volume;
- Water absorption (%): Water absorption of LWA can be determined via the loss of water in given days (3, 7 and 28 days);
- Strength testing: Maximum compressive strength (MPa) of LWA is required to be measured in MPa. LWA possessing 2 MPa of compressive strength is considered as good quality;
- Pore structure: Chemical morphology of LWA can be determined by scanning electron microscopy (SEM) or transmitted electron microscopy (TEM). Mercury Intrusion Porosimetry

(MIP) technique can be used to determine the pore structure & porosity of LWA (before and after);

- Phase change behaviour: Thermal gravimetric analysis (TGA) can be used to comprehend its phase changing behaviour i.e. phase change temperature and thermal energy storage. This is important for proof of fire resistance;
- Chemical properties: pH value and leaching tests of the end product, LWA, need to be measured for safety reason. Leaching tests determines the leaching quantity of heavy metal contents (As, Sb, Cu, Pb, Cd, Zn, Hg, Ag, Sn, Fe, Al, Mn, Tl, U, Th, and W) from LWA where this can be determined via a diffusion test;
- Thermal conductivity: Thermal conductivity of LWA can be determined using a heat flow meter to measure the heat conductance for two samples (control & LWA).

Furthermore, the viability of implementing waste materials in this technology also relies on the fact that production cost so optimisation of energy consumption and sintering temperature are the utmost priority in this study followed the compressive strength of LWA.

Current development in LWA research

In spite of serious environmental consequences resulted from mining activities, a limited amount of research outputs in lightweight aggregate have been found in the literature to address the global environmental issues. The search using these two sets of keywords ("lightweight aggregate" and "lightweight aggregate waste") on the library search engine of Central Queensland University has only found a total of 1231 and 202 peer-reviewed articles (as shown in **Figure 6**), respectively, over the past 20 years of this research period. When assessing the research outputs for the past 10, 5 and 2 years, 1113, 732 and 352 articles have been yielded in LWA research whilst only 193, 136 and 67 articles have been reported for LWA research produced from waste materials. It is important to note that the search result using the keyword of "lightweight aggregate waste" evaluates the research outputs on LWA from the non-specific type of waste materials. When quoting the specific keyword of "lightweight aggregate mining waste" and "lightweight aggregate mineral waste", mere 4 and 6 research papers have been obtained over the course of 20 years. This has a strong indication to show the research in lightweight waste recycling has been overlooked in the last 20 years. The search result of 1231 articles in LWA research is exceptionally low output when compared to the research publications in natural or medical science.

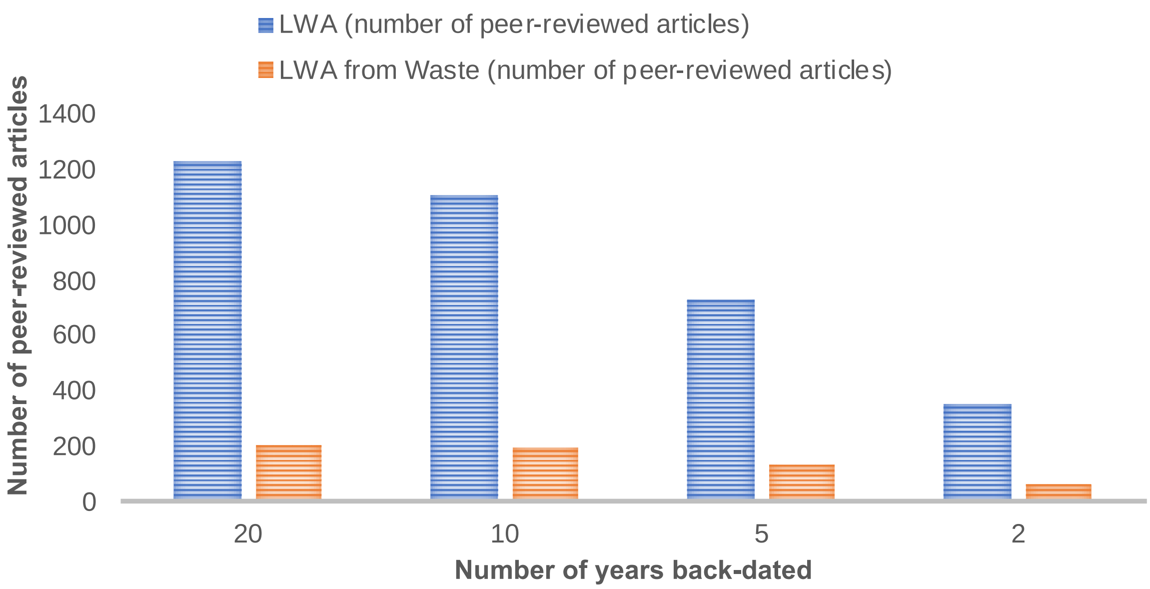


Figure 6 Number of peer-reviewed articles reported in LWA and LWA from waste materials spanning over a course of 20 years

When comparing the numbers of research papers obtained using these three sets of keywords, namely "LWA", "LWA waste" and "LWA mining waste", the proportion is 300:50:1. Using this proportion, as a guide, to comprehend the composition of commercially available lightweight aggregate, the interpretation is that the LWAs are yielded from ~86% of non-renewable raw materials, ~14% of non-specific waste materials and ~0% of mining or mineral wastes. Therefore, the commercially available green building materials typically comprise only 14% of waste materials.

Based on the authors' opinions, the reasons why the LWA research has been well overlooked could be attributed to the following:

1. Lack of research funding support from the government as this research theme is not within the scope of government's research focuses;
2. LWA research is typically conducted inhouse by industry laboratory so there will be a discrepancy from the total number of publications obtained;
3. Waste management is not considered as a necessity in society and the obvious example in that no university offers a course in waste management as compared to other management courses, such as financial management, business management, and construction management. Consequently, the gap of knowledge in this area is distinctly obvious and needs further research.
4. Research themes conventionally focus on remediation of mining activities for mining-related projects and/or cost management for the production of LWA. Lack of research leaders in waste management/recovery/reuse/recycle, certainly in the area of mining waste recycling is minimal. This has been outlined by the fact of a limited amount of research outputs found in using waste materials for LWA production.

From the authors' perspective, research theme in mining waste recycling is critical and the justification is discussed herein. As mentioned, the production of mining wastes is enormous and needs alternative solutions. The by-products essentially leach high levels of sulfide and heavy metal contents into soil and water. Firstly, the contamination of soil has meant that the agricultural crops produced from the neighbourhood possess can have high levels of heavy metal contents, causing a series of detrimental health risks to local residents. Secondly, the leached heavy metal contents in water have the potential of reaching the ocean where the contaminated water is consumed by marine species, resulting in high levels of heavy metals in their bodies. Most importantly, these marine species may potentially end up being our daily meals for human consumption, eventuating human being absorbing the carcinogenic heavy metal contents.

The way governments work is that the research funding is primarily designated to medical research focussing on prevention and curation of diseases so that the use of funding can reach its full capacity in this respect. However, governments have overlooked the fact that the prevention of diseases goes beyond medicine and is in a critical need to backdate all the way to its origin, i.e. resolving the contamination resulted from mining wastes. However, these hazards need to be elevated by mining activities to support individual well-being and community prosperity via environment and marine ecology then this research is important.

Conclusions, challenges & perspectives

The reliance on mineral export has been questionable in relation to the non-habitability of Australia, due to the mining activities undertaken. Mining wastes, by-products of mining activities, possess a drastic environmental hazard, primarily due to leaching of its heavy metal contents into the soil, resulting in potent contamination of agricultural soil as well as underground water. This has become a long-term ecological issue to the residents living within the community, potentially the extinction of animal, plant and marine species due to biotoxicity.

Despite the efforts from academia, governments and industry in developing various remediation techniques to alleviate the issues, the impacts of these applications have been found to be minimal. This is because some applications have been found to be effective but require high cost in maintenance whilst the cost-effective applications are not responding positively to the acid mine drainage (AMD) issues. The challenge remained is the remediation cost which is likely to compromise a substantial portion of enterprises' profits. In one of the research studies (Kefeni et al., 2017), the experts provided their perspectives on shifting the remediation of the AMD consequences to recovery and reuse where a recently developed waste recycling technology has perfectly situated to account for the AMD issues, serving as an attractive solution.

The feasibility discussion has reviewed the viability of the application where it was deemed highly probable to use sludge, tailings and coal bottom ash in the application for the conversion to value-added lightweight aggregates (LWAs), initially; where these aggregate materials can further be utilized for various value-added green building applications, including lightweight partition wall, thermal insulative panel, and lightweight brick.

The perspective discussed in this study has rectified not only the AMD impacts, in terms of contamination of soil and drinking water, but also provided additional benefits in the application by turning contaminated waste materials to be in-demand lightweight green building materials. The demand for lightweight green building materials is enormous and the conversion is deemed highly probable but the challenges in this field are the production costs. Consequently, the energy consumption of manufacture dictates its ultimate viability.

References

ABROSIMOVA, N., GASKOVA, O., LOSHKAREVA, A., EDELEV, A. & BORTNIKOVA, S. 2015. Assessment of the acid mine drainage potential of waste rocks at the Ak-Sug porphyry Cu–Mo deposit. *J. Geochem. Explor.,* 157**,** 1-14.

ALVARENGA, P., PALMA, P., GONÇALVES, A. P., FERNANDES, R. M., DE VARENNES, A., VALLINI, G., DUARTE, E. & CUNHA-QUEDA, A. C. 2009. Organic residues as immobilizing agents in aided phytostabilization: (II) Effects on soil biochemical and ecotoxicological characteristics. *Chemosphere,* 74**,** 1301-1308.

ANAWAR, H., FREITAS, M. & CANHA, N. 2011. *Evaluation of atmospheric particle dispersion at a contaminated mine using biomonitors*.

ANAWAR, H. M. 2015. Sustainable rehabilitation of mining waste and acid mine drainage using geochemistry, mine type, mineralogy, texture, ore extraction and climate knowledge. *J. Environ. Manage.,* 158**,** 111.

ASHLEY, P. M., CRAW, D., GRAHAM, B. P. & CHAPPELL, D. A. 2003. Environmental mobility of antimony around mesothermal stibnite deposits, New South Wales, Australia and southern New Zealand. *J. Geochem. Explor.,* 77**,** 1-14.

ASHLEY, P. M., LOTTERMOSER, B. G., COLLINS, A. J. & GRANT, C. D. 2004. Environmental geochemistry of the derelict Webbs Consols mine, New South Wales, Australia. *Environ. Geol.,* 46**,** 591-604.

BHATTACHARYA, A., ROUTH, J., JACKS, G., BHATTACHARYA, P. & MÖRTH, M. 2006. Environmental assessment of abandoned mine tailings in Adak, Västerbotten district (northern Sweden). *Appl. Geochem.,* 21**,** 1760-1780.

BURTNYSKI, E. 2007. Double Threat of Cyanide Leach Mining and Acid Mine
Drainage (AMD) Imperils the Futaleufu River Valley-Kinross Gold and Geocom
Resources Responsible. Mine Tailings, Sudbury Ontario.

CLAY, A., MCKENNA, N., MHLANGA, S. & DYKE, S. 2013. Acid Mine Water Drainage Debating a Sustainable Solution to a Serious Issue.

COURTIN-NOMADE, A., GROSBOIS, C., BRIL, H. & ROUSSEL, C. 2005. Spatial variability of arsenic in some iron-rich deposits generated by acid mine drainage. *Appl. Geochem.,* 20**,** 383-396.

EAMUS, D., YUNUSA, I., TAYLOR, D. & WHITLEY, R. 2013. Design of store-release covers to minimize deep drainage in the mining and waste-disposal industries: results from a modelling analyses based on ecophysiological principles. *Hydrol. Process,* 27**,** 3815-3824.

EVANGELOU, V. P. 2001. Pyrite microencapsulation technologies: Principles and potential field application. *Ecol Eng.,* 17**,** 165-178.

FELLET, G., MARCHIOL, L., DELLE VEDOVE, G. & PERESSOTTI, A. 2011. Application of biochar on mine tailings: Effects and perspectives for land reclamation. *Chemosphere,* 83**,** 1262-1267.

GAZEA, B., ADAM, K. & KONTOPOULOS, A. 1996. A review of passive systems for the treatment of acid mine drainage. *Miner. Eng.,* 9**,** 23-42.

GONZÁLEZ-CORROCHANO, B., ALONSO-AZCÁRATE, J. & RODAS, M. 2014. Effect of prefiring and firing dwell times on the properties of artificial lightweight aggregates. *Constr. Build. Mater.,* 53**,** 91-101.

HAMILTON, E. I. 2000. Environmental variables in a holistic evaluation of land contaminated by historic mine wastes: a study of multi-element mine wastes in West Devon, England using arsenic as an element of potential concern to human health. *Sci. Total Environ.,* 249**,** 171-221.

JAIN, S., BARUAH, B. P. & KHARE, P. 2014. Kinetic leaching of high sulphur mine rejects amended with biochar: Buffering implication. *Ecol Eng.,* 71**,** 703-709.

JUILLOT, F., ILDEFONSE, P., MORIN, G., CALAS, G., KERSABIEC, A. M. D. & BENEDETTI, M. 1999. Remobilization of arsenic from buried wastes at an industrial site: mineralogical and geochemical control. *Appl. Geochem.,* 14**,** 1031-1048.

JUNG, M. C. 2008. Contamination by Cd, Cu, Pb, and Zn in mine wastes from abandoned metal mines classified as mineralization types in Korea. *Environ. Geochem. Health,* 30**,** 205-217.

KASTIUKAS, G., ZHOU, X. & CASTRO-GOMES, J. 2016. Development and optimisation of phase change material-impregnated lightweight aggregates for geopolymer composites made from aluminosilicate rich mud and milled glass powder. *Constr. Build. Mater.,* 110**,** 201-210.

KEFENI, K. K., MSAGATI, T. A. M. & MAMBA, B. B. 2017. Acid mine drainage: Prevention, treatment options, and resource recovery: A review. *J. Clean. Prod.,* 151**,** 475-493.

KHALIL, A., HANICH, L., HAKKOU, R. & LEPAGE, M. 2014. GIS-based environmental database for assessing the mine pollution: A case study of an abandoned mine site in Morocco. *J. Geochem. Explor.,* 144**,** 468-477.

KIM, M.-S., MIN, H.-G., KOO, N., PARK, J., LEE, S.-H., BAK, G.-I. & KIM, J.-G. 2014. The effectiveness of spent coffee grounds and its biochar on the amelioration of heavy metals-contaminated water and soil using chemical and biological assessments. *J. Environ. Manage.,* 146**,** 124-130.

LÈBRE, É., CORDER, G. D. & GOLEV, A. 2017. Sustainable practices in the management of mining waste: A focus on the mineral resource. *Miner. Eng.,* 107**,** 34-42.

LEE, K., LEE, J., LEE, K. & YAO, Z. 2019. Bloating Mechanism of Lightweight Aggregates due to Ramping Rate. *Adv. Mater. Sci. Eng.,* 2019.

LOTTERMOSER, B. 2011. *Recycling, Reuse and Rehabilitation of Mine Wastes*.

LUPTAKOVA, A., UBALDINI, S., MACINGOVA, E., FORNARI, P. & GIULIANO, V. 2012. Application of physical–chemical and biological–chemical methods for heavy metals removal from acid mine drainage. *Process Biochem. ,* 47**,** 1633-1639.

MODABBERI, S., ALIZADEGAN, A., MIRNEJAD, H. & ESMAEILZADEH, E. 2013. Prediction of AMD generation potential in mining waste piles, in the Sarcheshmeh porphyry copper deposit, Iran. *Environ Monit Assess. ,* 185**,** 9077–9087.

NG, B. K., DAI, Y., XU, Q.-C. & TAN, T. T. Y. Energy-Efficient Recycling of Contaminated Marine Clay and other Solid Wastes to Lightweight Aggregates. Urban Sustainability R&D Congress Posters, 2015 Singapore.

PAKTUNC, D., FOSTER, A. & LAFLAMME, G. 2003. Speciation and Characterization of Arsenic in Ketza River Mine Tailings Using X-ray Absorption Spectroscopy. *Environ. Sci. Technol.,* 37**,** 2067-2074.

PARVIAINEN, A., MÄKILÄ, M. & LOUKOLA-RUSKEENIEMI, K. 2014. Pre-mining acid rock drainage in the Talvivaara Ni–Cu–Zn–Co deposit (Finland): Natural peat layers as a natural analog to constructed wetlands. *J. Geochem. Explor.,* 143**,** 84-95.

SATUR, J., HIROYOSHI, N., TSUNEKAWA, M., ITO, M. & OKAMOTO, H. 2007. Carrier-microencapsulation for preventing pyrite oxidation. *Int. J. Miner. Process.,* 83**,** 116-124.
SCHAIDER, L. A. & HAURI, J. F. 2009. Remediation of Acid Mine Drainage with Sulfate Reducing Bacteria. *J. Chem. Educ.,* 86**,** 216.
SHEORAN, A. S. & SHEORAN, V. 2006. Heavy metal removal mechanism of acid mine drainage in wetlands: A critical review. *Miner. Eng.,* 19**,** 105-116.
TAN, T. Y. T. & XU, Q. 2016. *Method of manufacturing a lightweight material*. Singapore patent application PCT/SG20 16/050082.
THAKUR JHA, R. K., SATUR, J., HIROYOSHI, N., ITO, M. & TSUNEKAWA, M. 2012. Suppression of Pyrite Oxidation by Carrier Microencapsulation Using Silicon and Catechol. *Min. Process. Ext. Met. Rev.,* 33**,** 89-98.
VALENTE, T., GOMES, P., PAMPLONA, J. & DE LA TORRE, M. L. 2012. Natural stabilization of mine waste-dumps — Evolution of the vegetation cover in distinctive geochemical and mineralogical environments. *J. Geochem. Explor.,* 123**,** 152-161.
WEI, X., WOLFE, F. A. & HAN, Y. 2014. Mine Drainage: Characterization, Treatment, Modeling, and Environmental Aspect. *Water Environ. Res.,* 86**,** 1515-1534.
WEINECKE, M. H. & FAULKNER, B. P. 2002. Production of lightweight aggregate from waste material. *Miner. Eng.,* 54**,** 1-5.
ZHUANG, P., ZOU, B., LI, Y. & LI, Z. A. 2009. Heavy metal contamination in soils and food crops around Dabaoshan mine in Guangdong, China: Implication for human health. *Environ. Geochem. Health,* 31**,** 707-15.

A REVIEW ON LEADERSHIP STYLES AND INNOVATION AND THEIR IMPACT ON PRODUCTIVITY

Hossein Sadeghzadeh Fasaghandis[1], Suzanne Wilkinson[2]

[1]Department of Civil and Environmental Engineering, The University of Auckland, Auckland, New Zealand

[2]School of Built Environment, Massey University, Auckland, New Zealand

Abstract

Leadership is the influencing process used to achieve organisational objectives. Since project managers often depend on employees who do not directly report to them to fulfil some of the tasks, they need to engage different types of leadership to motivate people to perform. Every organisation has the potential for improvements in productivity through leveraging how employees operate. In particular, how employees assist in driving innovation can create beneficial and practical results for the construction industry. Unrealised potential for innovation can be managed through leadership. This study aims to explore different leadership styles within construction organisations to uncover attributes for improved productivity through innovation. Literature (Kloppenborg, Anantatmula, & Kathryn, 2018; Liu & Chan, 2017; Zheng, Wu, Xie, & Li, 2019) believe that managers within the construction industry have leadership traits that lead to creating an organisational culture that supports innovation. The literature indicates that a mix of Transformational and Transactional leadership attributes positively impact the potential for innovative behaviour among employees. Little research has been undertaken to study innovative leadership within the NZ construction context. Therefore, the novel results of this research will allow construction practitioners to better implement an innovative culture and improve the productivity of their organisations.

Keywords

Leadership, Innovation, Organizational Culture, Productivity, Construction, Management

Introduction

Low productivity is considered as a set back and in recent years, many attempts have been made to increase productivity within the construction industry. Literature indicates that while there has been some improvements in finding ways to raise construction productivity, there is still huge room for improvement (Chan & Kaka, 2003; Hughes & Thorpe, 2014). Research indicates that leadership style and management experience are a number of factors influencing productivity (Naoum, 2015).

The economic growth of any country largely depends on the productivity of its main industries, and the construction industry is considered one of the major industries of the world economy. Similar to most countries, the New Zealand building industry is a main contributor to its employment and economic growth (PricewaterhouseCoopers [PWC], 2011) as the sector takes a vital role with national investments in the local economies. While Ministry of Business, Innovation and Employment [MBIE] (2014) claimed that the sector contributes about 6.3% to the gross domestic product (GDP) and represents over 40% of the national budget revenue; PWC (2011) affirmed that construction accounts for more than 8% of employment creation and an average of 50% of the gross fixed capital formation (GCFC). However, being too conservative in regards to innovative culture is identified as one of the most common traits of not only the NZ but also the global construction community (Ozorhon et al., 2010; Mcmeel & Sweet, 2016).

A greater focus on the productivity of the construction industry is needed. Unfortunately, many of the construction companies, do not know how to improve construction productivity. A survey on 77 UK construction contractors indicated that only less than half of the contractors focus on productivity related issues while performing (Chan & Kaka, 2003). Research also found that management and leadership issues, also poor levels of innovation are among the main causes of low productivity in the construction sector (Hughes & Thorpe, 2014).

By reviewing the result of previous researchers, this study has tried to provide an insight into the factors that affect innovative leadership in the construction industry as an influential factor for increasing the productivity of the companies. If innovation leadership improves productivity then the results could potentially help practitioners by offering guidance to construction project managers for focussing on innovation to improve productivity.

Innovation

Innovation is defined by Drucker (1985) as "the means by which the entrepreneur either creates new wealth-producing resources or endows existing resources with enhanced potential for creating wealth". Tushman & Nadler (1986), focus on the novelty aspect and defined innovation as the making of any product, service or process that in novel to an industry. For the purpose of our research, innovation is classified in accordance to its application. We classify innovations into product, process or organisational innovations. Product innovations, focuses on developing novel services, features or products. Process innovation, attempts to increase the efficiency and the effectiveness of the organisational processes. Organisational innovation which is more emphasised in our research, tries to develop better effective and better efficient systems and standards that the company benefits from while trying to deliver value to its clients (Shahbazpour, 2010).

The amount of innovation taking place in the construction sector has both people who support (Seaden & Manseau, 2001), and praise it and people whom criticise (Blayse & Manley, 2004) it and claim that innovation needs improving. The main concern being that the level of innovation is not comparable against innovations in the manufacturing sector (Reichstein et al., 2005). Other scholars (Pries & Janszen, 1995), believe that innovations are high and have always happened in the construction sector through construction companies choosing project-based structures which lead to more efficiency and performance (Buvik & Rolfsenand, 2015).

Focusing on technology and innovation could help bring new methods, knowledges and approaches into the industries. De Man (2008) states that innovation could be defined as a method for implementing fresh ideas into the world and applying them into the projects, systems, frameworks and shared projects to develop innovative products or services. These activities could add more value to the society. It is vital for construction companies to come up with new innovations since today's clients demand more productivity, better products at a cheaper price and shorter project durations. In many instances, how effective a leader is, defines the profitability of the projects. Yi and Chan (2014), on the impact of technology, shows that technology has hugely affected the productivity of the employees. Adapting innovative products into the organisations and benefiting from innovative information systems have boosted the strength and modified the required skills (Hewage et al. 2008). Putting more emphasis on new technologies and innovations is vital for increasing productivity and reducing costs.

For a firm to stay in competition, innovation is essential (Lam, 2005). Changes in construction have put pressure on companies to implement innovation to survive (Damanpour & Aravind, 2006). Numerous studies have focused on product innovations within the construction industry (Damanpour & Aravind, 2006; Foss et al., 2011; Gumusluoglu & Ilsev, 2009), but fewer studies have focused on organisational innovation (Camisón & Villar-López, 2014). Organisational innovations have a huge effect on the success of a company. Organisational innovation also takes organisational processes and practices into account and tries to better address organisational objectives (Lam, 2005).

Leadership

Since higher productivity is a major goal for construction organisations, there is need to foster the wellbeing of the employees. Leadership plays a critical role in fostering employee wellbeing. The right kind of leadership is required for every stage of the projects (Ailabouni et al., 2009).

The fulfilment of the objectives of the project, depend on how effective a leader manages the resources available. Different leadership styles produce different outcomes, although studies suggest that good leadership could reduce waste in time and costs (Shahata & Zayed, 2011). Based on a research performed by Rojas and Aramvareekul (2003), demonstrating the right skills by the leader hold potential for improving the productivity of the construction sector.

Past studies on organisational leadership indicate that the main role of the leader is to engage followers into practices which facilitate the success of the organisational goals (Ilies, et al., 2006). Historically, researchers have adopted different leadership traits as their focus of study and amongst them transformational and transactional studies have been more focused in the construction sector (Avolio & Bass, 2004, Bass, 1985). In definitions, transformational leadership is perceived as the leadership that concentrates on addressing higher-order intrinsic needs of their people and employees. This results in the followers reciprocally addressing the requests of the leader (Bygballe & Ingemansson, 2014). Transformational leadership has four dimensions, charisma (or idealised influence), inspirational stimulation, intellectual stimulation and individualised consideration (Bass, 1985). There exist different definitions for different leadership styles. Naoum (2015), expressed transformational leadership with four core dimensions: charisma (idealised influence), inspiration stimulation, intellectual stimulation and individualised consideration. On the other hand, unlike transformational leadership, transactional leadership, refers to leaders who pay more attention on addressing the extrinsic requirements of their followers. A clear example of this is directly compensating the value that the employee adds to the project with clear, cash rewards. This will result in the followers fulfilling the tasks that the leader asks for (Bygballe & Ingemansson, 2014).

The productivity of the different phases of the project depend on the leader. Researchers have previously focused to some extent on the impact of leadership and its styles on the productivity of the industry. According to a number of researches, charismatic leadership and participative leadership styles mainly define the employees' satisfaction rate (Cheung et al., 2001). Chan et al., (2014) expressed that transformational leadership has a positive impact on the innovative climate, and development exchange leadership has a negative impact on the innovative climate. In the research literature, the role of "innovation champion" has always been focused. Earlier researchers (Nam & Tatum, 1997) expressed that the construction projects usually choose centralised decision making organisational structures. Therefore within construction projects, a sole person will take on the role of the champion, develop an idea from concept and turn it into a product or process. The innovation business champion will act as a provider of framework for the technical ideas. More recently, Sergeeva, (2016), expressed that an executive champion will sponsor the idea at the highest level using the power to protect the idea, move it forward and benefit from the opportunities.

Much research has indicated the priority of transformational leadership for innovation over other leadership styles (Prasad & Junni, 2016). Researchers like Chan et al. (2014), Ozorhon et al. (2016), and Zheng et al (2017) agree that leadership is a key factor for allowing innovations to happen within the construction industry. Leadership plays a decisive part on the core of the projects (Aronson et al., 2013). Transformational leaders mainly focus on facilitating their employees' requirements (Bygballe, 2014), display charisma, stimulate the employee's vision, encourage intellectual behaviour and pay special consideration to individuals (Bass, 1985). It is hypothesised that such behaviour, may cause the employees to display a better understanding and respect to one another (Li, 2014). Leaders affect the level of engagement from employees and support their proactive behaviour (Dong et al., 2017).

Methodology

This study, is a theoretical research and focuses on literature review. The research illustrates concepts based on methodological approaches to evaluating the impact of innovative leadership on the productivity of the New Zealand construction industry. The resources were selected amongst top-tier journals for the chosen topic. The focus of the selection criteria was to choose publications that mainly consisted analysis results based on surveys. The literature were obtained from databases that allowed access to numerous conference papers, national reports and journal papers, theses and text books. In such a way, a comprehensive survey on literature was conducted. The outcome were practical information which represented issues relevant to the topic. For the purpose of this research, Scopus, Google and Google Scholar, also Emerald, databases were used. This approach facilitated the use of previous research results.

Basically, this method is used to represent a framework for developing the emphasis of the research topic and to illustrate a benchmark which will allow to study other research publications (Cresswell, 2014). Therefore, this methodology facilitates deeper view into the topic.

Impact of Innovative Leadership on Construction Productivity

In the most recent research, Zheng et al. (2019) showed that cooperation and congruence between either of transformational and transactional leadership styles and the organisational culture could lead to better innovations. Faried, et al. (2018), conducted a study on the key success factors impacting the success of innovation within the construction projects of the United Arab Emirates and identified ten factors as critical for the innovation within the construction industry within which leadership style is one of ten. Zhang et al., (2018), undertook research to examine the role of the transformational leadership in shaping employees' innovative behaviour. They showed that transformational leadership has the potential for nurturing innovativeness within the organisations. Liu and Chan, (2017), published the results of a study which investigated the role of innovative climate and learning transfer climate on the relationships between leadership and innovation in the construction industry. The findings revealed that a mix of different leadership styles, particularly transformational and transactional leadership styles are required to foster an innovative climate within the construction industry. Zheng et al., (2017) also attempted to study the impact of leadership on project-based organisational innovation. They focused mainly on performance as an indicator of innovation success and emphasised on the role of knowledge sharing as a mediator and social capital as a moderator. Their research found that both transformational and transactional leadership have great and positive effects on knowledge sharing and innovation performance (Zheng et al., 2017). Similarly, Prasad and Junni, (2016) conducted a survey on top management team members in 163 companies in services, construction, manufacturing and other industries in the USA and showed that CEO transformational and transactional leadership styles have a positive impact on innovations within the organisations. Finally, Naoum (2015) indicated that management skills, manpower planning and leadership style have potential for affecting productivity and that investment in technology and innovation can greatly impact the level of productivity demonstrated by the company.

The finding of this research indicate that there exists a relationship between transactional leadership, transformative leadership and innovation. The research also shows that there is a link between innovation and productivity. The results illustrate that different leadership styles, combined with the right factors, could benefit the innovative culture of an organisation and also further lead to more productivity. It was concluded that leadership is a key factor and the leadership's innovation supportive style plays a role in the required traits for the innovative organisation. Amongst the many research results that were investigated for the purpose of this paper, we could conclude that Transformational Leadership and Transactional Leadership styles more than other leadership styles, positively impact the innovative capability of the organisation. In fact, results indicate that a mix of Transformational and Transactional leadership attributes positively impact the potential for innovative behaviour among employees. The next stages of the research are to: 1. Confirm the finding in New Zealand that the leadership traits found are good for fostering innovation, and, 2. Investigate the types of innovation that different leadership styles produce and 3. Understand further how different innovation types created by different leadership styles increase productivity.

Table 1: Summary of Sample Research on Innovative Leadership

Year	Author	Country	Study Topic	Respondents	Data Collection Method	Data Analysis Method	Results
2019	*Zheng et al.*	*China*	*-joint congruence effect of leadership styles and organisational culture on employees' innovative behaviours in construction projects*	*217 Project managers And employees within construction industry*	*Questionnaire*	*Polynomial regression and response surface modelling*	*-Cooperation and congruence between either of transformational and transactional leadership styles and the organisational culture could lead to better innovations.* *-elicit relations between employee's level of innovativeness, organisational culture and leadership styles*
2018	*Faried, et al.*	*United Arab Emirates*	*-Key success factors impacting the success of innovation within the construction projects.* *-Responsible party for each factor*	*5 pilot + 28 actual study*	*Literature review* *Quantitative survey*	*Correlation and regression*	*-Three major players main influencers of the innovation process* *-ten critical factors for the innovation within the construction industry*
2018	*Zhang et al.*	*China*	*-the role of the transformational leadership in shaping employees' innovative behaviour*	*251 professionals from the construction industry*	*Questionnaire survey*	*Hierarchical linear modelling (HLM)*	*-Transformational leadership has the potential for nurturing innovativeness within the organisations*
2017	*Liu and Chan*	*China*	*-role of innovative climate and learning transfer climate on the relationships between leadership and innovation in the construction industry*	*158 developers, consultants and contractors from the construction industry*	*Questionnaire survey*	*Confirmatory Factor Analysis*	*-A mix of different leadership styles, particularly transformational and transactional leadership styles are required to foster an innovative climate within dynamic contexts such as the construction industry*
2017	*Tabassi et al*	*Malaysia*	*-leader's transformational leadership behaviour* *-team's condition* *-team's performance*	*282 members from 94 construction project teams, their team leaders, supervisors*	*Questionnaire survey*	*-Smart PLS path modelling* *-nonparametric bootstrapping* *-repeated indicators*	*-Team's condition, including leadership, has great implications on the performance of the team.* *-leadership behaviour, especially transformational leadership, demonstrates a mediating role between the team condition and the team performance*

2017	*Zheng et al.*	*China*	*-impact of leadership on project-based organisational innovation* *-performance as an indicator* *-knowledge sharing as a mediator*	*project managers and engineers from construction firms*	*The researchers constructed a theoretical model and validated it with empirical data*	*Regression analysis and path analysis*	*-Both transformational and transactional leadership have great and positive effects on knowledge sharing and innovation performance.* *- Knowledge sharing -which is also an enabler for innovation- partially mediates the relationship between transformational leadership and/or transactional leadership and innovative performance.* *- Transformational leadership has the potential to positively impact on knowledge sharing.*
2016	*Prasad and Junni*	*USA*	*-the influence of chief executive officer (CEO) transformational and transactional leadership styles on organisational innovation*	*TMT members in 163 companies*	*MLQ-5X Questionnaire survey*	*Multiple regression analyses*	*-Their study revealed that CEO transformational and transactional leadership styles have a positive impact on innovations within the organisations.* *- Organisations benefit more from transformational leadership in dynamic environments.*
2015	*Naoum*	*UK*	*-factors that can impair productivity on site*	*36 professionals of contract managers and site managers*	*Literature review and face-to-face interviews (structured (close-ended) questionnaires)*	*Management skills, manpower planning and leadership style have huge potential for affecting productivity*	*-Organisational factors such as investment in technology and innovation can greatly impact the level of productivity*

Conclusion and further research

For the purpose of this research, a comprehensive study was undertaken. The results of this paper, referring to the previous literature, demonstrates a better awareness around attributes and traits that need particular consideration from the management of innovation. The results will allow the mangers working within the construction sector to implement methods that will result in higher productivity within the construction industry. The outcomes of this paper, can support professionals working in the construction sector in making changes and paving the way for more innovations in today's competitive market. Innovative solutions can boost the productivity of the manager's company and the construction industry as a whole. This research is part of an ongoing research which attempts to develop a tool for facilitating innovations within the construction industry. The focus of the tool will be more on leaders in the New Zealand construction industry. The tool will be allow for better uptake of innovations to produce a more productive construction industry.

References

AILABOUNI, N., GIDADO, K. and PAINTING, N., 2009Factors affecting employee productivity in the UAE construction industry, *25th Annual ARCOM Conference, Nottingham, UK* 2009, pp. 7-9.

ARONSON, Z.H., SHENHAR, A.J. and PATANAKUL, P., 2013. Managing the intangible aspects of a project: Quantitative and qualitative evidence on the effect of vision, artifacts, and leader values on project spirit and success in technology driven projects. *Proj.Manag.J,* **44**(1), pp. 35-58.

BASS, B.M., 1985a. *Leadership and performance beyond expectations.* Collier Macmillan.

BASS, B.M., 1985b. *Leadership and performance beyond expectations.* Collier Macmillan.

BASS, B.M. and AVOLIO, B.J., 2004. *Multifactor Leadership Questionnaire: MLQ; Manual and Sampler Set.* Mind Garden.

BLAYSE, A.M. and MANLEY, K., 2004. Key influences on construction innovation. *Construction innovation,* **4**(3), pp. 143-154.

BUVIK, M.P. and ROLFSEN, M., 2015. Prior ties and trust development in project teams–A case study from the construction industry. *International Journal of Project Management,* **33**(7), pp. 1484-1494.

BYGBALLE, L.E. and INGEMANSSON, M., 2014a. The logic of innovation in construction. *Industrial marketing management,* **43**(3), pp. 512-524.

BYGBALLE, L.E. and INGEMANSSON, M., 2014b. The logic of innovation in construction. *Industrial marketing management,* **43**(3), pp. 512-524.

CAMISÓN, C. and VILLAR-LÓPEZ, A., 2014. Organizational innovation as an enabler of technological innovation capabilities and firm performance. *Journal of business research,* **67**(1), pp. 2891-2902.

CHAN, I.Y., LIU, A.M. and FELLOWS, R., 2013a. Role of leadership in fostering an innovation climate in construction firms. *Journal of Management in Engineering,* **30**(6), pp. 06014003.

CHAN, I.Y., LIU, A.M. and FELLOWS, R., 2013b. Role of leadership in fostering an innovation climate in construction firms. *Journal of Management in Engineering,* **30**(6), pp. 06014003.

CHAN, P. and KAKA, A., 2003Construction labour productivity improvements, *Proceedings of the third international postgraduate research conference* 2003, pp. 583-598.

CHEUNG, S.O., NG, S.T., LAM, K.C. and YUE, W.M., 2001. A satisfying leadership behaviour model for design consultants. *International Journal of Project Management,* **19**(7), pp. 421-429.

COOPER, H., 2015. *Research synthesis and meta-analysis: A step-by-step approach.* Sage publications.

CRESWELL, J.W., 2014. *A concise introduction to mixed methods research.* SAGE publications.

DAMANPOUR, F. and ARAVIND, D., 2006. Product and process innovations: A review of organizational and environmental determinants. *Innovation, science, and industrial change: A research handbook,* , pp. 38-66.

DE MAN, A.P., 2008. *Knowledge management and innovation in networks.* Edward Elgar Publishing.

DONG, Y., BARTOL, K.M., ZHANG, Z. and LI, C., 2017. Enhancing employee creativity via individual skill development and team knowledge sharing: Influences of dual-focused

transformational leadership. *Journal of Organizational Behavior,* **38**(3), pp. 439-458.
FARIED, M., SAAD, M. and ALMARRI, K., 2017Key Success Factors Impacting the Success of Innovation in UAE Construction Projects, *International Sustainable Buildings Symposium* 2017, Springer, pp. 482-505.
FIEDLER, F.E., 1964. A contingency model of leadership effectiveness. *Advances in experimental social psychology.* Elsevier, pp. 149-190.
FOSS, N.J., LAURSEN, K. and PEDERSEN, T., 2011. Linking customer interaction and innovation: The mediating role of new organizational practices. *Organization Science,* **22**(4), pp. 980-999.
GUMUSLUOGLU, L. and ILSEV, A., 2009. Transformational leadership, creativity, and organizational innovation. *Journal of business research,* **62**(4), pp. 461-473.
HEWAGE, K.N., RUWANPURA, J.Y. and JERGEAS, G.F., 2008. IT usage in Alberta's building construction projects: Current status and challenges. *Automation in Construction,* **17**(8), pp. 940-947.
HORNER, M. and DUFF, R., 2001. A Contractor‟ s Guide To Improving Productivity in Construction. *CIRIA, London,* .
HUGHES, R. and THORPE, D., 2014. A review of enabling factors in construction industry productivity in an Australian environment. *Construction Innovation,* **14**(2), pp. 210-228.
ILIES, R., JUDGE, T. and WAGNER, D., 2006. Making sense of motivational leadership: The trail from transformational leaders to motivated followers. *Journal of leadership & organizational studies,* **13**(1), pp. 1-22.
KERR, S., SCHRIESHEIM, C.A., MURPHY, C.J. and STOGDILL, R.M., 1974. Toward a contingency theory of leadership based upon the consideration and initiating structure literature. *Organizational behavior and human performance,* **12**(1), pp. 62-82.
KLOPPENBORG, T., 2014. *Contemporary project management.* Nelson Education.
LAI, C., HSU, J.S. and LI, Y., 2018. Leadership, regulatory focus and information systems development project team performance. *International Journal of Project Management,* **36**(3), pp. 566-582.
LAM, A., 2004. Organizational innovation.
LI, G., SHANG, Y., LIU, H. and XI, Y., 2014. Differentiated transformational leadership and knowledge sharing: A cross-level investigation. *European Management Journal,* **32**(4), pp. 554-563.
LIU, A.M. and CHAN, I.Y., 2017a. Understanding the interplay of organizational climate and leadership in construction innovation. *Journal of Management in Engineering,* **33**(5), pp. 04017021.
LIU, A.M. and CHAN, I.Y., 2017b. Understanding the interplay of organizational climate and leadership in construction innovation. *Journal of Management in Engineering,* **33**(5), pp. 04017021.
MARSHALL, C. and ROSSMAN, G.B., 2014. *Designing qualitative research.* Sage publications.
MCMEEL, D. and SWEET, K., 2016. *Roadmap for Supporting innovation in the New Zealand Construction Sector.* Auckland, NZ: BRANZ.
MINISTRY OF BUSINESS, INNOVATION AND EMPLOYMENT. (2014). Annual Report. *New Zealand Government*, New Zealand.
NAM, C.H. and TATUM, C.B., 1997a. Leaders and champions for construction innovation. *Construction Management & Economics,* **15**(3), pp. 259-270.
NAM, C.H. and TATUM, C.B., 1997b. Leaders and champions for construction innovation. *Construction Management & Economics,* **15**(3), pp. 259-270.
NAOUM, S.G., 2016. Factors influencing labor productivity on construction sites: A state-of-the-art literature review and a survey. *International Journal of Productivity and Performance Management,* **65**(3), pp. 401-421.
NEWELL, J., 2016. The Strategic Project Leader: Mastering Service-Based Project Leadership. *Project Management Journal,* **47**(2), pp. e1.
OZORHON, B., ABBOTT, C. and AOUAD, G., 2013. Integration and leadership as enablers of innovation in construction: Case study. *Journal of Management in Engineering,* **30**(2), pp. 256-263.
OZORHON, B., ORAL, K. and DEMIRKESEN, S., 2015. Investigating the components of innovation in construction projects. *Journal of Management in Engineering,* **32**(3), pp. 04015052.
PARK, M., NEPAL, M.P. and DULAIMI, M.F., 2004. Dynamic modeling for construction innovation. *Journal of Management in Engineering,* **20**(4), pp. 170-177.
PEACE, S., AOUAD, G., OZORHON, B. and ABBOTT, C., 2010. Facilitating innovation in construction. *Construction innovation,* .
PRASAD, B. and JUNNI, P., 2016. CEO transformational and transactional leadership and

organizational innovation: The moderating role of environmental dynamism. *Management Decision,* **54**(7), pp. 1542-1568.

PRICEWATERHOUSECOOPERS, 2011. Valuing the role of construction in the New Zealand economy.

PRIES∗, F. and JANSZEN, F., 1995. Innovation in the construction industry: the dominant role of the environment. *Construction Management and Economics,* **13**(1), pp. 43-51.

REICHSTEIN, T., SALTER, A.J. and GANN, D.M., 2005. Last among equals: a comparison of innovation in construction, services and manufacturing in the UK. *Construction Management and Economics,* **23**(6), pp. 631-644.

Rojas, E.M. and Aramvareekul, P. (2003), "Is construction labor productivity really declining?", *Journal of Construction Engineering and Management*, Vol. 129 No. 1, pp. 41-46.

SERGEEVA, N., 2016. What makes an "innovation champion"? *European Journal of Innovation Management*, **19**(1), pp. 72-89.

SHAHATA, K. and ZAYED, T., 2013. Simulation-based life cycle cost modeling and maintenance plan for water mains. *Structure and Infrastructure Engineering,* **9**(5), pp. 403-415.

SHAHBAZPOUR, M., 2010. *Strategic manufacturing system and process innovation : a framework for small and medium sized enterprises*.

SHAO, Z., FENG, Y. and HU, Q., 2016. Effectiveness of top management support in enterprise systems success: a contingency perspective of fit between leadership style and system life-cycle. *European Journal of Information Systems,* **25**(2), pp. 131-153.

TABASSI, A.A., ROUFECHAEI, K.M., BAKAR, A.H.A. and YUSOF, N., 2017. Linking team condition and team performance: A transformational leadership approach. *Project Management Journal,* **48**(2), pp. 22-38.

TUSHMAN, M. and NADLER, D., 1986. Organizing for innovation. *California management review,* **28**(3), pp. 74-92.

YI, W. and CHAN, A.P., 2013. Critical review of labor productivity research in construction journals. *Journal of Management in Engineering,* **30**(2), pp. 214-225.

ZHANG, Y., ZHENG, J. and DARKO, A., 2018. How does transformational leadership promote innovation in construction? The mediating role of innovation climate and the multilevel moderation role of project requirements. *Sustainability,* **10**(5), pp. 1506.

ZHENG, J., WU, G. and XIE, H., 2017. Impacts of leadership on project-based organizational innovation performance: The mediator of knowledge sharing and moderator of social capital. *Sustainability,* **9**(10), pp. 1893.

ZHENG, J., WU, G., XIE, H. and LI, H., 2019a. Leadership, organizational culture, and innovative behavior in construction projects: The perspective of behavior-value congruence. *International Journal of Managing Projects in Business,* .

ZHENG, J., WU, G., XIE, H. and LI, H., 2019b. Leadership, organizational culture, and innovative behavior in construction projects: The perspective of behavior-value congruence. *International Journal of Managing Projects in Business,* .

ARE CONSTRUCTION MANAGERS PRACTISING A PROFESSION, OCCUPATION OR TRADE?

Ron Webber [1], Gesa Ruge [2]

[1]Associate Professor, Construction Management, Central Queensland University, Rockhampton, Australia

[2]Senior Learning Designer, Centre for Learning and Teaching, Edith Cowan University, Perth, Australia

Abstract

Professions such as doctors and lawyers are defined through self-regulating associations, government legislation and university accredited standards for professional education, knowledge and ethical practice. In construction, the boundaries defining professions and less formalised occupations and trades appear to be increasingly unclear. The modern construction manager is highly knowledgeable with a skills base adapting from traditional building practice to digital resource and process management. This raises the question: Are construction managers today practicing a profession, occupation or trade? This research firstly presents a temporal review of the major historical influences and meanings of profession, and combines this with a thematic literature review to identify six key criteria defining and assessing profession today. The research highlights that against the identified criteria the role of construction manager does currently not qualify as a profession, but is an occupation with a number of professional responsibilities. Construction sector roles are today in need of renewal to reflect changes in industry practice, educational qualifications and acquisition of knowledge as opposed to traditional skills. These findings provide a baseline for further research and encourage discussion between industry, education, government and community stakeholders.

Keywords

Profession, occupation, ethical standards, education, knowledge acquisition, construction industry

Introduction and context

The internationalisation of the construction industry sectors within global markets has stipulated increasing reconceptualisation and adaptation of traditional professions, occupational roles, and trades over recent decades (Noordegraaf 2007; Evetts 2013; Brint 2015). In addition, the increased mobility of professional practitioners nationally and internationally with varying knowledge, skills and practices has also resulted in local and national governments needing to review, align and update processes for licensing, building quality controls as well as benchmarks for education levels and professional training (Olofsson 2007; Agevall & Olofsson 2013).

In the Australian construction industry, technical standards and legislation have increased in complexity and are directly impacting on the management of projects, corporate practice and community engagement parameters (Ball 2002; Gorse 2003). As one of the largest industries and employment sectors in Australia, the construction industry is currently undergoing a transformation due to globalisation and digitisation of products and processes, which in turn affects the organisational and cultural adaptation of industry management practices (ABS 2018). The employability skills debate for undergraduate degree programs has an added dimension for industry-specific professions (Toner & Coates 2006; Australian Parliamentary Library 2015-16).

Employers, industry bodies, and government regulators expect university graduates to begin work with developed generic, technical and early professional skills suited to diverse demands and needs of the industry (Ruge & McCormack 2017). Nationally and internationally, building and construction management students and graduates are gaining employment in a range of roles, such as site administrators, junior project or construction managers, contracts manager or site engineer. As their career experiences expand these professionals are seeking to continually adapt their skills to ensure future employability in the industry (Emmitt 2016).

Methodology

In construction, the boundaries defining professions and less formalised occupations and trades appear to be converging. The modern construction manager is highly knowledgeable, with a changing skills base away from traditional building practices to digital resource and project process and stakeholder management. This raised the research question for this paper: Are construction managers today practicing a profession, occupation or trade?

To investigate this research question, the authors developed the following research methodology and design. Firstly, a detailed literature review was undertaken utilising a keyword search across international and inter-disciplinary academic publications and journals dating back to the 1950s (Hsieh & Shannon 2005; Bryman & Bell 2011). This allowed to contextually capture and frame the historical development and defining criteria for professions, occupations, and trades over the last sixty years (Cooper 1988; Tsang 2013). The review of over 50 publications across the fields of higher education, sociology, management education, organisational management, construction, and engineering education as well as professional development provided a cross-disciplinary basis for the longitudinal development stages of professions, occupations, and trades over the last 200 years and is outlined in Section 3 below.

The researchers have both extensive industry expertise and as part of the research methodology consciously engaged in a collaborative and iterative reflective process of identifying, reviewing, reflecting and interpreting of the research data from the literature (Alvesson & Harley 2008; Woolgar 1988). Following the temporal analysis, the researchers undertook a secondary contextual analysis of the same literature, utilising a deductive thematic analysis (Tsang 2013) to identify more specific aspects and issues informing the meanings and practices determining profession, occupation, and trades. This thematic analysis via triangulation with the initial temporal content analysis (Bowen 2009; Buchanan 2007) led to the identification of six key criteria and sub-criteria aspects to assess construction manager in relation to the research question. These criteria are presented as new findings in Table 1 below. The discussion section outlines insights and findings in more details, highlighting with practice focused examples, current and emerging challenges for educators, construction industry professions and associations as well as government and broader community.

Historical baselines for professions

The early years - professional association in pre-industrial European societies

The early years of transition from medieval guilds and trades towards occupations and professions took place in England and Germany from the late 17th to the early 20th century. Neal and Morgan (2007) provide a detailed historical account of the professionalisation of key trades and occupations in the United Kingdom including chartered surveyor, chartered structural engineer, a chartered architect and in Germany for a land surveyor, building engineer and architect.

For example, a chartered surveyor in England became a full-time professional in the 18th century, with articles and national association established in 1868, exams required from 1881, academic courses available at university from 1904 and CPD for members commenced in 1981. Likewise, a chartered structural engineer was a full-time professional engineer from 19th century, the national association was established in 1908, exams were held from 1920, a charter agreed in 1934, academic degrees started in 1969 and CPD from 1996. Chartered Architects took up the full-time profession in the 17th century, an association with articles was established by 1834, exams for held from 1882, academic courses offered from 1902 and CPD commenced in 1993 (Neal and Morgan 2007, Tables 1 and 2, pp.14-15). The professional associations controlled the entry requirements for members, standards of education and skills. The professional associations also actively policed members and prevented non-members from practice. In addition, shifting occupation from trade to professions required support from Government and society for legal protection and self-determination to engage and provide these service (Trank & Rynes 2003; Pfeffer and Fong 2003; Neal & Morgan 2000).

As an extension of this social demarking of specific professions several centuries ago, a subsequent social separation and elevation of professions from trades and occupations resulted. The literature identifies a set of structured processes for changing trades or occupations towards a profession, which was implemented and expanded from the earlier to the later professions (Neal & Morgan 2000; Wilensky 1964; Black 2007). These characteristics include:

1) Moving towards a full-time occupation and agreement on a name for the profession.
2) Developing a formal training system and examinations at universities with a focus on current scientific knowledge and professional education. The trades-based pathway through training colleges with a practice focus skills and employment continues in parallel.
3) Establishment of a professional association, including several under a royal charter, admitting members committed to code of conduct and ethical standards for the profession.
4) The government legislated and supported licencing for the profession and thereby assured standards and differentiation between profession, occupation, and trades.
5) Professional associations inform and accredit the educational courses and apply membership standards for post-education entry into the association.
6) Associations were largely self-regulating and introduced continuous professional development (CPD) to support the professionalisation of members.

The classical age of professions – ethical value, trust and in association

The initial process of moving from a trade or occupation to a profession is described by Black (2007), utilising the history of physicians in England, as follows:

> Granting a trade the status of a profession represents a deal between society (government) and the occupation. In return for gaining considerable freedom of self-determination and legal protection… (the profession) pledges to act honestly and altruistically in the interest of the members of the public they serve and to advance both their subject and her personal knowledge and skill.... a profession controls who can join its privileged ranks by determining the entry requirements and minimum standards of practice. (Black 2007, p.224)

Greenwood (1957) and Wilensky (1964) argued that professional work required a long and expensive education and training to acquire the necessary knowledge and expertise. Professionals were autonomous and performed a public service. They were guided in their decision-making by a professional ethic or code of conduct and were expected to act altruistic and motivated by universalistic values acting for their clients and society, primarily not for their own benefit or profit. The recognition of professional knowledge and skill provided an elevated social status for which society offered title and trust in the knowledge and skill of the professional and their association (Di Luzio 2006; Evetts, 2006). This resulted in further increase of social and political influence of occupational groups and professions, which in the literature is discussed as a socio-cultural 'market closure' mechanism to retain occupational control over the role and service (Goldthorpe 1982).

For groups that did not strictly fulfil all criteria of professions in the 19th and early 20th century, the label 'occupation' or 'semi-profession' was suggested as more appropriate for differentiation (Etzioni 1969). A further level of differentiation between profession, trade, and occupation is noted in the literature by Billsberry and Birnick (2010), who argue that a profession combines all three of the 'intellectual virtues', being knowledge of science, professional skill, and practical wisdom. The emphasis in this classical era of professions being formally established and gaining recognition as part of the social and political structures are the specific code of conduct relating to personal, professional and ethical behaviour for each member of a professional association (Wright 1951; Billsberry & Birnik 2010). Another interpretation notes the differentiation of professions as a combination of professional knowledge, ethos (ethics) and professional training, thereby allowing individuals to be able to abstract and extend their knowledge to contexts of their expertise (Spender 2007; Trank and Rynes 2003).

Post-industrial era: professionalisation of occupations

From a socio-cultural research perspective over time, the literature offers further insights into the drivers for change in the role and relevance of profession, occupation, and trade. One of the early references on a shift occurring in the 1950s by sociologist Hughes, who proposed that differences between an occupation and a profession where 'of degree and not kind' (Hughes 1958). Rather than seeking hierarchical differentiation as had been done previously, he identified the extensive common ground between profession and occupation in that both take on authoritative roles to thinking about a problem that is in their area of expert knowledge and that they are granted the trust by their clients and society at large to determine a good solution or answer for (Hughes 1958; Hallida 1987). From the 1960s to the 1980s the diversifications of professional occupations and subsequent growth of university degree programs saw occupations previously trained at technical colleges now moving into university degrees and subsequent management career pathways (Olofsson 2009). Examples of this educational shift from technical and vocational to university education are healthcare and nursing, media and communications, teaching and education. Building and construction programs offered at technical schools and colleges followed the same trend and since the early 1980s, higher education building and construction degrees programs have been established at most states and territories of Australia. Higher education degrees, accredited by Tertiary Education Quality Standards Agency (TEQSA) as well as the Australian Institute of Building (AIB) or Australia Institute of Quantity Surveyors (AIQS) offer access into management careers through a bachelor or masters in building, construction, project management, construction management, quantity surveying, and other specialisations. The trends are today common across the higher education sector, seeking to diversify, differentiate and financially grow its degree programs in an internationally highly competitive education market.

Evetts (2003, 2006, 2011 and 2013) has extensively researched and written about modern development and differentiations between profession, occupation, and trade. Evetts developed the following definition and delineation for today's context:

> …professions are regarded as essentially the knowledge-based category of service occupations which usually follow a period of tertiary education and vocational training and experience. A different way of categorizing professions is to see them as the structural, occupational and institutional arrangements for work associated with the uncertainties of modern lives in risk societies. Professionals are extensively engaged in dealing with risk, with risk assessment and, through the use of expert knowledge, enabling customers and clients to deal with uncertainty. (Evetts, 2013, p 781)

The phase of professionalisation of occupations since the 1980s appears to have reduced the barriers and social boundaries of a smaller number of professions limiting entry to its association. However, the diversification and expansion of professionalisation have blurred the previously clear boundaries of who and what defines a profession and professional occupation in many fields. For example, responding to an advertisement for 'building professional – construction management' an employer may consider an applicant with a university degree in construction management, a vocational educated project manager in construction or a trade based educated site manager with experience in managing construction sites.

The review of the literature on profession, occupation, and trades has allowed identifying the historical basis and development of professions and how over the last centuries in Western European societies the definition of professional role, education and recognition has diversified. This has led to a complex and internationalised expert stratum of professionalised occupations, which advocate market knowledge as managers in their own professional fields of expertise, rather than being defined the classical professions. It appears, that this has also led individuals being less defined by the ethical professional responsibilities to society and communities as they are providing knowledge and skills to individual clients and project (Noordegraaf & Schinkel 2011; Freidson 2001; Evetts 2013).

Re-mapping criteria for becoming a professional

The section above outlined the origins and changes of time in the definition and understanding of what is a profession and a professional. The increase in new occupations and diversification of industries and roles has over the last decades led to a further blurring of boundaries on what is defined as profession, occupation or trade in the construction industry in Australia today. Before a comparison can be established there is some confusion between the term's commercial builder and construction manager. For the purposes of this article commercial builder and construction manager are interchangeable. It appears that many occupations and trades use the term professional without a clear understanding of what this entails. In many instances, the term professional refers to higher levels of service or conduct from an occupation or trades, like salespersons and general managers or bricklayer and tilers for example, who may in fact not be a member of the profession. This then begs the question of what is required to be a professional (Hotho 2008; Evetts 2011; Brint 2014).

To develop a current understanding of the criteria and specific aspects which inform the understanding of the profession, the researchers undertook a second thematic analysis of the literature. This occurred in an iterative inductive and deductive sequence to firstly draw out the key themes, values, and issues followed by grouping and aligning these to higher-order aspects, which were further reduced to six key criteria for a profession:

1. Professional associations set and review member entry standards
2. Higher education with knowledge and skills for profession
3. Ethical standards and code of conduct
4. Public trust and service to the community
5. Regulation, licence, and self-certification
6. Continued professional development advancing knowledge and skills

These six criteria were then each tested against the current predominant roles of a construction manager in Australia. The findings are collated in Table 1 and are discussed here in more detail.

Professional association setting and reviewing member entry standards

One of the key identifying requirements noted in the literature is that the professional belongs to a professional institution or regulatory body (Evetts 2003; Balthazard 2015). These include close links between the professional institution and universities and associate right of admission through a university qualification. Schultze (2007) further notes that apart from professions obtaining their education from a university the professional institutes accredit the various courses and their content to ensure the quality of graduating professionals. This then establishes links between a specific body of knowledge acquired by the professional and their ability to perform at a professional level. The Australian Institute of Building the professional institute representing building professional does require a degree as the basis for becoming a member. In the case of construction management, there is no single professional institute or association that represent all construction managers, nor is it compulsory to be a member of an institute to practice as a construction manager. The university sectors providing construction management degree based on a research and scholarship approach for professional qualifications, meeting the educational qualification of criteria 2 of Table 1.

Higher education with knowledge and skills for profession

Freidson (1989, p. 425) states that professional work requires "formally organised, theoretical or abstract knowledge" to ensure adequate performance. Friedson (1989, p. 427) further notes that this knowledge "is so complex and esoteric that laypeople are not able to employ it themselves". As cited in Webber el ta (2015) and Shulman (2005) professional education centres on cognitive (learning to think), generally through university education, practical (learning to perform) and moral (learning to act ethically). As previously noted, practical learning for professionals is generally undertaken post their university course or post-qualifying. In the case of medical doctors and lawyers, as previously note the earliest professions, they either perform residency or internship post-university qualification (Freidson 1989).

In Australia, there are several universities who provide a bachelor's degree in construction management. However, in the State and Territories of Australia, it is not compulsory to have a bachelor degree to become licensed or registered as construction managers. In some States and Territories, there is no requirement for any construction management degree qualifications to construct commercial, industrial buildings or a hotel as examples.

In the first instance trades are clearly not professionals because trades generally don't require a higher educational degree to practice, nor are they committed to public service or a defined set of ethics as in the medical profession. However, some trades are required to be registered through a government department like electrician and plumbers and have specific trade qualifications (Billsberry & Birnik 2010; Stichweh 1997). However, they are generally not required to be members of the industry association, e.g. the Master Plumber Association. To practice, the tradesperson needs to be licensed or registered with the relevant State or Territory government department (Victoria Plumbing Regulations 2018). Likewise, some industry occupation associations may or may not have a code of ethics. Whilst State government offer and fund vocational training and certificate programs, many trades in Australia are not required to have formal training to practice e.g. carpenters, steel fixers, concreters, tiles, plasters and painters and generally develop their skills while working at the trade.

Ethical standards and code of conduct

The main feature that distinguishes members of a profession from those of occupation is their conduct within an agreed ethical framework (Billsberry & Birnik 2010; Fryer & Gardner 2007; Trank & Rynes 2003). The main defining feature of almost all codes of conduct is that the professional considers the welfare of his client and community before themselves (Schultze 2005).

The ethical learning and understanding related to a professional commences during their university education and again when they agreed to the ethical code of conduct upon joining their professional association or institute. The original professions (medicine, law, and theology) had codes of ethics based on Hippocratic oath whose centrepiece is "to do no harm" to others. The lawyer's ethics are based on the solicitor and client relationship and recognized as a "fiduciary relationship" i.e. one of trust between the lawyer and their client. Like doctors, they supposedly put the welfare of their client first (Freidson 1989; Evetts 2003). The ethical behaviour should be the basis for the beginning of the professional's engagement with their client and therefore enforcement should be rarely required, apart from totally unscrupulous behaviour.

As noted by Balthazard (2015, p.1) occupations don't necessarily have a code of ethics that is centred on "public commitment to a high standard of performance, to integrity, and to public service". However, occupations are endeavouring to establish themselves as professions for an important reason. This is to maintain and extend their market employment share whilst trying to establish a protected and monopolistic status of employment through limiting access to what they consider is their specific markets. Recent examples of occupations trying to establish their professional status include: general management, specifically project management, marketing, business administration, and human resources management even though these occupations can complete a university degree, it's not compulsory for practice (Balthazard 2015; Neal & Morgan 2000). In contrast with long-established professions like law and medicine a university degree as the minimum benchmark requirements for entry into that profession. There are similarities in the construction industry between quantity surveyors considered professionals, and building estimators, not considered professional (Hackett & Hicks 2007).

Public trust and service to the community

Evetts (2003) and Balthazard (2015) note that in addition to ethical behaviour professionals also have a commitment to public service. This is usually exhibited through altruistic and universalistic values for their clients and the community. This was reinforced by Balthazard (2105 p. 2) as noted that members of a profession are expected to hold "higher levels of integrity and trustworthiness" and place their client and the community ahead of profit motivation. Unlike lawyers or doctors, construction managers generally, due to insurance and legislated responsibilities, do not provide free public service through pro bono work in their professional capacity.

In construction, for example, commercial and high-rise buildings require specific high levels of knowledge that a layperson cannot readily obtain without higher education. The layperson, therefore, needs to trust construction managers expertise (Brown 2012; Evetts & Jefferies 2005; Hughes & Hughes 2013). However, this trust has been substantially damaged due to the recent high levels of published building faults associated with these types of buildings.

Regulation, licence, and self-certification

Qualifications of construction managers are nationally not aligned and vary between States and Territories and are therefore inconsistent and not necessarily regulated uniformly across Australia. In some State and Territories construction management employment is regulated and regulations stipulate that only qualified practitioners can construct higher-rise buildings. While in others States and Territories this work is not regulated by law.

Professionals can also be regulated by statute. Examples are doctors or lawyers where persons cannot practice as a doctor unless registered by the Medical Board of Australia and lawyers are registered by the Australian state or territory supreme courts. In both cases, professionals cannot practice without compliance of the prescribed statue for registration (Freidson 1989).

Professional status is established through self-certification of professional work. The literature is not clear as to what exactly constitutes self-certification. From a construction managers perspective and due to the very complexity of higher-rise building many individual checking procedures are included. Consequently, self-certification is not conducted by construction managers. Authors Stichweh (1977), Evetts (2003) and Freidson (1989) note that professional employment is usually associated with monopoly exclusivity mandated generally by statues to the particular profession work e.g. medicine and law. This is sought after by occupational groups, to increase their market share of employment as well as establishing professional status in the eyes of the public (Evetts 2003).

Construction managers generally have a high degree of independence and control over their work. This independence is not total as they only control the management of the construction process with intervention from the various consultant and building surveyors and certifiers. However, this intervention is largely from quality control perspective and to ensure legislative compliance.

Continued professional development (CPD) advancing knowledge and skills

For lawyers and doctors the practical skills training or specialisation, depending on their preferred professional area of expertise usually takes place post-undergraduate degree qualification through CPD or additional formal education like a Master's degree (Neal & Morgan 2000; Greenwood 1957). This is to ensure that these professions have the necessary broad theoretical knowledge and understanding obtained in their undergraduate degree before they begin to practice within their preferred area of expertise. Contrary to these professions many construction managers who undertake a degree qualification tend to complete their training and gain employability skills already during the time they are studying (Emmitt 2012; Ruge & Mc Cormack 2017).

The six key characteristics of profession drawn from the literature and outlined above have been collated in Table 1 below. In a tabulated form, the current practice and contexts of construction manager are assessed against each characteristic of profession and discussed in the findings sections below.

Table 1. Characteristics of Profession for Construction Manager

Characteristics of professions	Is the construction manager meeting the characteristic for a profession? (Yes / No / Partial)	Literature
Criterion 1. Professional association set and review member entry standards		
The profession offers an established institute or association, recognised by community and government. The professional association sets entry requirements and educational standards for profession.	**No** – While there are professional institutes, it is not compulsory for construction managers to join, in order to practice.	Evetts 2003; Webber, Todhunter & Love 2015; Freidson 1989; Stichweh 1997; Balthazard 2015; Schultze 2007.
Criterion 2. Higher education with knowledge and skills for profession		
Higher education degree theory bases and complex esoteric as well as discipline-specific knowledge.	**No -** University courses are available but not compulsory as educational qualification. Trade, VET and occupational careers paths also provide entry points to construction managers.	Billsberry & Birnik 2010; Stichweh 1997; Freidson 1989.
Higher education is based on current research and scholarship	**Yes -** universities courses are based on this criteria	Freidson 1989
Criterion 3. Ethical standards and code of conduct		
Governed by code of conduct and ethical behaviour, ie as established by the professional association. Commitment to ongoing education and advancement of the profession.	**Yes** – only for those that are members of the Institute for the Profession, i.e. AIB, AIQS, CIOB	Wright 1951; Billsberry & Birnik 2010; Fryer & Gardner 2007; Trank & Rynes 2003; Pfeffer & Fong 2004; Edwards 2012.
Present altruistic and universalistic values for their clients and the community.	**No**	Etzioni 1969; Evetts 2003; Freidson 1989; Balthazard 2015.
Because they process specialised knowledge a layperson places trust in the profession.	**Yes** –for the commercial building sector. Currently, the specialised knowledge in the residential building sector is not recognised.	Evetts 2003; Billsberry & Birnik 2010.
Criterion 4. Public trust and service to the community		

Respect and status in society. Public trust professed by the profession.	**Partial** – due to the recent increase in building defects and inquiry into building services.	Freidson 1989; Evetts 2003;
Public service i.e. pro bono	**No**	Evetts 2003
Criterion 5. Regulation, licence, and self-certification		
Qualifications and practice regulated by Statute.	**Partial -** Applicable in some States and Territories of Australia	Neal and Morgan 2000
Professionals can self-certify their work. Basis of their pay is a fee for service.	**No**	Freidson 1989
Professional monopolies of employment, not entered by other professions, offers independence and control.	**No**	Stichweh 1997; Freidson 1989; Evetts 2003.
Criterion 6. Continued professional development advancing knowledge and skills		
Professional training conducted post-graduation for professions. Training during or after obtaining higher education qualifications.	**Partial -** Not compulsory by the professional institute. Some government department requires ongoing CPD for builders and construction managers licensing.	Freidson 1989; Neal and Morgan 2000

Findings

As previously noted, the term professional or acting professionally is used by many occupations and trades and generally refers to higher levels of service or conduct from either an occupation like salespersons or a trade perspective like a painter. Table 1 was developed to provide specific criteria to compare and differentiate what constitutes profession in terms of role, responsibility and public engagement. The criteria 1 to 6 listed in Table 1 can now provide clarity on how to better determine what constitutes a profession.

Table 1 developed from the literature lists six key criteria and subsections against which construction managers currently meet only three areas. These relate to higher education (criterion 2) and two aspects of ethical standards and code of conduct (criterion 3). In comparison, trades are also not professions because trades generally are not required to have a higher education degree to practice, nor are they committed to public service or work within a defined set of ethics standards, i.e. criteria 2 and 3 are not met.

Having further analysed construction manager against the all criteria listed in Table 1 the following finding can be distinguished: The initial findings suggest there are currently three main areas that align with Table 1. Section 2 of Table 1 requires a higher degree based on current research and scholarship and the professional institutes (AIB) require a bachelor's degree as the entry point for membership. Universities education for construction management in Australia is based on research and scholarship and ensure graduates in construction management have a knowledge acquisition based and not a skills-based education.

In Table 1, criterion 3 requires ethical conduct for professional status. Construction managers are currently not required to comply with a code of ethics as they may choose but are not compelled, to be members of a professional institute having a code of ethics. Some Australian State and Territories that register construction managers legislate compliance with their code of ethics and conduct (Building Act, Vic, 1993, s 177 to 177D). Table 1, criterion 3 requires professionals to abide by ethics and code of conduct and requires that members of the profession having specialised knowledge. Given the complexity of high-rise buildings and building generally, then it is arguable that a construction manager does have specialised knowledge. This specialise knowledge then forms part of the community trust referred to in criterion 3 where the layperson needs to rely on the construction manager for their expertise. However, this would be based on the proviso that construction managers meet criterion 2 of university degree qualification.

In light of this analysis construction managers do not currently meet or only partially meet several other key criteria for the profession. These are criterion 1 not met, criteria 2 and 3 partly met, criteria 4, 5 and 6 only partially met. Criterion 1 related to professional association is currently not met, as construction managers are not required to be members of a professional association which sets and monitors entry and education standards for construction management degrees. Criterion 2 is only practically met due to the university degree provided not being compulsory. Additionally, trades and VET also provide pathways to employment as construction managers.

Construction managers partially meet the requirements of criterion 3. A code of ethics is required for membership by the professional institutes (e.g. AIB). However, as membership is not compulsory then this excludes construction managers from professional status. Furthermore, construction managers do have specialised knowledge that cannot be readily obtained by the layperson and consequently the community needs to rely on their expertise.

Construction managers only partially meet criterion 4 on public trust and service to the community. This is based on the ongoing poor publicity received due to building faults and lack of rigour in quality of licensing and registration across Australia. Criterion 5 relates to regulated licencing, self-certification and monopoly of employment associated with professional status. As discussed in this paper, construction managers do not meet these requirements for professional status, as there is currently no consistent legislation and defined licensing category for construction managers across Australia.

The final criterion 6 requires continued professional development to advance knowledge and the profession within the community. This refers mainly to knowledge and not basic training and as noted, this is part of a university degree, based knowledge that is complex and centres on cognitive (learning to think), practical (learning to perform) and moral (learning to act ethically).

If all six criteria listed in Table 1 were substantively achieved then construction manager could be considered a profession and potentially be a strong basis to build community trust and recognition.

Conclusion and limitations

This research was triggered by the current issues facing the Australian building and construction industry. Findings outlined above indicate that the construction manager is not a profession or trade but an occupation in a professionalising work environment of the building and construction sector.

It appears timely now for industry members and associations to reflect, renew and reaffirm the values and responsibilities more broadly of the profession, occupations, and trades in today’s digital and internationalised industry. The authors aim with this research is to provide a baseline position for further research and engagement with industry, government, education providers and community stakeholders.

Currently, construction managers cannot be classified as professionals utilising the referenced literature analysis six criteria developed in this study of: professional association, higher education, ethical code of conduct, public trust and service, regulation and licence, continued professional development.

This research suggests, that Australian trained construction managers at this point only meet limited sections in Table 1. This includes higher degree based on current research and code of conduct and ethics. Further construction managers have specialised knowledge and the layperson needs to rely on the construction manager for this expertise.

- Those that undertake a construction managers degree based on knowledge acquisition as distinct for skills training form the basis to become a professional, assuming that over time other criteria listed in Table 1 could be achieved.
- A construction manager is not a trade as they are not required to obtain skills training. Generally, trade qualifications are not obtained through a higher educational degree based on knowledge acquisition and are not committed to public service or a defined set of ethics.
- While various occupations refer to themselves as professionals, if they are compared to the six criteria proposed in this research, they cannot nominate themselves as member of a profession.

This research is limited in that is has focused on academic literature and is shaped by the authors' own insights and experiences. This work, therefore, does not reflect or represent the views of any institution, association or interest group. It rather seeks through the methodology of a temporal review and a thematic analysis of the current international research literature to provide a robust and transparent basis for further investigations. Given for example the eclectic nature of the construction management content in current university curriculum only the degree descriptor of 'construction management' was used and it was assumed that curriculum content is knowledge acquisition based. A further limitation is that this research has adopted a Western-European perspective in the historical analysis of professions. This is due to the predominant socio-cultural and legal influence on the development of the Australian construction industry to date. Further studies are needed to broaden this perspective and incorporate Asia-Pacific and other international influences currently shaping Australian building and construction policies, processes and practices into the future. As future extension of this research, it would be interesting to apply the six criteria identified here to other professions and occupations and establish how theses compare to construction manager and investigate in more detail which other current trends and contexts are influencing professions today.

References

Abbott, A. 2014, *The system of professions: An essay on the division of expert labor*. University of Chicago Press, Chicago, USA.

ABS Australian Bureau of Statistics. 2018, '8165.0 – Counts of Australian Businesses, including Entries and Exits Jun 2013 to Jun 2017'. Retrieved from: http://www.abs.gov.au/ausstats/abs@.nsf/mf/DetailsPage/8165.0Jun+2013+to+Jun+2017

Agevall, O., Olofsson, G. 2014, 'Tensions between academic and vocational demands'. In: Jens-Christian Smeby, Molly Sutphen (ed.), *From Vocational to Professional Education: Educating for Social Welfare*, pp. 26-49, Routledge, London and New York.

Alvesson, M., Hardy, C., & Harley, B. 2008, 'Reflecting on reflexivity: Reflexive textual practices in organization and management theory'. *Journal of Management Studies*, vol. 45(3), pp. 480-501.

Australian Parliamentary Library. 2015-16, 'Employment by industry statistics: A quick guide'. *Research Paper Series 2015 -16*, 14 April 2016. Retrieved from: http://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/rp/rp1516/Quick_Guides/EmployIndustry.

Ball, J. 2002, 'Can ISO 14000 and eco-labelling turn the construction industry green'? *Building and Environment*, vol. 37(4), pp. 421-428.

Balthazard, C. 2015, 'What Does it Mean to be Professional'. *HRPA Series on Professionalization, Professionalism, and Ethics for Human Resources Professionals*. Retrieved from; https://www.hrpa.ca/Documents/Designations/Job-Ready-Program/What-it-means-to-be-a-professional.pdf

Billsberry, J., & Birnik, A. 2010, 'Management as a contextual practice: the need to blend science, skills and practical wisdom'. *Organization Management Journal*, vol. 7(2), pp. 171-178.

Black, N. 2007, 'From trades to professions'. *Journal of the Royal Society of Medicine*, vol. 100(5), pp. 219-224.

Bowen, G. A. 2009, 'Document analysis as a qualitative research method'. *Qualitative Research Journal*, vol. 9(2), pp. 27-40.

Brint, S. 1996, *In an age of experts: The changing role of professionals in politics and public life*. University Press, Princeton, New Jersey.

Brint, S. 2015, 'Professional responsibility in an age of experts and large organizations'. In *Professional Responsibility,* pp. 89-107, Springer, Cham, Switzerland.

Broadbent, J., Dietrich, M., & Roberts, J. 1997, *The End of the Profession. The Restructuring of Professional Work*, Routledge, New York.

Brockmann, M., Clarke, L., & Winch, C. 2009, 'Competence and competency in the EQF and in European VET systems'. *Journal of European Industrial Training*, vol. 33(8/9), pp. 787-799.

Brown, M. A. 2012, 'Construction management: the management of the development, conservation and improvement of the built environment'. *Organization, technology & management in construction: an international journal*, vol. 4(2), pp. 457-460.

Bryman, A., & Bell, E. 2011, *Business research methods*. Oxford, United Kingdom: Oxford University Press.

Buchanan, D. A., & Bryman, A. 2007, 'Contextualizing methods choice in organizational research'. *Organizational Research Methods,* vol.10(3), pp. 483-501.

Building Act, Victoria, 1993, Section 177 to 177 D.

Building Regulation Review (BRR) 1991, 'Professional Certification of Building: Model National Approach', developed by *the National Committee on Certificate to Promote Informed Public Consideration*, Australia.

Burrage, M., & Torstendahl, R. 1990, *The formation of professions: Knowledge, state and strategy*. Sage Publications, London, United Kingdom.

Cooper, H. M. 1988, *Organizing knowledge syntheses: A taxonomy of literature reviews. Knowledge in Society,* vol. 1(1), p.104; Springer, Netherlands.

Di Luzio, G. 2006, 'A sociological concept of client trust'. *Current Sociology,* vol. 54(4), pp. 549-564.

Edwards, A. and Daniels, H., 2012, The knowledge that matters in professional practices. *Journal of Education and Work*, vol. *25*(1), pp. 39-58.

Emmitt, S. 2016, 'The construction design manager–a rapidly evolving innovation'. *Architectural engineering and design management,* vol. 12(2), pp. 138-148.

Evetts, J. 2003, 'The sociological analysis of professionalism: Occupational change in the modern world'. *International sociology*, vol. 18(2), pp. 395-415.

Evetts, J. 2006, *Introduction: Trust and professionalism: Challenges and occupational changes*, pp.515-531.

Evetts, J. 2011, 'Sociological analysis of professionalism: Past, present and future'. *Comparative Sociology,* vol. 10(1), pp. 1-37.

Evetts, J. 2013, 'Professionalism: Value and ideology'. *Current sociology*, vol. 61(5-6), pp. 778-796.

Evetts, J., & Jefferies, D. 2005, The engineering and science institutions in the UK: changes, ambiguities and current challenges. *European journal of engineering education*, vol. 30(3), pp. 299-308.

Etzioni, A. 1969, *The semi-professions and their organization: Teachers, nurses, social workers*. Free Press, New York.

Freidson, E. 1989, *Medical work in America: Essays on health care*. Yale University Press.

Freidson, E. 2001, *Professionalism, the third logic: On the practice of knowledge*. University of Chicago press.

Ghoshal, S. 2005, 'Bad management theories are destroying good management practices'. *Academy of Management learning & education*, vol. 4(1), pp. 75-91.

Gosling, J., & Mintzberg, H. 2006, 'Management education as if both matter'. *Management learning,* vol. 37(4), pp. 419-428.

Gorse, C.A. 2003. 'Conflict and conflict management in construction'. *In Proceedings of 19th Annual Conference of the Association of Researchers in Construction Management*, pp. 173-182.

Greenwood, E. 1957, ‘The Attributes of a Profession’, *Social Work*, vol. 2, pp. 44–55.
Goldthorpe, J.H. & Marshall, G. 1992. ‘The promising future of class analysis: a response to recent critiques’. *Sociology*, vol. 26(3), pp.381-400.
Hackett, J.A. and Hicks, C.M., 2007. Estimating as a profession in UK construction. *Engineering, Construction and Architectural Management*, *14*(1), pp.26-51.
Halliday, T. C. 1987, *Beyond monopoly: Lawyers, state crises, and professional empowerment*. University of Chicago Press, Chicago, USA.
Hsieh, H.-F., & Shannon, S. E. 2005, ‘Three approaches to qualitative content analysis’. *Qualitative Health Research*, vol. 15(9), pp. 1277-1288.
Hotho, S. 2008, ‘Professional identity–product of structure, product of choice: linking changing professional identity and changing professions’. *Journal of Organizational Change Management*, vol. 21(6), pp. 721-742.
Hughes, E. C. 1958, *Men and their work*, vol. 958, Free Press, New York, NY.
Hughes, W., & Hughes, C. 2013, ‘Professionalism and professional institutions in times of change’. *Building Research & Information*, vol. 41(1), pp. 28-38.
Krause, E. A. 1996, *Death of the Guilds*, Yale University Press, New Haven and London.
Larson, M. S. 1977, *The Rise of Professionalism: A Sociological Analysis London*. University of Chicago Press.
McClelland, C. E. 1990, ‘Escape from freedom? Reflections on German professionalization 1870-1933’. *The formation of professions: Knowledge, state and strategy*, pp. 97-113.
Neal, M., & Morgan, J. 2000, ‘The professionalization of everyone? A comparative study of the development of the professions in the United Kingdom and Germany’. *European Sociological Review*, vol.16(1), pp. 9-26.
Noordegraaf, M. 2007, ‘From “pure” to “hybrid” professionalism: Present-day professionalism in ambiguous public domains’. *Administration & Society*, vol. 39(6), pp. 761-785.
Noordegraaf, M., & Schinkel, W. 2011, ‘Professional capital contested: A Bourdieusian analysis of conflicts between professionals and managers’. *Comparative Sociology*, vol. 10(1), pp. 97-125.
Olofsson, G., 2007, September. The dark side of professions–the role of professional autonomy in creating'great professional disasters'. In *The 8th Conference of the European Sociological Association Glasgow* (pp. 3-6).
Oxford Dictionary 2013, Definition of professional. http://www.oxforddictionaries.com/definition/english/professional. Accessed 28 August 2019
Parsons, T. 1951, *The Social System*. Free Press, New York, NY.
Pfeffer, J. 2005, ‘Why do bad management theories persist? A comment on Ghoshal’. *Academy of Management Learning & Education*, vol. 4(1), pp. 96-100.
Polelle, M. J. 1998, ‘Who's on First, and What's a Professional’. University of San Francisco Law Review, vol. 33, p. 205.
Ruge, G., & McCormack, C. 2017, ‘Building and construction students’ skills development for employability–reframing assessment for learning in discipline-specific contexts’. *Architectural Engineering and Design Management*, vol. 13(5), pp. 365-383.
Schultze, R., 2007, ‘What does it mean to be a self-governing regulated profession’. *Journal of Property Tax Assessment & Administration*, vol. 4(3), pp. 41-53.
Shulman, L.S., 2005. Signature pedagogies in the professions. *Daedalus*, *134*(3), pp.52-59.
Spender, J. C. 2007, ‘Management as a regulated profession: An essay’. *Journal of Management Inquiry*, vol. 16(1), pp. 32-42.
Stichweh, R. 1997, ‘Professions in modern society’. *International Review of sociology*, vol. *7*(1), pp. 95-102.
Svensson, L., & Evetts, J. (Eds.) 2003, *Conceptual and comparative studies of continental and Anglo-American professions* (Vol. 129). Dept. of Sociology, Göteborg University, Göteborg, Sweden.
Toner, P., & Coates, N. 2006, ‘Competition and the growth of non-standard employment: the case of the Australian construction industry’. *Labour & Industry: a Journal of the Social and Economic Relations of Work*, vol. 17(2), pp. 99-118.

Trank, C. Q., & Rynes, S. L. 2003, ‘Who moved our cheese? Reclaiming professionalism in business education’. *Academy of Management Learning & Education*, vol. 2(2), pp.189-205.
Tsang, E. W. K. 2013, ‘Case study methodology: causal explanation, contextualization, and theorizing’. *Journal of International Management*, vol. 19(2), pp. 195-202.
Webber, R., Todhunter, A., & Love, P. 2015, ‘The concept of signature-agogy in an undergraduate program in construction management’. In *RICS COBRA AUBEA 2015: The Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors; The Australasian Universities’ Building Educators Association Conference* (pp. 1-11). Royal Institution of Chartered Surveyors.
Wilensky H.L. 1964, ‘The professionalization of everyone?’ *American Journal of Sociology*, vol. 70(2), pp. 137–158.
Woolgar, S. 1988, *Knowledge Reflexivity*. Sage publication, London, United Kingdom.

HOW KNOWLEDGE FROM INNOVATION COMPETITIONS CAN ADVANCE SUSTAINABLE INNOVATION TARGETS IN ARCHITECTURAL DESIGN COMPETITIONS

Christopher A. Jensen

Melbourne School of Design, University of Melbourne, Melbourne, Australia

Abstract

Modern interpretations of sustainable building design are founded upon innovative application of new products and technology, often for the first time. Such examples are at the forefront of the 'prototype' nature of buildings that result from both design and technological innovations. Architectural design competitions are the primary competition in the construction industry, primarily concerned with design innovation, and are a popular procurement method for large public projects. Although such conceptual competitions often lack the physical dimension such as prototyping, they have been shown to be very effective in generating project specific radical designs. More broadly industry-based contests can be used to trigger research and knowledge creation, as well as investment in industry, with the competition rules and judging criteria critical to directing the entrants towards radical designs and technological solutions. The limitation of architectural design competitions to design criteria is limiting to the advancement of functional, performance criteria in the industry. This lack of emphasis is restricting the application of innovative sustainable solutions in the building industry through such competitions. This research demonstrates how knowledge from innovation contests in other industries can benefit the application of sustainable innovation and technology in architectural design competitions. This can be achieved primarily from a modification to the design of the competition environment, including scope and judging criteria and expected degree of resolution. The results of this study show that a design competition with a comprehensive scope and demonstrable outputs are more likely to result in more focussed sustainable innovation solutions.

Keywords

Sustainable design, buildings, innovation, competition, Architectural Design Competitions

Introduction

Competitions as a source of innovation

A central theme of the literature on industry competitions is that innovation is enhanced by 'staged' competitions (where teams compete for a prize). Such staged competitions are usually an ex ante prize to determine the best technological or constructed idea or outcome in response to a specific target. Staged competitions are referred to in different fields as global challenges (X-prize.org, 2017) recognition prizes (Stine, 2009) innovation contests (Kay, 2011). Competitions of this nature are shown to provide numerous benefits over typical market responses to progressing innovation such as reaching a broad range of entrants, pay only for performance, leverage of outside resources, creating parallel innovation, and attract public interest (Wagner, 2011). Early innovation stage competitions are broadly categorised as ideas, concept or design competitions, where individuals or firms are invited to design a response to the competition brief. Early stage competitions often lack the physical dimension however have been shown to be very effective in ideas generation and promotion (Carvalho, 2009). As well as early stage concept, ideas or design competitions, industry competitions can be designed to address a more advanced stage of the innovation development, and individuals or teams are judged on a working prototype or market ready outcome. In contrast, Ex post competitions such as industry awards that are common in the construction industry, recognise innovation development that occurred independently from the awards judging. The industry awards mechanism therefore tend to reward the outcome of innovation which are typically best practice and high achievement projects (Khan, 2015). Such ex post competitions have less direct impact on the innovation process.

Despite the use of innovation competition in other industries, the construction industry is relatively backwards, and is repeatedly found to have lower overall rates of adoption of innovation than other industries (Dibner & Lemer, 1992; Johnson & Tatum, 1993; Slaughter, 1993). So despite being described as "a lively source of new ideas" a general conclusion is that "the rate of innovation lags behind most other sectors, and appears to be falling further and further behind" (Graham, 1998). Architectural design competitions exist within the construction industry as a beacon of hope as a pre-existing competition framework that is well accepted by the industry and offers the potential for similar gains in sustainable innovation as seen in other industries.

Literature Review

Despite their widespread use in other industries, technological focussed innovation competitions are in their relative infancy in the construction industry, despite the long-standing existence of architectural design competitions. This represents an inconsistency between the current competition outcomes and the needs of the industry, as construction projects can no longer target purely aesthetic architectural goals without specific performance targets.

Architectural Design Competitions (ADC's)

Despite their long history and increasing interest, research on architectural design competitions (ADC's) is relatively poor (Adamczyk, Chupin, Bilodeau, & Cormier, 2004; Volker, 2010; Zettersten G, 2009). Research on ADC's tends to focus on the history of their use (Andersson, 2013), the make-up of the jury, fair and equitable judging and specifics of the competition rules and the responsibility of the jury for the interests of the client, teams, society, the winning entry and the organisation that the jury represents (Kazemian & Rönn, 2009).

ADC's are a well-established pathway to generate a large number of quality design proposals at relatively low cost (Lipstadt, 1989; Nasar, 1999). The ADC as a procurement strategy is therefore well established within the industry and in theory provides an excellent case of industry relevant competition, with benefits also to architects evident from the active marketing of winning competitions entries on their websites (Rönn, 2013). For Robert Gutman, the premier sociologist on Architectural practice "the basic intention of the design competition method… is to bring architectural markets closer to the condition that economic theory calls 'perfect competition' (Larson, 1994). According to Lipstadt (2006) there are two main competition structures - open and invited; and two main competition populations - national and international. The objectives of the competition can be ideas only, or less commonly 'tout court', which is the submission of resolved designs. Such a narrow focus on design considerations in ADC's ignores the important technological aspects related to modern buildings, such as demonstrable sustainability performance requirements. Such omission is rendering the current Architectural design competition irrelevant to the industry. However, with learnings from the innovation competition experience from other industries, it is possible to introduce new criteria to the judging of architectural design competitions that addresses key concerns relevant to industry requirements.

Innovation Contests

Innovation contests generally are defined as "IT-based and time-limited competitions arranged by an organization or individual calling on the general public or a specific target group to make use of their expertise, skills or creativity in order to submit a solution for a particular task previously defined by the organizer who strives for an innovative solution" (Adamczyk, Bullinger, & Möslein, 2012). Competitions of this type can be one-offs or repeated competitions such as those used regularly by the

US Government or the X-Prize Foundation, both of which tend to focus on development of technological prototypes in response to a challenge or need unmet by industry. In the context of buildings, this could include the innovative technological solutions to achieve net-zero energy or net-zero carbon buildings. Despite the 'pure' competition format, such prize incentivised challenges are often in pursuit of a private outcome for a new innovation that is not currently available, such as the provision of private space flight, and others are in response to a more direct need such as development of autonomous vehicles (Stine, 2009). Such competitions usually target an issue specific to the competition organiser in isolation of other industry goals and although held by repeat organiser, they are not a repeated competition.

Such contests often have large prize money attached, and these large-scale competitions have attracted the attention of policy makers to the point that U.S. government agencies now use prizes more commonly(Stine, 2009). McKinsey & Co. estimates that that sector may be worth as much as $2 billion if rewards offered by all types of prizes are included. Prizes may be more relevant in certain industries, with the aviation and aerospace industry being good examples.

Table 1: Innovation competition datasets recently compiled by the literature

	Knowledge Ecology International (2008)	**Masters & Delbecq (2008)**	**McKinsey & Company (2009)**	**Stine (2009)**
Dataset content	204 awards and prizes	89 technology prizes	219 prizes worth $100,000 or more	14 U.S. federally-funded innovation inducement prizes
Coverage (years)	1567-2007	1567-2008	1769-2007	2004-2011
Rewards (cumulative total in parentheses)	From $2.56 to proposal of $80 billion (>$80 billion)	From less than $50,000 to $53 million ($400 million)	From $100,000 to $30 million ($357 million)	From $250,000 to $10 million ($51 million)
Top technology areas (share of prize competitions in parentheses)	Medicine (18%) Aerospace (8%) Agriculture/food (8%)	Aviation (20%) Medicine (11%) Transport (10%)	Climate/Environment (11%) Medicine (9%) Aerospace (5%)	Aerospace (43%) Energy (29%) Defence (14%)

Luciano Kay (2012) comprehensively analysed the prize incentive category with specific focus on how prize entrants respond to prize incentives, how they organize R&D activities, and how technology advancement takes place in the context of prize competitions. The research findings show that there is a wide range of motivation for an entrant to participate and notes the importance of entrants from outside the field, with non-monetary incentives shown to have the greatest incentive power. A key finding of this extensive research on prize incentivised challenges is that they can induce innovation over and above what would have occurred anyway, although this depends on the context and entrant specific factors. Breakthrough innovation can be enabled but not directly induced. It is notable that this extensive research and data set does not include a single building or construction focussed project, despite the need for innovation in this sector. Although the ADC is a well-established competition format, it is currently underutilised when considering the need for technological innovation, such as is required for sustainable outcomes. Haller, Bullinger, and Möslein (2011) suggest that innovation contests can be used to trigger research and knowledge creation as well as investment in industry, demonstrating the industry level benefits of a sustainable performance focussed innovation competition.

Methods

This research uses the well-established Innovation Decision Model (IDM) from the Diffusion of Innovation (DOI) theory (Rogers, 1995) with critical case study analysis to analyse two cases.

The DOI Theory

Rogers (1995) DOI theory addresses many aspects of innovation with the specific emphasis on the generation (idea), diffusion (movement) and adoption (uptake) of innovations. The generation phase begins with the recognition of a problem or need, leading to research and development (R&D) and eventual commercialisation if the innovation is successful. Innovation generation does not automatically mean it will be adopted by the market regardless of if it is radical or incremental. The generation of innovation is most commonly in response to an identified need, although this is not always the case. Idea generation can be collectively referred to as ideas generation, project definition, problem-solving, design and development, production and marketing and communication, which describes the various stages of development (Gopalakrishnan & Damanpour, 1994). Diffusion is defined as the process by which "an innovation is communicated through certain channels over time among the members of a social system (Rogers, 2003) and represents the primary mechanism of spreading an innovation for adoption or implementation by the end user. Following successful diffusion of an innovation an organisation or individual must still decide to adopt it for use. Rogers differentiates the adoption process from the diffusion process in that the diffusion process occurs within society, as a group process; whereas, the adoption process pertains to an individual. The 'Innovation-Decision Model' (IDM) can be used to explain how innovations proceed to adoption within an organisation in an industry environment. Table 2 (below) indicates the stages of decision making that occurs about an innovation. In most competitions, innovations decisions are limited to the first three stages due to the lack of implementation criteria of an innovation in a competition.

The five stages of the Innovation Decision Model are as follows:

Table 1: Stages of the DOI Innovation Decision Model

Stages of the Innovation Decision Model	
Stage	**Definition**
Knowledge	The Decision Maker is first exposed to an innovation but lacks information about the innovation. During this stage the individual has not yet been inspired to find out more information about the innovation.
Persuasion	The Decision Maker is interested in the innovation and actively seeks related information / details.
Decision	The Decision Maker takes the concept of the change and weighs the advantages / disadvantages of using the innovation and decides whether to adopt or reject the innovation. Due to the individualistic nature of this stage, Rogers notes that it is the most difficult stage on which to acquire empirical evidence.
Implementation	The Decision Maker employs the innovation to a varying degree depending on the situation. During this stage the individual also determines the usefulness of the innovation and may search for further information about it.
Confirmation	The Decision Maker finalizes his / her decision to continue using the innovation. This stage is both intrapersonal (may cause cognitive dissonance) and interpersonal, confirmation the group has made the right decision.

Case study analysis for theory development

Case studies are appropriate to be used to test or generate theory and are particularly appropriate for areas where the research is still in its infancy, formative stages where there are no solid theoretical foundations. It is preferred when "how" or "why" questions are being posed (Yin, 1994). According to Eisenhardt (1989),the case study research method represents an inductive approach and that allows the in-depth study of individual cases (or innovations), which will provide a detailed understanding that would not be possible using more cross-sectional methods. It can include data from direct observation and systematic interviewing as well as from public and private archives. Any fact relevant to the stream of events describing the phenomenon is a potential datum in a case study, since context is important (Leonard-Barton, 1990). The case study approach has been used extensively in the analysis of the decision making process (Pettigrew, 2014). A critical case is used in order to generalise about other innovations, in this case to view how innovations have progressed through the IDM. The case study data is collected via content analysis (Bell & Bryman, 2007).

Following data collection, innovation factors were compared with the DOI Decision Implementation Model categories. This analysis highlights where the competition has strengths and weaknesses related to innovation progression and will identify key factors that drive innovation. The historical case-based perspective involves matching patterns in the data with theoretical explanations (Yin, 1994).

Case Studies

Architectural Design Competitions (ADC's)

In Australia, the Architects Institute of Australia (AIA) and the newly released guidelines by the Office of the Victorian Government Architect (OVGA) provide guidance and model conditions for competitions (AIA, 2015; OVGA, 2018). In addition, the Australian Institute of Landscape Architects (AILA) also produced their own guidelines for promotion and conduct of competitions (AILA, 2009). Although the AILA guidelines do not specifically relate to buildings, it is a valuable cross-reference to the third-party management of construction related competitions in Australia. ADC's are often beneficial to smaller firms as an opportunity to gain exposure on a project that's scale and budget would normally exclude them. However, the nature of the submission process results in countless hours of work that may never result in a successful submission. Such time spent on competitions therefore present a risk to a firm of any size but are particularly risky as a strategy to smaller firms, but is also representative of the importance given to ADC's.

The ADC is most often an 'open source' design competition designed to explore design possibilities from a number of different designers, to a single functional brief. The winning design is subjectively selected by an independent jury of design professionals and client representatives. The independence of the jury is vital to the fair conduct of a competition (International Union of Architects, 2017). ADC's offer a unique mechanism for architectural design procurement which would normally consist of a client tendering a project or selecting an architect directly to work with, prior to the commencement of design.

In accordance with the Innovation Decision Model, ADC's are limited to the knowledge and persuasion stages, although a decision is made to determine the winning entry, this is not always continued through to construction. The ADC process therefore represents a modified procurement process more than a true competition environment, with the finalist awarded based on a number of merits that extend beyond the best design, such as past work or existing relationships, as well as the capacity of the firm to complete the project, representing an inherent bias in the judging process. The ADC rarely includes criteria related to actual performance, representing a significant weakness in the competition in regards to sustainable targes for buildings. The nature and scale of buildings does prevent prototyping to be included as part of the competition process, however simpler targets like energy modelling outcomes, assessment of carbon impact, thermal comfort, could be easily introduced. In the absence of such targets the competition criteria remains narrowly focussed on design outcomes. Outside of performance targets, a strength of the ADC process is the transparency to the selection process Architecture competitions which is important for public buildings and in some countries architectural competition is mandatory for these projects.

X-Prize

In contrast to the ADC, the X-Prize competition is a U.S. based global initiative that represents a more typical 'innovation contest' with repetitive but disconnected competitions that drive focussed innovation.

The X-Prize is organised by the X-Prize foundation, a not-for-profit organisation which is the brainchild of Peter Diamantis, an entrepreneur (X-prize.org, 2019). The X-Prize foundation determines, directs and facilitates competitions in response to internally chosen global challenges and needs. X-Prize competitions occur in many different industries and in some cases, the organisation of the competition criteria extends up to a year before the competition is opened to ensure the criteria is relevant to the industry. Administratively the competitions are relatively simple to manage, this being a key strength of the format. X-Prize participants are usually specialised teams (like ADC's), however there are examples of all student teams in the competitions. Unlike most innovation contests, the X-Prize competitions are judged on 'finish line' requirements of the competition criteria, rather than a selection committee discussing the relative merits of different endeavours, described as 'best on simultaneous submission' (Davis, 2002) as is used in awards and design competitions that dominate the construction industry. The finish line criteria provide a different type of motivation for competing teams to target a final result, with a specific emphasis on timeframes.

The finish line criteria, which can be best described as the achievement of a functional or performance target aligns with the Innovation Decision Model 'decision' stage on the basis that the entry has demonstrated innovation with a satisfactory level of performance as dictated by the competition brief. This additional step over the ADC competition results in a higher chance of implementation based on the proven performance. With regards to innovation radicalness, the finish line criteria are particularly relevant where the method of achieving the goal is not important, thus creating a wide solution space for entrants to operate within. The equivalent approach for sustainable targets in an ADC is to require net-zero energy performance to be demonstrated but not to indicate how this should be achieved. The unique X-Prize format necessarily focusses the competition on innovation outcomes rather than subjective design choices. The X-Prize format provides many beneficial lessons from the series; the format is highly focussed on innovation development, is cheap and easy to implement, although requires a significant amount of funding or sponsorship. A key factor in the open 'global challenge' format used by X-Prize is attracting sponsorship for the prize money, which is comparatively difficult in building projects that have a budget constraint. This innovation focus is easily adaptable to the ADC platform through the use of specific competition criteria, which is then reflected in the judging.

Results

The following analysis of the two competition platforms against the DOI Innovation Decision Model demonstrates how the X-Prize format favours performance-based outcomes which leads to a more likely decision and implementation.

Table 2: Case study comparison with IDM

Case study comparison with the Innovation Decision Model			
Stage	IDM Definition	ADC Outcome	X- Prize Outcome
Knowledge	The Decision Maker is first exposed to an innovation but lacks information about the innovation. During this stage the individual has not yet been inspired to find out more information about the innovation.	Achieved - Like all competition, ADC's are highly effective at delivering new knowledge of design innovation to the Decision Maker. No performance innovation is provided	Achieved - Like all competition, X-Prize very publicly provides knowledge about design and performance of the innovation to the Decision Maker
Persuasion	The Decision Maker is interested in the innovation and actively seeks related information / details.	Achieved – The design innovation is easily identified and able to be considered against the assessment criteria No performance innovation is provided	Achieved – The innovation is easily identified and able to be considered against the assessment criteria. The finish line criteria pre-establishes the

			innovation as fit for purpose for design and performance.
Decision	The Decision Maker takes the concept of the change and weighs the advantages / disadvantages of using the innovation and decides whether to adopt or reject the innovation.	Partially achieve – The Decision Maker is likely to consider the benefits of the design innovation alongside other subjective criteria, such as past experience	Achieved – The competition criteria requires the entrant to demonstrate the suitability of the innovation for the proposed use., which enhances the ability of the Decision Maker to make a decision
Implementation	The individual employs the innovation to a varying degree depending on the situation. During this stage the individual also determines the usefulness of the innovation and may search for further information about it.	Beyond Competition – There is specific commitment to the innovation beyond the concept stage	Potentially Achieved – The proving of the innovation in the competition criteria provides observability and trialability for the Decision Maker to proceed to implementation immediately.
Confirmation	The individual finalizes his / her decision to continue using the innovation. This stage is both intrapersonal (may cause cognitive dissonance) and interpersonal, confirmation the group has made the right decision.	Beyond Competition – There is specific commitment to the innovation beyond the concept stage	Beyond Competition – There is specific commitment to the innovation beyond the concept stage

Discussion

The comparison of the ADC and X-Prize formats raise a number of relevant points that can be used to refocus the ADC on sustainable innovation.

- Other industries place a high value of competitions for innovation benefits, however the construction industry is behind despite the strong existing ADC platform.

- The current ADC format is not effective in judging performance-based criteria because it is primarily subjective, and narrowly focussed on design not performance.

- Judging performance-based criteria is difficult in a concept stage competition, due to a lack of prototype level trialability or observability, however the introduction of demonstrated performance targets would significantly enhance the innovation efforts towards sustainable targets.

- Introducing performance-based criteria to the judging is possible based on predicted performance (e.g. modelling), limitation to certain outcomes (net-zero calculation) or a demonstration of performance based on the selection of components.

- The ADC's are primarily a procurement decision model, where firms are judged based on their submission along with numerous other factors related to their ability to deliver the project. This dilutes the quality of the submission from a performance perspective compared to the innovation contest model.

- The scale of buildings makes it very difficult to proceed to prototyping of innovation and therefore construction industry projects are limited to the combination existing technology rather than the generation of new technology. It is also likely that early stage competition criteria will be required such as computer modelling in place of tested performance of prototypes.

- The X-Prize model requires proof of the performance of the innovation prior to winning the competition, which provides a measurable criterion.

- The X-Prize format provides an extensive competition environment that involves the industry beyond the competitor and organiser. This has the effect of diffusing innovation through the industry beyond the innovation developed in competition.

- The X-Prize is reliant on large prize money that is consistent with the grand challenge nature of the competitions.

- Competitions are shown to be valuable in the diffusion of technological innovation irrespective of if the innovation is adopted into the final production version.

- Despite the potential benefits, both competitions are limited to drive adoption of innovation into building projects, resulting in a lack of implementation and confirmation as described by the DOI innovation decision model.

Conclusion

Industry based competition is demonstrated to be successful in driving and diffusing innovation beyond what would have occurred normally. Industry specific competitions vary in their design and criteria, which is critical to the direction taken by the entrants. In the case of the X-prize, a finish-line criterion provides a large solution space for teams to explore performance based innovation. In contrast, the ADC format is limited to design innovation and this is inconsistent with the needs of the industry. Modification to the ADC format to include performance-based criteria, as well as adopting other strengths of the X-Prize format such as sponsorship and industry involvement would further enhance architectural design competitions ability to target sustainable outcomes.

References

Adamczyk G., Chupin J., Bilodeau D. & Cormier A. (2004). Architectural competitions and new reflexive practices. *Between Research and Practice*.

Adamczyk S., Bullinger A. C. & Möslein K. M. (2012). Innovation Contests: A Review, Classification and Outlook. *Creativity and Innovation Management, 21*(4), 335-360. doi:10.1111/caim.12003

AIA. (2015). Architectural Competitions Policy.

AILA. (2009). Guidelines for the Promotion & Conduct of Competitions.

Andersson J. E. Z., Gerd Bloxham; Ronn, Magnus (Eds.). (2013). Architectural Competitions – Histories and Practice. *The Royal Institute of Technology and Rio Kulturkooperativ*, p. 7–34.

Bell E. & Bryman A. (2007). The ethics of management research: an exploratory content analysis. *British Journal of Management*, *18*(1), 63-77.

Carvalho A. (2009). In search of excellence-Innovation contests to foster innovation and entrepreneurship in Portugal.

Davis L. N. (2002). *Should we consider alternative incentives for basic research? Patents vs. prizes.* Paper presented at the DRUID summer conference.

Dibner D. R. & Lemer A. C. (1992). *The Role of public agencies in fostering new technology and innovation in building* Washington, D.C. : National Academy Press, 1992.

Eisenhardt K. M. (1989). Building theories from case study research. *Academy of Management Review, 14*(4), 532-550.

Gopalakrishnan S. & Damanpour F. (1994). Patterns of generation and adoption of innovation in organizations: Contingency models of innovation attributes. *Journal of Engineering and Technology Management, 11*(2), 95-116. doi:https://doi.org/10.1016/0923-4748(94)90001-9

Graham W. (1998). Zephyrs of creative destruction: understanding the management of innovation in construction. *Building Research & Information, 26*(5), 268-279. doi:10.1080/096132198369751

Haller J. B. A., Bullinger A. C. & Möslein K. M. (2011). Innovation Contests. *Business & Information Systems Engineering, 3*(2), 103-106. doi:10.1007/s12599-011-0147-7

International Union of Architects. (2017). UIA Competition Guide.

Johnson K. D. & Tatum C. (1993). Technology in marine construction firms. *Journal of Construction Engineering and Management, 119*(1), 148-162.
Kay L. (2011). *How do prizes induce innovation? Learning from the Google Lunar X-Prize.* Georgia Institute of Technology,
Kay L. (2012). *Technological innovation and prize incentives: The Google Lunar X Prize and other aerospace competitions*: Edward Elgar Publishing.
Kazemian R. & Rönn M. (2009). Finnish architectural competitions: structure, criteria and judgement process. *Building Research & Information, 37*(2), 176-186.
Khan B. Z. (2015). Inventing prizes: a historical perspective on innovation awards and technology policy. *Business History Review, 89*(4), 631-660.
Larson M. S. (1994). Architectural competitions as discursive events. *Theory and Society, 23*(4), 469-504. doi:10.1007/BF00992825
Leonard-Barton D. (1990). A Dual Methodology for Case Studies: Synergistic Use of a Longitudinal Single Site with Replicated Multiple Sites. *Organization Science, 1*(3), 248-266.
Lipstadt H. (1989). The Experimental tradition: essays on competitions in architecture.
Lipstadt H. (2006). The Competition in the Region's Past, the Region in the Competition's Future. *The politics of design: Competitions for public projects*, 7-28.
Nasar J. L. (1999). *Design by competition: Making design competition work*: Cambridge University Press.
OVGA O. o. t. V. G. A. (2018). Architecture Design Competitions.
Pettigrew A. M. (2014). *The politics of organizational decision-making*: Routledge.
Rogers E. (1995). Diffusion of innovations. *New York*.
Rogers E. (2003). *Diffusion of Innovations, 5th Edition*: Free Press.
Rönn M. (2013). Judgment in the architectural competition-Rules, policies and dilemmas. *NA, 21*(2-3).
Slaughter S. (1993). Builders as sources of construction innovation. *Journal of Construction Engineering and Management, 119*(3), 532-549.
Stine D. D. (2009). *Federally funded innovation inducement prizes*: Diane Publishing.
Volker L. (2010). *Designing a design competition: the client perspective*. Paper presented at the Conference proceedings design research society international conference: design & complexity Montreal: Universite de Montreal.
Wagner E. B. (2011). Why Prize? The Surprising Resurgence of Prizes to Stimulate Innovation. *Research-Technology Management, 54*(6), 32-36. doi:10.5437/08956308X5406013
X-prize.org. (2017). What is an X-Prize? Retrieved from http://www.xprize.org/about/what-is-an-xprize
X-prize.org. (2019). X-Prize about Peter Diamandis. Retrieved from https://www.xprize.org/about/people/peter-h-diamandis-md
Yin R. K. (1994). Case study research: design and methods. Applied social research methods series, 5. *Biography, Sage Publications, London*.
Zettersten G. (2009). Nordisk Arkitekturforskning. *Nodic Journal of Architectural Research*.

MODULAR CONSTRUCTION IN ADELAIDE'S RESIDENTIAL CONSTRUCTION SECTOR. WHAT FACTORS INFLUENCE ITS USE?

Edward Smart, Jacob Grieger, Dang To, Aviraj Baryah, Rob Freda, Ki Kim

Natural and Built Environments, University of South Australia, Adelaide, Australia

Abstract

In the Australian construction industry, there have been many innovations in building products and methods which have altered the mode of construction throughout the years. However, construction has and still is built from the ground up on-site. Modular construction is a method that has begun to build momentum in recent years due to the benefits it can offer. Frequent use of modular construction has become popular overseas in countries such as United States, Canada, and South Korea but has been slower to gain popularity in Australia. Modular construction aims to deliver faster and smarter projects, utilising efficient off-site manufacturing of pre-fabricated modules combined with traditional construction techniques. Within the commercial sector particularly overseas modular construction has made progression where an economy of scale is present. Repetition is easily achieved where a large quantity of the same module is repetitively craned into position as each floor takes shape solely with the use of the prefabricated modules. The purpose of this research was to establish whether modular construction could be used within the residential construction sector in Adelaide, where it is currently neglected, along with what factors influence peoples' decisions when building a house.

Keywords: Modular Construction, Residential Construction, Pre-fabricated Construction, Adelaide Residential Construction

Introduction

Over the past few decades, the Australian construction industry has encompassed consistent innovations in building methods and products, however the construction process itself has experienced relatively minimal change (AUSCO Modular 2016).

The traditional construction process requires a linear construction sequence in which every step needs to be completed before the next can start. In terms of project delivery and construction safety, the traditional methods are labour intensive and fraught with risks resulting in low productivity and high costs (AUSCO Modular 2016). The traditional construction industry in Australia has been characterised as adversarial, inefficient and in need of a structural reform (Phillips, Guaralda & Sawang 2016). A growing demand for flexibility has encouraged construction firms to consider alternate types of products and construction processes. As an alternative to the traditional constructional method, a modern form of the construction process has recently been gaining momentum, known as modular construction.

Modular construction is a combination of traditional construction methods mixed with efficient manufacturing techniques to deliver faster and smarter projects (Gunawardena 2016). Modular construction involves prefabricating building modules off site in a controlled factory environment, ensuring the highest quality is achieved. These modules are then transported to site and assembled, forming a safe and stable structure (Gunawardena 2016). The intense labour required in traditional construction is replaced with specialist workmanship and machinery in a factory environment. Some of the key benefits of modular construction are improved quality, speed of construction and early return on investment for developers, due to significantly faster completion times, as most of the construction is done off site and designed in the early stages of the project (Rogan 2015).

As discussed by Wilke (2011, p. 52) the cost factor of building a house is the most important aspect to consider. This was emphasised by multiple clients, as well as builders, with the consensus that a strict budget determines most other factors when building. If clients cannot afford to build it, they will not. Therefore, in response to the question put forth, a key portion of the outcome related to the cost significance of modular construction, and whether it could provide a cost-effective alternative.

Modular Construction

Despite contrasting information regarding the 'first' prefabricated home and building elements, it is clear that from the literature, prefabrication has been around for many centuries. Reports suggest that in the 16th Century, from around 1624, the United States of America and Great Britain began manufacturing building components and homes that were transported by ship to new settlements (Panjehpour & Ali 2013; prefabAUS 2018). It was noted that locally available materials were not known by the British, leading towards prefabrication (Panjehpour & Ali 2013).

Similarly, throughout the 1850s, due to a booming population brought about by the gold rush, Melbourne turned to kit homes that were prefabricated overseas, dismantled, and then reassembled in Melbourne (Mills 2018). Approximately half of the homes came from Britain. These homes were required as the manufacturing industry was not established in conjunction with a lack of skilled tradesmen (Mills 2018).

Fast forward to 2018, Ingram (2018), writing for the Australian Institute of Building 'Construct Magazine', senses that modular construction has gained momentum and is driving the construction industry. The reasoning behind this drive; a skills shortage, therefore a need to adopt a 'new technology', or as we have investigated, an improving long-standing technology is needed (Ingram 2018).

From the literature, the history of prefabricated homes exists distinctly in periods of pre-war, war, and post-war. Pre-war refers to new colonies being established, with fast tracking methods of prefabrication evident (Panjehpour & Ali 2013). As mentioned previously, there was a perceived lack of skills and materials were not widely accessible, which therefore brought about this movement (Panjehpour & Ali 2013). During wartimes, there was a demand for mass production of kit homes. For example, during one of these periods, there was an increase in the market demand for prefabricated homes for soldiers in the United States (Panjehpour & Ali 2013).

Prefabrication may not be a new technology, yet there is a perception that prefabricated are semi-permanent structures of poor quality, used for construction site offices or for outback towns to provide affordable housing. Post-war and moving through the late 1990s and early 2000s, modular construction has become a discussion term again, with a focus on committing to quality construction with high aesthetics, sustainability values, through innovation and the transformation of technology (prefabAUS 2018).

As such, the data revealed in this report aims to address the substance of modular construction in Adelaide and determine whether the method could be implemented and adopted. Furthermore, factors influencing the use, such as cost, time and quality have been identified in order to propose an outcome, evaluating whether or not modular construction has a place in the construction industry in Adelaide's housing. Consequently, an assessment of modular construction in Adelaide was undertaken, to formulate an outcome with justification.

Accordingly, the framework for the review was to define the term modular construction, offering examples of the method, along with an initial history of prefabrication 'off-site' construction. As a result, a clear understanding of the concept has supported the intention of this research. Thus, the benefits and barriers will be discussed to determine the prior research and suggest if modular construction could become frequently used in the Adelaide domestic market, in conjunction with the subsequent data and information detailed in this report.

Cost Benefits

Amongst several pieces of literature, the potential cost reduction on the overall project when using modular construction was noted. Kamali and Hewage (2016) mention in a study by the Construction Industry Institute, the overall cost savings of modular construction can be up to 10%. Similarly, the case study by Lopez & Froese (2016), undertaking a quantitative methodology suggested modular construction at a level 3 construction could provide 7 – 11% cost reduction compared to the commonly used panelised construction (level 2).

Throughout many countries, including Australia and more locally Adelaide, a challenge within the construction industry has been providing affordable housing due to the demand by clients (Dave, Watson & Prasad 2016; Generalova, Generalov & Kuznetsova 2016; GSA 2017). Affordability comes from cost effectiveness during the construction phase, and it is clear that this is highly sought after by clients. Looking at the overall project costs of modular construction, there are reductions to the on-site overheads as a result of less work on-site, along with another benefit, faster assembly speed, which will be discussed later in this thesis (Kamali & Hewage 2016). Furthermore, due to the high percentage of work in a controlled indoor environment, the risks of extra charges, back charges and latent costs are significantly reduced since some of the typical risk factors encountered on site such as extreme weather and unforeseen conditions are mitigated.

A survey conducted in the United States by McGraw Hill regarding the factors influencing the cost benefits of modular construction indicated that 65% of companies using modular construction reported reductions in their project budget (Javanifard et al. 2013). The majority of the reductions aroused from a shorter construction schedule, increased quality control, reduction of expensive labour and reduced waste (Javanifard et al. 2013).

Multiple sources of literature indicate that modular construction provides a cost-effective method of construction, thus, it could find a place in Adelaide’s housing market due to the demand for affordable housing (Generalova, Generalov & Kuznetsova 2016; Mohammad et al. 2016; O’Neill & Organ 2016). However, first and foremost, as Lawson, Ogden and Goodier (p. 1, 2014) indicate, modular construction requires an economy of scale to drive the financial benefits.

Barriers Related with Modular Construction

Conversely, the associated barriers of modular construction may negatively impact the feasibility of modular construction for housing in Adelaide. Therefore, a number of known barriers will be considered to understand the current situation of modular construction and why the current usage is presently low. Some barriers, in addition to benefits of off-site manufacturing adoption in various countries is shown below in Figure 1 (Rahimian et al. 2017).

Conducted Studies	Context	OSM Benefits										Barriers to OSM Adoption								
		Speed	Reduced Whole Life Cost	Improved Quality	Sustainability	Health & safety	Consistent Product	Waste Reduction	Logistics & Operations	Reduced Defects	Increased Value	High Initial Cost	Limited Design Flexibility	Shortage of Local Skills & Knowledge	Lack of Government Policies & Regulations	Nature of Industry	Negative Image	Client Resistance	Infrastructure and Equipment	Logistics and Supply Chain
Arif and Egbu (2010b)	China	*		*	*		*					*		*				*	*	
Arif *et al*. (2012a)	India	*	*	*	*		*			*	*	*	*	*	*	*	*	*	*	
Blismas *et al*. (2005)	UK	*	*	*	*	*						*	*	*				*		*
Blismas *et al*. (2006)	UK	*		*		*			*											
Elnaas *et al*. (2014)	UK			*	*	*						*		*	*		*		*	*
Fussell *et al*. (2007)	Australia	*		*	*	*		*	*			*	*	*	*	*	*			*
Goodier and Gibb (2005)	UK	*		*	*		*			*	*	*		*	*		*	*		
Gorgolewski (2003)	UK	*	*	*	*	*		*	*	*										
Jaillon and Poon (2010)	Hong Kong	*		*		*		*				*	*	*			*			*
Larsson and Simonsson (2012)	Sweden	*			*	*													*	
McGraw-Hill Construction (2011)	USA	*		*		*						*		*				*		*
Nawi *et al*. (2011)	Malaysia	*		*	*	*		*				*		*	*				*	
PrefabNZ Incorporated (2013)	New Zealand	*		*		*						*		*			*			
Zhai *et al*. (2014)	China											*	*	*	*	*		*	*	*

Figure 1 - Benefits and barriers of modular in various countries (Rahimian et al. 2017)

Cost Barriers

In contradiction to the perceived benefits mentioned above, a number of literature articles suggest some scepticism regarding the cost benefits of modular construction. It has been noted that modular construction has a significant barrier of higher initial start-up costs of construction (Hwang, Shan & Looi 2018; Mohammad et al. 2016; Rahman 2014, p. 70). Additionally, it is clear that there needs to be an economy of scale to realise the potential of modular construction (Lawson, Ogden & Goodier 2014; LePree 2016; Mohammad et al. 2016; Nanyam, Sawhney & Gupta 2017). Cost benefits are associated with repetitive modules being created, and at a large scale, rather than single residential houses. Rahman (2014), highlights that there are higher modular construction costs if the project is small. In a case study focusing on qualitative methodology, Rahman (2014) identified numerous cost-related perceived barriers through a conducted survey. Nonetheless, modular construction provides less variables in the costs, with early predictability possible (LePree 2016, P. 22). Although, the cost barriers require further investigation within the Adelaide domestic market.

Research Question

Despite the acceptance of modular construction in the commercial sector, it has not been widely used in the residential sector (AUSCO Modular 2016). Furthermore, there was a lack of literature surrounding modular construction in Adelaide, and typically the domestic market. Hence, the aim of this research is to determine if modular construction has a place in the Adelaide residential sector as a viable construction method. The viability of modular construction was investigated, delving into the influences such as cost, time and quality, that may affect the position it has in Adelaide. Subsequently, a key component of the research was based around the construction industry in Adelaide with the following question proposed:

‘What place does modular construction have in Adelaide’s domestic market, and what factors influences its use?’

Through various methodologies, this question was explored in order to help understand the future of modular construction in the residential sector in Adelaide. Critically, industry stakeholders and modular experts portrayed their views of modular construction in order to develop an outcome.

Research Method

The initial research is guided by the literature review, which prompted the questions that would determine the viability of modular construction in Adelaide, and more specifically, ‘What place does modular construction have in Adelaide’s domestic market, and what factors influence its use’. The research is separated into three main quadrants:

1. What is the opinion of the local Adelaide stakeholders. The target audience is comprised of developers, engineers, architects, builders and the end users (clients). These opinions focussed on their perceptions of quality, time and cost and their overall understanding of modular construction.

2. The manufacturing process of modular construction and how it translates here in Adelaide. This arose, as research and case studies in modular construction are largely based overseas, and not in Australia. Therefore, the research of ‘if it can be constructed here in Adelaide’ evolved. Particular company’s interstate were investigated to determine how they build modular.

3. The cost as hypothesised is identified as a major contributing factor to the viability of modular as a whole.

The research used is a mixed method consisting of a questionnaire survey and interviews. The data addressed the variable that was Adelaide and a key determination was whether the local Adelaide stakeholders require modular construction or not through a questionnaire survey and interviews. In aspects, the collected data was compared to the findings from literature review. Based theoretical literature studies and collected data from a survey and interviews, plausibility of modular construction in relation to its cost, time, quality and manufacturability was examined.

Questionnaire Survey

The questionnaire survey was a key component in understanding the perceptions and opinions of modular construction by local Adelaide stakeholders. Quality, time and cost were the key factors portrayed to developers, builders, clients and the like. Initially, literature identified a great misconception around modular construction, which is that all modular homes and buildings look like mobile homes (Ganiron & Almarwae 2014). This could provide potential doubt within the public, therefore, receiving qualitative information from various stakeholders in the domestic housing market, intended to draw comparisons on the perceptions of the industry and the knowledge throughout various literature. The questionnaire survey aimed to understand the perceptions surrounding modular construction, whilst defining a term that could be used as a description. Furthermore, determining the demand of stakeholders in identifying what is most important when building a home, highlighted some potential shortcomings to the success of modular construction.

Interviews

To gain a more in-depth understanding of the topic of modular, further than the survey answers, four experts were interviewed to determine current knowledge in this building technique. The interviewees were selected through the recommendation of a successful modular company as well as reaching out to experts in the field. Conducting these interviews provided beneficial knowledge to help direct the research. Additionally, it helped reiterate some of the answers being received through the survey questions. From undertaking these interviews, valuable access to the understandings of modular construction was possible. By conducting these interviews, it was hoped that a more in-depth understanding of the question in which this thesis asks would be gained. Why is modular construction not currently being utilised here in Adelaide while the eastern states have grown quite a strong market for the construction technique? In order to determine these answers, specific questions were assembled to provide a clear conclusion.

Results and Discussion

The findings from the questionnaire survey where specifically designed around the information gained from the literature review, which focused on cost, time and quality benefits as well as barriers of modular construction. Throughout the participants answers, cost was highlighted on numerous occasions as a large influence in whether modular construction would be successful or not in Adelaide. Similarly, the time outcomes modular construction could potentially have, was regarded as an important factor also. Consequently, the results indicate that the major influences that would determine the viability of modular construction was cost and time. If cost savings are evident, modular construction would certainly have a place in Adelaide. The time savings through a faster manufacturing process would also advance modular construction in comparison to traditional construction methods. It was decided that a case study cost comparison would be undertaken to investigate whether cost savings are available when using modular construction in Adelaide.

Upon analysing the data, the key benefits of modular construction that were mentioned in the interviews related to the information ascertained in the literature review. The three benefits identified in the interviews were; cost, quality and time. Interviewee A declared that the benefit of modular construction was a reduction of construction duration. Comparatively, interviewee C suggested that modular construction was faster and cheaper compared to traditional construction. Interviewee C also mentioned that modular construction provides better quality and is a safer form of construction due to the building components manufactured in a controlled environment. Furthermore, Interviewee B and D similarly stated that the efficiencies of time and cost was a major benefit of modular construction.

It was indicated that quality, transportation and lack of design flexibility are currently seen as limitations of modular construction. Fundamentally, it is important to be aware of the limitations presented to understand the relevance and whether this would affect the feasibility of modular construction in Adelaide.

The overall trends and perceptions of modular construction within the South Australian construction industry have been investigated. Data has been collected through delving into various literature, receiving individual responses of stakeholders through a questionnaire survey, information and knowledge from interviews of modular experts, and cost comparisons of construction methods. Both qualitative and quantitative data has been obtained, in order to assess the viability of modular construction and ultimately form an outcome of the research question.

Conclusion

This research set out to discover what place modular construction has in the residential space of the Adelaide market. Throughout the research the term modular was defined as a three-dimensional module with the majority of the works built in a factory environment and transported to site. From surveys targeted at experts within the construction industry, builders, architects, engineers along with the end user, key information was found. Firstly, that the preconception of modular housing, which was transportable, low quality housing used for remote areas like mining, was as far as modular housing has progressed here in Australia. This conception through analysis of the surveys has transformed to be known as a possible pathway of constructing an aesthetically pleasing, high quality home. This key finding was important in deciphering how difficult it would be to implement modular homes in Adelaide, as it is evident that people are unlikely to have to be aware of what modular can now achieve. The second key element of data found from the surveys was the key concern of people within the industry and end users when building a house. This key piece of information was the most important piece of data received as ultimately if this finding did not match up with the modular profile it would prove difficult for modular to find its way here in the Adelaide residential market. This key element that was the biggest contributing factor to when building a house was cost.

As found through Case Study One, cost was found to currently be higher than standard residential construction on a cost per m^2 calculation. Construction mode for standard housing still favoured traditionally built homes in lieu of modular. Various reasons for this were discussed, but for now it would seem the standard home is better off built when cost is of concern traditionally. What information this did present though was how these modular companies were successfully operating. Case Study Three compared end users' thoughts on the aesthetic design between an architecturally built home and a home built by Modular Company One. The results showed the modular house was comparable to that of high-end homes and there may be a market in which modular could compete here in Adelaide, in high end residential construction.

Concluding, through detailed surveys of perceptions and values of modular construction and residential housing respectively, modular may not have an immediate market for standard residential housing with its current progression and methods here in Australia to compete in Adelaide. However, the high-end residential sector may have a place for this form of construction to contribute to the current construction methods use in this market.

References

AUSCO Modular 2016, *A guide to: modular construction in the Australian healthcare sector,* AUSCO, viewed 28 May 2018, <www.ausco.com.au>.

Dave, M, Watson, B & Prasad, D 2016, 'Performance and perception in prefab housing: An exploratory industry survey on sustainability and affordability', *Procedia Engineering,* vol. 180, pp. 676 – 686.

Ganiron Jr, T & Almarwae, M 2014, 'Prefabricated technology in a modular house', *International Journal of Advanced Science and Technology,* vol. 73, pp. 51 – 74.

Generalova, E, Generalov, V & Kuznetsova, A 2016, 'Modular buildings in modern construction', *Procedia Engineering,* vol. 153, pp. 167 – 172.

Gunawardena, T 2016, 'Behaviour of prefabricated modular buildings subjected to lateral loads', PhD thesis, The University of Melbourne, Melbourne.

Hwang, B, Shan, M & Looi, K 2018, 'Key constraints and mitigation strategies for prefabricated volumetric construction', *Journal of Cleaner Production,* vol. 183, pp. 183 – 193.

Javanifard, N, Markert, D, Strobel, K & Yap, J, 2013, 'Modular prefabricated residential construction constraints and opportunities', Post Graduate Thesis, University of Washington, Washington.

Kamali, M & Hewage, K 2016, 'Life cycle performance of modular buildings: a critical review', *Renewable and Sustainable Energy Reviews*, vol. 62, no. 1, pp. 1171 – 1183.

Lawson, M, Ogden, R & Goodier, C 2014, *Design in modular construction,* CRC Press, Taylor & Francis Group, Boca Raton, USA, <https://books.google.com.au/books?hl=en&lr=&id=JxzlAgAAQBAJ&oi=fnd&pg=PP1&dq=modular+construction++background&ots=vSLBQqN7tG&sig=642OLPjm4nZ38J6WcjP2mfhNH-o&redir_esc=y#v=onepage&q=modular%20construction%20%20background&f=false>.

LePree, J 2016, 'Is modular right for your project?', *Chemical Engineering,* vol. 123, no. 1, pp. 20 – 24.

Lopez, D & Froese, T 2016, 'Analysis of costs and benefits of panelized and modular prefabricated homes', *Procedia Engineering,* vol. 145, pp. 1291 – 1297.

Mills, N 2018, *The original tiny kit homes that helped solve Melbourne's gold rush housing crisis,* Good News, viewed 28 May 2018, <http://www.abc.net.au/news/2018-05-03/tiny-kit-homes-helped-solve- melbournegold-rush-housing-crisis/9680898?section=good-news>.

Nanyam, N, Sawhney, A & Gupta, P 2017, 'Evaluating offsite technologies for affordable housing', *Proceida Engineering,* vol. 196, pp. 135 – 143.

O'Neill, D & Organ, S 2016, 'A literature review of the evolution of British prefabrication low-rise housing' *Structural Survey,* vol.34, no. 2, pp. 191 – 214.

Panjehpour, M & Ali, A 2013, 'A review of prefab homes and relevant issues', *Constructii,* vol. 14, no. 1, pp. 53 -60.

Phillips, D, Guralda, M & Sawang, S 2016, 'Innovative housing adoption: modular housing for the Australian growing family, *Journal of Green Building*, vol. 11, no. 2, pp. 147 – 153.

prefabAUS 2018, *Prefab in history,* prefabAUS, viewed 28 May 2018, <http://www.prefabaus.org.au/prefab-in-history/>.

Rahimian, F, Goulding, J, Akintoye, A & Kolo, S 2017, 'Review of motivations, success factors, and barriers to the adoption of offsite manufacturing in Nigeria', *Procedia Engineering*, vol. 196, pp. 512-519.

Rahman, M 2014, 'Barriers of implementing modern methods of construction', *Journal of Management in Engineering,* vol. 30, no. 1, pp. 69 – 77.

Woo, J 2017, 'A post-occupancy evaluation of a modular multi- residential development in Melbourne, Australia', *Procedia Engineering,* vol. 180, pp. 365 – 372.

Wilke, G 2011, *Building your own home a comprehensive guide for owner builders,* New Holland Publishers, Australia

ENHANCING TRANSNATIONAL KNOWLEDGE TRANSFER: THE CONTEXT OF CROSS-BORDER AND LOCAL FIRMS IN PRIVATE REAL ESTATE COLLABORATIONS IN SUB-SAHARAN AFRICA

Ndlovu Pride[1] and David Root[1]

[1]School of Construction Management and Economics, University of the Witwatersrand, Johannesburg, South Africa

---

Abstract

Over the last decade, Sub Saharan Africa has seen a rise in the demand for high quality commercial real estate. Some of the factors driving this include the rapid growth in some of these economies, highly favourable demographics, emerging middle class as well as huge foreign direct investments (FDI) by local (African) and global companies in these economies. This study focuses on the emerging trend of Africa to Africa investments by real estate developers. It examines how local (country of origin) and cross-border (South African) firms interact, navigate and bridge contextual differences to meet project objectives. The study also tests the relevance and applicability of the **Model of Contextual Complexity in Transnational Networks** to close contextual distances in the private real estate context in SSA. A case study approach was used to collect data through semi-structured interviews with both local and cross border firms to understand their contextual differences and how they bridge them to meet project goals. The findings signify that contextual difference and knowledge differences exist and both parties in this type of collaboration see value in the other and that facilitates transnational knowledge transfer of a bi-directional and multi-directional nature within the network. The study concludes by developing a set of generic principles informed by existing practices utilized by (local and cross-border) firms that are based on their experiences navigating the contextual differences.

Keywords

Transnational knowledge transfer, collaborations, Sub-Saharan Africa, knowledge transfer, contextual difference (distance), transnational networks

Introduction

There has been a notable shift in the trade relations of Sub-Saharan Africa (SSA). Multiple countries in Sub-Saharan Africa are consciously opening up to multiple possibilities of trade and investments on offer. They are no longer limiting themselves to traditional trading partners and are beginning to diversify and appraise new partners that have not traditionally transacted with Africa. In the past, Africa's trade pattern was largely influenced and dictated to by the colonial ties it had with various developed economies. This seems to be slowly changing as Africa explores options that seek to open up the continent and improve regional integration. Regional integration generally appears to be a highly attractive policy and one of the major inteventions, which can be adopted to structurally transform African economies (ACBF, 2014). However, it still remains predominantly difficult to move around the continent doing business, due in part to the poor level of infrastructure and lack of development in various countries. Recently, countries in Africa made progress and history, at least symbolically, on 21 March 2018 when 44 of the African Union's (AU) 55 member states signed the African Continental Free Trade Agreement (AfCFTA) in Kigali, Rwanda (van Staden et. al, 2018). This agreement aims at creating a single continental market for various products besides ensuring that there is ease in the manner in which business people and investments move (ibid). It gives Africa prospects of becoming a billion person market, putting it in the same group as India and China (ibid). In order for this to succeed, Kararach et al. (2015) suggests that Africa needs to pay more attention to creating enabling environments in the social, political, cultural, institutional, regulatory and legal contexts in which private sector operates.

Whilst these developments are promising and represent a giant step forward, the challenge of making old colonial borders to trade dissolve remains. Real impediments to economic regionalisation, such as poor infrastructure, inadequate productive capacity, incompetent and immoral customs control and extreme red tape at borders remain – affect the costs of trading around Africa (DailyMaverick, 2018). Even though these challenges exist, there is notable rise in foreign direct investment on the continent, particulary an emergence of investment between countries within Sub-Saharan Africa (SSA).

Sub Saharan Africa has witnessed a rapid increase in the demand for high quality commercial real estate because of a number of factors, key among them being the rapid growth in these economies, highly favourable demographics as well as the huge investments by the local and global companies in these economies (ibid).

Emphasis on a growing population, an emerging middle class and high levels of urbanization (McKinsey, 2010; Shimeless and Ncube, 2015), present a set of attractive opportunities and challenges for investors, particularly in real estate. The continent of Africa has immense growth investment opportunities. Yet it remains an important consideration for investors in Africa to assess their risk appetite adequately. Real estate companies should not only accept the risks they are exposed to, but should also strive to ensure that risks are managed effectively to gain the rewards that are associated with them (PWC, 2015). Investors with foresight are able to identify real estate investment opportunities and are keen to invest on the continent (ibid.). These real estate investment opportunities require professional advice from the entire real estate development supply chain including built environment professionals in areas such as legal and town planning matters, conceptual development, project feasibility and execution of the investment project.

The Knight Frank Africa Report (KFAR, 2015) has outlined the likely growth trajectory of the African continent. The report indicates that by the year 2100, the African population will quadruple to more than four billion, with approximately one billion of these individuals being in Nigeria alone (ibid.). The report further forecasts that urbanization will continue to rise, with millions more people moving to cities (ibid.). This will inevitably create a massive demand for infrastructure upgrades, residential accommodation, offices, industrial and retail centers among other needs. In preparation for this growth projection, real estate developers with resources are increasingly diversifying beyond the shores of their principal domain into the wider African continent. There has been a rapid rise in the number of South African corporations looking for opportunities in countries like Kenya, Angola, Zambia, Tanzania, Nigeria, Mozambique and Ghana among others.

Most South African property companies have a strong appetite for investment in the rest of Africa. For example, towards the end of 2015, Growthpoint Properties announced that they would make an investment of about $50m while the International Finance Corporation would make an investment of about $40m in the venture, which will develop assets in the other African regions (Growthpoint, 2015). Similarly, in November 2015, retail-oriented property group Hyprop Investments as well as capital growth fund Attacq made the announcement that they had purchased Ikeja City Mall, which is the biggest shopping centre within Lagos (at the time of writing). This was mainly aimed at complementing Hyprop's strategy of investing in high quality, income-generating shopping centres, in the major cities across different countries in the Sub-Saharan Africa (Hyprop, 2015). RMB Westport, which is a joint venture between Westport Property Group and Rand Merchant Bank (RMB) pointed out that they had reserved various Sub-Saharan Africa territories as the major jurisdictions for the development of retail and commercial property (RMBWestport, 2015). Equally, Delta Africa also announced late in 2015 that they were expanding their footprint with the acquisition of Barclays House in Mauritius, Cybercity, Ebene (MaraDelta, 2015). The table below shows a detailed analysis of the Sub-Saharan Africa transactions for the period 2015-2016.

Selected Sub-Saharan Africa investment transactions, 2015-16

Date	Property	Location	Sector	Seller	Buyer	Estimated price (US$ million)	Reported yield
Q4 2015	Ikeja City Mall	Lagos, Nigeria	Retail	Actis/RMB Westport/Paragon	Hyprop (75%)/ Attacq (25%)	91.0	>8.00%
Q2 2015	Two Rivers Development (39% stake)	Nairobi, Kenya	Mixed Use	Centum	Aviation Industry Corporation of China (AVIC)	70.0	N/A
Q4 2015	East Park Mall, Acacia Office Park & Jacaranda Mall (50% stakes)	Lusaka & Ndola, Zambia	Retail/Office	Casilli Group	SA Corporate	49.6	8.68%
Q3 2015	Wings Oando Development (37.1% stake)	Lagos, Nigeria	Office	RMB Westport	Pivotal	49.0	N/A
Q2 2015	Vodacom Building	Maputo, Mozambique	Office	Sociedade De Construçoes Catemba	Delta (now Mara Delta)	46.0	6.63%
Q4 2016	Cosmopolitan Mall (50% stake)	Lusaka, Zambia	Retail	Rockcastle	Mara Delta	37.1	7.75%
Q4 2015	Bagatelle – Mall of Mauritius (34.9% stake)	Bagatelle, Mauritius	Retail	Atterbury	Ascencia	28.9	c.7.00%
Q4 2015	Makuba Mall & Kafubu Mall (50% stakes)	Kitwe & Ndola, Zambia	Retail	Rockcastle	Delta (now Mara Delta)	21.6	7.75%
Q4 2015	Greenspan Mall	Nairobi, Kenya	Mixed Use	Greenspan Mall Limited	Stanlib Kenya Fahari I-REIT	20.0	8.10%
Q1 2016	Barclays House	Ebene, Mauritius	Office	Jade Group	Delta (now Mara Delta)	13.4	8.30%

Source: Knight Frank Research/Real Capital Analytics/Company reports and financial statements

Figure 1: Sub-Saharan Africa investment transactions

KFAR (2015) pointed out that the growth potential of Africa has made a number of overseas investors as well as South African funds to initiate various activities in the past two years. Asia Pacific, China, North America, Europe, Middle East, as well as South Africa are reported amongst these key investors on the African continent (ibid).

These initiatives indicate that many South African real estate development supply chain companies are set on diversifying their investment beyond their borders in the rest of Africa. Opportunities in Africa can be approached better by using both the competitive advantage of the individual countries into a well-coordinated business model. A model like that may combine the South African capital markets, which are highly developed with the high retail growth within the nations that are less developed (PWC, 2015). Whilst technical skill is crucial in real estate development, local knowledge is just as important. SA companies may be particularly competent technically but they lack an understanding of the local market and context. This local knowledge is important especially in the planning stages to try and understand the market, needs and culture of the locals among other things. In order to create a winning formula, it is best to combine the technical skill with the local knowledge to attain a broader understanding of the context and create a context specific solution for the market.

There is a huge disparity in several African economies when it comes to the demand and supply of highly skilled labour (PWC, 2014). Big corporations can leverage a regional workforce to good effect through sending highly skilled individuals on secondment or setting up 'hub' operations within the markets with a stronger skills base (ibid). Other corporations can outsource skills within the growth markets or they can also use third parties such as subcontractors (who may come from foreign countries) (ibid). There is evidence of South African companies that bring in their core professional teams into the local markets to assist in the execution of projects (Wadiwalla, 2003). These core teams are brought in largely due to the fact that the SA company is moving into less developed markets in terms of skills and institutional framework. Most markets in SSA (with the exception of South Africa) are predominantly informal and local professional companies have less exposure and experience in providing high quality real estate product, due to a lack of high quality real estate that exist within these market.

Thus there is a need to bring in the right skill to execute and provide the high quality real estate product that the market now demands. The real estate development opportunities require the appropriate skill set for proper execution. Successful corporations ought to develop strategies for doing business within the emerging markets, which are different from the ones that they are using at home. They should find better ways of making sure that they are effectively implemented (Khanna, Palepu and Sinha, 2005). The SA companies' strategy to bring in their core professional teams and form collaborations with local partners (Wadiwalla, 2003) to assist each other in the planning and execution of real estate development projects seems prudent. Each partner in collaboration should have some knowledge to contribute and this results in a bidirectional transfer of knowledge. This business model seem to provide positive results for SA companies and is largely adopted when they move beyond their borders to execute real estate projects.

Literature Review

Cooperative alliances are always created with the aim of enjoying economies of scale, minimizing or sharing different kinds of risks (Hennart 1988, Buckley and Casson 1998) for gaining international competitiveness (Porter and Fuller 1986, Harrigan 1988), and for learning and internalizing new knowledge and skills (Hammel 1991, Inkpen 2000, Kogut 1988, Lyles 1988, Makhija and Ganesh 1997, Mowery, Oxley and Silverman 1996). This is especially applicable when cross-border corporations get into new markets; they arrange collaborative relationships with domestic firms as one of the viable strategies for overcoming foreignness (Pak and Park, 2004).

The interaction of partners within the network is a complex process. The context under which the interaction takes place is key in facilitating the process. In this study, context is defined as circumstances under which the interaction takes place. The research seeks to understand the circumstances the partners in a collaboration encounter when they collaborate with partners outside their home country or partners that are from outside their home country. Knowledge transfer is contextually bound so its transfer is constrained by the context in which it is embedded (Duan et. al 2010). This context can be divided into three layers, which include: national, organizational and the knowledge and information contexts (Dawes, et. al. 2012). In their Model of Contextual Complexity, Dawes et. al. (2010) further indicate that these three layers result in nine contextual differences that participants in a network are confromented with, namely cultural, political, organisational, relational, intentional, technical, knowledge, resource and physical difference.

Social Capital Theory

For theoretical grounding, this research adopts a social capital theory view and will use this theory as a lens through which to view the performance and interaction of the cross border firms and local firms in private real estate collaborations. Social capital refers to a kind of cultural and economic capital where social networks are central and transactions are characterised by trust, reciprocity, as well as by cooperation (Adler and Kwon, 2002). The collaboration is viewed as a platform through which actors can create social relations that can potentially benefit or even disadvantage them, depending on the level of trust and connectednes established. The study will review and analyse the interaction of cross border partners within a collaboration to understand how transnational knowledge transfer takes place between the actors within the network. Social capital is also synonymous with embeddedness (Granovetter, 1985). In this perspective, it is not possible to comprehend the behaviours of economic actors without considering the social structure in which these economic actors are located The different actors in a network (e.g. a joint venture) come to the interaction with different ideas that shaped their view of the world. These ideas are influenced by various internal and external factors or conditions.

Scholars have increasingly been of the argument that the value of social capital is dependent on its context (Burt, 1997; Xiao and Tsui, 2007; Stam et al., 2013). Adopting a contingency view on the value of transnational knowledge transfers for the recipient unit, the value of obtaining and using knowledge should be accessed by evaluating the benefit of the received knowledge to the recipient unit, rather than by measuring the quantity of the knowledge flow (Ambos and Ambos; 2009). Recent literature contends that it is the benefit, relevance or performance rather than the mere occurrence of knowledge flows that matters (Schultz, 2003; Mahnke et al.; 2004; Haas and Hansen, 2005). The contingency view infers that significant contextual variables are highly likely to affect the degree to which the recipient unit is capable of benefiting from the transfer of knowledge.

Context can be defined as circumstances under which the interaction occur; knowledge transfer is contextually bound therefore its transfer is inhibited by the context in which it is embedded (Duan et. al 2010). This context is divided into three layers, namely national, organizational and the knowledge and information context (Dawes, et. al. 2012).

Knowledge Creation Theory

Nonaka's (1994 and 2004) and Nonaka and Konno (1998) central theme of knowledge creation theory has relevance in this study. These transnational network are viewed as a constant exchange structure where knowledge is shared and transferred between actors. Taking form of a SECI model, one can view the interaction of parties as creating new knowledge that is constantly changing shape from explicit to tacit and tacit to explicit gaining refinement to create new knowledge. Constant communication within a network signifies sharing and transfer of knowledge that result in creation of new knowledge that enables actors to deal with differences that exist within the network to enable them to provide new and creative ways of bridging their distance.

Research Methodology

The study adopted a qualitative study approach which makes it easy for researchers to identify issues or factors, which were previously not known. It is an in depth study and uses a case study design approach. The case study is best suited to answer questions of why and how in situations where researchers do not have much control on research conditions – especially when studying complex phenomena. A mono method (single method) approach for qualitative survey design and corresponding data collection techniques and analysis procedures were used. The interpretivist approach is a naturalistic approach, which generally strives to understand a phenomenon in context-specific settings (Patton, 2001). This approach is followed by qualitative researchers who seek illumination, understanding as well as extrapolation to same situations (Hoepfl, 1997). Interviews and observations are dominant in the interpretivist approach (ibid). The qualitative sample was selected using purposive sampling of firms known to the researcher for delivering real estate projects transnationally and the researchers have in turn used snowballing sampling to select local firms that the first sampled firm worked with in a collaboration.

Using the purposive sampling method, the researcher selected the respondents based on her own judgment, knowledge of the population, eligibility criteria (of having done some work transnationally in the past and possessing at least over 10 years of experience in the real estate and built environment for SA firm). The firms will be located in a variety of places within SSA. Within the identified and referred firms, further snowballing sampling took place as firm representatives referred the researcher to various people within the firm who may be more appropriate to be interviewed for different questions depending on their knowledge and experience. The firms' main eligibility criteria will be that: the firm has experience of doing work in a transnational joint venture (local and cross-border joint venture). The criteria used for participants in a collaboration was, SA firms with over 10 years experience in real estate projects, SA firms that have completed at least one project outside SA within SSA, SA firm that completed at least 1 project in SSA (outside SA) working with a local partner. Non-English speaking participants were excluded.

This criterion was established based on the rationalization that firms with this main characteristic would possess the information the researcher needs in order to be in a position to address the research problem. A sample of 5 cases was planned to be investigated for the study, each case consists of a minimum of 2 participants (local and cross-border).

Sampling Method

A case study approach was adopted for a case between cross-border and local firms in SSA. Interviews were conducted with participants using a semi-structured schedule. These were held with each participant/firm in a collaboration. Face-to-face interviews were first conducted with cross-border firms based in South Africa as they were easier to access for the researcher and later telephonic interviews were administered with local firms based across different countries in SSA. SA firms that participated in the study were seasoned private sector firms with over 10 years experience in commercial real estate developments. Participants were a combination of real estate developers and built environment professional firms that included quantity surveyors, engineers and architects. These firms had also worked on various commercial projects in Sub-Saharan Africa (outside SA). Some have a presence outside SA running satellite offices and others prefer to use SA as their home base and only travel outside SA on an ‘as-and-when-required’ basis, depending on their involvement on each project (on a project by project basis). A purposive sampling of a total of 10 SA firms was selected and invited to participate in interviews. For this purposive sampling, researchers relied on their experience in the industry, personal contacts, marketing material and trade notifications to select a sample that meet the characteristics of the study. The main characteristic was, a cross-border firm that has worked outside in SSA (outside SA) in collaboration with a local firm. From this sample, an additional 3 SA firms were added based on a snowballing sampling technique, this was recommendation from some of the first 10 firms/participants interviewed, who believed the additional 3 firms may deepen our understanding in this study based on their experience working in SSA with local firms. A total of 13 South African firms (cross-border firms) were then interviewed in this study.

Similarly with local firms, participants were a combination of real estate developers and built environment professional firms that included among others quantity surveyors, engineers and architects. Firms that participated in the study were private sector firms with extensive experience in their home countries working on various projects, particularly public sector projects. Most of these firms had limited experience and exposure to big scale commercial real estate developments. At least one of the firms that participated in this study had extensive experience and exposure to commercial real estate developments locally and internationally and had been in business for over 20 years.

Using a snowballing sampling technique, a total of 20 local firms were invited on email to participate in the study. SA firms that had already been interviewed in the study recommended these 20 local firms, they had worked with and each gave at least one to three names of local firms they have worked with in their home country. This fitted the main criterion of the study that local firms to be interviewed must have worked with an SA firm on at least one project. There was no response received from at least 9 local firms to confirm their interest in taking part in the study, after follow up. A total of 11 local firms expressed interest and these firms were from Ghana (4), Tanzania (1), Nigeria (1), Kenya (2), Zambia (1), Mozambique (1) and Botswana (1). Telephonic interviews were held with these firms that lasted about an hour for each interview. 13 face-to-face interviews were held with SA firms and 11 telephonic interviews were conducted with local firms from various parts in Sub-Saharan Africa. A total of 24 firms were interviewed in this study.

Table 1: Breakdown of firms that responded

	Cross-border Firm	Local Firm
Developers	4	3
Architects	4	1
Quantity Surveyors	2	3
Engineers	3	4
TOTAL	**13**	**11**

**Each cross border firm recommended multiple firms they worked with in multiple countries in SSA*

Data Collection

Cross-border Firms

Interviews were scheduled on email with directors of selected firms. Acceptance of interviews was received on email and date of interviews confirmed. Face to face interviews were conducted with all cross-border participants in their offices. The interviews lasted on average approximately 1,5hrs. Some respondents were audio recorded and some indicated they did not wish to be recorded. Data was audio recorded where researchers were permitted to do so and also notes were taken during all interview sessions.

Local Firms

Directors of local firms were contacted on email and some telephonically to discuss the prospects of taking part in the study. It was explained to them how they were selected, which was based on the cross-border's recommendation having worked with them in the past in their home country. A confirmation from some firms was received and they expressed interest in taking part in the study. This was followed by further email correspondence to agree the most appropriate time for researchers to call in for the interviews. Once date was confirmed, interviews were conducted and data was collected using hand written notes. No audio recording was used for all local firms' interviews, only comprehensive notes were taken. This was largely due to the technical glitches of the telephone used but also only two respondents out of 9 agreed to be recorded on the consent form.

Data Analysis

The study also aimed to test the relevance and applicability of Dawes et. al (2012) conceptual model of contextual complexity in transnational projects. The contextual differences identified by Dawes et. al (2012) in their model served as a framework/ benchmark in which the results of the study are presented. Whilst identifying the contextual differences that exist in these collaborations, the results of the study were then matched, organized and allocated to a corresponding category of the responses received from participants. Pattern matching of recurring themes was grouped together to formulate a dominant view. The results of the interviews were matched to the nine themes corresponding to the nine-differences/ distance in the model. These nine themes forming differences are: Cultural, Political, Organisational, Intentional, Resource, Technical, Knowledge, Relational and Physical. Most respondents discussed some or most of the nine themes in the model. After matching the responses of participants with each theme/ relevant category, the dominant responses were captured and reported; also differing responses are also captured. Under each theme, if majority of responses are similar, that is recorded as the dominant response for the particular theme. But also if a diverse view from a few participants is submitted, it is recorded as such and highlighted. Continuous analysis, matching different parttens together continued for each theme to produce findings that can be interpreted. The results of each category/theme are discussed in detail below.

Thematic analysis was the basis for analyzing this data. Thematic analysis is concerned with breaking information into themes. Due to the amount of data produced in the study, thematic analysis is the appropriate choice of analysis and helped with producing appropriate content that will be understandable from the data collected. Data was broken down into nine themes representing the distance experienced by these collaborations. The nine differences come from the Model of Contextual completity which we test for its relevance and applicability in private real estate.

Based on an extensive analysis of responses from different participants/ firms, the table below summarises the dominant differences under each theme with different ways indicating how these differences are navigated/ bridged:

THEMES	Cross-border	Local	How differences are navigated/bridged
CULTURAL DIFFERENCE	Majority of respondents did not appear to have a major issue with cultural differences, these were acknowledged but were identified to be dominant outside project setting (eg language,communication style and decorum) respondents (built professionals) indicated they were not a big issue hindering project.Whereas developers believed these were important to understand and observe/respect as they may affect the project directly. They relied on local partner to lead and advise on these nuances of behaviour.	Respondents indicated that local partner understands the local culture, local language and has a good sense of decorum or behavior observed in different spaces and environments which SA partner may not be aware of, or care for much. These may be minute nuances of behavior in a particular environment but may produce big results because there is understanding, trust and acceptance between parties dealing with each other. Most participants indicated that there are a lot of behind the scenes consultations (with chiefs, communities, officials etc.) that generally need to be facilitated in order to ease things for the project, that SA partner may not even be aware of, oftentimes they do a lot of groundwork for SA patner to smoothen the processes e.g. introducing projects to relevant (traditional) stakeholders in line with cultural expectations. The local partner plays a pivotal role in this.	Local partner champions these cultural differences for ease of the project, SA partner relies on local partner for guidance and facilitation
POLITICAL DIFFERENCE	Respondents were concerned with the political stability in country, elections and change of government. They continously assess possible threats that may affect project. Examples such as tax rate increases (twice in one year), withholding tax issues, currency depreciation, volatility and various laws (eg expatriation of funds out of country) that are enacted during project life span impacted on projects negatively and were raised as a huge concern for by most respondents. In Tanzania as an example the law stipulates that only local partner (Architect) can submit drawings to municipality for approval. Contracting was not a big issue as often SA contracts are used.	Respondents indicated they play a huge role facilitating political and governmental processes for the project. These may include work visas for SA partners, municipal approvals, land ownership issues, local standards etc.). SA partners just submits an application and gets approval, whereas generally there would have been discussions and facilitations that occured prior from local partner.	Local partner does facilitation in home country to ensure smooth progress of project. If this is not done it causes delays to project and progress.
KNOWLEDGE DIFFERENCE	Respondents indicated that there is a huge technical and skills gap that exists. This is also largely due to local partners lack of exposure and experience in large scale commercial projects as this product is non-existent in some parts or uncommon. So most professionals had not been exposed to working on these type of projects. One respondent argued that the basic skill (professional) exist, its exposure thats lacking. The gap is reported to widen as you go down the ladder with examples of handrawn drawings submitted by tenants.	Local partners are well networked and have a good understanding of local standards and deal better with issues on the ground. Whereas SA partner may provide financial capital and technical competence on the project among other things but local partner invests huge social capital on the project. There is room for both to learn from each other. One respondents indicated that in their experience SA partner appreciates what we offer and they understand its value, hence they tend to identify knowledge/ technical gaps that exist and often send us to their head offices for training on various tasks in South Africa	SA partners offers training to expose local partner to various technical aspects they may not be familiar or competent in whereas local partner does a lot of site monitoring and advises on processes and local standards.
INTENTIONAL DIFFERENCE	Respondents indicated that often intentions are aligned between parties. SA partner wants to deliver the project and get remunerated, create a portfolio of successes and experience for the business.	Respondents also indicated that the intentions are generally aligned between parties. Local partner wants to deliver the project and get remunerated, they also want exposure and experience on a different type of project.	There is alignment in intention and both parties work towards to achieve their project objectives. There were no differences identified.

PHYSICAL DIFFERENCE	Respondents indicated that physical distance was not an issue. They formulate a travel plan of how many visits are required per month and plan in advance what is to be accomplished with each visit, otherwise on a day to day basis the local partner is the eyes and ears on the ground and telephonic and email communication is often used on a regular basis between parties. Network was reported to be good and in some cases even better than SA. Too much travelling was repoted to be strenous at times.	This was not indicated as an issue for local partners and they seemed to be able to connect in other ways with their partners. Face to face interactions take place per the planned programme and in between, electornic communication is used.	SA partner relies on a local partner for site monitoring on the ground and communication a combination of monthly face to face and telephonic comms. No major differences were reported here, just that too much travelling could be strenous for the body
RELATIONAL DIFFERENCE	Respondents indicated that they spend a lot of time vetting their partners initially and once they work together on one project, they always prefer to continue the relationship as they understand each other better. Generally these relationships tend to span over long term dependent of availability of more work. One Architect indicated that their partner has been working with them for over 10 years. Most of this work is not tendered but awarded based on previous working relationship and track record.	Respondents indicated that they generally get involved in these projects through referrals and word of mount coupled with their track record in home country. They also look after relationship in hope of securing more future work as its always easier to continue the relationship as they understand each other better. Generally these relationships are over long term dependent of availability of more work.	As these relationships are largely based on referrals, both parties look at building a long term relationship with each other and they endeavour to handle these relationships with care. Some SA firms reported to have been invited to other projects by local firms and vise versa.
ORGANISATIONAL DIFFERENCE	Respondents indicated that they did not seem to be affected much by this difference as largely people/ representatives that participate in these networks are largely senior (mostly directors) and can easily make decisions representing their organisations.	SA partner tend to be used to a fast paced environment and processes compared to what they find outside SA. The pace of doing things and processes in reality is slower than SA partner is used to and this may sometimes frustrate SA partner and make them want to push harder and take control which does not always work well. SA partner tend to be used to be in control and project teams generally have a dominant person (SA) who always directs and dictate direction within the team but this does not always work because its not always just about the technicalities of the project but there are a lot of behind the scenes consultations that take place	The organisational differences (culture, processes, authority, hierarchy and work ethic or way of doing things) exists. Local partner indicated that SA partners may find new environment different to what they are used to and this may be somewhat uncomfortable for them. SA partner needs to understand that not all things that work well in SA works the same in other places and they need to have faith in other people's systems.
TECHNICAL DIFFERENCE	Generally there are software differences that exist between firms. Drawings often need to be converted to PDF to be shared. Other QS software had to be purcahsed and local staff trained in SA office on new software for partners to be compatable. A particular standard is emphasised as most professionals have ISO creditation and other forms of creditation to be adhered to.	The pushing and wanting to take control of SA partner due to frustration (caused by things not progressing as speedily as they believe they should) may be perceived by some and may come across as 'arrogance' but some participants indicated that they purely believe that it is more of a different work ethic than arrogance. Also the pushing in my view is as a result of their clear understanding of the negative implication time delays have on the overall feasibility of the scheme, as these projects are privately funded.Hence they tend to identify knowledge/ technical gaps that exist and often send us to their head offices fro training on various tasks just to ensure that the project progresses smoothly and technical differences are minimized.	Best practise is largely adopted. Differences exist in the way things are done (different processes, software and systems), exposure and training is employed to standardise and work off the same script to meet standards and adhere to best practise. Whereas also when SA partner starts off with a credible local partner who understands the pace of processes, the culture and the environment these 'perceived delays' can easily be factored in the programme with ease because local partner has this understanding
RESOURCE DIFFERENCE	SA firms bring financial capability and technical competence or know how on the projects. Technical training is often afforded to local firms. One respondent detailed how a group of students from a local office/firm were involved and given exposure on the project	Local partners are well networked and have a good understanding of local standards and deal better with issues on the ground. Most respondents indicated that largely day to day site monitoring is done by local partner	Mostly SA company uses their resources to support and expose local firms by offering design or software training for local firm to be compatable with the latest technology and systems used by industry.

This is followed by a set of generic principles informed by existing practices utilized by both local and cross-border firms navigating their environments in SSA

<u>Generic Principles utilized by both local and cross border firms</u>:

Whilst exploring how cross-border and local firms bridge contextual distance inorder to perfom optimally to achieve project goals, the study was able to formulate generic principles informed by existing practises utilized by both local and cross border firms to navigate their differences inorder to meet project objectives.

1. <u>Go in the field to collect up to date, correct and relevant information</u>. Market research is the cornerstone of a succesful project. It is not possible to assume that what works in one country will work in another. Unorthodox methods of doing market research are adopted in new markets. This kind of research is coupled by a thourough due dilligence. Often times lack to no information online exist and also poorly stored in documents. Other times what is available on paper is unlikely what you find on the ground. So its always best to conduct physical site visit to verify or produce/document new information. Physical visits to country are key to getting a sense of how things work, in terms of culture, environment, politics and social setting. Desktop research is often inapt. In real estate development environment, research information is fundamental in making important decisions.

2. <u>Partnering is key</u>. Working with local partners is often preferred and adopted. This strategy is adopted to help understand the local nuances better. Selecting the right partner requires extensive due dilligence to be conducted. This due diligence is often undertaken on potential partners to do business with, including word of mouth in instances where official documents/ web searches are unavailable (particular software used to assist with this). Partners are oftne seen as the other piece of the 'missing puzzle', meaning they have a role to play to complete the picture or the project. In the real estate development scenario, each partner makes a meaningful contribution for the success of the project.

3. <u>Social capital is recognised and treasured</u>. Understanding of local networks, culture, local processes and procedures is fundamental in getting the project done. Partners that understand the value of social captial are able to choose partners that are equally fit for task and get things done.

4. <u>Technical know how is fundamental in project success</u>. Inorder to find balance and establish a cohesive working relationship, tasks are often divided and training offered to enhance areas that require improvement.

5. <u>Professional Ettiquette is valued and opens most doors</u>. As the saying goes "when in Rome do like Romans do". When cultural sensitivities are recognised and understood, this eases the burden on the project. This goes a long way in project acceptance by communities, officials and locals. Bullying tactics, cow boy mentality and dominance have not worked well in the past. Respect however has reigned supreme and managed to open most doors.

Conclusion

No matter how deeply embedded in their own context each partner may be, there seems to be a shared interest and a general understanding that ultimately both parties seek the same goal of completing the project. There is a point of convergence (using SECI model) where both parties meet and create new information and understand each other better. This benefits both partners. Transnational collaboration between cross-border firms and local firms in SSA seems to work well for both parties with each having something to contribute and also something to gain from the other. This confirms the transnational knoweldge transfer of a bi-directional nature/ multi-directional nature among parties to the network. The study also revealed the importance of treating each country uniquely (individually) as what may have worked in another country often may not work in another. This emphasises the importance of tailor made solutions for each country.

References

ACBF, (2014). Africa Capacity Report 2014: Capacity Building for Regionalism in Africa. Harare. Available at:http://www.acbf-pact.org/sites/default/files/ACR%20Web%202014%2023122014_0.pdf

Ambos, T. and Ambos, B. (2009). The impact of distance on knowledge transfers effectiveness in multinational corporations, *Journal of International Management*, 2009, vol. 15, issue 1, 1-14.

Burt, R. (1997). A note on social capital and network content, Social Networks, Vol. 19, Issue 4, pp. 355-373.

Dawes, S. Gharawi, M. and Burke, B. (2012). Transnational public sector knowledge networks: Knowledge and information sharing in a multi-dimensional context. Government Information Quarterly 29 (2012) S112-S120.

Duan, Y. Nie, W. and Coakes, E. (2010). Identifying key factors affecting transnational knowledge transfer, Information & Management, Vol. 47, Issues 7-8, pp. 356-363.

Granovetter, M. (1985). Economic action and social structure: The problem of embeddedness, American Journal of Sociology, Vol. 91, No. 3.

Growthpoint Properties Limited, 10 November (2015). www.growthpoint/pages/media.co.za, accessed: 03 March 2016

Haas, M. and Hansen, M. (2005). When using knowledge can hurt performance: The value of organizational capabilities in a management consulting company. Strategic Management Journal, Vol., 26, issue 1

Hyprop Investments, 17 November (2015). www.hyprop.co.za_news_article, accessed: 03 March 2016.

Inkpen, A. (2000). Learning through joint ventures: a framework of knowledge acquisition, Journal of management Studies, Vol. 37, Issue 7, pp.1019-1044.

Inkpen, A. and Tsang, E. (2005). Social Capital, Networks and Knowledge Transfer, The Academy of Management Review, Vol. 30, No. 1.

Kararach, G.; Besada, H. and Shaw, T. (2015). Development in Africa: Refocusing the lens after the Millennium Development Goals. The Policy Press.

Khanna, T. Palepu, K. G. and Sinha, J. (2005). Strategies that fit emerging markets. Hardard Business Review. www.hbr.org, accessed: March 2018-03-13.

Knight Frank Africa Report (March 2015), Real Estate Markets in a continent ofgrowthandopportunity,www.content.knightfrank.com/research/155/documents/en/africa-report-2015-2802.pdf, accessed 20 February 2016.

Kostova, T. (1999). Transnational transfer of strategic organizational practices: A contextual perspective. Academy of Management Review, Vol. 24, No. 2 308-324.

Mara Delta, 10 November (2015).www.maradelta.com, accessed: 20 March 2016.

McKinsey & Company, (2012). Urban world: Cities and the rise of the consuming class. June 2012, McKinsey Global Institute, www.mckinsey.com

Nonaka, I. (1994). A dynamic theory of organizational knowledge creation. Organization Science, **5** (1), 14-37.

Nonaka, I. (2004). A dynamic theory of organizational knowledge creation. In: Starkey, K, Tempest, S and McKinlay, A (Eds.), How organizations learn. London: Thomson.

Nonaka, I. and Konno, N. (1998). The concept of "Ba": Building a foundation for knowledge creation. California Management Review, **40** (3), 40-54.

Price Waterhouse Coopers (PWC), (2015). Real Estate, Building the future of Africa, pwc.co.za, accessed November 2017.

Price Waterhouse Coopers, (2014). Trends, challenges and future outlook. Capital projects and infrastructure in East Africa, Southern Africa and West Africa. www.pwc.co.za, accessed January 2016.

RMB Westport Investments and Developments, 18 November (2015). www.rmbwestport.com, accessed: 05 March 2016.

Shimeles, A. and Ncube, M. (2015). The making of the middle-class in Africa: Evidence from DHS Data. Journal of Development Studies, Vol 51, Issue 2, 178-193

Van Staden, C., Alden, C. and Wu, Y. (2018). In the Driver's Seat? African Agency and Chinese Power at FOCAC, the AU and the BRI, South African Institute of International Affairs (SAIIA), Occasional Paper 286, African Perspectives Global Insights, September 2018.

Wadiwalla, F. (2003). The evaluation of selected risks and opportunities associated with Globalization of South African construction companies into Southern Africa. University of Pretoria: Unpublished MSc Thesis in Project Management.

COLLABORATION IN THE NEW ZEALAND COMMERCIAL CONSTRUCTION SECTOR – A CASE STUDY OF A MEDIUM SIZED CONSTRUCTION COMPANY

Maria Zaiat[1], **Neil Laing**[1], **Linda Kestle**[1]

[1]School of Building Construction, Unitec Institute of Technology, Auckland, New Zealand

Abstract

The New Zealand commercial construction sector is experiencing a significant economic boom. During this boom many companies are struggling to operate efficiently, resulting in failures to meet project expectations, clients being un-happy with results, and financial stress causing, in some cases, companies to become insolvent. Many of these issues relate back to the competitive nature of the industry. In an effort to become more effective, the NZ construction industry is discussing strategies for addressing the problems it faces. One strategy receiving increasing interest is how the industry could work more collaboratively across the supply-chain to improve performance. The research seeks to answer 'is collaboration occurring in the New Zealand commercial construction sector'? An investigation of a medium sized construction company was undertaken to assess at what stages it was working collaboratively, and whether there was an untapped opportunity for the company to be more collaborative. Findings have shown that participants are demonstrating high levels of cooperation and teamwork on-site, with a willingness to work collaboratively. However, much of this behaviour is confined to the on-site team, with limited evidence it extended beyond the construction site. Barriers to collaboration included communication problems, different mind-sets, and the diversity of understanding regarding collaborative work practice. Participants felt that a more formalized structure would be beneficial, and could provide them with the means to develop and maintain a collaborative culture. The research recommended that there needs to be greater input by leadership for facilitating effective collaborative practice in the workplace.

Keywords

collaboration, communication, construction industry, culture

Introduction

Working in the construction industry quickly exposes the need for understanding that working effectively and efficiently together is key to a project's success. Many scholars agree that the construction industry can be classified as one of the most complex industries in the world making the process of successfully constructing a building extremely challenging (Behm, 2008, Shen et al., 2010, Wu, Greenwood and Steel, 2008). Traditional construction methods have encouraged competitiveness and adversarial behaviour, which does not necessarily improve project outcomes. Whereas the collaborative approach provides better outcomes, and are favoured by project participants. Rahman *et al*. (2013) highlighted that working in collaboration substantially benefits organisations in delivering projects to the set requirements, and to survive in a complex construction environment. Currently, the New Zealand construction industry is experiencing high demand, which is placing ever-increasing pressure on resources. With the industry expanding at a fast rate, it is important that best project delivery practices are implemented, which includes using collaborative working approaches (Ibrahim,Costello and Wilkinson, 2015). This investigation sought to understand whether there is a coherent understanding in the industry regarding the value of collaboration, and to what extent it is being practiced.

From the collected data it could be used to further develop understanding, and enhance the quality of the way the construction industry operates. Gaining understanding of where the industry currently is, in terms of collaboration, could assist the government, companies and individuals with identifying actions for improvement. The research investigation also highlights how creating a collaborative environment can create potential innovation in construction practices that could enhance the future of the New Zealand construction industry

Literature Review

The need for collaboration

The construction industry is considered to be one of the most complex industries in the world due to the diversity of individuals, projects, and the requirements involved (Behm, 2008, Shen *et al.*, 2010). Creating a collaborative culture offers many advantages for construction project teams and companies. Advantages such as increased end product quality, high efficiency among individuals and increased innovation and learning is offered once this type of culture is in place in the project team environment (Greenwood, 2011, Torneman, 2015). Stepping into the collaborative environment and understanding the need for it is important, as it will open up prospects for the individuals and/or companies to reach the best outcome for the project.

Purpose of collaboration in the construction industry

The construction industry is overflowing with management difficulties related to managing individuals and communication among team members that affects the success of projects (Chiocchio *et al.*, 2011, Behm, 2008). There is an apparent lack of communication, and management difficulties have developed through the diversity of individuals involved in the project lifecycle. Xue,Shen and Ren (2010) found that construction is one of the most erratic and complex industries with ongoing issues of “poor performance, low productivity and no competition” (p.1). As a result of the complexity and diversity of individuals involved in projects, construction is in need of a system that encourages “trust, commitment, safety, interdependence, a win/win philosophy, mutual understanding and respect, communication, problem solution mechanisms, sharing of risk and benefits, innovation and creativity” (Greenwood, 2011, pp. 301). Hughes,Williams and Ren (2012) added support for why collaboration should be adopted in the construction industry, this includes ‘external pressures’ for example, public image and government influence on how the company is run and operates and ‘internal pressures’ to achieve a more efficient working environment, enhancing productivity (p.3). This points to the construction industry being incomplete without a collaborative working environment.

Companies that work collaboratively have been able to improve project quality, efficiency, and increase innovation and learning. Quality is enhanced by creating open lines of communication, trust, transparency between individuals, and sharing knowledge, where the project team can focus and work together to achieve the best quality outcomes (Dulami and Dalziel, 2009, Hoonakker,Carayon and Loushine, 2010). Quality failures are often caused by individuals being focused on their own tasks, and not considering how communication and sharing of information reduces opportunities for solving complex problems (Jiang and Lu, 2017). Efficiency is increased in the construction process through better integration, open lines of communication, trust, transparency between individuals and sharing knowledge. As a result, the project team can focus and work together to achieve the best product (Koolwijk *et al.*, 2018, S Rahman *et al.*, 2013). Fulford and Standing (2013) also confirmed that the construction industry experiences waste from a lack of communication, technology usage, and innovative systems, when not actively or diligently employed. Working in unity will enable the project team to effectively work to create an enhanced quality of product (Meng, 2012) and collaboration increases the chance of organisations being innovative due to the project team promoting individuals to interact with each other, share valuable information, and suggest alternative solutions to difficult problems (S Rahman *et al.*, 2013, Torneman, 2015). According to Greenwood (2011) collaborative practices enhance organisational learning through sharing knowledge among all of the project participants, and can best be realised when supported by modern procurement methods such as Design

Build and Integrated Project Delivery (Franz *et al.*, 2016).

Understanding collaboration

In order to move from the traditional adversarial system to a collaborative culture, a clearer understanding is needed of associated concepts and motivations from the perspectives of researchers, clients, contractors, and subcontractors. Currently, there is a broad range of understanding of what collaboration is, and the reasons for adopting it. Aapaoja *et al.* (2013) pointed out the reason why collaborative approaches are being promoted, due to the traditional procurement approach not encouraging cooperation and providing the advantages offered by a collaborative system. Given the diversity of individuals involved in the construction industry, Wu,Greenwood and Steel (2008) highlighted that in order for collaboration to be effective, cooperation of participants is needed to tackle issues like poor communication, poor quality, cost overruns, program delays, and disputes between key individuals. Son and Rojas (2011) identified collaboration as being individuals working closely together, having shared objectives, and building trust and respect. Further, Ibrahim,Costello and Wilkinson (2015) described collaboration as a system that encourages team contribution and team reward.

Clients define collaboration as an involvement of all the project participants in the organisation that share knowledge and learning, transfer valuable information to individuals, encourage trust and communication, and promote respect (Hughes,Williams and Ren, 2012). The team then works toward the best outcome in achieving the project requirements, evenly sharing risk, and celebrating project success together. Eriksson and Torbjorn (2008) supported a definition where clients define collaboration as a win – win approach. Increased co-operation among individuals and feedback from the client's side can be more easily facilitated through established trust, communication links, and respect between individuals. Once feedback is obtained from the client, they can expect to see increased quality, work efficiencies, learning and innovation and most importantly awareness that a win - win outcome is achievable (Greenwood, 2011, Wu,Greenwood and Steel, 2008).

Hughes,Williams and Ren (2012) defined collaboration as early contractor involvement and increased communication between the client and subcontractors, to increase the quality of the end product. Through incentives offered by this relatively new concept, individual talent is captured and developed through widespread teamwork and comradery among individuals in the entire organisational environment (Eriksson and Westerberg, 20ll). Once contractors have defined collaboration they are then able to focus on the characteristics of early contractor involvement (M Rahman and Alhassan, 2012). Typically, once introduced, the benefits to the overall project delivery include; increased innovation, contribution to the design stage, high quality finishes, enhanced risk management and significantly increased communication, trust and problem-solving mechanisms (Eadie and Graham, 2014).

The view of collaboration by subcontractors should be considered as being critical for the success of construction projects. Chalker and Loosemore (2016) identified that subcontractors are considered, by clients, as key for ensuring the finished product is delivered to the quality, time and cost requirements expected. Collaboration from a subcontractor's can be viewed as a way of working together, easy transfer of communication, a trusting environment, respect among individuals, willingness of top management to provide subcontractors with required information, and a no-blame culture (Hughes,Williams and Ren, 2012). Loosemore (2014) stated that co-operation is favoured among subcontractors compared to the traditional method of procurement, as one of the key benefits of a system that ensures successful communication links among individuals in the organisation.

Mechanisms that enhance collaboration

There are a wide range of recommended approaches for enhancing collaboration. The key approaches are discussed in order of their significance and impact. Technology use is providing some of the greatest improvements for enhancing collaboration. Building Information Modelling (BIM) is considered one of the most influential processes available. Portwal and Hewage (2013) found that the use of BIM in construction projects significantly encourages the project team to collaborate. Azhar (2011) supported this by highlighting that the use of BIM benefits productivity and efficiency. BIM allows team members to work interactively, rather than in isolation, allowing project information to be transferred faster, enhancing innovation, increasing quality and enabling project budgets, to be achieved according to the initial plan (Azhar, 2011, Hurtado and Sullivan, 2012, Succar, 2009). Mobile technology is advancing the use of software, such as BIM, on site by providing immediate and up-to-date access to information (Changyoon *et al.*, 2013).

A focus on creating a collaborative culture is important for achieving the benefits that integrated systems offer. Ibrahim,Costello and Wilkinson (2015) identified that leadership and management support is needed for delivering a collaborative project. Top management need to support the project team, to push the project team to work together, and to respect and communicate effectively with each other. Dulami and Dalziel (2009) pointed out that workshops are a great way to encourage individuals to interact with each other. Workshops can help create a collaborative culture by enabling the key participants to feel more comfortable in sharing information, brainstorming and developing innovative solutions (Dulami and Dalziel, 2009, Kadefors, 2011, Wu,Greenwood and Steel, 2008). A learning culture can also be achieved through these workshops as individuals share valuable information. Ibrahim,Costello and Wilkinson (2015) highlighted that through sharing of information and engagement of top management, project commitment and efficiency is enhanced.

Shelbourn *et al.* (2007) pointed out that three key elements are needed – business, people and technology, to be present for collaboration to truly work. Dulami and Dalziel (2009) recommended that providing the project team with a shared project office is a way to bring those elements together. The project team can interact with each other building trust and respect, Ibrahim,Costello and Wilkinson (2015) added, incorporating a shared project office in the organisation once collaboration is established greatly motivates individuals to work together increasing individual job satisfaction. Incorporating collaborative tools creates co-operation, flexibility, and adaptability in the project team (Erdogan *et al.*, 2008).

Behaviours that enhance collaboration

Communication, trust, a learning culture and motivation must be present in when creating a collaborative culture. These four characteristics highlight the importance of including behavioural approaches in the construction industry for creating collaboration. Gamil and Rahman (2017) defined communication as an exchange of ideas and information, transferring valuable information and data without delay. According to Gamil and Rahman (2017) effective communication among the project team means project outcomes can more likely be successfully achieved. In addition, Gluch and Raisanen (2009) confirmed that in the construction industry communication has been researched for years, perhaps due to the complexity of the construction industry. Erdogan *et al.* (2008) suggested that technology such as BIM greatly increases communication among individuals in the construction industry.

Wong *et al.* (2008) believed that trust plays a major role in the construction industry, especially in a collaborative environment. Accurate transfer of information in the construction industry is critical to the project team, when working together. Trust among participants is essential for open communication related to problem-solving, Laan *et al.* (2011) have identified the benefits from trust generating behaviour as having a positive influence on project outcomes. In order for construction projects to benefit from trust, there needs to be an understanding of the types of trust and how it affects a project. Research into how trust is generated on construction projects has identified two forms. The first is developed during the initial stages of working with a person through interactions and the second form is historical trust, created from either past experiences or from the reputation of an organisation (Jiang and Lu, 2017). Both forms of trust need to be understood and managed effectively in order for a culture of collaboration to emerge.

Wu,Greenwood and Steel (2008) found that the project team once stepping into the collaborative environment must be willing to learn and change from the traditional adversarial method to a collaborative environment in delivering a project. Ibrahim,Costello and Wilkinson (2015) identified those working in an environment, aiming at collaborative practices, need individuals to exhibit relationship behaviours supportive of collaboration and there needs to be processes to promote or allow such behaviour. For the individuals to be motivated towards working collaboratively, an individual's needs must be considered (Tohidi, 2011). It was suggested by Osipova and Eriksson (2011) that incentives should be present to encourage individuals to work toward the goal and to motivate individuals towards learning and delivering high quality products. Through creating an environment that promotes collaborative relationships it can encourage those from different organisational cultures to integrate enabling effective transfer of information (Ibrahim,Costello and Wilkinson, 2015). Organisations must share information between each other, for example, problems that they have faced and how they overcame the problem (Osipova and Eriksson, 2011). By sharing information, organisations can learn and perhaps tackle and be ready for a similar problem that they could potentially face in future. Courtesy of the communication characteristic that collaborative culture provides, a learning culture can be established.

Research Methodology

The research approach used in this investigation was a case study of a medium scale construction company located in Auckland. A case-study approach was chosen because it is an effective way to understand social interactions and how various interrelationships associated with collaborative practice are being manifested (Denscombe, 2007). The company was selected based on convenience and it is currently working towards being more effective through using collaborative practices. Eight participants were selected from a range of construction industry professionals working on the same project. The participants were selected to enable a diverse range of perspectives and opinions for answering the research question. These individuals were from diverse areas of a typical commercial construction project.

Data was gathered using face-to-face semi structured interviews with the aim to obtain descriptive data providing insights into current practice at various levels on a project. Analysis of the response data was coded to identify key terms and phrases for comparison with recommended practice (Fellows and Liu, 2009). Open and closed questions were presented to the participants and this included information regarding their role, background and experience in construction. Collaborative practice questions covered definitions used by participants, views on the level of collaboration practiced on site, the attributes they believe contributed to collaboration, the tools and techniques that best supported collaboration, and finally what the greatest barriers to collaboration were and how they could be or may have been overcome.

Table 1. Participant roles, years and project involvement

Role	**Industry Experience**	**Project Involvement**
Project Manager	*35 years*	*Commercial*
Director/CEO	*33 years*	*Commercial, industrial, warehousing, retail, health, retirement, community, seismic retrofitting and strengthening, building reclads, design & build*
Director/Construction Manager	*33 years*	*Commercial, health, retirement and education*
Client	*20 years*	*Industrial*
Quantity Surveyor	*25 years*	*Commercial*
Site Manager	*14.5 years*	*Commercial and retirement*
Subcontractor (Plumber)	*7 years*	*Commercial, warehousing and residential*
Construction Manager Cadet	*2 years*	*Commercial*

Collaboration is a concept that requires a wide range of people to work effectively together solving complex problems. Participants needed to be chosen to represent a range of working roles within a construction project. The aim was to choose participants who have had different construction industry experience to gain diverse data for analysis and comparison with the literature. A convenience sampling approach was used to select participants that represented clients, main contractors and subcontractors from a commercial construction project, see Table 1

Findings & Discussion

The participants were questioned relating to how they would define collaboration. Participants provided a varying array of descriptions, as seen in Table 2. Six of participants' responses aligned with the notion that working collaboratively included elements of an environment of open communication, freely sharing information and having a supportive culture of trust and respect in order to create an atmosphere for effective problem solving. Participants commented that working together as a team achieving the project requirements successfully is the short answer to defining collaboration. There was a strong sense of the value of teamwork amongst the participants when asked to define collaboration. This was evident when analysing the definitions, as most of them mentioned either 'team work', 'team' or 'working together' in all the collected data. All participants felt that they have a good understanding of what collaboration involves, and were able to articulate many key requirements as described in literature.

Table 2. Collaboration defined from construction industry professionals

Participants	Definitions
Client	*Working as a team to get "buy in" to the project by consultants, contractors, sub-contractors and clients.*
Director/CEO	*We are seeing an increase in collaboration with some clients generally through and ECI process. This is generally with clients or teams who see the benefit of a collaborative approach. The ECI process allow buildability, traffic management, construction management, financial management all to become part of the design process with the end goal being a better outcome for the client and team.*
Director/Construction Manager	*The sharing and gathering of information/experience to aid and support the commercial benefits for the partner involved in the dialogue.*
Project Manager	*A number of people/companies working together to complete a task/project.*
Site Manager	*When individuals work together as a team, communicating freely sharing information, respecting one another and motivating each other to achieve the outcome set by the client.*
Quantity Surveyor	*Using combined knowledge to come up with most efficient design and implementation.*
Construction Manager Cadet	*Sharing problems with one another and achieving project requirements together in a joint effort.*
Subcontractor (Plumber)	*Involvement from all parties in the project. Sharing information with the construction industry chain, as well as communicating unforeseen problems and fixing them together and having a no-blame culture.*

The construction company's focus was on promoting collaborative practices in its projects. Using the definition of collaboration from the perspective of clients, contractors and subcontractors, participants were asked to identify the extent they believed the construction company works collaboratively. Participants were asked to identify the key issues that would increase collaborative practices. Two key components were identified being: a positive attitude towards working collaboratively; and top management providing support and encouragement.

Another question focused on whether the participants had a collaborative working environment in their project team. Table 3 provides a summary of participant comments, where data showed that a collaborative working environment was present in the project team. Most of the participants commented that sharing ideas, problems and working jointly together to encourage an atmosphere of teamwork was what they are doing to achieve a collaborative working environment. The participants' discussion regarding the outcomes of the project once collaboration is implemented highlighted that project outcomes cost, quality and time are achieved. Osipova and Eriksson (2011) pointed out in their report that once a collaborative system is introduced/implemented in the company and religiously followed, quality outcomes are achieved. One of the participants (Director/CEO) strongly encouraged collaboration, but limitations exist at the construction stage, where the project team lacked input during the construction stage thereby limiting the opportunity to realise the full benefit of collaboration. The Director/CEO's observation reflected research where the traditional Design-Bid-Build procurement approach can limit the scope of the benefits available from early contractor involvement and collaboration on construction projects (Nikou Goftar,El Asmar and Bingham, 2014, Franz *et al.*, 2016)

Table 3. Summary of current collaborative working environment outcomes

Participant	*Collaborative environment*	*Outcomes*
Client	*Yes*	*Allows everyone an equal opportunity to have a say over important decisions.*
Director/CEO	*Yes*	*We encourage collaboration but are often limited to our input during the construction phase. Unfortunately, too often it is too late to make the most of it and our inputs become more reactive in regard to design documentation.*
Director/Construction Manager	*In part*	*Increasing the number of meetings between the parties to try and bridge the individual/company barriers.*
Project Manager	*Yes*	*We work as the conductor of information transfer between all parties to facilitate the timely turnaround of queries/shop drawing reviews/programming requirements, etc.*
Site Manager	*Yes*	*We are sharing information and working together to achieve the required outcomes. It looks like by having collaboration in the project team, work efficiency and better working environment in achieved.*
Quantity Surveyor	*Yes*	*Questioning site staff for easier/accurate costing of variations. Listening to site staff and communicating to encourage team work hence achieve project outcomes.*
Construction Manager Cadet	*Yes*	*Sharing information in the project team, working together results in less stress and better project delivery. We share information by communicating, due to communicating freely we have better decision making and prevent major issues on site, all of this is due to good communication links.*
Subcontractor (Plumber)	*Yes*	*Navigating through a list of tasks given to junior cadet/apprentice. In this way they and I develop collaborative working environment. We are constantly communicating between co-workers that builds a good relationship which later really helps to finish the job successfully due to everyone working jointly.*

Participants were then given a statement *"Collaboration is a key mechanism for improving project success"* and asked to identify to what degree they agreed or disagreed. Out of the 8 participants, 4 strongly agreed and 4 agreed with the statement. It was found that participants shared the view that working as a team and sharing project information was a pathway toward collaborative practices being implemented in the company. This was consistent with Rahman et.al., (2013) who stated that with increased communication levels between project participants within a collaborative project environment, increased quality finish, timely project completion meeting the cost target was one of many positive attributes when working collaboratively. Therefore, it is considered to not only be good practice to encourage a collaborative working environment to achieve project outcomes, but to also maintain a friendly social atmosphere, and a win – win philosophy, innovation and creativity, all resulting in project outcome success (Dulami and Dalziel, 2009).

Attributes achieved when undertaking collaboration

Participants were then asked to identify the attributes they believed are achieved when working collaboratively in projects. The participants' responses showed they believed all the attributes presented to them in the questionnaire are achieved. The attributes were based on the work by Wu,Greenwood and Steel (2008), which these included: improved project outcomes, problem solving, chances of a win-win outcome, more openness and teamwork, no-blame culture, learning opportunities, better communication and commitment, and greater respect amongst project participant.

Support for a collaborative working environment

Participants were asked to complete the following statement: *I enjoy working collaboratively because…* The responses in Table 4 indicated that all the respondents enjoy an environment that encourages problem solving and knowledge-sharing-practices, because they improve the project environment and project outcomes. None of the participants provided negative statements regarding collaborative working. Overall, the responses demonstrate the types of positive attitudes needed by individuals for an effective collaborative working environment, as discussed by Xue,Shen and Ren (2010).

Table 4. Responses to statement – "I enjoy working collaboratively because…"

Participants	*Responses*
Client	*Everyone has different experiences, which could add to an improved outcome*
Director/CEO	*Project success is subjective. There are many factors that affect and define success. Collaboration is only 1 factor*
Director/Construction Manager	*Project outcomes are achieved as well as better working environment.*
Project Manager	*A problem shared is a problem halved which results in increased productivity.*
Site Manager	*Everyone can contribute to the job equally by sharing information and communicating. Equal opportunities to participate in the project make the atmosphere at work more enjoyable.*
Quantity Surveyor	*Tapping into knowledge of other parts of the team is the most efficient way of working.*
Construction Manager Cadet	*New skills are learned from experienced colleagues because of the sharing of information that is held by individuals.*
Subcontractor (Plumber)	*It creates fewer problems, no blame culture. Creates a better working atmosphere as well as a social team-working environment.*

Enhancing collaboration through tools/methods

Participants were asked to indicate which tools are currently used in their projects to facilitate collaboration. Most of the participants identified that phones, tablets for job site coordination; company cloud, joint project office and joint project team workshops are being used. Phones were used to communicate between individuals; tablets for jobsite coordination are used to record, and check and send data to the appropriate personnel to action certain remedial work; company cloud was used to store information, joint project office was used to undertake monthly meetings, and joint project team workshops were used to undertake meetings where individuals discussed problems, solutions and general strengths gained in the project cycle.

Table 5. Tools/methods ranking

Participants	Phone	BIM	Tablets	Cloud data	Joint project Office	Joint project Weekly/Monthly workshops
Client	4	5	4	4	3	3
Director/CEO	5	3	4	5	5	4
Director/Construction Manager	4	2	3	3	2	4
Project Manager	5	4	5	4	5	5
Site Manager	5	3	5	5	5	5
Quantity Surveyor	5	3	5	4	3	3
Construction Manager Cadet	5	4	5	5	5	5
Subcontractor (Plumber)	4	2	5	5	5	5
Total Score	37	25	36	35	33	29

According to Baiden, Price and Dainty (2016) collaborative tools and methods need to be present in a company to encourage communication among key participants and to be effective within the organisation. Participants were asked to rank the tools they felt were the most effective for enhancing collaboration (refer to results in Table 5), based on 1 being not effective and 5 being highly effective. The majority of scores were positive, BIM had the lowest overall score. Most of the tools are used on site, with the exception of BIM. This was due to the high cost and skills required to operate the system. The majority of participants used phones and/or tablets for jobsite coordination, and the company cloud for data sharing, joint project office and joint project weekly/monthly workshops as a way to enhance collaborative practices. This was in line with Dulami and Dalziel (2009) who pointed out that there is a need to incorporate tools like workshops and joint project office where the team can cooperate with each other. The participants were given a chance to state what systems they would like to have in the company that would contribute towards increased collaboration on projects. While workshops received the second lowest rating, participants thought that running more frequent workshops would encourage social interaction and contribute towards better collaboration on projects. In a study conducted by Ibrahim,Costello and Wilkinson (2015) frequent team building workshops needed to be present to create a positive team environment, where co-workers can feel that their knowledge and input to the project are appreciated by the project team.

Barriers preventing effective collaboration within the company

Barriers for the participants included matters such as, open communication among project participants and different mindsets that were preventing effective collaboration within the company. Behm (2008) supported this finding that due to the diversity of individuals in the construction industry, different mindsets can be a barrier for collaboration in project teams. Gamil and Rahman (2017) also found the significance of communication in a collaborative project delivery approach where the exchanges of ideas and transferring project information is only done through open lines of communication. Participants identified language and cultural differences across the projects as two of the many barriers that prevent collaboration within the company. This is reiterated in a study-conducted by Behm (2008) that found that the construction industry is the most complex industry in the world due to the diversity of individuals involved in the construction process.

Behaviours and methods required for supporting a collaborative environment

The participants were asked which behaviours individuals need, and what methods can support those behaviours in order to have a collaborative environment. The results showed that behaviours listed included: openness; trust; honesty; authenticity; being a team player; a bias for learning and discovery; tolerance; consistent transparency; motivation; and striving for continuous improvement. This is in line with Xue,Shen and Ren (2010) who suggested that in the construction industry, especially when undertaking a collaborative project delivery approach, individuals must have behaviours that encourage collaborative project delivery practices. Some participants expressed other behaviours that individuals should have, such as strong leadership, being enthusiastic towards work, self-drive, and most importantly being able to work with diversity. Ibrahim,Costello and Wilkinson (2015) added that strong leadership must be present to encourage and facilitate effective worker behaviour toward a collaborative environment. Participants recommended that leaders needed to model collaboration – “be prepared to do what you want others to do”, to ensure bonding as a team, more formalised meetings at the end of the project discussing what went wrong, what went well and what could have been done better. Wu,Greenwood and Steel (2008) findings support these findings, which point out that formalised meeting/workshops provides a solid structure for fostering collaboration in the project team. A subcontractor commented that leadership/top management should visit the site more frequently; as this would encourage better involvement among the project team members. A quantity surveyor noted that site meetings run by leadership/top management would result in everyone being on the same page. The director added that top management should set clear objectives for the team and actively be part of a team. This is in line with Shelbourn *et al.* (2007) who pointed out their strategies such as shared vision where goals can be set and met, technology that could aid with information transfer, and top management commitment to encourage and help the lower construction hierarchy workers to work in cooperation be built into the company’s vision.

Finally, participants thought that having competent people in the construction project cycle with everyone participating and encouraging one another is required for a collaborative working environment. The main theme identified in the findings, which respondents have pointed out is that extensive teamwork is required to maintain a successful team-working environment. However, this was not a focus of the investigation, but was reaffirmed in a study conducted by Tohidi (2011) who stated that extensive teamwork is required in a collaborative environment as its one of the branches that can lead to an improved work atmosphere.

Conclusion

The research has presented a snapshot of an Auckland commercial construction project with a representative sample of project participants from diverse roles and experiences. The questions asked were designed to elicit responses regarding the level of ‘collaboration’ in the New Zealand commercial construction industry. When looking at whether or not individuals are experiencing collaborative practices on site, the study clearly indicated that there are, however many gaps and inconsistences in collaborative practices. There is strong evidence of effective teamwork occurring, but the findings pose a question as to whether all participants interviewed fully understood collaboration, as studies indicated that before working collaboratively, individuals must first understand its meaning.

In terms of collaborative practices occurring on site, it was evident that a positive and supportive attitude existed towards the extent the company was promoting collaboration. Participants identified that key attributes associated with collaborative practices were present on site and that the work methods and tools used were positively contributing towards the facilitation of a collaborative working environment. However, there were limitations for the company regarding the use of technology, such as cost and capability, which impacted on their ability to fully engage in collaboration as facilitated by technology. Of the barriers preventing effective collaboration within the company, the biggest barrier was effective communication, due to the diversity of people working on-site. In terms of promoting collaboration, participants pointed out that more frequent meetings or workshops would help enhance a collaborative working atmosphere by allowing the opportunity, for example, to open up, share ideas and problems, and to encourage and facilitate a cooperative atmosphere.

The literature on collaboration identified the types of antecedents needed in order for collaboration to occur. A key factor was for leaders to have a clear understanding of collaboration and how to actively promote collaboration in order to achieve the best results. The study provided some guidance as to where the New Zealand construction industry, and in particular the company investigated, sits in relation to collaborative practices. The research concluded that the Auckland commercial construction company is not 100% familiar with what is required for collaboration, but is well aware of the advantages achieved through a collaborative working environment, and are actively promoting collaborative practices. In order to move forward, it appears that participants want more input from their leadership and management.

References

Aapaoja, A. *et al.* (2013) 'The characteristics of and cornerstones for creating integrated teams'. *International Journal of Managing Projects in Business,* 6 (4), pp. 695-713.

Azhar, S. (2011) 'Building information modeling BIM: Trends, Benefits, Risks, and Challenges for the AEC Industry. '. *Leadership and Management Engineering,,* 11 (3), pp. 241-252.

Baiden, B.K., Price, A.D.F. and Dainty, A.R.J. (2006) 'The extent of team integration within construction projects'. *International Journal of Project Management,* 24 (1), pp. 13-23.

Behm, M. (2008) 'Construction sector'. *Journal of Safety Research,* 39 (2), pp. 175-178.

Chalker, M. and Loosemore, M. (2016) 'Trust and productivity in Australian construction projects: a subcontractors perspective'. *Engineering Construction and Architectural Management,* 23 192-210.

Changyoon, K. *et al.* (2013) 'On-site construction management using mobile computing technology'. *Automation in Construction,* 37 415-423.

Chiocchio, F. *et al.* (2011) 'Teamwork in integrated design projects: understanding the effects of trust, conflict, and collaboration on performance'. *Project Management Journal,* 42 (6), pp. 78-91.

Denscombe, M. (2007) *Good Research Guide; for small scale social projects.* Third edn. Open University Press

Dulami, M.F. and Dalziel, R.C. (2009) *Effects of collaboration in projects on construction project performance.* Masters in Business Administration Lulea University of Technology.

Eadie, R. and Graham, M. (2014) 'Analysing the advantages of early contractor involvement'. *International Journal of Procurement Management,* 7 (6), pp. 661-676.

Erdogan, B. *et al.* (2008) 'Collaboration Environment for construction: Implementation case Studies'. *Journal of Management in Engineering,* 24 (4), pp. 234-244.

Eriksson, E. and Torbjorn, N. (2008) 'Client perceptions of barriers to partnering'. *Engineering, Construction and Architectural Management,* 15 (6), pp. 527-539.

Fellows, R. and Liu, A.M.M. (2009) *Research Methods in Construction.* Oxford Blackwell Publishing Ltd.

Franz, B. *et al.* (2016) 'Impact of Team Integration and Group Cohesion on Project Delivery Performance'. *Journal of Construction Engineering and Management,* 143 (1), pp.

Fulford, R. and Standing, C. (2013) 'Construction industry productivity and the potential for collaborative practice'. *International Journal of Project Management,* 32 315-326.

Gamil, Y. and Rahman, I. (2017) 'Identification of causes and effects of poor communication in construction industry: a theoretical review'. *Emerging Science Journal,* 1 (4), pp. 239-247.

Gluch, P. and Raisanen, C. (2009) 'Interactional perspective on environmental communication in construction projects.'. *Building Research and Information,,* 37 (2), pp. 164-175.

Greenwood, D. (2011) 'Establishing the association between collaborative working and construction project performance based on client and contractor perceptions.'. *Construction Management and Economics,* 30 (4), pp. 299-308.

Hoonakker, P., Carayon, P. and Loushine, T. (2010) 'Barriers and benefits of quality management in the construction industry: an empirical study'. *Total Quality Management & Business Excellence,* 21 (9), pp. 953-969.

Hughes, D., Williams, T. and Ren, Z. (2012) 'Differing perspectives on collaboration in construction'. *Construction Innovation,* 12 (3), pp. 355-368.

Hurtado, K. and Sullivan, K. (2012) 'How to measure the benefits of BIM - a case study approach'. *Automation in construction,* 24.

Ibrahim, C., Costello, S. and Wilkinson, S. (2015) 'Key indicators influencing the management of team integration in construction projects'. *International Journal of Managing Projects in Business,,* 8 (2), pp. 300-323.

Jiang, W. and Lu, Y. (2017) 'Influence of initial trust on control from client perspective: construction industry in china'. *Engineering Construction and Architectural Management,* 24 (2), pp. 326-345.

Kadefors, A. (2011) 'Organizing collaboration in construction projects- formal models meeting practioner perspectives'. *Management and Innovation for Sustainable Built Environment.* Amsterdam, Netherlands, Available at: https://repository.tudelft.nl/islandora/object/uuid:32390b8c-ceef-4c8c-ae72-a91e42346b12/datastream/OBJ.
Koolwijk, J.S.L. *et al.* (2018) 'Collaboration and integration in project-based supply chains in the construction industry'. *Journal of Management in Engineering,* 34 (3), pp. 04018001-04018013.
Laan, A. *et al.* (2011) 'Building trust in construction partnering projects: an exploratory case study'. *Journal of Purchasing and Supply Management,* 17 (2), pp. 98-108.
Loosemore, M. (2014) 'Improving construction productivity: a subcontractor's perspective'. *Engineering construction and Architectural Management,* 21 (3), pp. 245-260.
Meng, X. (2012) 'The effect of relationship management on project performance in construction'. *International Journal of Management,* 30 (2), pp. 188 -198.
Nikou Goftar, V., El Asmar, M. and Bingham, E. (2014) 'A Meta-Analysis of Literature Comparing Project Performance between Design-Build (DB) and Design-Bid-Build (DBB) Delivery Systems '. *Construction Research Congress 2014: Construction in a Global Network.* Atlanta, Georgia.
Osipova, E. and Eriksson, P. (2011) 'How procurement options influence risk management in construction projects'. *Construction Management and Economics,* 29 (1), pp. 1149-1158.
Portwal, A. and Hewage, K. (2013) 'Building Information Modeling (BIM) partnering framework for public construction projects'. *Automation in construction,* 34 204-214.
Rahman, M. and Alhassan, A. (2012) 'A contractor's perception on early contractor involvement'. *Built Environment Project and Asset Management,* 2 (2), pp. 217-233.
Rahman, S. *et al.* (2013) 'The importance of collaboration in construction industry from contractors' perspective'. *Procedia - Social and Behavioural Sciences,* 126 (6), pp. 414-421.
Shelbourn, M. *et al.* (2007) 'Planning and implementation of effective collaboration in construction projects'. *Construction Innovation,* 7 (4), pp. 357-377.
Shen, W. *et al.* (2010) 'Systems integration and collaboration in architecture, engineering, construction, and facilities management: A review '. *Advanced Engineering Informatics* 24 (2), pp. 196-207.
Son, J. and Rojas, E. (2011) 'Evolution of collaboration in temporary project teams: an Agent based modeling and simulation approach '. *Journal of construction Engineering and Management,* 137 (8), pp. 619-628.
Succar, B. (2009) 'Building information modeling framework: A research and delivery foundation for industry stakeholders '. *Automation in Construction,* 18 (3), pp. 357-375.
Tohidi, H. (2011) 'Teamwork productivity & effectiveness in an organization base on rewards, leadership, training, goals, wage, size, motivation, measurement and information technology'. *Procedia Computer Science,* 3 1137-1146.
Torneman, C. (2015) *Collaboration in construction project delivery: strategic implications for technical consultancy firms.* Master's Programme Design and Construction Project Management Chalmers University of Technology.
Wong, W. *et al.* (2008) 'A framework for trust in construction contracting'. *International Journal of Project Management,* 26 (8), pp. 821-829.
Wu, S., Greenwood, D. and Steel, G. (2008) 'Exploring the attributes of collaborative working in construction industry'. *Interdisciplinary Studies in the Built and Environment,* 1 (2), pp. 135-147.
Xue, X., Shen, Q. and Ren, Z. (2010) 'Critical review of collaborative working in construction projects environment and human behaviours'. *Journal of Management in Engineering,* 26 (4), pp. 196-208.

CAUSES OF VARIATIONS AND THEIR IMPACTS UPON CONSTRUCTION PROJECTS IN CHINA

Shu An[1], Tony Ma[1]

[1]School of Natural & Built Environments, University of South Australia

Abstract

Irrespective of the alternative procurement routes, traditional lump sum contract is still pre-dominantly used in the construction industry. In practice, variations seem inevitable and their frequent occurrence has substantial impacts upon time and cost overruns, affecting the relationship of contracting parties. Also, a lot of studies showed variations triggered more than half of the contractual disputes. China has recorded a high growth in economy and the building industry has generated numerous projects in the past 20 years. However, due to the level of management maturity varies in projects, excessive number of variations has been observed. The aim of this research is to identify the causes and sources of variations and their impacts upon the project performance. A quantitative and a qualitative questionnaire survey is conducted in the regions including Sichuan Province and Chongqing in China to investigate the causes and the impacts of variations on projects cost performance. The results indicate that both clients and contractors be held responsible for most of the variations. The most obvious impact of variations is the increase of project cost. Therefore, process improvements and mitigation actions are needed to reduce the amount of variations.

Keywords

Procurement, traditional lump sum contract, variations, projects, cost performance

Introduction

Even though each construction project has its own unique conditions and circumstances, liability to change is claimed as a common attribute that characterizes most construction projects (Alsuliman et al. 2012). There are two major reasons making variation seem inevitable to the majority of construction projects. The complexity and uncertainty nature of construction industry and involvement of various contracting parties cause construction projects particularly prone to a high degree of variations. Another reason lies in the widely adoption of traditional procurement method. The design and construction of a building are seen as two separate functions and performed by different professionals working independently. The fragmentation of design and construction process generates the design being lack of concerns on buildability and constructability, leading to variations followed by perpetuation of costly mistakes (Kwakye 1997).

As variation has become so prevalent in construction that it is a rarity to deliver a project without changes (Oladapo 2007, Levy 2010). Their impacts upon project performance have been examined by plenty of studies in international context. Various research works observed variation orders are vital to project performance and claimed that most of the variation orders issued during project execution are the main causes of project time and cost overruns (Oladapo, 2007, Alnuaimi et al. 2009, Ismail et al.2012, Ismail et al., 2012). Evidently, Homaid et al (2011) identified that the overall average increase in total cost of construction projects due to variation orders was 11.3%. A study in United States revealed that 13-26 US billion dollars were spent in construction industry in a year for variation orders while the average project change was more than 11% of project cost in Virginia (Hameed Memon et al., 2014). Likewise, Mahamid 2017 examined on 24 construction projects in Western Canada which concluded that the main cause of contract claims was due to excessive variation orders, accounting for 50% of all claims recorded during that period of study. Figure 1 shows the various causes of variation order and their categorization (Alnuaimi et al. 2009, Arain & Pheng 2006, Sunday 2010, Hwang et al.2014, Mahamid 2017).

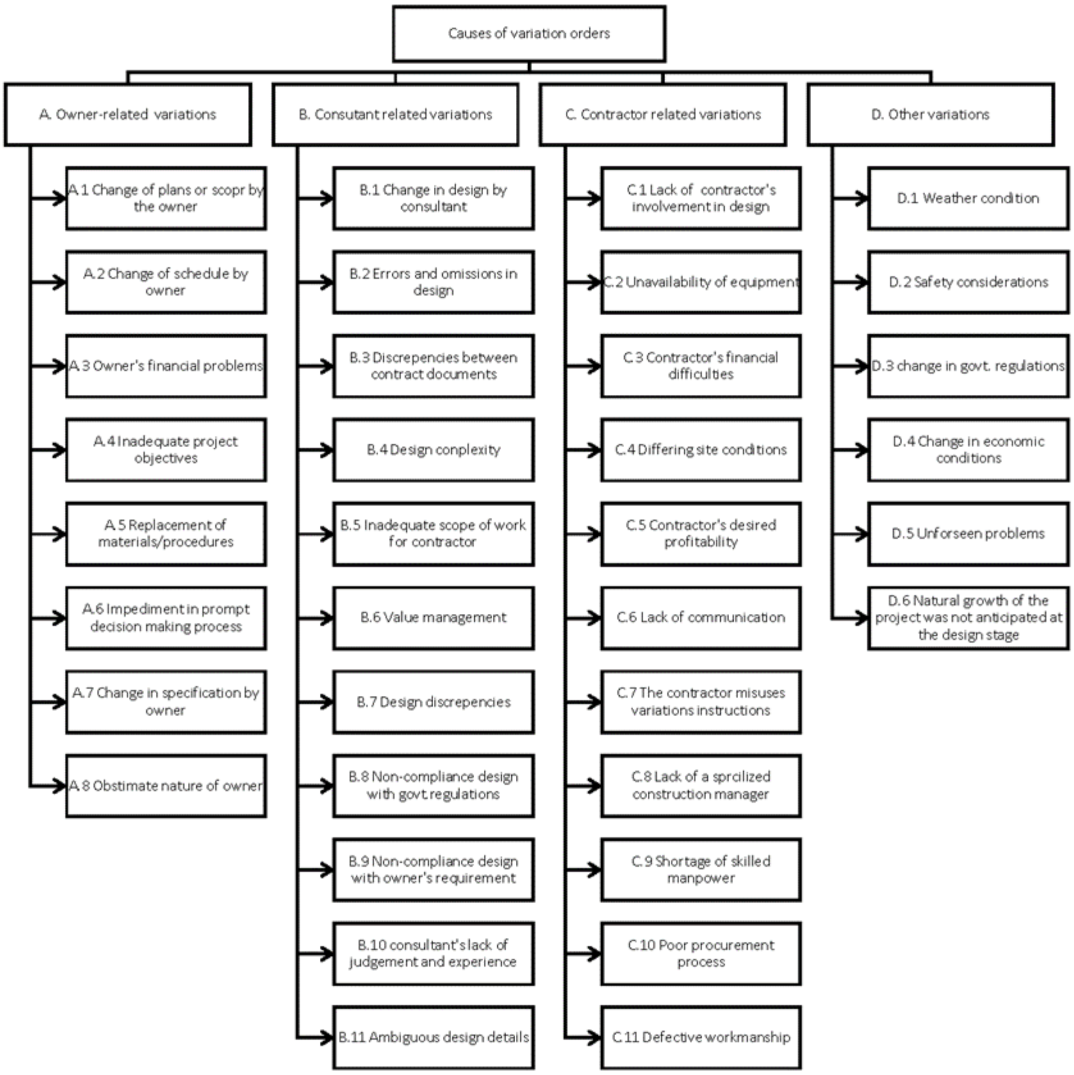


Figure 1: Causes and sources of variation orders

Causes and sources of variations orders

Most studies found out the client contributed the most to the variations in construction projects, followed by their representatives, consultants. Alnuaimi et al. (2009) generated opinions of three parties in a construction project including the client, the consultant and the contractor through a questionnaire survey and they all agreed that 'the owner instructing additional work' is the most prevalent cause of change orders, followed by 'the owner instructing modification to design'. Levy (2009) emphasised that clients and consultants initiate the majority of the variation orders in the design. Mohammad et al. (2010) observed that most of the causes of variation orders were initiated by the client in Malaysian construction projects, accounting for 65% of all variations. Similarly, Yana et al (2015) classified two group of influential factors of design changes and revealed that the client was the most critical factor that causes a design change in a construction project.

Various researchers asserted changes of work by client, design errors and omission, and financial problems are prevailing causes of variations in international context. Oladapo (2007) investigated 7 root causes of variation in building projects operating in Nigeria, building client initiated the most variation orders while changes in clients' income and financial ability was identified as the most important reason for the cause of client-related variations. Additionally, "design errors" by consultants, "insufficient time for preparation of contract documents" allowed by owners and "improper briefing by clients" were the three most critical causes of consultant-related variation orders. Similarly, A study conducted in Iran was able to isolate the causes of variation orders and suggested the change of plans or scope by the client, errors and omissions in design and owner's financial problem were the crucial factors contributed to variation orders in roadway projects (Ismail et al. 2012). Arain and Pheng (2006) surveyed developers of institutional building projects in Singapore and identified the most significant causes of variation orders through 53 causes were errors and omissions in design, change in specifications by owner, design discrepancies, change in specification by consultant, and non-compliance of design with government regulations.

Impact of variation orders on project performance

Although projects may benefit from positive changes, the occurrence of variation orders continues to pose a serious threat to involving parties due to their adverse effects on construction projects. The most obvious effects of project changes were increment in the project cost and an extended duration of completion as identified by most studies (Sun and Meng 2009). Change events have both direct or indirect impact on various aspects of a project. According to Bower and Aritua (2006) indicated that research undertaken by the authors, funded in conjunction with leading civil engineering clients, contractors and consultants had demonstrated that additional costs due to the direct effects of a variation, such as a change in resource requirements were relatively easy to estimate but it was often difficult to evaluate the indirect effects of delay and disruption. Loss of productivity due to reprogramming, loss of rhythm, unbalanced gangs and acceleration were good examples.

In most cases, variations negatively affect project performance. There are various statistical findings in previous studies with regards to the contribution of variation to project time and cost. A study measuring the proportion of total project cost and time overruns directly attributable to variation orders pointed out 78.77% of the total cost overruns and 68.33% of the total time overruns were resulted from variations (Oladapo 2007). Hwang et al. (2014) surveyed 226 projects with client-related variations found variations increased project cost by an average rate of 7.1% and caused 3.3 weeks' delay on average. Similarly, Charoenngam et al. (2013) highlighted that the average cost escalation attributed to variation orders was 7% of the original project cost with an average time extension of 30% than the original project duration scheduled in contract.

Some studies attempted to quantify the cost of variations and the results ranges mostly from 6% to 50% of project costs. Yana et al. (2015) identified that design and construction variation account for 12.4 % of the total cost, contributing the greatest deviation of construction costs. A total average of 13% was observed in terms of variance of nominal project cost among different types of construction projects (Hsieh et al., 2004). A statistical model was developed by Lee (2008) to quantify the cost impact of variation orders on contract price for 161 completed transport projects. The result showed that 95% and 100% of road and rail projects had a maximum cost overrun of 50%.

Halwatura and Ranasinghe (2013) claimed that though there were examples where variation costs accounted for as much as 90% of the budget funds, the industry norm has been determined that the average cost escalation was about 10% of the original project cost. Results of the study conducted by Alsuliman et al. (2012) indicated that cost overruns due to variation orders were in the magnitude of 6% to 10% of the original contract value. Also, based on a statistical analysis, a 10-17% ratio of variation order cost to total project cost were identified in Taiwan's metropolitan public works (Ismail et al. 2012). Sunday (2010) examined different types of construction project, including school building, clinics, hospital, gas storage plant and showed that the 25.29% of cost overruns and 27.25% time overruns were due to variation orders.

Conditions of the Standard Form of Construction Contract GF-2013-0201 in China

In Chinese construction industry, the issue of variation order is primarily extracted from the conditions in the standard form of construction contract (GF-2013-0201). The standard form of contract is issued by the Ministry of Construction and the State Administration for Industry and Commerce of China. It is widely adopted in most building construction projects for either public or private projects, especially for major capital projects in China. The general conditions of the contract stipulate a procedure covering the issue of variation orders. Generally, the owner is required to notify the contractor the occurrence of change events in the form of written instructions for which the contractor is obliged to claim additional reimbursement. According to the contract clause 29 and clause 31 (GF-2013-0201), the process of variation order during a construction project can be illustrated in Figure 2 below:

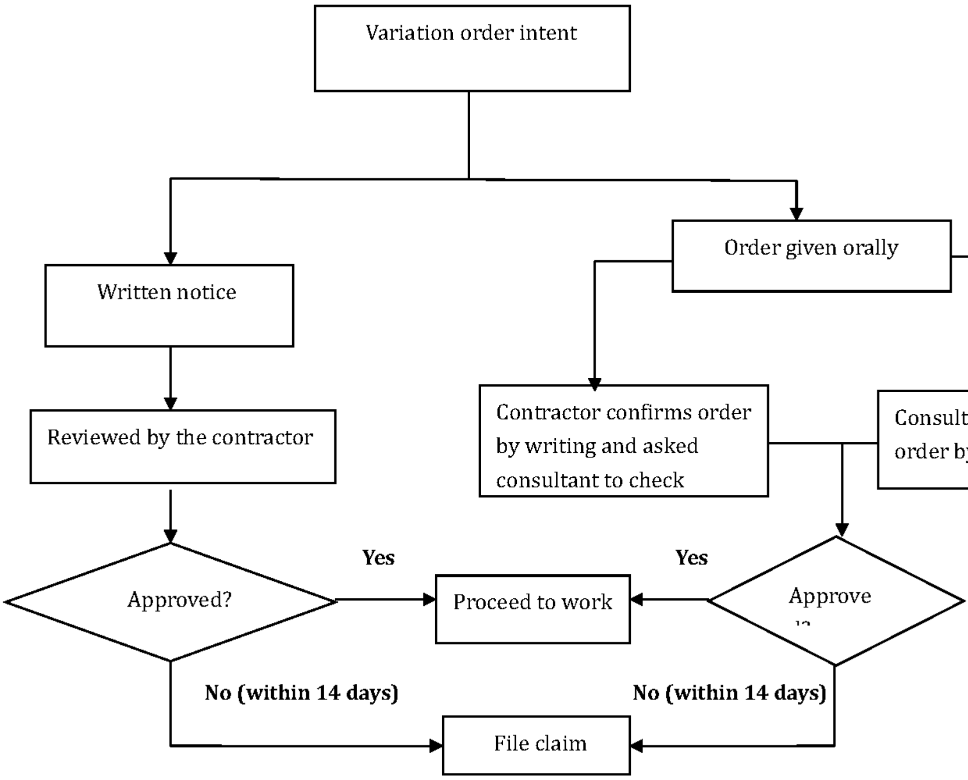


Figure 2: Process of variation order according to GF-2013-0201 in China

In addition, measures of assessment of variation order are included in the special conditions of GF-2013-0201, which allows contracting parties designated specific valuation for variations. It also stipulates that cost valuation shall be in line with one of three contract types, namely, traditional lump-sum, remeasurement or cost plus. The cost effect can have an impact upon final project cost and the additional cost incurred may contribute to the cost overruns.

The economy of China has experienced a huge boom with its exposure to global market in the last 20 years. In 2016, China's construction industry continued to develop rapidly, achieving 17% growth in industry value. There was an increase of 5% from 2015, marking a strong contrast to the slow-down of other traditional industries. By 2017, the Chinese construction industry is estimated to contribute about 5.7 percent to the Chinese GDP (China Statistic Yearbook, 2016). The burst mode of Chinese construction industry and higher living standards of general population have generated numerous projects in building sectors with even a stronger expansion in domestic demand. Large and complex projects have been built, attracting developers and contractors all over the country. However, the level of their management maturity varies. Qualification and assessment of variation claims highly depended on professionals' understanding on variation orders and their level of experience. Excessive number of change orders causing project delays and cost overruns and even a reduced project utility is observed as one of the endemic problems the clients have to face during the construction (Zou et al.2007).

However, little academic attention has been drawn to the issues of variation orders for projects in China and there are limited convincing studies for process improvement in this respect. The research will identify the main causes of variations and investigate the contribution of the project participants to the occurrence of variations. It is anticipated that proactive measures will be recommended to reduce the impacts of variation orders on construction projects.

Research methodology

As traditional lump sum and remeasurement contracts are pre-dominantly used in China and contracted in accordance with GF-2013-0201, it would be interested to see how variations occur and understand their impact upon project performance. The design involves the use of a questionnaire survey to obtain respondents' opinions regarding the causes of variation orders and to gain professional insights of issues on variations. The questionnaire consists of 10 questions which are divided into three parts. The first section collects the demographic information of the respondents. The second section attempts to examine the causes of variation orders and their impacts on project delivery based on the respondent's experiences. The third section involves two open questions to collect their opinion on the issues they encountered when negotiating variation orders and recommended actions of how it could be managed.

100 questionnaires were distributed to tier 1 and tier 2 construction organizations in China. Due to the work experience and network connection of the first author, the survey was only limited to Sichuan province, Chongqing (Southwest of China), Shen Zhen and Guang Dong province. Totally, 64 copies of completed questionnaire were received and found suitable for analysis. On the other hand, the extracts of cost data for the 30 completed construction projects were provided by cost managers and quantity surveyors in various developers where the first author once worked with.

The demographic information indicated all respondents have achieved the minimal qualification, which is higher national diploma required for professional registration in most disciplines in Chinese construction industry. 73% of the questionnaires were responded by professionals who work for clients (developers). 16% of respondents are working for contractors and the remaining 11% are from consulting firms. Above 78 % of the respondent have over 5 years of industrial practices while 40% of them have more than 10 years professional experiences. The demographic information of respondents' official designations was listed in the Table 1 below:

Table 1: The demographic information of respondents' official designations

Official Designations	Percentage	Number
Client (management)	10%	6
Civil engineers	22%	14
Strucutral engineers	6%	4
Quantity surveyors	39%	25
Architects	6%	4
site supervisors	17%	11
	100%	64

Results and Discussion

Causes of variation on building construction projects

There are 15 causes identified from the literature as the potential causes of variation orders listed in the questionnaire. Figure 3 shows the significance of the causes of variation ranked by the respondents. It revealed that errors and omission in design with the mean score of 2.72, followed by contractor's desired profitability with mean score 2.70, changes of plan or project scope by the owner with mean score of

2.67, changes in specification by the owner with mean score of 2.63 are the prevalent causes of variation in Chinese construction industry.

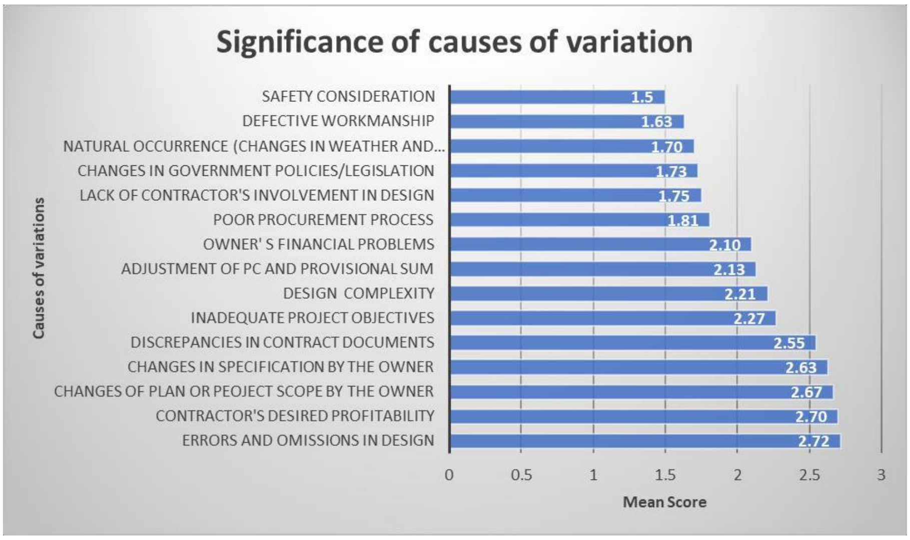


Figure 3: Causes of variations

The finding highlighted Contractor’s desired profitability as main causes of variation in China’s context. The underlying philosophy of variation orders is a mechanism of fast momentary compensation to the contractor due to the incompetence of the contract (Ismail et al. 2012). In China, competition among contractors is vigorous due to the low operating threshold of the industry. In some cases, contractors inclined to submit a low tender to be awarded the contract at the early stage and find variation orders a means to compensate the profit. Another possible reason lies behind the cost adjustment of variation orders are not explicitly stated in conditions of GF-2013-0201, which provide contractors opportunities to argue for extra cost. Basically, when a variation order occurs, the contractor is very likely to charge higher rates or argue for measures of assessment which benefit them more.

Sources of Variations on Building Construction Projects

Variations as a tool to create profit also explains why contractor was ranked closely with clients as the major contributor to variations. Four contributing parties of variations were identified in the questionnaire. Figure 4 shows the initiators of variation orders. This finding is also different from studies conducted in other cultural context where contractors were observed as less likely to initiate variations.

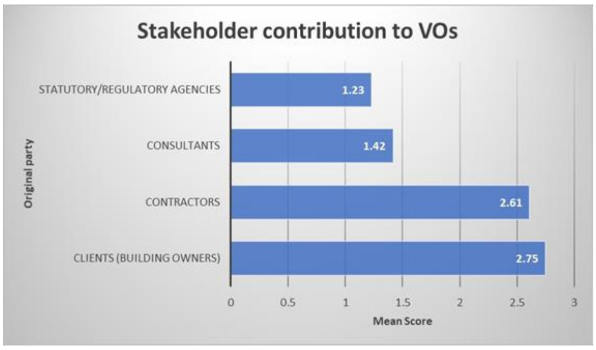


Figure 4: Contributors of variation orders

Factors Influencing the Occurrence of Variation Orders

Eight Factors have been included in the questionnaire and All the factors are identified to be important as they are "likely" (possibility > 50%) to induce variations on building construction projects. Figure 5 indicates the significance of factors that influence the occurrence of variation orders.

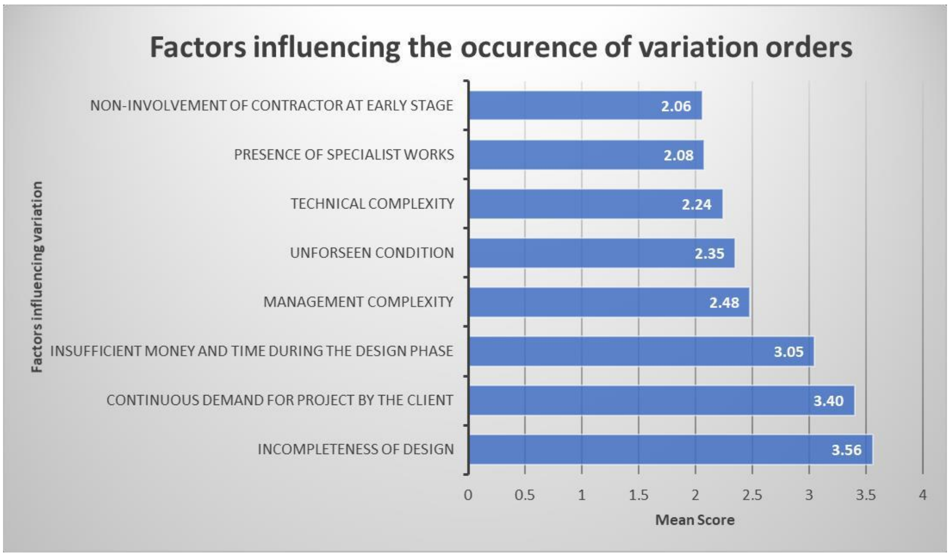


Figure 5: Factors influencing the occurrence of variation orders

Incompleteness of design with the mean score is ranked highest among all the factors, which is closely followed by continuous demand for project by the client and insufficient money and time during the design phase. This result is in line with findings from previous studies concluded issues on design and additional demands from clients were crucial factors triggering variations.

Impacts of Variation Orders on Project Delivery

A range of impacts including cost, time, quality has been examined based on respondents' opinion. Figure 6 showed the respondents' perspective on the impacts of variation orders.

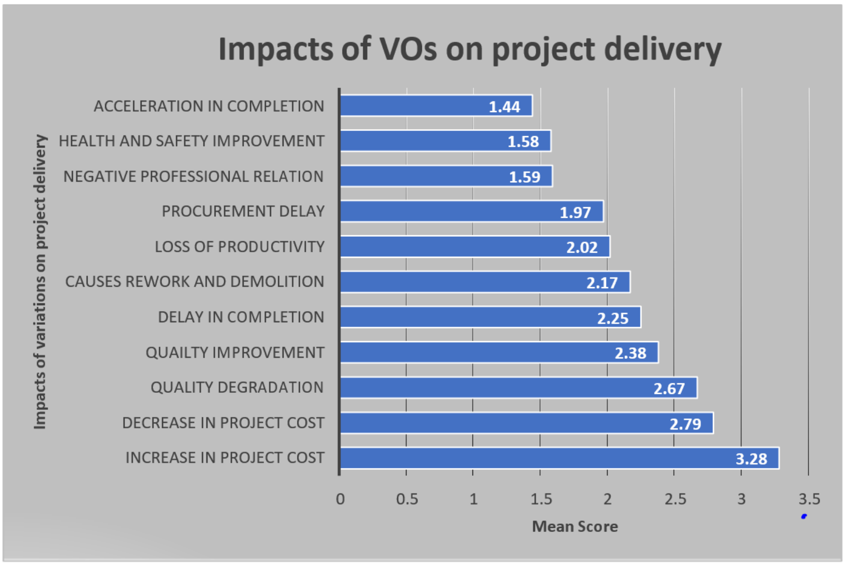


Figure 6: Impacts of variation orders on project delivery

Clearly, increase in project cost with mean score of 3.28 is identified as the most likely effect of variations. Meanwhile, the results show project cost saving is a likely result from variations. Notably, delay in completion ranked the fifth. In most previous studies, time and cost overruns are claimed as corelated and are main impacts of variation orders. This seems not the case in China as “delay in completion” falls into the weaker side of “likely to happen, 50%-80%”. This can be due to the fact that acceleration is common in Chinese construction industry, resulting from clients’ strategy of resource allocation. Project duration is closely watched by client during the projects. The earlier completion they achieve, the sooner the end-product could be presented on the market. Also, the high interest rate of bank loan pressurises developers paying strong attention to the duration of a project. Therefore, even acceleration can lead to additional cost, variation orders not always cause time overruns.

Issues of current variation process and recommended actions

Issues of variation orders during different stages of project have been identified through the open questions and recommended actions have been collected and summarised into three aspects of a project.

1) Design

- Reasonable time and enough fund should be allocated to design for developing details and specifications in order to reduce variations arising from incompleteness of designs and continuous design changes. Also, drawings should be audited by authorised parties, which would help to eliminate design discrepancies and errors.
- Early involvement and direct communication at the design phase should be organized by the client. This provides professionals from different disciplines an opportunity to review the design thoroughly, reducing variations arising from conflicts in contract documents.

2) Contract documents

- Ambiguous definition of variation results in disputes on variations and miscommunication between parties. A lot of construction projects rely on definition of variation in general conditions of GB-2013-0201, which do not specify activities and actions. A clear definition of variations should be explicitly included in the special conditions of contract.
- Project objectives should be clearly defined and a through scope of work is provided in contract document. This can reduce the chance that contractor submits a low tender based on an unclear scope of works, then initiate massive variations for compensation during construction.
- Disagreement on unit price adopted for items incurring by variations is a major issue when negotiating variations. The mechanism for assessment should be explicitly defined in the contract, especially for items/work that are not including in the Bills of Quantities or Schedule of Rate.

3) Management process

- In practice, a number of variations work due to change of site conditions and technical complexity were initiated by contractors. Without a robust management process, the work could be completed even before contractors get approval from the clients. It is recommended that a process of variation orders be clearly defined, including the accountabilities and responsibilities of involving parties, required documentation and evidence for assessment.
- Documentation should be thoroughly recorded and archived for the reference of assessment, this is especially for variations in relation to latent conditions and change of work in a large scale where sufficient supporting evidence is essential to value the cost.
- The current practice allows clients to withhold the payment for variations until project final account are concluded, which resulting in subsequent delays and cost overruns by contractors. The assessment of variation works should be undertaken at the end of each month and amount due to contractors should be included in the payment for progress of work.

Conclusions

This research attempts to investigate the main causes and sources of variations orders in Chinese construction projects, as well as the impacts of variation on project performance. After an extensive study and analysis of the findings, it can be concluded that:

- Client and contractor initiate most of variations in Chinese building industry
- Errors and omissions in design, Contractor's desired profitability, Changes of plan or project scope by owner are main causes of variations
- Incompleteness of design, continuous demands for project by the client (management maturity of the client), insufficient money and time during the design phase are critical factors influencing the occurrence of variation orders
- The most obvious impact of variation is the increase of project cost.

The findings indicate that contractor plays an active role in initiation of variations in China due to the incompetence of contract at the stage of signing contract and contractor's the desire of profit-adding. Delay in completion is not ranked as major impact in association with cost increase, which is mainly due to acceleration is often encouraged by clients in accordance with their strategy of resources allocation. However, it contributed to the main part of project cost overruns.

Also, recommended actions for three major involving parties of variation orders have been generated and can be implemented at different stage of project lifecycle to improve the current management process of variations according to the conditions of standard form of construction contract (Gf-2013-0201) in China.

In China, traditional lump-sum contract is not always preferred by clients except for project with clear scope or low value. Although it seems contractor bears most of the risks during the course of contract, for the most of time, clients can only blame themselves for the cost overruns due to variations initiated by them. On the other hand, the next common approach is the use of remeasurement contract based on bills of approximate quantities. However, the main drawback of remeasurement contract is when additional work or changes include new items which are not covered by the original bills of quantities or schedule of rates, dispute on unit price and amount of work can easily arise, causing substantial time and cost increase. As a result of this research or analysis, may be there is a need to shift the procurement route to other alternatives.

Reference

Alnuaimi, A. S., Taha, R. A., Al Mohsin, M. & Al-Harthi, A. S. 2009. Causes, effects, benefits, and remedies of change orders on public construction projects in Oman. *Journal of Construction Engineering and Management, 136, 615-622.*

Alsuliman, J., Bowles, G. & Chen, Z. 2012. Current practice of variation order management in the Saudi construction industry. *Association of Researchers in Construction Management, 1-10*.

Arain, F. M. & Pheng, L. S. 2006. Developers' Views of Potential Causes of Variation Orders for Institutional Buildings in Singapore. *Architectural Science Review, 49, 59-74.*

Bello, A.M. and Saka, A.B., 2017. Impact of variation on project delivery in Oyo state, Nigeria. *World Scientific News*, 86(3), pp.265-282.

Bower, D. & Aritua, B. 2006. Evaluation of the indirect costs associated with contractual change: the influence curve approach. *Paper presented at PMI® Global Congress 2006—EMEA, Madrid, Spain. Newtown Square, PA: Project Management Institute*.

Charoenngam, C, Coquinco, S. & Hadikusumo, BH. 2003, 'Web-based application for managing change orders in construction projects', Construction Innovation, vol. 3, no. 4, pp. 197–215.

Halwatura, R. U. & Ranasinghe, N. P. N. P. 2013. Causes of Variation Orders in Road Construction Projects in Sri Lanka. ISRN *Construction Engineering,* 2013, 1-7.

Homaid, N., Eldosouky, A. and AlGhmdi, M. 2011, “Change orders in Saudi linear construction projects”, *Emirates Journal for Engineering Research,* Vol. 16 No. 1, pp. 33-42.
Hameed Memon, A., Abdul Rahman, I. & Faris Abul Hasan, M. 2014. Significant Causes and Effects of Variation Orders in Construction Projects. *Research Journal of Applied Sciences, Engineering and Technology,* 7, 4494-4502.
Hiseh, T.-Y., Lu, S.-T. & Wu, C.-H. 2004. Statistical analysis of causes for change orders in metropolitan public works. *International Journal of Project Management*, 22, 679-686.
Hwang, B.-G., Zhao, X. & Goh, K. J. 2014. Investigating the client-related rework in building projects: The case of Singapore. *International Journal of Project Management*, 32, 698-708.
Ismail, A., Pourrostam, T., Soleymanzadeh, A. & Ghouyounchizad, M. 2012. Factors causing variation orders and their effects in roadway construction projects. *Research Journal of Applied Sciences, Engineering and Technology,* 4, 4969-4972.
Kwakye, AA & Building, CI 1997, Construction project administration in practice, Longman [co-published with] *the Chartered Institute of Building, Harlow*.
Levy, SM 2010, Construction process planning and management an owner's guide to successful projects, *Butterworth-Heinemann, Amsterdam; Boston*.
Lee, J 2008, 'Cost overrun and cause in Korean social overhead capital projects: Roads, rails, airports, and ports', *Journal of Urban Planning and Development*, vol.134, no. 2, pp. 59-62.
Mahamid, I. 2017. Effect of change orders on rework in highway projects in Palestine. *Journal of Financial Management of Property and Construction*, 22, 62-76.
Mohammad, N., Ani, A. C., Rakmat, R. & Yusof, M. 2010. Investigation on the causes of variation orders in the construction of building project–a study in the state of Selangor, Malaysia. *Journal of Building Performance*, 1.
National bureau of statistic of China 2016, China statistic year book, viewed 20 September 2017, https://www.statista.com/statistics/605372/china- construction-industry-gdp-share/
Oladapo, A. A. 2007. A quantitative assessment of the cost and time impact of variation orders on construction projects. *Journal of Engineering, Design and Technology,* 5, 35-48.
Sun, M. & Meng, X. 2009. Taxonomy for change causes and effects in construction projects. *International Journal of Project Management*, 27, 560-572.
Sunday, O. A. Impact of variation orders on public construction projects. 26th *Annual ARCOM Conference*, Leeds, UK, 2010.
Yana, A. A. G. A., Rusdhi, H. A. & Wibowo, M. A. 2015. Analysis of Factors Affecting Design Changes in Construction Project with Partial Least Square (PLS). *Procedia Engineering*, 125, 40-45.
Zou, P. X. W., Zhang, G. & Wang, J. 2007. Understanding the key risks in construction projects in China. *International Journal of Project Management*, 25, 601-614

REVIEW OF THE EFFECTS OF CONDENSATION IN LOW-RISE RESIDENTIAL BUILDINGS

Tom Bulic[1], Vidal Paton Cole[1], Bircan Erbas[2]

[1]Melbourne School of Design, University of Melbourne, Melbourne , Australia

[2]Department of Public Health, La Trobe University, Bundoora, Australia

Abstract

The presence of water vapour within the built envelope in low-rise residential buildings can lead to condensation within wall and roof systems. Condensation, if not treated, can cause damage to the wall framing members and linings and may subsequently impact the structural integrity of the building and affect the performance of wall insulation and cladding of typical low-rise residential buildings. High relative humidity within a structure can lead to severe dampness and the subsequent growth of mould and the promotion of mites within habitable spaces. In Australia, recent changes to the National Construction Code (NCC) have seen shifts in regulatory positions towards energy efficiency with less emphasis on associated problems arising from condensation. Despite one of the NCC key performance requirements being health and amenity with the objective to "safeguard the occupants from illness or injury", there is no clear provision to address design issues that mitigate condensation within the built envelope. Consequently, inhabitants in residential buildings often coexist with the inherent risk of respiratory illnesses arising from the presence of condensation. This paper presents an evaluation of the current legislative framework regarding condensation towards the minimisation of mould and mites in residential buildings, an overview of health impacts and provides an assessment of construction methodologies contributing to condensation risk in residential buildings.

Keywords

Condensation, Mould, Building Fabric, Water Vapour, Pliable Membranes, Respiratory illness.

Introduction

The integrity of residential building systems is dependent on being free from any form of water. Timber framed houses are the predominant building form in Australia for low-rise residential buildings and needs to remain dry to maintain their structural integrity. The various wall systems used in Australia, such as brick veneer, cement sheet, XPS or timber cladding, rely on a combination of pliable membranes and/or sarkings and air cavities to allow structural framing to remain dry and free from moisture. If these barriers are breached and moisture is trapped between the cavities, then numerous problems will eventuate. Water vapour condensation forming within the fabric of residential buildings represents a threat to not only the structural integrity of a building but also to the health and wellbeing of its occupants. The World Health Organisation guidelines for indoor air quality estimates that 10 – 50% of indoor environments in Europe, North America, Australia, India and Japan are affected by the prevalence of indoor dampness (WHO 2009). In a recent study concentrating specifically on the Australian condition it was found that up to 40% of new housing stock built since 2004 had some issues with condensation (Dewsbury et al. 2016). These measures are significant as the trigger for growth of mould is simply the amount of water present on or in materials (WHO 2009). One of the primary functions of the building fabric other than protection from the elements and structural integrity is the elimination of condensation from walls, floors and roof spaces. The current regulatory framework in Australia regarding condensation and how best to deal with it in residential buildings is inadequately described in the National Construction Code. Regulation is geared towards thermal considerations, however other than broad overarching statements regarding the health and safety of occupants, there isn't a concerted effort that best describe condensation related problems and how best to alleviate it. The consequences of this poor coordination are significant as there is a growing body of evidence internationally that suggests that exposure to mould can have detrimental effects on human health and wellbeing. A scoping study conducted to measure the levels of moisture damage in an Australian context found that the effects were also expressed through hardship experiences by home owners when faced with remediation bills to remove the problem with costs for rectification ranging from a few thousand dollars to tens of thousands of dollars. (Dewsbury et al. 2016). When extrapolated across all residential building stock built since the introduction of new thermal guidelines the cost of rectification could be significant.

Generation of condensation and its sources

Water vapour can be generated from several sources within a building. Cooking, cleaning, clothes dryers, plants and people produce water vapour in varying quantities as depicted in Figure 1.

A family of four could produce in the range of between 7 and 22 kilograms of water vapour per day, depending on the amount of mechanical ventilation within a dwelling (Dewsbury et al. 2016). When moist air within a building comes in contact with a surface at a particular temperature and a dew point is reached, it condenses onto that surface. This type of pattern, given the right circumstances, is one which reoccurs within wall and ceiling systems. Water vapour within a wall, roof or floor system can condense onto surfaces within it, and if not given the opportunity to evaporate can lead to damp and in turn lead to decay and rotting of timber and the subsequent growth of mould and mites.

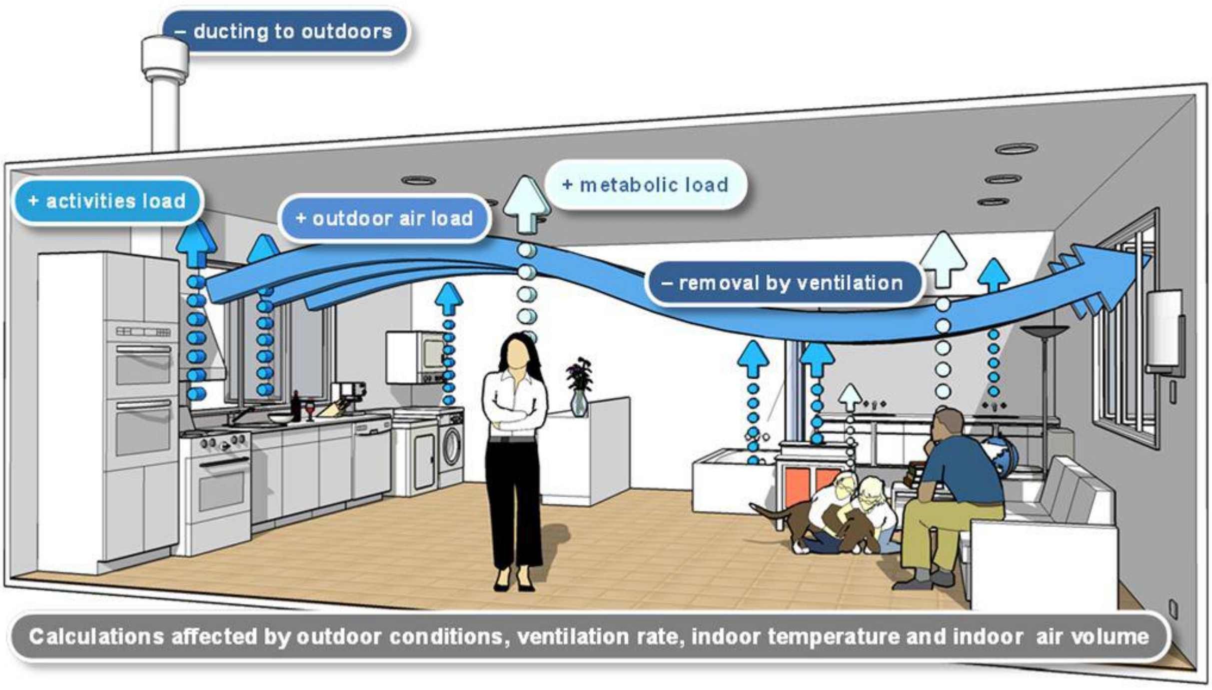


Figure 1: Different sources of water vapour within a building (Source: ABCB Condensation in Buildings Handbook)

The mechanics of how water vapour acts on materials is a complex interrelated problem governed by relative humidity, temperature, local climatic conditions and occupant actions. The existing regulatory framework is predicated on members of the construction industry understanding that complexity and being able to implement a solution in the form of walls, roof and floor systems to mitigate the effects of condensation. Under the current regulatory framework, confidently navigating through this complexity is made difficult by the non-regulatory nature of some of the documents and elements of industry supplying product that are blatantly deficient.

What is mould and why is it a problem?

Mould is a colloquialism for a range of micro fungi belonging to different systemic categories. They live on the surfaces of materials, produce airborne spores and use easily assimilated nutrients for growth. Moulds act as decomposers in the natural cycle, and their spores are found everywhere in the air and on various kinds of surfaces (Johansson et al. 2012). Conditions for mould growth include nutrient availability, temperature, pH, and moisture. In general , the availability of water in the material is regarded as the crucial element for growth to occur (Johansson et al. 2012). The presence of mould within building systems can not only lead to the decomposition of building materials including critical structural elements but also affect the indoor air quality of a dwelling. Condensation could further act upon chemical preservatives in materials, corrode metallic fixings, such as nail plates and brick ties and also lead to short circuiting around electrical fittings (ABCB 2019). The World Health Organisation, in their guidelines for indoor air quality concluded that the most important means of avoiding the adverse health effects of mould is to prevent (or minimise) the presence of dampness in building structures in the first instance (WHO 2009). The guidelines acknowledge that many biological agents in indoor environments can be attributed to dampness and poor ventilation to the extent that dampness itself can be a 'strong consistent indicator of risk of asthma and respiratory symptoms (WHO 2009). In 2018, an Australian government parliamentary committee enquiry into Biotoxin related illnesses in Australia, examined condensation in buildings and recommended that further research be undertaken into the adequacy of current building codes and standards related to the prevention and remediation of dampness and mould in buildings (House of Representatives Standing Committee on Health 2018).

Current legislation provision on condensation in the building code

The Building Code of Australia is represented by three volumes in the National Construction Code (NCC) Volumes 1, 2 & 3. Volume 1 applies to Class 2 to 9 buildings (commercial, industrial and multi residential), Volume 2 applies to Class 1 and 10 buildings (houses, sheds and carports) and Volume 3 applies to plumbing and drainage for all buildings. The National Construction Code provides the minimum necessary requirements for safety, health, amenity and sustainability in the design and construction of new buildings including new building work in existing buildings throughout Australia (ABCB 2019). Compliance with the NCC is achieved by meeting the governing requirements of the NCC and the relevant performance requirements (ABCB 2019). The governing requirements are a set of governing rules outlining how the NCC must be used, while the performance requirements set out a minimum set of requirements relating to building and building elements. To meet the performance requirements three options are available:

1. A Performance Solution
2. A Deemed to Satisfy (DTS) Solution
3. A combination of a Performance Solution and a DTS Solution (ABCB 2019)

One method of achieving compliance with the performance solution is via verification of condensation management where a solution is deemed to have complied when modelling has assessed the effects of a number of different criteria (such as indoor and outdoor temperature and humidity, heating and cooling set points, rain absorption, wind pressure, solar radiation and material hygrothermal properties) to determine that moisture will not accumulate internally to the primary water controlling layer (ABCB 2019).

The detrimental effect of condensation on a building is highlighted by NCC Volume 2, P2.4.7 'Condensation and water vapour management'. It notes that 'Risks associated with water vapour and condensation must be managed to minimise their impact on the health of occupants'(ABCB 2019). This may seem like a vague overarching statement short on specifics, however it shouldn't be taken lightly.

In a recent VCAT ruling by Justice Woodward regarding the combustible cladding fire at Lacrosse Towers at Docklands, time and again the inconsistencies within the regulatory framework over claddings and classification were clarified by a similar overarching statement that claddings not be combustible in buildings over 3 storeys in height (VCAT 2016). Future litigation regarding pliable membranes could possibly be adjudicated using a similar reference i.e. the vagueness of the existing regulatory frameworks may not be an excuse when in the first instance the imperative is centred on the health of the occupants.

There is a non-committal 'looseness' to the NCC and the relevant Australian Standards (AS4200.2 2017; AS/NZS4200.1 2017) regarding condensation. The NCC refers to the relevant Australian Standards for clarification on material classification and installation. The Australian Standards in turn refer to the ABCB 'Condensation Handbook' for further guidance on how membranes are to be installed in particular climate zones. The ABCB Handbook however is predicated on the premise that as a document it is intended only as a non-binding guide. (ABCB 2019):

> The Condensation in buildings Handbook assists in understanding the condensation requirements and provisions within the National Construction Code (NCC). It addresses the issues in generic terms and is not a document that sets out specific requirements in the NCC but rather aims to explain their intent. It is expected that this Handbook will be used to guide solutions relevant to specific situations in accordance with the generic principles and criteria contained herein (ABCB 2019).

The understanding and guidance regarding how to deal with condensation is therefore captured within a document that doesn't have a regulatory role. AS 4200.2 which directs the installation of membranes, predicates that 'consideration' be made to condensation (AS4200.2 2017). AS/NZS 4200.1 which outlines the material nature of membranes, outlines a non-mandatory set of instructions that manufacturers may or may not choose to print onto their product (AS/NZS4200.1 2017). Because of the lack of mandatory labelling guidelines some manufacturers produce a product referred to as a 'breather membrane' which is not vapour permeable under Australian Standard criteria but gives the impression that it is. In a similar vein, other products may serve as a reflective foil, liquid water barrier and an air barrier but are not vapour permeable. Both types of products comply under AS/NZS 4200.1, in that they are manufactured to a particular standard. However, given inherent ambiguities within the standard itself, these products do not act in a way that limits condensation particularly within building systems

Consequently, a series of documents (NCC, Australian Standard AS4200.1 and AS4200.2 and the Handbook for Condensation in Buildings) meant to detail how best to safeguard building systems and occupants from the effects of condensation, create an atmosphere of ambiguity which has presented the construction industry with serious problems. Architects, Building Practitioners, Contractors, Building Designers and Building Surveyors rely on a body of regulation that provides little to no specifics on how best to deal with an important issue. Figure 2 presents a schematic diagram showing the primary industry practitioners that commonly employs the available documentation that vaguely outlines condensation management in residential buildings.

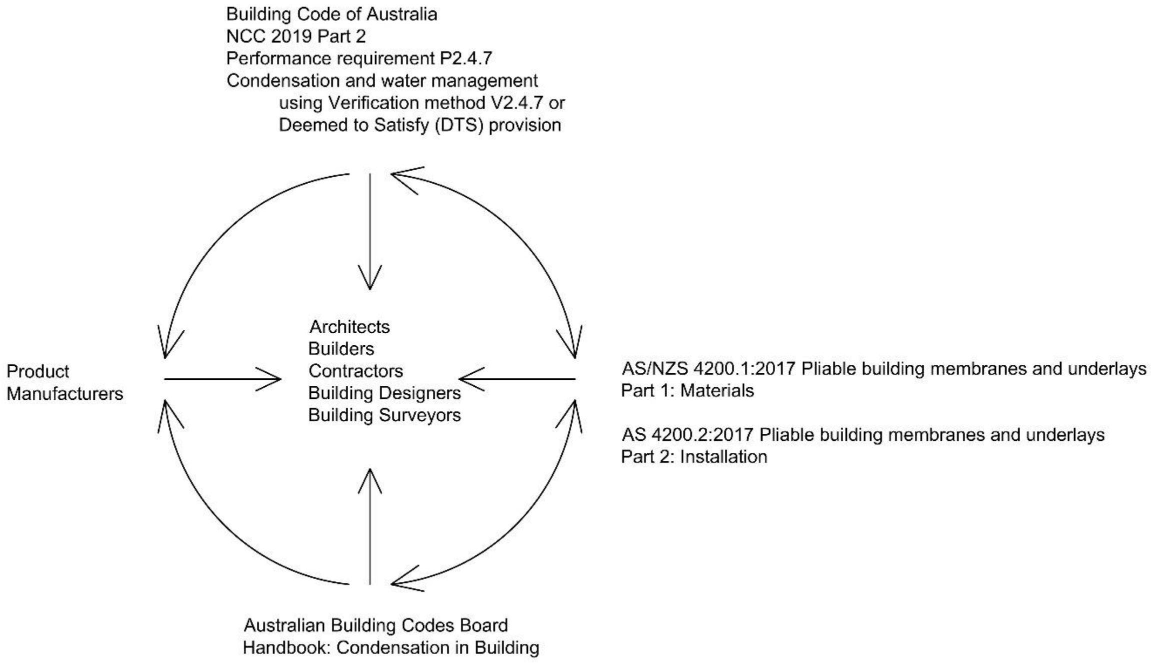


Figure 2: Relationship between design and building practitioners and regulatory framework

Energy efficiency requirements exacerbating condensation

In 2003, a program was introduced nationally to improve the energy efficiency of Australian housing stock via a series of measures outlined in the Building Code of Australia (BCA). The goal was to reduce greenhouse gas emissions through a rating system based on minimum criteria. This was extended to all building categories in 2016. This endeavour is essential and acknowledges that introducing new building stock with poor energy efficiency would detrimentally impact greenhouse gas emissions (ABCB 2019).

In Victoria, when applying for a building permit, a building thermal performance is assessed on the basis that it receives a minimum 6-star rating. The three main accredited energy rating tools: First Rate, BERS and Accurate, all use the same core analysis engine (Chenath engine) developed and licenced by the CSIRO energy rating team (NatHERS 2012). This software examines the composition of walls, roofs and floors relative to climate zone and orientation to produce a series of recommendations regarding thermal performance. What the software doesn't assess is how best to remove or alleviate condensation within building systems. Architects, Builder Practitioners, Contractors and Building Surveyors in complying with a recommendation generated based on thermal performance are producing buildings that do not operate to alleviate dampness and condensation.

Volume 2 of the NCC has since 2003 used Performance Requirements, Verification Methods and Deemed to Satisfy Provisions to effect reducing greenhouse gas emissions, firstly in Class 2 housing, then progressively Class 3 buildings (apartments and hotels) and then the remainder of the building classifications (ABCB 2019). In assessing a building's performance the criteria examine: building fabric e.g. walls, floors and roofs, external glazing and shading, sealing of the building and the effects of air movement (ABCB 2019). The approach examines buildings within their own particular climatic zone, such that there are varying criteria depending on whether the building is located in a warmer climate, colder climate or temperate climate (ABCB 2019). As depicted in Figure 3, Melbourne falls in climatic zone 6 which covers mild temperate zone.

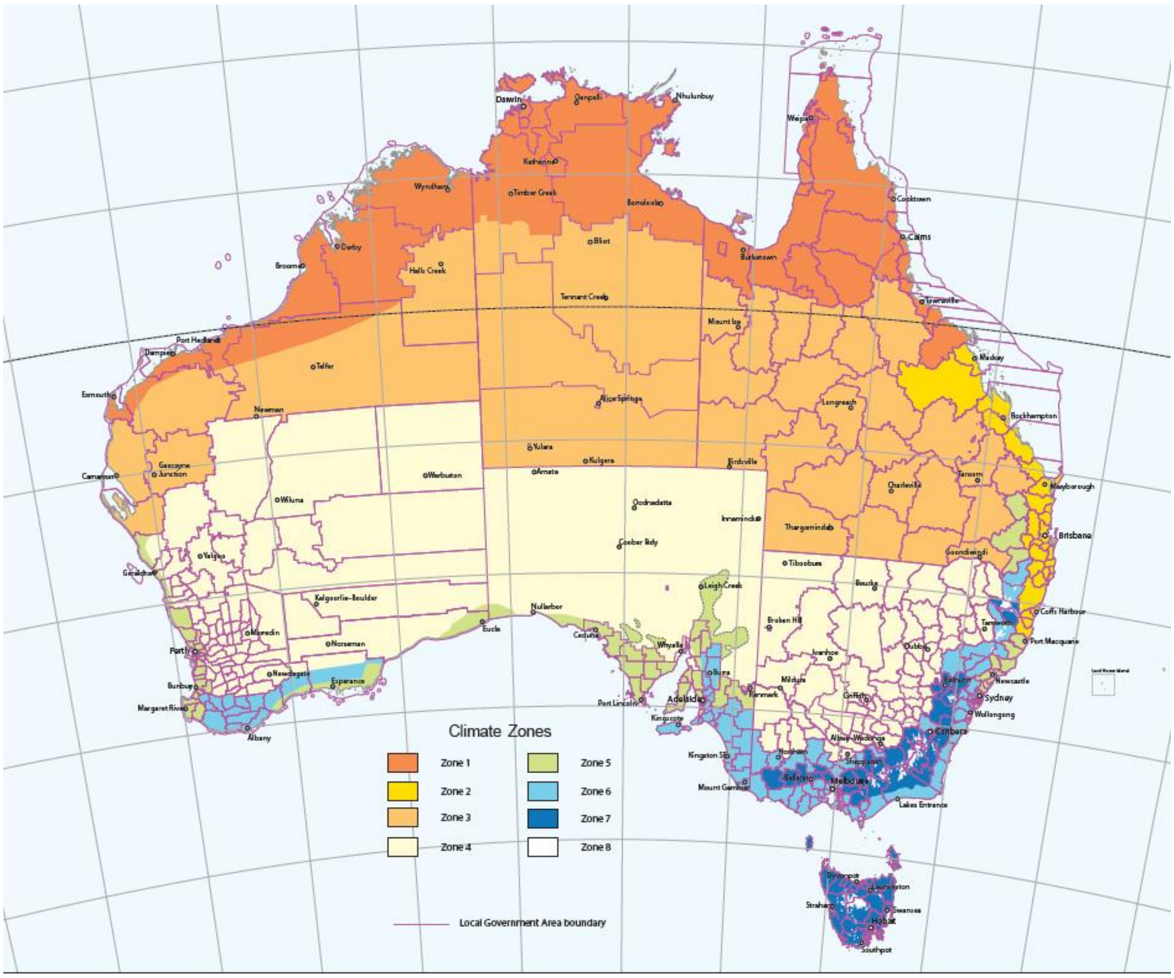


Figure 3: Australian Climate zones 1-8 used as basis of NCC thermal determinations

The Handbook on Energy Efficiency produced by the ABCB as a way of improving understanding of key issues surrounding the energy efficiency provisions of NCC Volume 2, outlines a correlation between the use of reflective insulation and the possible advent of condensation:

> When determining the location of the bulk and reflective insulation, careful consideration should be given to avoid possible condensation forming inside the layers of the building envelope particularly in certain climates and where there are high concentrations of water vapour. The ABCB has produced a non- mandatory handbook, Condensation in Buildings, to assist in understanding condensation risk and to detail measures that can be taken to help keep buildings dry (ABCB 2019).

The understanding that condensation should be considered when designing and building residential dwellings is present at all levels of the legislation surrounding Class 1 construction. However, the emphasis is again geared towards the non-mandatory handbook on Condensation in Buildings, not the NCC or Australian Standards (or in suspense as the responsibility of manufacturers). The complex interrelationship between temperature, relative humidity, and types of wall systems is presented within a 163-page document from which non expert practitioners are meant to understand the complexities of water vapour thermodynamics, choose appropriate products and build suitable wall, roof and floor systems for their particular project in that particular climate zone. The thermodynamics of water vapour vary not only in particular climate zones but also across the course of a day and across the seasons of the year. Where condensation may form on the outside of an insulated stud frame in winter, it may form behind the interior lining of say plasterboard during summer as depicted in Figure 4.

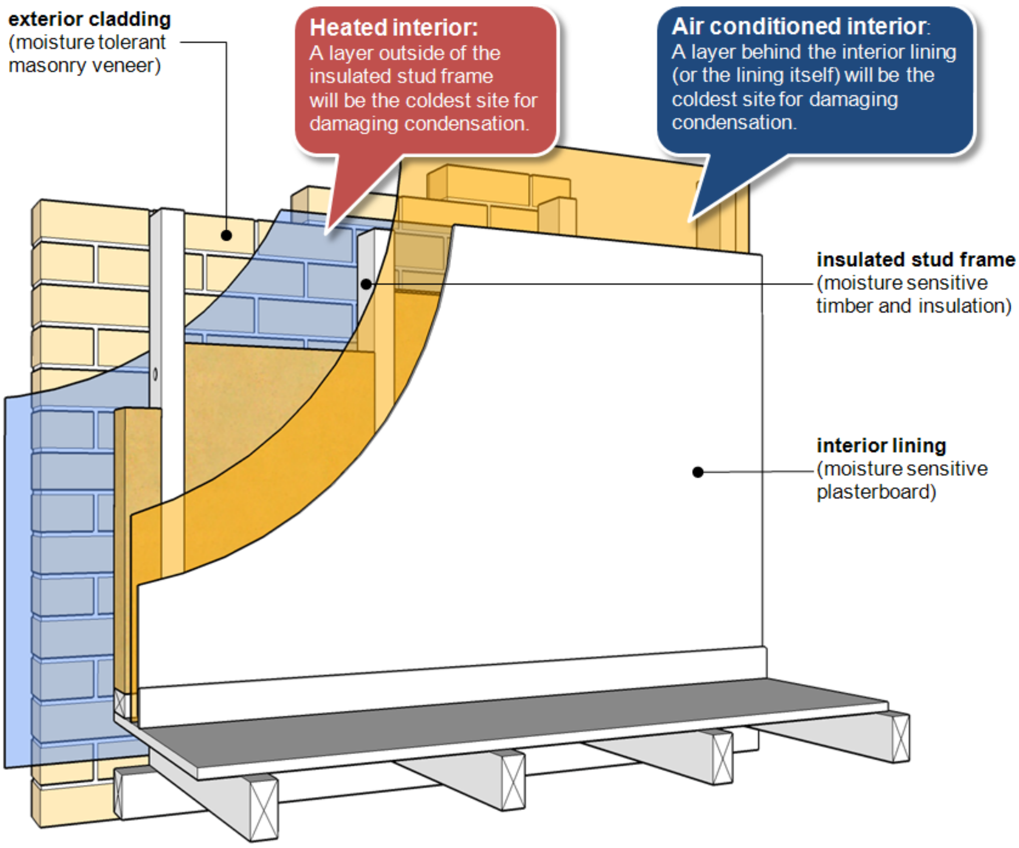


Figure 4: Typical masonry veneer construction (Source: ABCB Condensation in Building Handbook)

Impact on occupants Health

Asthma is a major health problem in Australia, with the prevalence being one of the highest in the world. More specifically, asthma affects approximately one in four primary-school age children, one in seven teenagers and one in ten adults. It is the most common long-term chronic condition diagnosed in childhood. The symptoms - coughing, wheezing, shortness of breath - undermine the quality of life of sufferers through, for example, limiting an individual's ability to participate in their usual activities, causing sleepless nights, and necessitating frequent visits to hospital when the asthma is not managed properly. Sudden onset acute severe asthma often requires a visit to the emergency department (ED) or actual hospitalisation.

The economic cost of admissions is substantial, and seasonal increases in admissions may place a substantial extra burden on hospital services. Furthermore, uncontrolled asthma in childhood is a risk factor for Chronic Obstructive Pulmonary Disease (COPD) and chronic severe asthma in adulthood (Trivedi & Denton 2019). Sudden-onset asthma exacerbations that require hospitalization are triggered by several factors. Among the most common are viral infections (Brand et al. 2015) and peak pollen periods (Erbas et al. 2018; Hew et al. 2019). Moreover, the built environment with indoor damp and mould also plays a part in the frequency and severity of asthma attacks (Cox-Ganser 2015; Jie et al. 2011). With Australians spending up to 90% of their time indoors (Rumchev et al. 2018) it is important to understand the contribution of indoor environment to the risk of asthma. This is especially so in children due to their extra sensitivity and therefore higher risk.

In Australian homes, the concentration of mould is among the highest in the world (Knibbs et al. 2018). Specific mould species with hazardous levels reported in homes include Alternaria (e.g. Alternaria alternate), Cladosporium, Aspergillus and Penicillium (Baxi et al. 2016) (Chapman 2006). Dampness in homes is also a major burden on families living with asthma (Cai et al. 2019). The importance of modifying some residential characteristics in controlling the levels of these fungi and mould and therefore reducing the asthma burden have been identified in local as well as international studies (Burge 2002; Haleem Khan & Mohan Karuppayil 2012) (Sharpe et al. 2015).

Although the association between the built environment and respiratory disease is emerging few studies have focused on children with many only focusing on the severe form of asthma (Nandasena, Wickremasinghe & Sathiakumar 2013; Tin Tin et al. 2016). For example, in samples of adult asthmatics attending asthma clinics (Trupin et al. 2010). These studies suggest that the severity of the disease may modify the association between the indoor built environment and asthma. Moreover, we know very little about the combined effects of indoor built environment and outdoor environmental factors including peak pollen seasons. It is highly possible that poor building construction and cumulative exposure to damp and mould over time combined with longer duration of peak pollen seasons (and fungi) will increase risk of asthma exacerbations. Therefore, investigation of these associations in asthmatics who are at risk is likely to clarify these associations, especially in Australia.

There is a persistent growing gap in our understanding of changing outdoor environment and poorly built living environments, especially in cities with dangerous environmental conditions. Recent studies in Australia are lacking and better understanding the relationship between poorly built indoor environments with substantial mould and damp and how it interacts with outdoor air and pollen and asthma is an essential first step towards effective early intervention to prevent or minimise asthma attacks in susceptible populations.

Although we have local public health preventative strategies for pollen exposure which often requires staying indoors on high pollen days this may not be enough for those with poor indoor environments. Damp remediation has been shown to reduced asthma symptoms in adults and children (Sauni et al. 2011) but little is known about these interventions in schools and workplaces where children and adult spend most of their time indoors.

Larger epidemiological studies in Australia are important. If the association between outdoor aeroallergens and their indoor counterparts were to be understood, that would be an important breakthrough in understanding the effect of the outdoor environment on the indoor environment. This advancement has the potential to enhance quality of life for Australians generally and particularly for those who have asthma. In the light of climate change, this advancement in knowledge has further implications in health planning and policy.

Discussion

The deemed to satisfy criteria of the NCC needs to clearly define how best to construct walls, roofs and walls within given the different climate zones. The expectation that building practitioners should read, understand and implement condensation mitigation strategies under the current framework clearly has not worked. The idea that placing the onus on building practitioners somehow cuts through regulatory 'red tape' is causing tens of thousands of homes to be built with inadequate building systems that do harm to the occupants and undermine the structural integrity of buildings. In the first instance manufacturers should cease supplying product to the market that is clearly inappropriate. Labelling materials as breather membranes when they are in fact not vapour permeable should cease. As a matter of urgency, the Chenath engine at the core of the thermal evaluation software needs to be modified to accurately include the effects that condensation can have on wall systems. As an example, the loss of a reflective foil layer within a wall system would be a minor loss of thermal performance when compared to the health and wellbeing of the occupants. Elements from the ABCB Handbook need to be codified into either the NCC or Australian Standards, to remove the idea that they are simply background or guidance, rather than a codified regulation. Finally, as stipulated in Dewsbury (2017), there needs to be a coordinated education program targeting design and construction students, building practitioners and building surveyors. This needs to be implemented through universities, TAFE colleges and through the various building bodies such as the AIA, HIA, Master Builders Association and BDAV. In addition, the following recommendations are proffered from this study:

- DTS criteria of the NCC need to clearly express construction preference for a given temperature zone
- Manufacturers to cease supplying inappropriate product to market
- Thermal assessment software needs to be updated to incorporate condensation management
- NCC to incorporate Condensation guidelines as regulation to eliminate ambiguity
- Design and building students and practitioners to be alerted to the severity of the problem and be given clear access to the solutions

Conclusion

The way condensation in building systems is dealt with in Australia within a regulatory context is inappropriate and needs to be altered as a matter of urgency. Given that evidence suggests that exposure to mould and damp has an adverse effect on human health, practical steps must be taken to exclude moisture both in liquid form and as vapour from within the building envelope of residential buildings. No system will be completely free of condensation, however our ability to remove it shouldn't be undermined by the regulatory system itself. Existing international evidence suggested that reducing damp and mould within residential buildings can have a significant effect on the health and wellbeing of occupants. Building authorities should be moving expeditiously to both achieve the thermal outcomes desired, but also ensure that the health and well-being of occupants is protected. The onus should be on authorities and manufacturers to ensure that practitioners are provided with the appropriate resources and knowledge to competently produce buildings that both save energy and protect occupants from harm.

Acknowledgement

The authors would like to express sincere appreciation to Dr Tim Law and Dr Mark Dewsbury for their invaluable contributions.

References

ABCB 2019, *Handbook Condensation in Buildings*, Canberra, Australian Building Codes Board.

ABCB 2019, *Handbook: Energy Efficiency NCC Volume Two 2019*.

ABCB 2019, *NCC 2019 Volume Two*.

AS4200.2 2017, *Pliable Building Membranes and Underlays Part 2: Installation*.

AS/NZS4200.1 2017, *Pliable Building Membranes and Underlays Part 1: Materials*, Standards Australia.

Baxi, SN, Portnoy, JM, Larenas-Linnemann, D, Phipatanakul, W & Environmental Allergens, W 2016, 'Exposure and Health Effects of Fungi on Humans', *The journal of allergy and clinical immunology. In practice*, vol. 4, no. 3, pp. 396-404.

Brand, PLP, Mäkelä, MJ, Szefler, SJ, Frischer, T & Price, D 2015, 'Monitoring asthma in childhood: symptoms, exacerbations and quality of life', *European Respiratory Review*, vol. 24, no. 136, p. 187.

Burge, HA 2002, 'An update on pollen and fungal spore aerobiology', *J Allergy Clin Immunol*, vol. 110, no. 4, pp. 544-52.

Cai, J, Li, B, Yu, W, Wang, H, Du, C, Zhang, Y, Huang, C, Zhao, Z, Deng, Q, Yang, X, Zhang, X, Qian, H, Sun, Y, Liu, W, Wang, J, Yang, Q, Zeng, F, Norbäck, D & Sundell, J 2019, 'Household dampness-related exposures in relation to childhood asthma and rhinitis in China: A multicentre observational study', *Environment International*, vol. 126, pp. 735-46.

Chapman, MD 2006, 'Challenges associated with indoor moulds: Health effects, immune response and exposure assessment', *Medical Mycology*, vol. 44, no. Supplement_1, pp. S29-S32.

Cox-Ganser, JM 2015, 'Indoor dampness and mould health effects - ongoing questions on microbial exposures and allergic versus nonallergic mechanisms', *Clinical and experimental allergy : journal of the British Society for Allergy and Clinical Immunology*, vol. 45, no. 10, pp. 1478-82.

Dewsbury, M, Law, T, Potgieter, J, Fitz-Gerald, D, McComish, B, Chandler, T & Soudan, A 2016, 'Scoping study of condensation in residential buildings-Final report'.
Erbas, B, Jazayeri, M, Lambert, KA, Katelaris, CH, Prendergast, LA, Tham, R, Parrodi, MJ, Davies, J, Newbigin, E, Abramson, MJ & Dharmage, SC 2018, 'Outdoor pollen is a trigger of child and adolescent asthma emergency department presentations: A systematic review and meta-analysis', *Allergy*, vol. 73, no. 8, pp. 1632-41.
Haleem Khan, AA & Mohan Karuppayil, S 2012, 'Fungal pollution of indoor environments and its management', *Saudi journal of biological sciences*, vol. 19, no. 4, pp. 405-26.
Hew, M, Lee, J, Susanto, NH, Prasad, S, Bardin, PG, Barnes, S, Ruane, L, Southcott, AM, Gillman, A, Young, A, Rangamuwa, K, O'Hehir, RE, McDonald, C, Sutherland, M, Conron, M, Matthews, S, Harun, N-S, Lachapelle, P, Douglass, JA, Irving, L, Langton, D, Mann, J, Erbas, B & Thien, F 2019, 'The 2016 Melbourne thunderstorm asthma epidemic: Risk factors for severe attacks requiring hospital admission', *Allergy*, vol. 74, no. 1, pp. 122-30.
House of Representatives Standing Committee on Health, ACaS 2018, *Report on the Inquiry into Biotoxin-related Illnesses in Australia*
Jie, Y, Ismail, NH, jie, X & Isa, ZM 2011, 'Do indoor environments influence asthma and asthma-related symptoms among adults in homes? A review of the literature', *Journal of the Formosan Medical Association*, vol. 110, no. 9, pp. 555-63.
Johansson, P, Ekstrand-Tobin, A, Svensson, T & Bok, G 2012, 'Laboratory study to determine the critical moisture level for mould growth on building materials', *International Biodeterioration & Biodegradation*, vol. 73, pp. 23-32.
Knibbs, LD, Woldeyohannes, S, Marks, GB & Cowie, CT 2018, 'Damp housing, gas stoves, and the burden of childhood asthma in Australia', *Med J Aust*, vol. 208, no. 7, pp. 299-302.
Nandasena, S, Wickremasinghe, AR & Sathiakumar, N 2013, 'Indoor air pollution and respiratory health of children in the developing world', *World journal of clinical pediatrics*, vol. 2, no. 2, pp. 6-15.
NatHERS 2012, 'NatHERS Software Accreditation Protocol June 2012'.
Rumchev, K, Soares, M, Zhao, Y, Reid, C & Huxley, R 2018, 'The Association between Indoor Air Quality and Adult Blood Pressure Levels in a High-Income Setting', *Int J Environ Res Public Health*, vol. 15, no. 9.
Sauni, R, Uitti, J, Jauhiainen, M, Kreiss, K, Sigsgaard, T & Verbeek, JH 2011, 'Remediating buildings damaged by dampness and mould for preventing or reducing respiratory tract symptoms, infections and asthma', *Cochrane Database of Systematic Reviews*, no. 9.
Sharpe, RA, Bearman, N, Thornton, CR, Husk, K & Osborne, NJ 2015, 'Indoor fungal diversity and asthma: a meta-analysis and systematic review of risk factors', *J Allergy Clin Immunol*, vol. 135, no. 1, pp. 110-22.
Tin Tin, S, Woodward, A, Saraf, R, Berry, S, Atatoa Carr, P, Morton, SMB & Grant, CC 2016, 'Internal living environment and respiratory disease in children: findings from the Growing Up in New Zealand longitudinal child cohort study', *Environmental Health*, vol. 15, no. 1, p. 120.
Trivedi, M & Denton, E 2019, 'Asthma in Children and Adults—What Are the Differences and What Can They Tell us About Asthma?', *Frontiers in Pediatrics*, vol. 7, no. 256.
Trupin, L, Balmes, JR, Chen, H, Eisner, MD, Hammond, SK, Katz, PP, Lurmann, F, Quinlan, PJ, Thorne, PS, Yelin, EH & Blanc, PD 2010, 'An integrated model of environmental factors in adult asthma lung function and disease severity: a cross-sectional study', *Environmental health : a global access science source*, vol. 9, pp. 24-.
VCAT 2016, *Owners Corporation No.1 of PS613436T, Owners Corporation No. 2 of PS613436T, Owners Corporation No. 4 PS61343* Victorian Civil and Administrative Tribunal.
WHO 2009, *WHO guidelines for indoor air quality*.

THE ROLE OF INDUSTRY 4.0 IN CONSTRUCTION HEALTH AND SAFETY (H&S)

James Beale[1], John Smallwood[1]

[1]Department of Construction Management, Nelson Mandela University, Port Elizabeth, South Africa

Abstract

Historical construction health and safety (H&S) challenges, in terms of a range of resources and issues, continue to be experienced, namely design process-related hazards are encountered on site, workers are unaware of the hazards and risks related to the construction process and its activities, activities are commenced on site without adequate hazard identification and risk assessments (HIRAs), difficulty is experienced in terms of real time monitoring of construction-related activities, workers handle heavy materials, plant, and equipment, and ultimately, the experience of injuries. Given the abovementioned, and the advent of Industry 4.0, a quantitative study, which entailed the completion of a self-administered questionnaire online, was conducted among registered professional (Pr) and candidate (Can) Construction H&S Agents, to determine the potential of Industry 4.0 to contribute to resolving the challenges cited. The findings indicate that a range of Industry 4.0 technologies can contribute to resolving the cited H&S challenges as experienced in construction. Conclusions include that virtual reality (VR), augmented reality (AR), VR based H&S training, drone technology, and wearable technology / sensors have the potential to contribute to resolving many of the H&S challenges experienced in construction. Recommendations include: employer associations, professional associations, and statutory councils should raise the level of awareness relative to the potential implementation of Industry 4.0 relative to H&S in construction; case studies should be documented and shared; tertiary construction management education programmes should integrate Industry 4.0 into all possible modules, especially H&S-related modules, and continuing professional development (CPD) H&S should address Industry 4.0.

Keywords

Keywords: Construction, Health and Safety, Industry 4.0, Performance

Introduction

According to the Council for Scientific and Industrial Research (CSIR) (2018), the Fourth Industrial Revolution (FIR), also known as Industry 4.0, is being driven by the rapid rise and convergence of emerging technologies. Industry 4.0 is a collective term for technologies and value chain organisation which draw together cyber-physical systems, the Internet of Things (IoT) and the Internet of Services (IoS), together with other emerging technologies such as cloud technology, big data, predictive analysis, artificial intelligence, augmented reality, agile and collaborative robots, and additive manufacturing. Considering the numerous challenges experienced in construction, H&S included, it is inevitable that Industry 4.0 is considered to overcome these. The fourth industrial revolution, or Industry 4.0, is gaining momentum, and entails a paradigm shift that will have a significant impact on the management of occupational H&S, and offers the construction industry a chance to improve efficiency, productivity, in addition to H&S.

Historically, construction has experienced more deaths and injuries than any other industry. Although not inherently dangerous, construction is known as a hazardous industry that presents many factors that are potentially dangerous to workers. Park and Kim (2013) reveal that most accidents associated with construction work were attributable to a lack of proactive and preventive measures such as H&S workforce training, HIRA, H&S awareness, and H&S education.

According to the Department of Labour (2013), “A lack of supervision and commitment by management and poor workmanship were some of the biggest causes of incidents that lead to injuries and fatalities in the South African construction industry”. “At the organisational and site level, poor construction H&S performance is attributable to a lack of management commitment, inadequate supervision and inadequate or a lack of H&S training” (Construction Industry Development Board (cidb), 2009). A lack of worker involvement, personal risk appreciation, and work pressure also contribute to poor performance. Until recently, the global construction industry has had a poor H&S record, and South Africa is no exception. Many technological advances have been made over the past few years that have the potential to provide great opportunities to improve this aspect of construction. The use of these technologies has a vast range of benefits, and the potential to achieve better on-site H&S management, which could result in healthier and safer working conditions.

Construction H&S monitoring relies heavily on manual observation to monitor and identify any potential hazards that may expose workers to H&S risks. This can become challenging as construction sites must be continuously monitored to detect unhealthy and unsafe working conditions in order to protect workers from potential injuries and fatal accidents. Industry 4.0 brings technology such drones, AR, VR, and wearable sensors that can mitigate many of these challenges.

Given the continuing poor H&S performance in South African construction, the aim of the study was to evolve an Industry 4.0 response to H&S challenges encountered in construction to determine the potential of:

- Industry 4.0 technologies to improve H&S performance;
- AR to assist workers in identifying design process-related hazards on site;
- VR to assist designers in identifying design process-related hazards on site;
- using VR systems as a method of training to enable workers to identify potential hazards and mitigate risks on site;
- using drone technology to improve HIRA before activities commence on site;
- using drone technology to assist real time monitoring of construction activities, and
- equipping workers with wearable technology / sensors to mitigate the hazards and risk accompanying the handling of heavy materials, plant, and equipment.

Review of the Literature

VR and AR in H&S Management

In recent years visualisation technologies such as VR and AR have been developed and used to improve construction productivity, H&S, and quality (Le et al., 2015). Both AR and VR have the potential to improve on site construction processes (Le et al., 2015). According to Park et al. (2013), AR based applications and systems have been developed to improve on-site tasks such as data visualisation, work inspection, and checking for omissions. These systems have improved on-site H&S performance to some extent.

VR systems as training modules

According to Silliker (2018), VR is rapidly gaining traction as a training tool in occupational H&S. VR technology provides a virtual environment that allows users to immerse themselves in a virtual world that uses sight, sound, and sometimes motion to provide a realistic experience (Silliker, 2018). Wang et al. (2018) state that the construction sector is a high-risk industry where accident rates remain high. It was highlighted that some of the reasons leading to the high level of risk include limited H&S knowledge of on-site workers and lack of H&S awareness and training of these individuals. Construction H&S training has traditionally been carried out in a classroom setting with slide presentations or videos. However, the H&S information provided in the presentations and videos often do not represent real construction site conditions (Wang et al., 2018).

A study conducted by Sacks et al. (2013) determined that VR-based training was more effective than traditional H&S training methods, which made use of classrooms and slide presentations. The study determined that workers had better recall in identifying and assessing construction H&S risks, than they would have using traditional conventional methods. According to Wang et al. (2018), there are currently a few VR-related technologies that have been developed to improve the current construction H&S training practices. VR is becoming more popular in the occupational H&S space as it provides a method of training workers relative to their actual job tasks in a safe environment (Silliker, 2018).

The use of drones for real time monitoring

A study conducted by Gheisari and Esmaeili (2016) determined that using unmanned aerial systems (UASs) commonly referred to as 'drones', to monitor construction activities could help identify potential on site hazards and therefore improve H&S management. Tatum and Liu (2017) determined that the construction industry is already making use of drones to carry out various tasks related to the construction processes and its activities. UASs provide an effective solution to carry out real-time monitoring and improve H&S monitoring and control practices on site (Gheisari and Esmaeili, 2016). According to Alizadehsalehi et al. (2017), UAS technologies can easily monitor the entire construction site by flying around the construction area under a H&S manager's control and transmit real-time information for inspecting H&S purposes related to the project. UAS technology can enable H&S managers to identify hazards at different stages of the project and develop suitable mitigation strategies (Alizadehsalehi et al., 2017).

Borck (2018) states that in addition to remote H&S inspections, drones are being used for many other tasks in the construction industry, including the following:

- Monitoring the progress of construction work and jobsite logistics without disrupting ongoing work;
- Assessing and determining the integrity of structures;
- Identifying problems before they develop using maintenance assessments;
- Facilitating communication and surveillance;
- Assisting search and rescue operations;
- Documenting jobsite conditions from the commencement to the end of the project, and
- Increasing the scope and frequency of inspections.

Wearable technology in H&S management

Seo et al. (2015) state that due to the hazardous working environments on construction sites, workers are frequently faced with potential H&S risks throughout the entire construction process. Nath et al. (2017) state that "construction works are labour-intensive and often stipulate the workers to go beyond their natural physical limits to cope up with the increasing complexities and challenges of their assigned tasks". Traditional approaches of measuring H&S performance indicators are largely manual in nature (Awolusi et al., 2018). To overcome these limitations of manual efforts, automated H&S monitoring is considered one of the most promising methods for accurate and continuous monitoring of H&S performance on construction sites (Awolusi et al., 2018). Wearable technologies can enable the continuous monitoring of a wide range of vital signals which can provide early warning systems for workers with high-risk health issues (Ananthanarayan and Siek, 2010). A study conducted by Nath et al. (2017) found that wearable technology was able to prevent work related injuries and fatalities by ergonomically designing the work environment based on previous data collected. The use of this technology was able to identify and eliminate the ergonomic risks at the source to prevent similar incident from re-occurring (Nath et al., 2017).

Research

Research Method and Sample Stratum

The exploratory study entailed a self-administered online questionnaire survey. The sample strata for the research study was limited to 92 Pr CHSAs, and 139 candidate CHSAs. The questionnaire consisted of eighteen questions – seventeen closed ended, and one open-ended. Twelve of the close ended questions were Likert scale type questions, and five were demographics related. 63 Responses were included in the analysis of the data, which entailed the computation of frequencies, and a measure of central tendency in the form of a mean score (MS), to enable the interpretation of percentage responses to Likert point scale type questions, and the ranking of variables. The 63 responses equate to a response rate of 31.2%.

Results and Discussion

Table 1 indicates the frequency at which ten H&S phenomena are experienced on projects in terms of percentage responses to a scale of never to constantly, and a MS ranging between 1.00 and 5.00. It is notable that 8 / 10 (80.0%) MSs are above the midpoint of 3.00, which indicates that in general the respondents can be deemed to perceive the phenomena to be experienced on projects. It is notable that no phenomena are experienced between often to constantly / constantly (MSs > 4.20 ≤ 5.00). 4 / 10 (40.0%) MSs are > 3.40 ≤ 4.20, which indicates the frequency is between sometimes too often / often – workers handle heavy materials, plant, and equipment; delays; on site hazards, and difficulty is experienced in terms of real time monitoring of construction-related activities. Activities are commenced on site without adequate HIRAs; workers are unaware of the hazards and risks related to the construction process and its activities; design process-related hazards are encountered on site; similar incidents reoccur; and accidents and injuries have MSs > 2.60 ≤ 3.40 - between rarely to sometimes / sometimes.

Table 1: Frequency at which H&S phenomena are experienced on projects.

Phenomenon	**Response (%)**						**MS**	**Rank**
	Unsure	**Never**	**Rarely**	**Some-times**	**Often**	**Con-stantly**		
Workers handle heavy materials, plant, and equipment	0.0	3.2	15.9	15.9	47.6	17.5	3.60	1
Delays	0.0	3.2	17.5	22.2	36.5	20.6	3.54	2
On site hazards	1.6	4.8	9.5	30.2	39.7	14.3	3.50	3
Difficulty is experienced in terms of real time monitoring of construction-related activities	1.6	6.3	12.7	31.7	28.6	19.0	3.42	4
Activities are commenced on site without adequate HIRAs	3.2	4.8	17.5	23.8	36.5	14.3	3.39	5
Workers are unaware of the hazards and risks related to the construction process and its activities	1.6	7.9	15.9	22.2	46.0	6.3	3.27	6
Design process-related hazards are encountered on site	3.2	3.2	19.0	39.7	23.8	11.1	3.21	7
Similar incidents reoccur	1.6	4.8	27.0	34.9	27.0	4.8	3.00	8
Accidents	3.2	4.8	27.0	44.4	17.5	3.2	2.87	9
Injuries	1.6	9.5	27.0	38.1	20.6	3.2	2.81	10

Table 2 indicates the extent of the need for improvements on projects in terms of percentage responses to a scale of 1 (minor) to 5 (major), and a MS ranging between 1.00 and 5.00. It is notable that all the MSs are above the midpoint of 3.00, which indicates that in general the respondents can be deemed to perceive the need for improvements to be major as opposed to minor. It is notable that 9 / 11 (81.8%) MSs are > 4.20 ≤ 5.00, which indicates the respondents perceive the need for improvement to be between near major to major / major - improved supervision, improved observation, improved HIRAs, healthier working conditions, safer working conditions, improved H&S training, reduced occurrence of H&S incidents / accidents, improved monitoring of worker health, and improved monitoring of worker activities. Many of these needs are frequently referred to in the literature and can be responded to by Industry 4.0 technologies. Real time monitoring, ranked tenth, has a MS of 4.15, which is marginally below the lower point of the upper MS range. The eleventh and last ranked need has a MS > 3.40 ≤ 4.20, which indicates the respondents perceive the need to be between some improvement to a near major / major improvement - automation of activities on site. This need is varied; however, it can be responded to by Industry 4.0 technologies. The empirical findings reflect the findings of the literature in terms of the implied need for performance improvement.

Table 2: Extent of the need for improvements on projects.

Need	Un-sure	Response (%)					MS	Rank
		Minor………………………….Major						
		1	2	3	4	5		
Improved supervision	0.0	0.0	1.6	14.3	23.8	60.3	4.43	1
Improved observation	0.0	0.0	3.2	6.3	34.9	55.6	4.43	2
Improved HIRAs	0.0	0.0	0.0	17.5	22.2	60.3	4.43	3
Healthier working conditions	0.0	0.0	1.6	15.9	27.0	55.6	4.37	4
Safer working conditions	0.0	0.0	1.6	14.3	31.7	52.4	4.35	5
Improved H&S training	0.0	0.0	1.6	17.5	25.4	55.6	4.35	6
Reduced occurrence of H&S incidents / accidents	0.0	0.0	1.6	15.9	34.9	47.6	4.29	7
Improved monitoring of worker health	0.0	0.0	0.0	19.0	33.3	47.6	4.29	8
Improved monitoring of worker activities	0.0	0.0	1.6	17.5	33.3	47.6	4.27	9
Real time monitoring	1.6	0.0	4.8	19.0	31.7	42.9	4.15	10
Automation of activities on site	0.0	4.8	6.3	27.0	36.5	25.4	3.71	11

Table 3 indicates the respondents' self-rating of their awareness of / exposure to the identified four Industry 4.0 technologies in terms of percentage responses to a scale of 1 (limited) to 5 (extensive), and a MS ranging between 1.00 and 5.00. It is notable that none of the MSs are above the midpoint of 3.00, which indicates that in general the respondents can be deemed to rate themselves below average. Only 1 / 4 (25.0%) MSs are > 2.60 ≤ 3.40, which indicates a rating of below average to average / average - drones. The remaining 3 / 4 (75.0%) MSs are > 1.80 ≤ 2.60, which indicates a rating of limited to below average / below average - virtual reality, wearable technology / sensors and augmented reality. The findings indicate that the respondents have generally had limited exposure to the identified technologies to date.

Table 3: Respondents' self-rating of their awareness of / exposure to four Industry 4.0 technologies.

Aspect	Unsure	Response (%)					MS	Rank
		Limited…………………….Extensive						
		1	2	3	4	5		
Drones	4.8	20.6	25.4	25.4	12.7	11.1	2.67	1
Virtual Reality	6.3	34.9	19.0	17.5	20.6	1.6	2.31	2
Wearable technology / sensors	6.3	33.3	27.0	22.2	3.2	7.9	2.20	3
Augmented Reality	11.1	34.9	25.4	17.5	9.5	1.6	2.07	4

Table 4 indicates the potential of Industry 4.0 technologies to improve H&S performance in terms of percentage responses to a scale of 1 (minor) to 5 (major), and a MS ranging between 1.00 and 5.00. It is notable that the MS is above the midpoint of 3.00, which indicates that in general the respondents can be deemed to perceive the potential to be above average. The MS is > 3.40 ≤ 4.20, which indicates between potential to near major / near major potential. Despite the respondents' generally low self-rating of their awareness of / exposure to the identified four Industry 4.0 technologies, they recognise the potential of Industry 4.0 technologies to improve H&S performance as per the literature.

Table 4: Potential of Industry 4.0 technologies to improve H&S performance

Unsure	Response (%)					MS
	Minor…………………….……Major					
	1	2	3	4	5	
9.5	1.6	3.2	15.9	33.3	36.5	4.11

Table 5 indicates the potential of Industry 4.0 technologies to improve H&S-related interventions / goals in terms of percentage responses to a scale of 1 (minor) to 5 (major), and a MS ranging between 1.00 and 5.00. It is notable that all he tMSs (100.0%) are above the midpoint of 3.00, which indicates that in general the respondents can be deemed to perceive the potential to be above average. It is notable that only one MS is > 4.20 ≤ 5.00, which indicates near major to major / major potential – observation. The remaining 10 / 11 (90.9%) MSs are > 3.40 ≤ 4.20, which indicates between potential to near major / near major potential. 7 / 11 (63.6%) of these phenomena fall in the upper half of the range, namely > 3.80 ≤ 4.20 – supervision, real time monitoring, monitoring of worker activities, HIRAs, monitoring of worker safety, H&S training, and improvement of working conditions. The remaining 3 / 11 (27.3%) MSs are > 3.40 ≤ 4.20, which indicates between potential to near major / near major potential - reduced occurrence of H&S incidents / accidents, monitoring of worker health and automation of activities on site. Despite the respondents' generally low self-rating of their awareness of / exposure to the identified four Industry 4.0 technologies, they recognise the potential of Industry 4.0 technologies to improve the stated H&S-related interventions / goals.

Table 5: Potential of Industry 4.0 technologies to improve H&S-related interventions / goals

Intervention / Goal	Un-sure	Response (%)					MS	Rank
		Minor……………...……..…Major						
		1	2	3	4	5		
Observation	3.2	0.0	1.6	9.5	49.2	36.5	4.25	1
Supervision	4.8	0.0	1.6	9.5	54.0	30.2	4.18	2
Real time monitoring	7.9	1.6	4.8	11.1	42.9	31.7	4.07	3
Monitoring of worker activities	3.2	1.6	3.2	12.7	49.2	30.2	4.07	4
HIRAs	4.8	1.6	4.8	9.5	50.8	28.6	4.05	5
Monitoring of worker safety	4.8	1.6	4.8	14.3	41.3	33.3	4.05	6
H&S training	7.9	1.6	3.2	15.9	42.9	28.6	4.02	7
Improvement of working conditions	7.9	1.6	6.3	15.9	42.9	25.4	3.91	8
Reduced occurrence of H&S incidents / accidents	6.3	1.6	11.1	20.6	36.5	23.8	3.75	9
Monitoring of worker health	6.3	1.6	7.9	23.8	42.9	17.5	3.71	10
Automation of activities on site	9.5	3.2	11.1	17.5	46.0	12.7	3.60	11

Table 6 indicates the potential of VR to improve aspects of H&S performance in terms of percentage responses to a scale of 1 (minor) to 5 (major), and a MS ranging between 1.00 and 5.00. It is notable that all the MSs (100.0%) are above the midpoint of 3.00, which indicates that in general the respondents can be deemed to perceive the potential to be above average. 3 / 3 (100.0%) MSs are > 3.40 ≤ 4.20, which indicates between potential to near major / near major potential - assist designers to identify potential design process-related hazards on site, enable workers to identify potential hazards and mitigate risks on site, and H&S training. Despite the respondents' generally low self-rating of their awareness of / exposure to the identified four Industry 4.0 technologies, they recognise the potential of VR to improve aspects of H&S performance as per the literature.

Table 6: Potential of VR to improve aspects of H&S performance

Aspect	Unsure	Response (%)					MS	Rank
		Minor………………..……..…Major						
		1	2	3	4	5		
Assist designers to identify potential design process-related hazards on site	7.9	1.6	1.6	15.9	27.0	46.0	4.24	1
Enable workers to identify potential hazards and mitigate risks on site	3.2	1.6	0.0	17.5	38.1	39.7	4.18	2
H&S training	3.2	0.0	3.2	17.5	36.5	39.7	4.16	3

Table 7 indicates the potential of AR to improve aspects of H&S performance in terms of percentage responses to a scale of 1 (minor) to 5 (major), and a MS ranging between 1.00 and 5.00. It is notable that the MS is above the midpoint of 3.00, which indicates that in general the respondents can be deemed to perceive the potential to be above average. The MS is > 3.40 ≤ 4.20, which indicates between potential to near major / near major potential - assist workers to identify potential design process-related hazards on site. Despite the respondents' generally low self-rating of their awareness of / exposure to the identified four Industry 4.0 technologies, they recognise the potential of AR to improve the aspects of H&S performance as per the literature.

Table 7: Potential of AR to improve aspects of H&S performance

Aspect	Un-sure	Response (%)					MS
		Minor……….………….…..…Major					
		1	2	3	4	5	
Assist workers to identify potential design process-related hazards on site	22.2	1.6	6.3	17.5	23.8	28.6	3.92

Table 8 indicates the potential of drones to improve aspects of H&S performance in terms of percentage responses to a scale of 1 (minor) to 5 (major), and a MS ranging between 1.00 and 5.00. It is notable that both MSs (100.0%) are above the midpoint of 3.00, which indicates that in general the respondents can be deemed to perceive the potential to be above average. 2 / 2 (100.0%) MSs are > 3.40 ≤ 4.20, which indicates between potential to near major / near major potential - assist in terms of real time monitoring of construction activities, and improve HIRAs before activities commence on site. Despite the respondents' generally low self-rating of their awareness of / exposure to the identified four Industry 4.0 technologies, they recognise the potential of drones to improve the aspects of H&S performance as per the literature.

Table 8: Potential of drones to improve aspects of H&S performance

Aspect	Un-sure	Response (%)					MS	Rank
		Minor………………..……..…Major						
		1	2	3	4	5		
Assist in terms of real time monitoring of construction activities	4.8	1.6	3.2	14.3	30.2	46.0	4.22	1
Improve HIRAs before activities commence on site	4.8	3.2	11.1	17.5	27.0	36.5	3.87	2

Table 9 indicates the potential of wearable technology / sensors to mitigate the hazards and risk accompanying the handling of heavy plant, equipment, and materials in terms of percentage responses to a scale of 1 (minor) to 5 (major), and a MS ranging between 1.00 and 5.00. It is notable that both the MSs (100.0%) are above the midpoint of 3.00, which indicates that in general the respondents can be deemed to perceive the potential to be above average. 2 / 2 (100.0%) MSs are > 3.40 ≤ 4.20, which indicates between potential to near major / near major potential. Despite the respondents' generally low self-rating of their awareness of / exposure to the identified four Industry 4.0 technologies, they recognise the potential of wearable technology / sensors to mitigate the hazards and risk and improve the aspects of H&S performance as per the literature.

Table 9: Potential of wearable technology / sensors to mitigate the hazards and risk accompanying the handling of heavy plant, equipment, and materials

Aspect	Unsure	Response (%)					MS	Rank
		Minor…………….…………..…Major						
		1	2	3	4	5		
Heavy plant, and equipment	12.7	4.8	7.9	14.3	44.4	15.9	3.67	1
Heavy materials	12.7	4.8	7.9	19.0	39.7	15.9	3.62	2

Conclusions

Given the frequency at which H&S phenomena are experienced on projects by respondents, it can be concluded that the respondents' experience the range of these phenomena on projects. It can further be concluded that there is a need for improvement, and a need for the implementation of Industry 4.0. related technologies.

Given the extent of the need for improvement on projects in terms of improved supervision, improved observation, improved HIRAs, healthier working conditions, safer working conditions, improved H&S training, reduced occurrence of H&S incidents / accidents, improved monitoring of worker health, improved monitoring of worker activities, real time monitoring, and automation of activities on site, it can be concluded that the respondents' experience is atypical of that experienced in South African construction, and that there is a need for the implementation of Industry 4.0.

In light of the respondents' self-rating of their awareness of / exposure to four Industry 4.0 technologies, it can be concluded that there is a need for interventions by government, statutory bodies, and tertiary education programmes to raise the level of awareness, and to integrate such technologies into built environment / construction education and training.

It can be concluded that there is a need for the implementation of Industry 4.0 in construction given the potential of Industry 4.0 technologies to improve H&S performance.

Taking into account the potential of Industry 4.0 technologies to improve H&S-related interventions / goals, it can be concluded that the implementation of Industry 4.0 in construction has the potential to achieve the desired H&S goals in terms of observation, supervision, real time monitoring, monitoring of worker activities, HIRAs, monitoring of worker safety, H&S training, improvement of working conditions, reduced occurrence of H&S incidents / accidents, monitoring of worker health, and automation of activities on site.

Given the potential that virtual reality could improve H&S performance aspects in terms of assisting designers to identify potential design process-related hazards on site, enabling workers to identify potential hazards and mitigate risks on site, and H&S training, it can be concluded that there is a need for the implementation of Industry 4.0 related technologies.

Given the potential that augmented reality could improve H&S performance aspects in terms of assisting workers to identify potential design process-related hazards on site, it can be concluded that there is a need for the implementation of Industry 4.0 related technologies.

Given the potential that drones could improve H&S performance aspects in terms of real time monitoring of construction activities and improve HIRAs before activities commence on site, it can be concluded that there is a need for the implementation of Industry 4.0 related technologies.

Given the potential that wearable technology / sensors to mitigate the hazards and risk accompanying the handling of heavy plant, equipment, and materials, it can be concluded that there is a need for the implementation of Industry 4.0 related technologies.

Industry 4.0 technologies such as VR, AR, drones, and wearable technology / sensors have the potential to contribute to resolving many of the H&S challenges experienced in construction.

Recommendations

Statutory built environment councils, construction employer associations, and built environment associations should promote Industry 4.0 by raising the level of awareness relative to the potential implementation of Industry 4.0 in terms of H&S in construction, through evolving guidelines and practice notes that are in line with continuing professional development (CPD).

Researchers should actively conduct and document Industry 4.0 case studies to record the benefits of implementing Industry 4.0 technologies where the findings are shared with the relevant bodies.

Built environment-related tertiary education should integrate Industry 4.0 into all possible modules in their programmes, especially H&S-related modules.

The Construction Industry Development Board should evolve a position paper relative to Industry 4.0 and its impact on H&S in construction, and deliberate the development of a related industry standard.

References

Alizadehsalehi, S., Asnafi, M., Yitmen, I. & Celik, T. 2017, ‘UAS-BIM based real-time hazard identification and safety monitoring of construction projects’, *The 9th Nordic Conference on Construction Economics and Organization proceedings*, Göteborg, Sweden, 13-14 June 2017, Lyngby, Sweden: Polyteknisk Forlag, pp. 22-32.

Ananthanarayan, S. & Siek, K.A. 2010, Health sense: A Gedanken Experiment on Persuasive Wearable Technology for Health Awareness, *The 1st Association for Computing Machinery (ACM) International Health Informatics Symposium*, Arlington, Virginia, USA, 11-12 November 2010, Ney York: ACM, pp. 400-404.

Awolusi, I., Marks, E. & Hallowell, M. 2018, ‘Wearable technology for personalized construction safety monitoring and trending: Review of applicable devices’, *Automation in Construction*, vol. 85, pp. 96-106.

Borck, N.C. 2018, ‘Using Drones to Monitor Construction Safety’, *Laborers' Health & Safety Fund of North America*, vol. 15, no. 3, Available: https://www.lhsfna.org/index.cfm/lifelines/august-2018/using-drones-to-monitor-construction-safety/ [Accessed 21 April 2019].

Çiçek, M. 2015, ‘Wearable technologies and its future applications’, *International Journal of Electrical, Electronics and Data Communication*, vol. 3, no. 4, pp. 45-50.

Construction Industry Development Board (cidb). 2009, *Construction Health & Safety Status & Recommendations*, cidb, Pretoria.

Department of Labour (DoL). 2013, ‘Lack of management and poor workmanship leads to injuries and fatalities in SA construction sector’, [online]. Pretoria: DoL, available from: https://www.gov.za/speeches/sa-construction-sector-9-mar-2017-0000 [accessed 13 October 2019]

Gheisari, M. & Esmaeili, B. 2016, ‘Unmanned aerial systems (UAS) for construction safety applications’, *The Construction Research Congress 2016: Old and New Construction Technologies Converge in Historic San Juan proceedings*, San Juan, Puerto Rico, 31 May-2 June 2016, *American Society of Civil Engineers (ASCE)*, pp. 2642-2650.

Hermann, M., Pentek, T. & Otto, B. 2016, ‘Design principles for Industrie 4.0 Scenarios’, *The 49th Hawaii International Conference on System Sciences (HICSS) proceedings*, Koloa, Hawaii, 5-8 January 2016, IEEE, pp. 3928-3937.

Le, Q.T., Pedro, A., Lim, C.R., Park, H.T., Park, C.S. & Kim, H.K. 2015, ‘A framework for using mobile based virtual reality and augmented reality for experiential construction safety education’, *International Journal of Engineering Education*, vol. 31, no. 3, pp. 713-725.

Machek, E., Frazier, J., Ingles, A. & Morton, T. 2016, ‘*Wearable Sensors in Transportation - Exploratory Advanced Research Program Initial Stage Investigation’*, Federal Highway Administration Office of Corporate Research, McLean.

Mandal, S. 2013. ‘Brief introduction of virtual reality & its challenges’, *International Journal of Scientific & Engineering Research*, vol. 4, no. 4, pp. 304-309.

McMillan, K., Flood, K. & Glaeser, R. 2017, ‘Virtual reality, augmented reality, mixed reality, and the marine conservation movement’, *Aquatic Conservation: Marine and Freshwater Ecosystems*, vol. 27, Iss. S1, pp. 162-168.

Nath, N.D., Akhavian, R. & Behzadan, A.H. 2017, ‘Ergonomic analysis of construction worker's body postures using wearable mobile sensors’, *Applied Ergonomics*, vol. 62, pp. 107-117.

Park, C.S. & Kim, H-J. 2013, ‘A framework for construction safety management and visualization system’, *Automation in Construction*, vol. 33, pp. 95-103.

Park, C.S., Lee, D.Y., Kwon, O.S. & Wang, X. 2013, ‘A framework for proactive construction defect management using BIM, augmented reality and ontology-based data collection template’, *Automation in Construction*, vol. 33, pp. 61-71.

Sacks, R., Perlman, A. & Barak, R. 2013, ‘Construction safety training using immersive virtual reality’, *Construction Management and Economics*, vol. 31, no. 9, pp. 1005-1017.

Seo, J., Han, S., Lee, S. & Kim, H. 2015, ‘Computer vision techniques for construction safety and health monitoring’, *Advanced Engineering Informatics*, vol. 29, no. 2, pp. 239-251.

Silliker, A. 2018, ‘Virtual reality shakes up safety training’, [online]. *Canadian Occupational Safety Magazine*, Canada: Canadian Occupational Safety, available from: https://www.cos-mag.com/personal-process-safety/36967-virtual-reality-shakes-up-safety-training/ {Accessed 13 October 2019]

Tatum, M. C. & Liu, J. 2017, ‘Unmanned aerial vehicles in the construction industry’, *The 53rd ASC Annual International Conference proceedings*, Seattle, Washington, USA, 5-8 April, Associated Schools of Construction, Fort Collins, pp. 5-8.

The Council for Scientific and Industrial Research (CSIR). 2018, *Industry 4.0*, PLM Centre of Technology, CSIR, Pretoria.

Wang, P., Wu, P., Wang, J., Chi, H.-L. & Wang, X. 2018, ‘A critical review of the use of virtual reality in construction engineering education and training’, *International Journal of Environmental Research and Public Health*, vol. 15, no. 6, pp. 1204-1222.

CRITICAL RISK FACTORS IN PRICING OF CONSTRUCTION RESOURCES OF SME CONSTRUCTION FIRMS IN GHANA

Ernest Kissi[1], Peter Amoah[1], Divine Kwaku Ahadzie[2], Caleb Debrah[1]

[1]Department of Construction Technology and Management, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

[2] Centre for Settlement Studies, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

ABSTRACT

The construction industry is embedded with risky situations that affect construction projects and therefore requires systematic processes to achieve project objectives and ensure business sustainability. In achieving project and business objectives, contractors usually experiment many techniques and management practices in addressing construction pricing risk. The aim of this study is to examine critical risk factors in pricing of construction resources of SME construction firms**.** To achieve the aim of the study, a quantitative research method was adopted where questionnaire was administered to professionals (Quantity Surveyors) with D3K3 and D4K4 construction firms. The quantitative data was analyzed with factor analysis. The results of the analysis of the risk factors were grouped under three categorizations: fiscal risk factors, engineering and environmental risk factors and human and socio-economic risk factors. It is suggested that pricing experts should consider these risks in the pricing in order to reduce unforeseen implications associated with the outcome. The implication of this study is that it will help pricing experts in safeguarding future cost implications as a result of the associated risk. This study critically considers the views of quantity surveyors in the construction industry, it is therefore recommended that further studies should take into consideration the views of other key stakeholders in the construction industry.

Keywords: SME, construction resources, risk factors, pricing

Introduction

According to Ofori (2006) the construction sector is a critical part of the economy of most countries. The construction sector forms an important aspect in the socio-economic direction of emerging economies. For instance, in various emerging economies, construction activities are responsible for about eighty percent (80%) of gross equity assets, ten percent (10%) of Gross Domestic Product (GDP) and over fifty percent (50%) of wealth invested in fixed assets. Probably next to agriculture, the construction industry has been a major source of massive employment opportunities in Ghana (Ofori, 2006). The Ghana Statistical Service (2015) published the revised GDP (2014) in January 2015 which indicated that, of all the industrial activities, the construction subsector recorded the highest growth rate of 7.4% in 2014, contributing up to 12.3% to Ghana's GDP, only second to the crop sector of the Agricultural industry with 15.2%. Moreover, the foundation of a higher growth rate most countries rests on a sound and efficient infrastructural development which makes the construction sector a key sector. The rapid expansion of infrastructure by both government and the private sector has triggered off construction activities and fuelled demand in many key sectors like cement, steel, paints and chemicals, glass, timber and earth moving equipment and machinery. The construction sector therefore remain a crucial industry having strong backward and forward growth linkages. It deals with all economic activities directed to the creation, renovation, repair or extension of fixed assets in the form of buildings, land improvements of an engineering nature. The unique nature of construction industry and how work is organised, makes contracting different from other industries. This is mainly as a result of peculiar factors relating to economic, contractual, political and physical environments within which products are manufactured. They include: necessity to price product before production, competitive tendering, low fixed-capital requirements, preliminary expenses, delay in cash-inflows, tendency to operate with too low a working capital, seasonal effects, fluctuations and their effects, government intervention, activity related to development, uncertain ground conditions, unpredictable weather, no performance liability or long-term guarantees, etc (Hughes and Hillebrandt, 2003).

In construction projects, it is virtually impossible to record a zero risk. Risk is inherent in all construction activities. The inherent nature of risks contributes to its inability to achieving the triple constraint factors of time, budget, and quality objectives (Loosemore *et al.,* 2012). Construction projects can be very complex and full of uncertainties. The risks and uncertainties can have potentially harmful effects on projects (Flanagan et al., 2006). Construction projects are affected by many risks that must be assessed and accounted for in tenders. Otherwise, a construction enterprise may suffer a tremendous loss and eventually fail. However, in practice, contractors may be unable or unwilling to make appropriate allowances for the risk. Formal risk models that contractors can incorporate into the bidding process have proliferated in recent years, but they are not used in practice. Introducing more models may, therefore, not necessarily help. A better understanding is needed of how contractors arrive at a price, and how that price is influenced by the apportionment of risk (Laryea and Hughes, 2006). Using the Ghanaian Construction sector, this study sought to identify the critical risks factors in pricing construction resources based on the perspective of SME construction firms.

Previous studies

The risk factors in construction business is very high. Construction objects are unique and built only once. Construction object's life cycle is full of various risks. Risks come from many sources: temporary project team that is collected from different companies, construction site, etc. Moreover, the size and complexity of construction objects are increasing which adds to the risks. This is in addition to the political, economic, social conditions where the object is to be undertaken (Zavadskas, et al., 2010). This question is the starting point for an ethnographic investigation into how contractor's price risks (Laryea and Hughes, 2006). The purpose is to identify the critical risk factors in pricing of construction resources in construction projects for the purpose of contingency allocation in a risk and reward sense. Construction risks are often perceived as events that influence the traditional project triple constraint objectives of time, cost, and performance (including quality) within the period of construction. Quite often, construction contractors are unable to effectively price for the risk in construction projects. Common risks contractors face include weather, unexpected job conditions, personnel problems, inflation, price fluctuations, errors in cost estimating and scheduling, delays, financial difficulties, workmen strikes and agitations, faulty materials, cash flow, contractual disputes, faulty workmanship, poor supervision, new regulations and legislation, operational problems, currency exchange rates, inadequate designs and specifications, politics, disaster, etc. (Ofori, 2006; Laryea *et al.,* 2007). Project Management Book of Knowledge (2013) classified risk factors in terms of their initial sources: the external and internal aspects of a construction project. The external risks are those changeable factors that relate to the national/regional market or the local construction industry which have significant impacts on the project. The internal risks are those uncertainties inherited by the companies involved or determined by the project's own nature. At the national or regional level, the risk factors can be classified into three categories: the political situation, the economic and financial situation, and the social environment. The risk factors at the construction industry level can be divided into four sub levels: construction market fluctuations, changes in construction law and regulations, differences in construction standards and codes, and differences in construction contract systems. Type of materials, their availability and the selection time are critical risk factors when it comes to material issues (Altoryman, 2014). Shortage of workface and the existence of unskilled labor are risk factors in relation to labor issues (Altoryman, 2014).

Tower and Baccarini (2008) conducted an interview survey in Perth, Australia by coming out with this report where interviewees were asked: who was involved in the process of pricing for risk? (online respondents were not asked this question). All respondents indicated that executive management was ultimately responsible for determining the price of risk, which usually occurs during a tender review or adjudication meeting. As Murdoch and Hughes (2008) and Brook (2016) contend that tender adjudication meetings are usually attended by those who have played a significant part in preparing the estimate and representatives from senior management. Akintoye and Fitzgerald (2000) also found that approval of tender sums for both small and large projects is undertaken by senior management.

The value of projects tends to have a relationship with the number of people involved in pricing for risk. Construction organizations tendering for projects less than $5 million may have as few as two people involved in the pricing of risk, the primary persons being the estimator and executive manager. If necessary, other members of the organization such as additional executive managers, contract managers or site managers may also be involved (Tower and Baccarini, 2008). A common terminology for the financial amount allocated for risk in tenders is a contingency sum (Burger, 2003). The main purpose of a contingency sum is counteracting the risks that may occur in the course of a construction project (Ford, 2002). Wang and Liu (2004) disclosed risks factors in pricing construction resources from their survey result and one of the risks, "price inflation of construction materials", is identified to be related to external environment. The price of construction materials is always changing in response to the inflation and the relation between supply and demand in the construction material market. As this risk is usually unavoidable, clients should choose an appropriate type of contract such as lump sum to transfer the risk to other parties; while contractor should always avoid using fixed price contracts to bear the risk. One fair way to deal with the potential price fluctuation is to add the contingency premium (Wang and Liu, 2004). Delay means loss of income to the owner or client. In the case of a contractor, delay refers to the higher costs due to longer work time, labor cost increase and higher fabrication costs. On time completion of project is an indicator of efficiency. But there are many unpredictable factors and variables resulting from various sources affecting construction projects. Some main sources of delays in projects are the involvement and performance of parties, contractual relations, environmental and site conditions, resources availability etc. (Faridi and El-Sayegh, 2006). According to Mishra and Regmi (2017), project delay was found to be one of the major effects of price increase. Delay caused by the contractors affects the contractor by making them vulnerable to effects of price increase. Among the common causes of project delays is the weather which is consistently rated as very frequent and harmful (AlSehaimi and Koskela, 2008). Weather can impact construction projects in multiple ways: by decreasing productivity and sometimes halting construction (Rogalska *et al.*, 2006); by ruining unprotected and exposed constructed elements (El-Rayes and Moselhi, 2001), by disrupting communications and/or blocking access to site locations. The impact of (adverse) weather is a common cause of delay leading to legal claims and economic losses in construction projects (Ballesteros-Perez *et al.*, 2018). In addition, fluctuations in the costs of construction resources in today's volatile market makes it difficult to execute construction projects due to significant losses or erosion of anticipated profits (Mishra and Magar, 2017). Mishra and Regmi (2017) posited that, sharp price increases leads to failure to complete projects within the acceptable margin of time and quality for the client and the failure to complete within the planned cost margin for them (Mishra and Magar, 2017). This, however, appears to be an uphill task given the incidence of inflation presently ravaging developing economies of the world. Inflationary increase in the price of construction materials has been one of the major banes to development and a contributing factor to frequent cost overruns and subsequently project abandonment (Oghenekevw *et al.*, 2014). According to Obiegbu (2003), the construction industry is vulnerable to inflation in prices of materials. Material resources are seen as the heart and life wire of any construction system. This simply means that the increase in the cost of materials will affect the total cost of construction and subsequently housing supply in no small measure (Nwachukwu, 2004). Cost estimation is an important part of project planning. Over the year's different approaches have developed, taking uncertainty into account in the cost estimation processes in order to tackle the dynamic nature of projects. However, when implementing these approaches, some challenges have been revealed. The aim in a cost estimation process is to establish a realistic overview of the total project costs and its uncertainties. Even though tools and methods for taking uncertainty into account are implemented, projects with cost overruns are often seen (Torp and Klakegg, 2016). Exchange rate is the price of domestic currency in terms of another countries currency. The worth of a nation's currency depends on several factors including the state of the economy, the competitiveness of the exports, the level of domestic production and the quantum of her foreign reserves. The objectives of exchange rate are to preserve the value of the domestic currency, maintain favorable external reserve position and ensure price stability (Ahuja, 2013). Construction projects are a high-risk business activity. When undertaking projects in an international context, it is further complicated by the risk of fluctuations in the foreign exchange rates. Construction business performance is affected by these fluctuations. They affect progress and cause delays, which in turn create problems for subcontractors like cost overruns, disputes, arbitration, total abandonment and litigation. Fluctuations also cause the price of raw materials to increase, leading to cost overruns (Mohd *et al.*, 2013).

Research methodology

The study adopted quantitative research method. This approach allows for the use of structured questionnaire surveys and enables researchers to generalise their findings from a sample of a population (Creswell, 2014). First, an extensive literature review was conducted on critical risk factors in the pricing of construction resources. The risk factors identified from this was used to develop a pilot questionnaire which was shared among a restricted number of professionals to assess clarity, focus and level of depth of the questions. Following this, quantitative questionnaire was developed based on rating (Likert items) and administered to professionals (quantity surveyors) working with D3 K3 and D4 K4 construction firms in Ghana. Respondents were asked to rate the risk factors based on a Likert scale of 1 to 5 where 1 – Very low, 2 – Low, 3 – Medium, 4 – High and 5 – Very high. For each construction firm a quantity surveyor, was considered. In all, a total of 80 questionnaires were administered and 60 were retrieved for analysis representing a response rate of 75%. This response for the study was considered as adequate for the research. Burns and Grove (2001), posited that a minimum of 30 subjects as a sample size can be used but describes 30 subjects as inadequate as a sample size for most research work. The respondents have long standing experience in the industry, for instance, 50% of the respondents had 5-10 years of experience and 50% had 15-20 years of experience. All the respondents for the study have enough and adequate experience in the construction industry. Confidence can therefore be reposed in their responses.

Data analysis

A list of factors (fourteen factors) were identified and two statistical approaches were used for the analysis. Mean score analysis was initially conducted to determine the importance of each variable relative to each other. From Table 1, all the risk factors had a mean average above 2.00 and with standard deviation below one (indicating high level of agreement among the respondents).

Table 1: Risk factors in pricing of construction resources

No	Risk Factors	Mean	Std. Deviation	Rank
1.	Higher costs due to longer work time, labor cost increase and higher fabrication costs as a result of construction delays	3.13	0.747	**1st**
2.	The impact of adverse weather conditions on construction resources	3.10	0.969	**2nd**
3.	Unexpected job conditions	3.05	0.699	**3rd**
4.	Personal problems or human errors when pricing construction resources	3.03	0.991	**4th**
5.	Inflationary increase in the price of construction materials	2.93	0.039	**5th**
6.	Price fluctuations in the costs of construction resources	2.82	0.854	**6th**
7.	Errors in cost estimating and scheduling	2.73	0.148	**7th**
8.	Poor financial analysis	2.68	0.049	**8th**
9.	Workmen strikes and agitations	2.58	0.944	**9th**
10.	The risk of fluctuations in the currency exchange rates that causes the price of raw materials to increase	2.43	0.927	**10th**
11.	Poor cash flow forecast	2.40	0.694	**11th**
12.	New regulations and legislation	2.20	0.953	**12th**
13.	Inadequate designs and specifications	2.18	0.892	**13th**
14.	Differences in construction standards and codes	2.05	0.928	**14th**

Following this, factor analysis was conducted aiming at reducing many variables into an easier understanding framework (Samuels, 2016). According to Pallant and Manual (2007), for this analysis, Kaiser-Meyer-Olkin (KMO) and Bartlett's tests, correlation matrix, communalities, principal component analysis and the component matrix are reported. In order to carry out factor analysis, two tests are initially done: KMO and Bartlett's tests. The essence of KMO is to determine the level of interrelation among the variables and the suitability of factor analysis (Netemeyer *et al.*, 2003). The measure for KMO ranges within 0.5-0.6, considered as poor, 0.6 – 0.7 as average, 0.7 – 0.8 are considered good, 0.8 – 0.9 are considered great and those above 0.9 are known to be magnificent (Field, 2005). The KMO for the risk factors is 0.761 which was considered good (Table 2). The Bartlett's test provides a null hypothesis that the original correlation is an identity matrix. This is being reflected in factor analysis when the significant value or p-value is greater than 0.05 thus for factor analysis to work, there should be some relationships among the variables. Where the R-matrix is found to be an identity matrix, all the correlation coefficients would be zero, hence it is needful for the significant value to be less than 0.05 and this will signify that the R-matrix is not an identity matrix, thus the existence of some form of relationship among the variables. From Table 2 below, the Bartlett's test is deemed highly significant since $p < 0.001$, hence factor analysis is appropriate.

Table 2: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.761
Bartlett's Test of Sphericity	Approx. Chi-Square	334.146
	Df	91
	Sig.	.000

The determinant or the R-matrix should also be greater than 0.00001 according to Field (2005) to prevent the values of variables that correlates very high ($R > 0.8$) from being excluded. The determinant for the correlation matrix for the risk factors faced in pricing of construction resources analysis is 0.002 which is greater than the limit hence deemed appropriate. According to Ahadzie (2007), the communality is used to determine how much an original variable is related to other variables. Field (2005) stated that for all the variable to be adequate to go through factors, then the variables must have their extraction values greater than 0.5. All the variables exceeded the limit of 0.5. From Table 3, the components to be created can be deduced based on the eigenvalues. In accordance with the Kaiser criterion, the component must have eigenvalues greater than or equal to 1.00.

Table 3: Total Variance Explained

Component	**Initial Eigenvalues**			**Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings**		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	5.290	37.789	37.789	5.290	37.789	37.789	3.430	24.503	24.503
2	1.669	11.921	49.710	1.669	11.921	49.710	2.824	20.170	44.673
3	1.231	8.791	58.501	1.231	8.791	58.501	1.936	13.828	58.501
4	0.985	7.037	65.537						
5	0.895	6.396	71.933						
6	0.741	5.292	77.225						
7	0.663	4.738	81.963						
8	0.567	4.047	86.010						
9	0.535	3.822	89.831						
10	0.448	3.200	93.031						
11	0.333	2.377	95.408						
12	0.255	1.824	97.232						
13	0.237	1.693	98.925						
14	0.151	1.075	100.000						

The factors extracted explained the variables by almost 59%. Table 4 represents the rotated component matrix showing the variables under each component. Each of the components denote the variables of common relations. This is to say that all the variables under a component are interrelated. From Table 3, all the three components sum up to 58.501% of the variance. The 3 components created represents 58.501% of the whole data as indicated in the Rotation sum of Squared Loadings in Table 4. It is evident in Table 4 that three factors were formed containing fourteen (14) variables.

Table 4: Rotated Component Matrix[a]

No	Risk factors	Component		
		1	2	3
1.	Higher costs due to longer work time, labor cost increase and higher fabrication costs as a result of construction delays	**0.603**		
2.	The impact of adverse weather conditions on construction resources		**0.816**	
3.	Unexpected job conditions		**0.535**	
4.	Personal problems or human errors when pricing construction resources			**0.799**
5.	Inflationary increase in the price of construction materials			**0.463**
6.	Price fluctuations in the costs of construction resources	**0.588**		
7.	Errors in cost estimating and scheduling	**0.643**		
8.	Poor financial analysis	**0.870**		
9.	Workmen strikes and agitations		**0.511**	
10.	The risk of fluctuations in the currency exchange rates that causes the price of raw materials to increase	**0.537**		
11.	Poor cash flow forecast	**0.741**		
12.	New regulations and legislation			**0.717**
13.	Inadequate designs and specifications		**0.711**	
14.	Differences in construction standards and codes		**0.701**	

Extraction Method: Principal Component Analysis., Rotation Method: Varimax with Kaiser Normalization. a. Rotation converged in 4 iterations.

Component 1: Fiscal Risk factors

Fiscal risk factors are the economic risks that affect pricing of construction resources. From Table 4, this cluster represents 37.789% of the variance. The categorized risk factors agree with Mohd et al. (2013) and Mohamed et al., (2013) who argued that price fluctuations is a major factor risk in the pricing of construction resources which needs to assessed by professionals when pricing.

Component 2: Engineering and Environmental Risk factors

The second component also had five risk factors as its variables with a total composition of the variance as 11.921%. The constituent variables include *the impact of adverse weather conditions on construction resources, Inadequate designs and specifications, Unexpected job conditions, Differences in construction standards and codes and Workmen strikes and agitations.* Rogalska et al. (2006) agreed that weather can impact construction projects. Laryea et al. (2007) and Ofori (2006) identified other risks to include workmen strikes and agitations, inadequate designs and specifications. Other categorized risks are differences in construction standards and codes (PMBoK, 2013). These critical risk variables are seen to be associated with the engineering and environmental risks connected with pricing of construction resources.

Component 3: Human and Socio-Economic Risk factors

The third component which is termed the Human and Socio-Economic Risk factors constituted three variables. The composition of the variables was *personal problems or human errors when pricing construction resources, inflationary increase in the price of construction materials and new regulations and legislation.* This component also represented 8.791% of the whole variance. The Social Economic Risk factors emerged second based on the average of variable means, thus 2.753. Obiegu (2003) and Oghenekevw et al. (2014) identified inflation in prices as a risk factor in construction. Errors in estimating, personnel problems, new regulations and legislation (Laryea et al., 2007; Ofori, 2006), changes in construction law and regulations (PMBoK, 2013) are the risk that was identified to be associated as the human and socio-economic risk factors. The findings of these authors authenticate the findings of the study. It is seen that human blunders and the social factors that are economic in nature have a risk impact on the pricing of construction resources.

Conclusion

This study principally sought to assess the critical risk factors in pricing of construction resources in Ghanaian construction industry. In order to achieve the aim, the objective was set to identify the risk factors that affects pricing of construction resources in Ghanaian construction industry. A critical review of literature was conducted. The quantitative research strategy was adopted. Questionnaires were used to gather data from respondents in D3K3 and D4K4 class of contractors. Statistical Package for Social Sciences (SPSS) software was used for the analysis. Descriptive statistics, factor analysis and mean score ranking were the analytical tools employed for the study. It is evident from the study findings that three categories of risk factors were identified which were *Fiscal risk factors, Engineering and Environmental risk factors; Human and Socio-Economic risk factors*. Furthermore, *price fluctuations in the costs of construction, the risk of fluctuations in the currency exchange that causes the price of raw materials to increase, and personal problems or human errors when pricing construction resources* were the top three risk factors generally identified in the Ghanaian construction industry prior to the categorization as ranked by the respondents. It is recommended that construction Quantity Surveyors must incorporate these risks factors in the pricing of tenders to reduce cost overruns and take care of the unforeseen accompanying these risks. Also, the contingency sum should not just be a standard percentage of the contract sum but should be determined with risk in mind. This would help implement an appropriate compensation mechanism to mitigate or offset the impact of this risk on the financial wellbeing of the Contractor. This study is limited to quantity surveyors with contractors, but future research on this topic should take into consideration the perspectives of other key stakeholders in the Ghanaian construction industry.

References

Ahadzie, D., (2007). A Model for Predicting the Performance of Project Managers in Mass House Building Projects in Ghana. Wolverhampton: PhD Thesis, University of Wolverhampton.

Ahuja, H. L. (2013). *Modern Economics*, *10*(4), 545. New Delhi: S. Chard & Company Pvt. Ltd.

Akintoye, A. and Fitzgerald, E., (2000). A survey of current cost estimating practices in the UK. *Construction Management & Economics*, *18*(2), pp.161-172.

AlSehaimi, A. and Koskela, L., (2008, July). What can be learned from studies on delay in construction. In *International Group of Lean Construction Conference, Manchester*.

Altoryman, A., (2014). *Identification and assessment of risk factors affecting construction projects in the Gulf region: Kuwait and Bahrain.* Manchester: University of Manchester.

American Association of Cost Engineers (AACE, 2000). International Risk Management Dictionary Cost Engineering, 42 (4), 28-31.

Ballesteros-Pérez, P., Smith, S.T., Lloyd-Papworth, J.G. and Cooke, P., (2018). Incorporating the effect of weather in construction scheduling and management with sine wave curves: application in the United Kingdom. *Construction Management and Economics*, *36*(12), pp.666-682.

Barlish, K., De Marco, A. and Thaheem, M. J., (2013). Construction risk taxonomy: An international convergence of academic and industry perspectives. *American Journal of Applied Sciences*, *10*(7), pp.706-713.

Brook, M., (2016). *Estimating and tendering for construction work*. Routledge.

Burger, R., (2003). Contingency, quantifying the uncertainty. *Cost engineering*, *45*(8), p.12.

Burns, N. and Grove, S., (2001). *"The practice of nursing research: conduct, critique and untilization"*. 4th ed. Philadelphia: WB Saunders.

El-Rayes, K. and Moselhi, O., (2001). Impact of rainfall on the productivity of highway construction. *Journal of construction engineering and management*, *127*(2), pp.125-131.

Faridi, A.S. and El-Sayegh, S.M., (2006). Significant factors causing delay in the UAE construction industry. *Construction Management and Economics*, *24*(11), pp.1167-1176.

Field, A., (2005). Factor analysis using SPSS. *Retrieved March 17*, p.2009.

Flanagan, M.E., Seixas, N., Becker, P., Takacs, B. and Camp, J., (2006). Silica exposure on construction sites: results of an exposure monitoring data compilation project. *Journal of occupational and environmental hygiene*, *3*(3), pp.144-152.

Ford, D.N., (2002). Achieving multiple project objectives through contingency management. *Journal of Construction Engineering and Management*, *128*(1), pp.30-39.

Ghana Statistical Service (2015). Ghana Statistical Service Annual Gross Domestic Product – 2014. Available online via https://statsghana.gov.gh/gssmain/ fileUpload/National%20Accounts/2015_Annual_GDP_September_2015_Edition.pdf [Accessed 29th June, 2019]

Ghosh, S. and Jintanapakanont, J., (2004). Identifying and assessing the critical risk factors in an underground rail project in Thailand: a factor analysis approach. *International Journal of Project Management*, *22*(8), pp.633-643.

Hughes, W.P. and Hillebrandt, P.M., (2003). Construction industry: historical overview and technological change.

Jarkas, A.M. and Haupt, T.C., (2015). Major construction risk factors considered by general contractors in Qatar. *Journal of Engineering, Design and Technology*, *13*(1), pp.165-194.

Laryea, S., Badu, E. and Dontwi, I., (2007). *The price of risk in construction projects: contingency approximation model.*. Singapore, Central Archive at the University of Reading.

Laryea, S. and Hughes, W., (2006). *The price of risk in construction projects.* Birmingham, University of Reading.

Loosemore, M., Raftery, J., Reilly, C. and Higgon, D., (2012). *Risk management in projects*. Routledge.

Mishra, A. and Magar, B., (2017). Implementability Of Municipal Transport Master Plan Of Bandipur Inner Ring Road. 6(8), pp. 306-.

Mishra, A.K. and Regmi, U., (2017). Effects of Price Fluctuation on the Financial Capacity of "Class A" Contractors. *Internafional Journal of Creafive Research Thoughts*, *5*(4), pp.1920-1937.

Mohamed, M.A.B., Trigunarsyah, B., Teo, M. and Kajewski, S., (2013). The impacts of forex fluctuations on construction business performance: an organisational capabilities perspective. In *Proceedings of the Seventh International Conference on Construction in the 21st Century: Challenges in Innovation, Integration and Collaboration in Construction and Engineering* (pp.2-2).

Mohd, A. B. M., Trigunarsyah, B., Teo, M. and Kajewski, S., (2013). The Impacts of FOREX Fluctuations on Construction Business Performance: An Organisational Capabilities Perspective. *Seventh International Conference on Construction in the 21st Century (CITC-VII) "Challenges in Innovation, Integration and Collaboration in Construction & Engineering"* , 19-21 December .

Murdoch, J. and Hughes, W. (2008) *Construction contracts*, 4ed, London: Taylor & Francis.

Netemeyer, R.G., Bearden, W.O. and Sharma, S., (2003). *Scaling procedures: Issues and applications*. Sage Publications.

Nwachukwu, G., (2004). The Impact of Materials Management on Projects Profitability and Corporate survival.. *NIQS Quarterly Journal,* 6(47), p. 12 – 14.

Obiegbu, M., (2003). *Effective project delivery in Nigerian Construction Industry.* Anambra: Rex Charles and Patrick Ltd.

Ofori, G., (2006). “Construction in developing countries: A research agenda”. *Journal of Construction in Developing Countries.* .
Oghenekevwe, O., Olusola, O. and Chukwudi, U.S., (2014). An assessment of the impact of inflation on construction material prices in Nigeria. *PM World Journal*, *3*(4), pp.1-22.
Olatunji, O.A., Orundami, A.O. and Ogundare, O., (2018). Causal relationship between material price fluctuation and project’s outturn costs. *Built Environment Project and Asset Management*, *8*(4), pp.358-371.
Pallant, J. and Manual, S.S., (2007). A step by step guide to data analysis using SPSS for windows. In *SPSS Survival Manual*. Open University Press.
PMBoK, A., (2013). A guide to the project management body of knowledge (PMBOK guide). *Project Management Institute, Inc*.
Rogalska, M., Czarnigowska, A., Hejducki, Z. and Nahurny, T., (2006). Methods for determining the duration of construction processes taking into account weather risk factors. *Construction review*, *77*, pp. 37-42.
Samuels, P., (2016). Advice on exploratory factor analysis. *Birmingham City University: In Progress. doi*, *10*.
Tah, J.H. and Carr, V., (2000). A proposal for construction project risk assessment using fuzzy logic. *Construction Management & Economics*, *18*(4), pp.491-500.
Torp, O. and Klakegg, O. J., (2016). Challenges in Cost Estimation under Uncertainty. *A Case Study of the Decommissioning of Barsebäck Nuclear Power Plant*, 6(14), pp. 1-21.
Tower, M. and Baccarini, D., (2008). Risk pricing in construction tenders-how, who, what. *Construction Economics and Building*, *8*(1), pp.49-60.
Wang, J. and Liu, C., (2004). *Risk Management for Construction Projects,* Beijing: China: Water Publication.
Zavadskas, E. K., Turskis, Z. and Tamošaitiene, J., (2010). Risk assessment of construction projects. *Journal of Civil Engineering and Management*, 1(16), pp. 33-46 .

PARTNERSHIP PEDAGOGY PATHWAYS FOR THE FIRE PROTECTION INDUSTRY INTO MAINSTREAM POST-GRADUATE PROGRAMS.

Grahame Douglas[1], Swapan Saha[1]

[1]School of Computing, Engineering and Mathematics, Western Sydney University, Sydney, Australia.

Abstract

In Australia, the fire protection industry provides an essential service in the safety of residences and workplaces from the potential impacts of building fires. The industry is characterised by many thousands of small-medium enterprises. The professional industry body is the Fire Protection Association of Australia which has a national reach of 1,500 businesses with a cohort of 30,000 individuals who are serving the fire protection industry. Government inquires and reviews have consistently identified the need for improved education and compliance for the building sector and for fire safety design in particular. From October 2017, the NSW government introduced requirements for competent persons to operate under a fair trading regulatory model within the fire protection industry. The existing cohort is largely trade qualified and the intention of the regulator is to provide for industry to accredit fire safety practitioners in areas of design, installation, servicing and auditing or fire safety systems in buildings. Western Sydney University has embarked on a blended learning platform for the delivery of three core industry competencies to support industry standards and as a pathway to entry into a possible fire safety design post-graduate program based on demonstrated knowledge and workplace experience. This project aims to develop a platform in collaboration with the FPAA and NSW Fire and Rescue using a collaborative and partnership pedagogy framework in which the FPAA and Western Sydney University will provide a micro-credential which can be used in conjunction with other formal training in support of regulatory expectations and industry needs. This project also illustrates that this sort of program can be used to improve the knowledge and understanding of other professionals in the building sector including architects, engineers, building managers and certifiers.

Keywords

Fire protection, blended learning, building, partnership pedagogy, micro-credential.

Introduction

The fire protection industry is an important aspect of the construction industry and provides essential fire safety services for class 2-9 buildings under the National Construction Code (ABCB 2019). Recent inquiries into the construction sector has identified major limitations with the delivery of building works, including those associated with fire safety in Australia (Lambert 2015, Shergold and Weir 2018).

The failure to address fire safety provisions can have both potentially fatal outcomes as well as significant cost implications for future residential where safety systems, including fire safety, have not been adequately addressed. In 2012, a fire in a Bankstown apartment block which did not conform to the NCC, resulted in the death of one woman and serious injuries for another when they attempted to jump from a fire in their unit (Lambert 2015).

In Australia, fire protection systems are designed either to comply with the deemed-to-satisfy provisions of the NCC or may be designed in accordance with the performance provisions of the NCC by qualified fire safety engineers. However, fire safety engineers may not be involved in the actual installation of these systems.

Since 2016, the industry has, through the Fire Protection Association of Australia, sought to improve the quality of design, installation, maintenance and auditing of the fire protection practitioner through its FPAS accreditation scheme. (FPAA, 2019).

The Fire Protection Association of Australia (FPAA) has a national reach of 1,500 businesses with a cohort of 30,000 individuals who are serving the fire protection industry, with many more individuals operating outside the Association. From 1 October, 2017 the NSW Government has introduced a requirement for 'competent persons' to operate under the 'fair trading' regulatory arrangements. This could be extended to other jurisdictions. This regulatory framework has introduced a requirement for both customer protection and accreditation associated with the delivery of this essential service. The nature of the industry is that it has developed in an ad hoc fashion with government now requiring improved standards of customer protection and safety. Operators interact with building surveyors and engineers (including civil, mechanical and fire safety engineers) as well as architects, building managers and residents.

Since major fires have occurred at Docklands in Victoria (Lambert 2015) and more significantly with the loss of life in Grenfell (UK) (Shergold and Weir 2015), building owners, body corporates, project managers as well as designers and certifiers are seeking to improve their skills in fire protection. The provision of appropriate and relevant levels of education is therefore needed, as well as pathways for progression within the construction industry and regulatory framework being adopted by both industry players and regulators alike.

To assist the construction industry and the community, Western Sydney University has embarked on the development and implementation of an educational framework which is tailored to the current skill set of the industry, as well as providing pathways for para-professional skills and competencies. This framework is based on the National Training Package *Diploma of Fire Systems Design* (Training.gov.au) under the 21C Makerspace program.

This paper considers the implications of public inquiries, reviews and recent regulations which give rise to the development of education strategies for the fire protection industry in NSW (and Australia more broadly). It then considers the pedagogical considerations and pathways being developed by Western Sydney University (WSU) in response to the environmental scan of the construction industry and expectations of the community and government in the delivery of safer buildings in relation to fire safety systems design and operation.

Public Inquiries and Reports

Fire Protection Systems Working Party report: October 2010

In 2006, the NSW Government established a working party to investigate concerns arising from complaints associated with fire protection systems including issues around the development of alternate solutions under the Building Code of Australia (now NCC) (Lambert 2015). The final report released in 2010 identified potential problems with current controls and industry practice in relation to design, approvals, installation, certification and maintenance which warranted further investigation. The issues included quality and adequacy of fire system design, non-complying installation, poor maintenance, and importantly that some fire safety protection practitioners are not up to date in relation to technical knowledge and have an insufficient understanding of the legislative framework which regulates building (including fire safety) in NSW (Lambert 2015).

The final report made 20 recommendations, of which two related to industry education and two to national competencies and training. These issues have implications not only for fire safety, but also architecture, building surveying, engineering and construction managers.

Better Buildings Model, 2012.

During 2012, the Buildings Professionals Board (BPB), consulted widely in relation to building regulation and certification. The BPB developed a draft model for expanding the building certification and accreditation system which included improving the design, approval and certification of critical building elements such as fire safety, as well as introducing a broader range of qualified persons who can be accredited by the BPB in relation to specific certification services (Lambert 2015).

Lambert Inquiry, 2015

In August 2015, Mr Michael Lambert, a former head of NSW Treasury, published his *Draft repor:t Independent Review of the New South Wales Building Professionals Act, 2005* (Lambert, 2015) which addressed issues identified over the previous 15 years of building regulatory framework. The report identified that amongst other matters, that the existing system and regulatory arrangements for the fire protection industry required clear competency for those practitioners that are designing, installing, certifying, testing and maintaining fire protection systems and equipment. His final report was published in October 2015 and the NSW Government Response was released in 2016.

Submissions to the draft report indicated general support for improving the regulatory arrangements for fire safety and fire protection in particular. The Fire Protection Association of Australia (FPAA) and other industry bodies indicated that they would be supportive of an accreditation scheme. The FPAA had a voluntary scheme, referred to as FPAS, which is discussed below. The Final Lambert Report (Lambert 2015) proposed that as an early priority, accreditation requirements for the design of fire safety systems be established in association with professional associations, such as the FPAA. This arises in part, due to the identification of gaps and deficiencies in the design, installation, commissioning and maintenance of active fire safety systems, and the poor installation of passive fire protection systems. One of the challenges identified is that home owners are not able to make an assessment about the “competence” of those providing annual fire safety certificates and whether these systems are compliant at occupation.

The report noted that there is ”no accreditation process for parties designing, installing, commissioning or maintaining fire safety systems ..” and as such the certifier cannot rely on nay certificates by a person without identifiable expertise or experience. In essence, fire safety is an area that was not regulated and is of critical importance for the safety of residents and occupants of buildings. The NSW Government’s response to the Lambert Review endorsed the review’s findings in relation to fire safety design and introduced new regulations to address this (NSW Government 2016).

Shergold and Weir Report: 2018

In August 2017, the Commonwealth Government commissioned Peter Shergold (Chancellor of Western Sydney University) and Bronwyn Weir (legal practitioner) to undertake a review of the compliance and enforcement systems for the building and construction sector and included recommendations for the development of a National Best Practice Model to strengthen the National Construction Code (NCC) (Shergold and Weir 2018).

The report identified a range of challenges including:

- Roles, responsibilities and accountabilities
- Education and training

- Licensing and accreditation
- Accuracy of design and documentation
- Competencies of practitioners
- Inspection and auditing.

Recommendation 1 of the report identifies the need for registration of various building practitioners, including architects and fire safety practitioners involved in the design, construction and maintenance of buildings. Recommendation 19 goes to the heart of inspection and certification of fire safety system installation and the need for competent practitioners in the design, installation and certification of fire safety systems. Education, training and ongoing professional development are central themes by Shergold and Weir (2018). The challenge is to identify the nature of the educational/training need and the opportunities for delivery to improve community safety in conjunction with industry.

It is to industry, notably the fire protection industry, to offer pathways which would assist government in delivering on not only the Shergold Weir (2018) recommendations, but also the consistent messages through past working parties and the Lambert Review (2015). This also applies to other building practitioners including architects, engineers and construction managers.

Changes to NSW regulatory requirements

In July 2017, the NSW Government, in response to the recommendations of the Lambert Review, announced new provisions under the *Environmental Planning and Assessment Amendment (Fire Safety and Building Certification) Regulation 2017* which came into force on 1 October, 2017. This regulation established the category of ‘competent fire safety practitioner’ in relation to fire safety design work.

The new regulatory provisions for 'competent fire safety practitioner' (CFSP) allow the NSW Government to recognise existing government accreditations, but also appropriate industry schemes referred to as a co-regulatory accreditation framework and will be administered by NSW Fair Trading.

The Regulation identifies that a competent fire safety practitioner may include:

> (a) A class of person holding a specified category of certificate of accreditation under the Building Professionals Act 2005;
>
> (b) A class of persons holding a specified category of certificate of accreditation under the Building Professionals Act 2005 and having some other characteristic or qualification; or
>
> (c) A class of persons who have undergone particular training or assessment carried out by a specified professional organisation or body or an industry organisation or body.

From January, 2020, the NSW Government has announced plans to formally recognise Fire Safety Assessment and Fire Systems Design under the FPAS scheme (FPAA, 2019a).

Fire Protection Association of Australia (FPAA) and FPAS

The FPAA launched its Fire Protection Accreditation Scheme (FPAS) in July 2013 designed to recognise the skills and competence of individuals working in the area of fire safety. The FPAS scheme seeks to initially cover four classes of individuals being:

- Inspect and test
- Fire System Design
- Fire Systems Certification
- Fire Safety Assessment

The scheme provides for three (3) accreditation pathways being:

- Qualified accreditation
- Transitional accreditation
- Trainee accreditation.

Those using transitional or trainee pathways are required to progress through to the qualified pathway within a period of time so as to complete suitable units of competency.

The objectives of the Scheme are “to specify the:

- scope of the role for each class and category of accreditation
- work activities for each class and category of accreditation
- knowledge, skills and experience required for individuals to be accredited
- application process
- assessment method for accrediting individuals
- insurance requirements for accredited individuals
- code of professional conduct for accredited individuals
- continuing professional development for accredited individuals.” (FPAA, 2019).

The FPAS scheme has identified the knowledge, skills and experience requirements (FPAA, 2019) to address the recommendations of the Lambert Inquiry (2015) and the Shergold-Weir Review (2018) in relation to fire safety system design and fire safety assessment at this stage.

In the light of these issues and the need for WSU to support the fire protection industry, a grant from WSU was sought to develop an educational framework which would address both the regulatory requirements and support the FPAS scheme.

21C Curriculum Makerspace

The “21C Curriculum Makerspace” initiative provides small grants whereby Schools within Western Sydney University were encouraged to undertake an Expression of Interest in developing Flagship Projects for industry partners (WSU, 2018a).

The program seeks to consider a number of key elements when developing and delivering such program including principles associated with:

- Partnership Pedagogy;
- Students as Partners;
- Evidence for the influence, contribution and impact of curriculum design.

It is anticipated that the program will assist students with adaptation strategies so as to address disruptive technologies and construction methods into the future. It should also cater for a pathway for further education within the Higher Education Sector, rather an simply a short course to assist with achieving a VET training outcome.

Partnership Pedagogy

Partnership pedagogy is a central aspect of the 21C project and seeks engagement of industry, community and commercial partners through co-designing, co-developing and co-credentialing in collaboration with a range of internal and external partners.

In the context of the fire protection project, initial discussions occurred through the University's normal external Advisory Committee which modified the original proposal from a post-graduate program to supporting industry through core competencies within the Diploma of Fire Systems Design.

Partners included former graduates working within the industry, the Fire Protection Association of Australia, internal fire safety academics, course designers and other specialists. It was important that the program be developed such that the goals and the course engaged industry.

Students as Partners

Student as Partners should be considered as part of the ongoing global focus on student engagement, however, the offering of the Diploma brought challenges in that such a course had not been previously offered and the only students available arose from post-graduate students in the Masters of Fire Safety Engineering program of at WSU. This also provided an opportunity, as these former students had clear examples of the need for such a course through current employees working with these senior managers and working within the fire protection industry. The identified cohort has existing skills in plumbing, electrical or building trades, many with extensive years of experience built without formal qualifications beyond their existing trade.

Evidence for the influence, contribution and impact of curriculum design.

When considering the content of the program, it was an important consideration to address the role of evidence-based practice which allowed for tailored delivery with a wider contribution to teaching practice. It was found that an important aspect of delivery was the need to provide for a blended learning environment in which on-line resources and assessment could be used, a short period of face to face teaching and group learning environment could be achieved as well as the identification of associated skills needed to demonstrate overall competence. Evaluation of the program (yet to be finalised) would also engage not only with participating students, but industry experts and regulators, seeking to ensure competent fire systems designers.

Therefore, in considering graduate outcomes, the design of the course also addressed:

- Formal learning outcomes;
- The learning experience;
- Learning designs; and
- And learning environments and enablers.

Pathways to Post-graduate programs.

WSU currently provides for four main post-graduate programs at AQF 7 and 8 at Post-graduate Certificate, Post-graduate Diploma and Masters courses (WSU, 2019) in:

- Building surveying,
- Fire safety engineering,
- Bushfire protection, and
- Project management (in conjunction with other fields).

The entry requirements for the Post-graduate Diplomas and Masters programs are highly restrictive, and fire safety engineering prefers candidates with engineering as a first degree, largely preventing fire safety design (fire protection) industry candidates form entry. The Post-graduate certificate provides an entry point for those who have both extensive experience and who have a Diploma (AQF 5) from a relevant VET course. In many cases, those operating in the fire protection industry do not have the relevant requisite qualifications at AQF 5 and hence have barriers to entry to university education.

These course utilise on-line reading materials, learning guides, major source and references for study, video media, chat and discussion forums, as well as assessment tasks details and submission portals.

The adoption of the Diploma in Fire Safety Systems Design National Training Package provides the opportunity for an appropriate level of education, with associated skills that can prepare candidates for post-graduate studies, at least to the Post-graduate Certificate level in the first instance.

WSU has identified the potential opportunity for a post-graduate program in fire safety design which would not necessitate an engineering qualification as the basis of entry and could be tailored to industry needs for competent practitioners in fire protection/design. Such a course would include building regulations (classes 2-9), fire technology and engineering principles, planning and development control, egress and risk assessment, building fire services (active and passive), as well as fire and building materials.

Course structure and design

Diploma in Fire Systems Design National Training Package

The National Training Packages include a qualification for Diploma of Fire Systems Design (training.gov.au 2017). Under this package (CPC50509) candidates need to meet 12 Units of competency, of which 4 are compulsory.

These four compulsory Units are identified as:

- Apply OHS requirements, policies and procedures in the construction industry,
- Define scope and hazard level of fire systems design,
- Research and interpret detailed fire systems design projects, and
- Research and evaluate fire systems technologies and components.

Whereas there are numerous providers in relation to OHS requirements, the remaining three competencies can be difficult to obtain using existing Registered Training Organisations (RTOs) and courses. In consultation with the FPAA and project team established under the C21 initiative, it was agreed to focus on these three core units, so as to deliver suitable training for the fire protection industry, as well as other building professionals, including architects, project managers and engineers.

In addition, the requirements for the overall qualification include:

- Communication skills (e.g. writing reports, drafting detail specifications, presentations, etc.)
- Teamwork (e.g. developing working relationships and working with others)
- Problem-solving (e.g. negotiation, performing complex calculations)
- Initiative and enterprise (e.g. proposing solutions)
- Planning and organising
- Self-management
- Learning and
- Technology (such as computer software).

These Units do not require pre-requisites, but in line with the Lambert Review and Shergold-Weir reports, a major focus of each unit includes a deeper understanding of the NCC and associated provisions relating to fire safety system design and assessment (training.gov.au 2017).

Fire Protection Industry Short Course structure and teaching mode.

Due to the nature of the industry, it was decided in collaboration with industry partners that delivery could not rely on a traditional model of weekly regularly scheduled class teaching, with many in the industry having completed trade courses prior to an extensive work life, often as an individual or at a small enterprise level. The industry assisted in the co-design of the program and co-development of resources, with a strong focus on the regulatory arrangements of the NCC.

This necessitated a careful consideration of pedagogical considerations for mature participants, whilst providing both on-line and face to face components to assess the overall skills identified above. It should also allow a pathway to post-graduate studies as well, in line with the competent fire safety practitioner arrangements in NSW.

The purpose of the project therefore is to provide a structured training/educational program to facilitate training and provide a pathway for admission into post-graduate studies within Western Sydney University for those in the fire protection and associated industries. It is intended that further work will also be undertaken to prepare a post-graduate program in fire protection/fire safety design.

The structure, topic areas, assessment and activities of the Fire Protection Industry Short Course are illustrated in Table 1 below.

Table 1: Fire design short course structure, topics and activities

Period	Topic areas	Activity (assessment value)
Pre-workshop	Legislation Fire Science and fire suppression principles	Per-workshop quiz (20%) On-line information prior to quiz completion.
Day 1	Fire Systems Technology and components	Lecture & group work.
Day 2	Detection and warning systems	Lecture & group work.
Day 3	Purpose and operation of fire systems	Lecture & group work.
Day 4	Passive Fire Safety Systems Interconnectedness of fire systems	Lecture & group work.
Day 5	Presentation of Final Design	Presentations and feedback (30%).
Post-workshop assessment	Specifications and documentation.	Final assessment (50%) (individual)

For the purposes of future articulation, the course includes arrangements for the delivery of:

- cognitive skills to review, analyse, consolidate and synthesise knowledge and identify and provide solutions to complex problems
- cognitive skills to think critically and to generate and evaluate complex ideas
- specialised technical and creative skills in a field of highly skilled and/or professional practice
- communication skills to demonstrate an understanding of theoretical concepts
- communication skills to transfer complex knowledge and ideas to a variety of audiences

- digital competencies in basic software to support problem solving in a disruptive environment.

Resources for students include on open-learning platform, visual communications (video), in-class training sessions, and online support for administration, enrolment and statements of attainment.

The Fire Protection Industry Short Course (as it is titled) is structured around on-line materials with completion of the associated quiz, prior to attendance at a 5 day workshop. The workshop entails morning sessions with information delivery (lecture), and afternoons working in teams to assess an existing building and design fire safety systems to address the deemed to satisfy requirements of the NCC. On the last day of the workshop, each group presents their assessments and designs to the other groups and have their delivery assessed in terms of compliance as well as assessing the requisite skills associated with the program (described above).

The program is about to be piloted with industry providing the initial cohort (about 20) participants and industry experts for the evaluation of the course. The aim is to provide for a joint credential from both WSU and FPAA and that the FPAA as an RTO will be able to engage in an ongoing co-delivery arrangement and profit sharing arrangement.

Video resources developed.

Three videos were developed as part of the program for inclusion in the open learning platform. These videos cover:

- The FPAA introducing the underlining policy perspective for improving fire safety system design and assessment;
- Fire and Rescue NSW presenting a case study, involving the Bankstown fire event discussed above;
- A former project manager, illustrating the importance of developing good construction practice for a complex project including fire safety system in Parliament House, Canberra.

Importantly, these videos were developed collaboratively with partner organisations and the scripting integrated into the learning outcomes and structure of the short course.

Future work.

At the time of writing, this project has not quite finalised, with a pilot program to be concluded with evaluation of the content, delivery and learning platform for any possible improvements. Upon its refinement, the course will be available for other sectors including architects, engineers and construction management practitioners.

Conclusion

Government review and inquiries have consistently identified the need for enhancing the skills and education of various building practitioners. Fire safety (protection) is a critical sector and is increasing required to ensure compliance with building codes and requirements, as well as ensuring community safety for residents and occupants of major buildings.

WSU has taken the initiative to undertake a collaborative project for the delivery of core competencies within the National Training Packages for the Diploma in Fire Safety Design. Not all competencies are being delivered, however, completion of the course provides the key foundations identified by past government reviews and inquires, which require a clearer understanding of the NCC and associated standards.

The project is innovative in its development, relying on direct (former) student course design taking into account the opportunities for a more flexible delivery model using open learning combined with in-class training and team role play. It has also relied on the use of partnership pedagogy through co-design, co-developing resources and will involve co-delivery and co-credentialing.

The program also provides an opportunity for pathways to further post-graduate and higher education opportunities, in line with government and community expectations. The building sector is under significant pressure to ensure buildings are fire safety compliant, maintained and audited by competent persons and fit for purpose. WSU seeks to engage in the development of ongoing educational pathways which support both government policies and industry standards.

Acknowledgements

The authors wish to acknowledge the cooperation and assist of the Digital Futures Team within the University and in particular Holly Kaye Smith for her help in the production of video resources for this project. We would also acknowledge the comments and feedback from Mr Chris Wyborn of the FPAA, General Manager of Education and Bushfire and Mr Chris Orr of the FPAA Board. Both gentlemen are also former students of WSU post-graduate courses. We thank the University for its seed funding so that this project could realise its potential.

References

Australian Building Codes Board (ABCB), 2019, *National Construction Code: Volume 1*. Commonwealth of Australia. Canberra.

Fire Protection Association of Australia, 2019, *Fire Protection Accreditation Scheme (FPAS): NSW Competent Fire Safety Practitioner for Fire Systems Design and Fire Safety Assessment.* Version 2. Downloaded July 2019. http://www.fpaa.com.au/media/272533/fpaa_accreditation_scheme_2_april_2019.pdf.

Fire Protection Association of Australia, 2019a, http://www.fpaa.com.au/fpas.aspx Accessed July 2019.

Lambert, M. 2015, '*Independent Review of the Building Professionals Act, 2005 – Final Report*. State of New South Wales. ISBN 978-921938-09-2.

NSW Government, 2016, NSW Government response to the statutory review of the Building Professionals Act 2005.

Shergold, P & Weir, B. 2018, Building confidence: improving the effectiveness of compliance and enforcement systems for the building and construction industry across Australia. Australian Government.

Training.Gov.Au ,2019, https://training.gov.au/Training/Details/CPC50509 Accessed July, 2019.

Western Sydney University, 2018, *21C Curriculum Makerspace 2 Program*. Digital Futures. Brochure.

Western Sydney University, 2019, *Postgraduate: Built Environment*. Brochure.

Legislation.

Environmental Planning and Assessment Amendment (Fire Safety and Building Certification) Regulation 2017 (NSW).

TEACHING BUILDING MEASUREMENT PRINCIPLES TO SUIT THE TRANSFORMING CONSTRUCTION INDUSTRY

Sepani Senaratne[1] and M.N.N. Rodrigo[1]

[1]Construction Management Program, Western Sydney University, Sydney, Australia

Abstract

With the wide use of computer-aided measurement currently practiced in the construction industry, the building measurement process taught within construction management undergraduate programmes needs to be revisited. It is observed that in most undergraduate teaching programmes, the traditional manual measurement process is introduced in detail to the students prior to software applications. As argued by key researchers in the quantity-surveying field, it is by understanding the basic principles in the traditional form that one would be able to adopt and extend to different forms available in relevant software programmes. While this argument is true to some extent, the traditional manual process currently taught to students demands them to learn too many rules and follow confusing steps, which would not be ultimately used in the practice. Recognising this issue, a simpler format that is compatible with most software was introduced in one of the construction management programmes, which is quite popular in Sydney, Australia. This paper discusses this new format and informal feedback received from students and teaching staff who used this format. With the positive outcomes that were received, it is hoped that a similar format could be used by other relevant programmes in an attempt to produce students who meet today's industry demands.

Keywords

Bills of quantities; Horizontal layout; Measurement process; Standard method of measurement; Taking-off.

Introduction

In a transforming economy, adoption of a Standard Method of Measurement (SMM) for preparation of a Bill of Quantities (BoQ) in building projects is considered essential to achieve better value for client's money (Yusuf et al. 2013). In a BoQ, if items of work are properly defined (identification and description of cost significant attributes), a more reliable rate could be obtained, which will serve as the basis for cost monitoring and control (Towey 2013). An SMM comprises of detailed rules for measurement of works, while providing guidelines to bidders in submitting accurate bids (Molloy 2007). Furthermore, SMM contains an agreed set of rules by defining what and how an item is to be measured (Amuda-Yusuf and Mohamed 2015). Nani et al (2008) opined that SMM is similar to a language, which provides meaning considering inclusions and exclusions along with quantified information in accordance with its rules.

However, in order to take-off quantities and prepare a BoQ, while adhering to an SMM, one should have a thorough and comprehensive knowledge on the rules indicated in SMM. Therefore, preparation of an accurate BoQ has become a tedious job for any quantity surveyor. The undergraduates studying quantity surveying and construction management undergo the same stressful process in taking-off using the traditional format. Hence, the need for a simplified process and a simplified format has become essential to improve efficiency and accuracy in the taking-off process. With the development of the technology, for example, introduction of BIM based taking off software, it is ideal to adopt a new format to suit the technological advancements. This paper is aimed at exploring the results of introducing a simpler format that is compatible with most software.

This paper initially reviews literature on importance of standard method of measurement followed by a discussion on different standard methods of measurement available that are actively in use in the current context. Subsequently, the transition from the traditional manual measurement process to computer-aided measurement process was elaborated by introducing the new simpler format. The final sections lead to discussion and drawing conclusions.

Literature Review

Construction industry is known as one of the most complex and dynamic industries. As a result, many construction projects undergo cost overruns and delays, causing many issues to the stakeholders. PWC (2013) declared that more than 75% percent of capital projects in the UK experience budget overruns. Cost overruns occur due to various reasons and an accurate estimate is one of the key important aspects to manage the project costs efficiently and effectively.

Importance of standard method of measurement

At the procurement stage, professionals often rely on schedules and BoQs, increasing the importance of preparing an accurate BoQ (Oti & Abanda 2017). Eadie, Millar and Harte (2013) opined that reliability in the creation of an accurate BOQ is key to a successful project. In order to prepare a BoQ, an SMM, which has a work structure and defined measurement criteria is generally referred to (Marrero & Ramirez-De-Arellano 2010). According to Akbar et al. (2014), an SMM determines a localised technique of construction measurement protocol in order to produce a meaningful BoQ, which is then incorporated into the contract document of the project. Similarly, Yusuf and Mohamed (2014, p. 120) stated that "SMM usually reflects local practices, statutory requirements to be complied with, acceptable materials as well as quality of workmanship required". SMM delivers consistency by providing guidelines on how the BoQ should be structured, which items should be measured, how they should be measured and what units should be used (Drogemuller & Tucker 2003). The definition rules of SMM that is incorporated in the items of BoQs need to include significant cost drivers as construction cost is obtained from the materials, labour and plant that are necessary to put the materials/components in place (Amuda-Yusuf and Mohamed 2015). SMM provides a uniform basis of measuring building works thus, facilitating consistency and benchmarking, while avoiding disputes to a greater extent. According to Hughes (1981) and Amuda-Yusuf and Mohamed (2015), the functions of an SMM are as follows;

- standardise the system of subdividing construction work into component parts for the purposes of separate measurement and description;
- define the limits of items inclusion and exclusion;
- define items of temporary works distinct from permanent construction;
- indicate the circumstances under which work will be carried out;
- indicate the circumstances which can affect costs significantly; and
- prescribe the method of determining the dimensions and calculating the quantities of the several items.

An effective SMM consists of the characteristics, ease of locating rules; consideration for cost significant items; simplicity; consideration for cost analysis purposes; and thoroughness of SMM by logical inclusion of all work (Nani et al 2008). There are several SMMs for Building Works that are currently used by industry practitioners as discussed in the next section.

Different standard methods of measurement for Building Works

A global survey by the Building Cost Information Service (BCIS) on behalf of the Royal Institution of Chartered Surveyors (RICS) identified that there are 32 SMMs in existence (RICS, 2003) for building works. Many of these SMMs have been revised or amended and published as updated versions. Few of the most popular SMMs currently used for preparation of BoQs for buildings in UK, Australia and globally have been discussed in this section.

New Rules of Measurement volume 2 (NRM 2) and SMM in UK

The 1st edition of the Standard Method of Measurement was published by RICS in 1922 and the last version in that series, Standard Method of Measurement 7th edition (SMM7) was published in 1988 and revised in 2012 (RICS 2019). SMM7 consists of detailed information, classification tables and measurement rules related to building works. It comprises of 22 work sections on preliminaries and general conditions to work sections such as ground work, masonry, waterproofing among others.

The New Rules of Measurement volume 2 (NRM2) was published in 2013 by RICS replacing the Standard Method of Measurement seventh edition (SMM7). The NRM suite of documents comprises of three volumes as listed below.

- NRM1 – Rules for order of cost estimating and elemental cost planning
- NRM2 – Rules for works procurement
- NRM3 – Rules for maintenance and operation cost planning and procurement

NRM 2 comprises of 41 work sections, whereas compared to SMM7, NRM 2 has detailed classification of work sections. RICS new rules of measurements has enabled to tackle the inconsistency within cost planning mechanism (Matipa, Cunningham & Naik 2010) by introducing a separate guidance for preparation of cost plans of buildings. Furthermore, it is identified that there is a greater potential in consolidating BIM schema with the information from the NRM in order to improve the consistency and efficiency in cost management.

ANZSMM in Australasia

In essence, adoption of classifications in SMMs from other countries may not meet the requirements of local industry practices (Amuda-Yusuf and Mohamed 2015). As a result, Australian Standard Method of Measurement (ASMM) was developed and published in 1959. Australia’s ASMM versions have been prepared based on the national specification of Australia published by NATSPEC (Amuda-Yusuf and Mohamed 2015). The latest edition ASMM6 which was published in 2016 was superseded by Australian and New Zealand Standard Method of Measurement (ANZSMM) for building works in the year 2018. This joint standard was introduced to provide greater opportunities for companies engaged in both Australian and New Zealand construction industries (ANZSMM 2018). ANZSMM was jointly published by the Australian Institute of Quantity Surveyors (AIQS), New Zealand Institute of Quantity Surveyors (NZIQS) and Master Builders Association (MBA), which provides a uniform basis for the measurement of building works. The methods of measurement incorporated in ANZSMM shall be applicable to preparation of BoQs before the works are commenced equally with the measurement of finished works and variations (AIQS 2019).

The research findings of Davis, Love and Baccarini (2009) found that only 9% of the Australian construction industry practitioners use ASMM as a measurement method, while 78% of them prefer using builder’s quantities to ASMM. On the other hand, in the practical context, as these SMMs are complex in nature, ambiguities can be created (Davis, Love & Baccarini 2009). For example, two quantity surveyors might interpret rules in a different manner and this can lead to disputes. Therefore, estimators should be thoroughly knowledgeable to interpret the rules in the SMM correctly. According to Molloy (2007) and AIQS (2014), building contracts, which were prepared adhering to SMMs with mandatory rules, where considerable time was taken by the quantity surveyors in preparing accurate BoQs, disputes concerning measurement matters are negligible.

International Construction Measurement Standards

The International Construction Measurement Standards (ICMS) is an international standard, which aims to provide greater global consistency in construction costing (ICMS 2017). ICMS was established by the International Construction Measurement Standards Coalition (ICMSC), which is a group of more than 40 professionals and not-for-profit organisations. ICMS is recognised as a high level benchmarking and reporting framework for international cost classification and reporting. ICMS is expected to provide an internationally-accepted consistent framework into which data generated locally can be mapped for the purposes of comparison (ICMS 2019). Therefore, it can be used as a primary basis in both local and global contexts. Smith (2015) opined that the ICMS covers buildings and infrastructure works along with capital cost and whole life cost.

All these standards are mostly similar in their overall settings and slightly differs in an attempt to localise or generalise to the context. While using any SMM, a similar measurement process is carried out to take-off quantities for the identified items.

Measurement Process

Traditionally, taking-off process was carried out by following a manual measurement process. However, with the advancement in technology, it was converted into a computer-aided measurement process. Both manual and computer-aided measurement processes have been discussed in this section.

Manual measurement process

Primarily the manual measurement process was followed by many quantity surveyors to take off quantities and prepare the BoQ. Initially, printed drawings laid on the table are manually measured and measurements are entered into a computer based Bill generation software (Drogemuller & Tucker 2003). Subsequently, to replace the printed drawings laid on the table, the softcopies were available through various CAD software. This enabled the quantity surveyors to take off some quantities within the CAD software improving efficiency and accuracy of taking off. Later on, computer aided measurement process was introduced. According to Smith (2001) conventional 2D CAD is currently used by well over 80% of CAD users in the industry and further stated that the shift to 3D CAD has been slow but there are now signs of acceleration in this shift. Similarly, Chandler (2019) stated that introduction of Construction 4.0 has created a hype in the industry to move towards digitalisation. Thus, the construction industry is moving towards adopting computer-aided measurement processes.

Computer aided measurement process

Computer aided measurement process has few similarities to the manual measurement process, such as preparation of taking off check list, taking off quantities. However, due to its possibility of automating and linking with the BoQ, the effort of creating the BoQ from scratch can be avoided. On the other hand, if a certain quantity was adjusted, the links will automatically update the change to all applicable workbooks in the BoQ. There are several commercial software such as Buildsoft, CostX, RapidBid, BUILDXACT among others, available for quantity surveyors to take off quantities using a computer aided measurement process. As with any computer-based process, the results are only as reliable as the input data (Drogemuller & Tucker 2003).

Computer aided measurement process could be incorporated with Building Information Modelling (BIM) creating efficiency and accuracy in converting the building design in a 3D model to a cost estimate enabling a 5D model. General Services Administration (GSA) of the United States considers Building Information Model as a data-rich, object-based, intelligent and parametric digital representation of a building (GSA 2006), in other words a digital twin. In BIM, a building project comprises of a single model instead of separate and independent CAD files (Tse, Wong and Wong 2009). Therefore, all changes made to the model is incorporated, correlated and coordinated. Revit is one of the BIM tools that has built-in materials take-off function. Ismail et al (2018) opined that BIM based quantities take-off would reduce changes and reworks, which effectively improves development of the costs.

However, Tse, Wong and Wong (2009) opined that when building information models are created the requirements of the SMM need to be accounted. Similarly, Ismail et al (2018) stated that quantity surveyors need to be competent in adapting BIM tools, while traditionally mastering the fundamentals of building measurements. Hence, despite invasion of technology, the profession of the quantity surveyor will survive and will not be washed away due to the requirement of domain knowledge to steer the technology. Similarly, Chandler (2019) opined that reinvigorated surveyors will be important advocates at the table to ensure the best outcomes are achieved in this digital transformation era.

However, learning to measure with a specific software will not suffice due to rapid change in technologies. Hence, the generic manual process of measurement is required, which could be readily adopted in any estimating software. This is similar to school children learning manual computation before using a calculator. Building Measurement books (for example, well-known text books such as Marsden, 1998; Lee et al, 2011; Seeley & Winfield, 1999) are still adopting very traditional manual taking-off procedures, which requires to follow too many rules of laying out measurement. It was noted that teaching these complex and lengthy rules of laying out measurements in the traditional format is tedious and should be simplified as students will not use them in the actual practice with the instruction of various estimating software. The introduction of more software friendly simplified measurement procedure was found in AIQS Detailed Building Measurement (Best et al., 2014; Best et al., 2015). This research aimed to explore the results of introducing this simple format in a teaching context.

Research Method

This research used a case study research approach. The building measurement unit in one of the construction management programmes, which is quite popular in Sydney, Australia was selected as the case study to achieve the aim. In particular, students were finding this building measurement unit quite boring and too demanding in terms of their time and efforts, which was also reflected in low student feedback on unit (SFUs) till 2015. Therefore, in 2016, they were introduced with this simpler format that is compatible with most of the software applications by replacing the old format that had been taught to them for years. Students had the freedom to use excel sheets or printed measurement sheets with this new template to use in tutorial exercises. After the changes were implemented in the unit, student feedback on the unit and informal feedback from teaching staff was used to -explore the success of the change. The results are discussed in the next section.

Discussion and Analysis of Findings

The traditional taking-off process follows a vertical layout using a format as illustrated in Table 1. In this format, the description is written in the first row and subsequently, the dimensions along with the calculations are entered below the description signifying the vertical layout. This vertical layout creates confusions in understanding what dimensions were entered (length/width/height), how the dimensions were calculated, and further creates clarity issue in understanding the location of the dimension. On the other hand, symbols used in the previous format for example, adding on, timesing and underlying symbols were confusing to students.

Table 1: Traditional taking-off process

	DESCRIPTION					
	Factor/ Timesing	**Take-off figures/ Dimensions**	**Extension / Squaring**	**Location**	**Side-cast / Waste calculation**	
	4/6/	3.25				
		2.10	163.80	Wall W-1		
		3.40				
		2.10	7.14	Wall W-2		
			170.94 m^2			

In order to avoid above identified issues in the traditional taking-off process, a new format was introduced. The new format consists of a horizontal layout (modified from Best et al. 2015) as illustrated in Table 2, whereas it is compatible with software and BIM applications.

Table 2: New taking-off process

Item	Description	Unit	Factor/Nr	Length	Width	Depth/ Height	Quantity	BOQ Quantity
	Wall W-1		4*6	3.25	2.10		163.80	
	Wall W-2			3.40	2.10		7.14	
							170.94	

Many rules that go with the vertical form need not be adopted in this simple horizontal layout and it could be easily created using an excel sheet, which also enables auto calculations. Detailed explanation on carrying out a sample calculation using the new format is demonstrated in Table 3.

Table 3: Example to demonstrate new taking-off process

Item	Description	Unit	Factor/Nr	Length	Width	Depth/ Height	Quantity	BOQ Quantity
a	Surface excavation to reduce levels and disposal of material offsite	m^3						5
	Length: 5000 + (2x 225) + (750-225) = 5975 Width: 4550 + (2 x 225) + (750 - 225) = 5525			5.98	5.53	0.15	4.96	

In the horizontal format, the description of the item is written in the description column and the dimensions are written in a horizontal manner. Then the waste calculations, are carried out just below the description, however waste calculations are carried out in millimetres. When transferring the lengths and width to the respective columns, the dimensions should be entered in metres rounded to 2 decimal points. Quantity column shows the multiplication of the lengths, widths and heights to identify the total quantity of a particular item. Finally, the BoQ quantity column is filled by rounding up the quantity to a whole number as this is the quantity transferred to the BoQ.

This new taking-off process and the format was introduced as mentioned in the research method section in one of the construction management programmes. The feedback received from students and teaching staff was positive, where many students mentioned that it was easier to understand the measurement sheet clearly as it indicated the columns clearly. Further, a student had mentioned that identifying the lengths, widths and depths separately, made it easier for cross-checking purposes as well. The teaching staff opined that compared to other years, students were able to grasp the format and the column headings as it was quite straight forward. With the positive feedback, the format was used in later years and the SFU had improved notably from 2015 in this later years. For example, from 2015 to 2016, the SFU increased by 28%, showing positive results of the changes implemented.

Conclusion

Digitalisation driven Construction 4.0 has emphasised on adopting technology in the construction industry. Moreover, the traditional manual measurement process is transforming towards a computer aided measurement process to adopt technological advancements. However, the usage of an SMM in preparation of a BoQ will be used in either of these measurement processes as it is the key standard set of rules that will be referred in order to maintain uniformity. Thus, this research paper explored the importance of SMMs, usage of various SMMs in the current context, different measurement processes and further followed by introducing a simpler format for manual taking-off process, which could be readily adoptable in different estimating software. A traditional taking-off format had been used in classroom teaching for decades, however, several issues were identified while using this format. Therefore, a new format consisting of a horizontal layout was introduced in one of the construction management programmes, which is quite popular in Sydney, Australia. Subsequently, feedback was received from students and teaching staff to analyse the results of introducing this new format to the curriculum. The feedback from both students and teaching staff was quite positive. This paper recommends other relevant construction management and quantity surveying programmes to introduce a similar format to produce students to meet the industry demands. The construction industry has fallen short in tasking the higher education system with reinvesting in modern content and delivery capabilities. Therefore, it is ideal to work towards a new plateau of positive opportunities to uplift the roles of quantity surveyors and construction managers.

References

AIQS, 2014, '*Practice Note No. A1 – Bills of Quantities*', AIQS.

AIQS, 2019, *'Australian Institute of Quantity Surveyors'*, [online] Available from: https://www.aiqs.com.au/imis/AIQS_Website/News/ASMM6.aspx

Akbar, A.R.N., Mohammad, M.F., Talib, N.A. & Maisham, M. 2014, The Implication of the Standard Method of Measurement (SMMs) for Building Works Toward Contractors' Works, *International Civil and Infrastructure Engineering Conference 2014 Proceedings*, Institute of Infrastructure Engineering and Sustainable Management, Malaysia, pp. 149-162.

Amuda-Yusuf, G. & Mohamed, S.F. 2015, 'Essential features of a building services standard method of measurement in Malaysia', *Engineering, Construction and Architectural Management,* vol. 22, no.6, pp. 749-770.

ANZSMM, 2018, '*Australian and New Zealand Standard Method of Measurement of Building Works'*, AIQS, NZIQS, MBA, Australia and New Zealand.

Best, R, Smith, P. and Doherty, J. 2014, *Detailed Building Measurement*, Vol 1, Australian Institute of Quantity Surveyors, Sydney, NSW.

Best, R, Smith, P. and Doherty, J. 2015, *Detailed Building Measurement*, Vol 2, Australian Institute of Quantity Surveyors, Sydney, NSW.
Chandler, D. 2019, 'Future QS Skills', *The Building Economist*, June 2019, AIQS.
Davis, P.R., Love, P.E.D. & Baccarini, D. 2009, 'Bills of Quantities: nemesis or nirvana?', *Structural Survey*, vol. 27, no. 2, 99-108.
Drogemuller, R. & Tucker, S. Automating the extraction of quantities. Paper presented at the *CRC for Construction Innovation, Program C - Delivery Management of Built Assets, Project 2003-037-C, Managing Information Flows with Models and Virtual Environments*, Brisbane, Australia
Eadie, R., Millar, P. & Harte, N. 2013, A comparison between CESMM3 and MCHW as methods of measurement for civil engineering work, *International Journal of Procurement Management*. Vol. 6, no. 5, pp. 523-543.
GSA, 2006, '*GSA Building Information Modeling Guide Series 01: Overview'*. United States General Services Administration, Washington, DC.
ICMS, 2017, '*International Construction Measurement Standards: Global Consistency in Presenting Construction Costs*'. 1st edition. International Construction Measurement Standards Coalition.
ICMS, 2019, '*International Construction Measurement Standards: Global Consistency in Presenting Construction Costs*'. 2nd edition. International Construction Measurement Standards Coalition.
Ismail, N.A.A., Idris, N.H., Ramli, H., Sahamir, S.R. & Rooshdi, R.R.R.M. 2018, 'Sustainable BIM-based cost estimating for quantity surveyors', *Chemical Engineering Transactions*, vol. 63, pp. 235-240.
Lee, S., Trench, W. & Willis, A. 2011, *Willis's Elements of Quantity Surveying*, 11th edition, John Wiley and Sons, UK.
Marrero, M. & Ramirez-De-Arellano, A. 2010, 'The building cost system in Andalusia: application to construction and demolition waste management', *Construction Management and Economic*s, vol. 28, no. 5, pp. 495-507.
Marsden, P.K. 1998, *Basic building measurement*, 2nd edition, New South Wales University Press, Kensington, N.S.W.
Matipa, W.M., Cunningham, P. & Naik, B. 2010, 'Assessing the impact of new rules of cost planning on building information model (BIM) schema pertinent to quantity surveying practice', *26th Annual ARCOM Conference proceedings*, Association of Researchers in Construction Management, Leeds, UK, pp. 625-632.
Molloy, J. 2007, '*Civil Engineering Measurement Claims in Hong Kong*' [Online], Available from https://www.fig.net/resources/proceedings/fig_proceedings/fig2007/papers/ts_3g/ts03g_02_molloy_1664.pdf
Nani, G., Edwards, P.J., Adjei-Kumi, T., Badu, E. & Amoah, E. 2008, 'Customisation and desirable characteristics of standard method for building works in Ghana', *Australia Journal of Construction Economic and Building*, vol. 8, no. 2, pp. 30-40.
Oti, A.H. & Abanda, F.H. 2017, 'A framework for integrating sustainability estimation with concepts of rules of building measurement', *International Conference on Engineering, Applied Sciences and System Modeling proceedings*, IOSEA, Accra, Ghana, pp. 175-185
PWC, 2013, '*Successful capital project delivery - The art and science of effective* governance', PWC
RICS, 2003 Standard methods of measurement in current use, International Survey. [online] Available from: www.rics.org/faculty/construction
RICS, 2019, '*RICS standards and guidance - SMM7: Standard method of measurement of building works'*, [Online], Available from https://www.isurv.com/directory_record/3081/smm7_standard_method_of_measurement_of_building_works#
Seeley, I.H. & Winfield, R. 1999, *Building Quantities Explained*, 5th edition, Springer, UK.
Smith, P. 2001, 'Information Technology and the QS Practice', *The Australian Journal of Construction Economics and Building*, vol. 1, no.1,pp. 1-21.
Smith, P. 2015, 'Global professional standards for project cost management', *29th World Congress International Project Management Association (IPMA) 2015*, Panama, pp. 124-131
Towey, D. 2013, *Cost Management of Construction Projects*, Willey Blackwell, Chichester

Tse, K.T.C., Wong, A.K.D. and Wong, F.K.W. 2009, ‘Building information modelling in material take-off in a Hong Kong project’, *Collaborative construction information management*, pp. 186-197.

Yusuf, G.A. and Mohamed, S.F. 2014 ‘Perceived Benefits of Adopting Standard – Based Pricing Mechanism for Mechanical and Electrical Services Installations’, *Australasian Journal of Construction Economics and Building*, vol. 14, no. 2, pp. 104-119.

Yusuf, G.A., Mohamed, S.F., Yusof, Z.M. & Misnan, M.S. 2013, ‘Adoption of Standard Based Pricing Method for the Procurement of Mechanical and Electrical Engineering Services in Malaysia’, *World Congress on Engineering proceedings*, London, UK, pp. 1-6.

IVESTIGATING THE ROOT-CAUSE OF LEGAL DISPUTES OVER DEFECTIVE CONSTRUCTION

Zhaorong Wu[1], Payam Zekavat[1], Sungkon Moon[2], Liyaning Tang[1], Sherif Mostafa[3]

[1]School of Computing Engineering and Mathematics, Western Sydney University, Sydney, Australia

[2]School of Engineering, Swinburne University of Technology, Melbourne, Australia

[3]School of Engineering and Built Environment, Griffith University, Gold Coast, Australia

Abstract

Construction industry is of critical significance to the development of Australia regarding economic and social aspect, contributing one of the largest portions to Australia's GDP and providing residential building, infrastructure and functional facilities to the operation of the cities as well as job opportunities to the country. Construction disputes are common trait of this industry causing detrimental consequences to the construction projects leading to financial loss and delays in construction projects. Although there is a considerable amount of research and knowledge contributing to the study of dispute causation, legal disputes remain prevailing and hinder the process of construction, especially from the cost perspective. In order to improve our understanding of the causation factors underlying the legal disputes this research was conducted by examining the details of recent legal cases in NSW. Our objective was to determine the extent of the impact of insufficient work-front instruction including missing specifications on occurrence of defective construction work. As a result, this research discusses that poor workmanship as a major causation factor is a direct derivative of vague job description. The observation that patent defects readily identifiable by inspection were a common source of dispute supports our hypothesis that ambiguity of the task provides tradespersons the opportunity to deliver a sub-standard job. Professional ethics and technical skills of the tradies have been discussed to have a moderating effect. Clear and precise specifications are inevitable if disputes are to be reduced.

Keywords

Construction defect, Information flow, Legal dispute, Poor workmanship

Introduction

The construction industry is a pillar industry of Australia's economic development. According to the Australian Bureau of Statistics (ABS 2015), the construction industry accounted for 7.8% of Australia's Gross Domestic Product (GDP) in 2014-15 financial year with the direct output of $204.5 billion. Meanwhile, the development of the construction industry would also support the upstream and downstream industries such as the manufacturing industry which provides the construction materials to the construction activities. Likewise, the real estate industry and the financial industry would also grow as the management of properties and the financial service such property mortgages would be required after the com let ion of the construction works.

Disputes caused by various reasons produce significant consequences including hindering the development of the construction industry (Chan and Suen 2005). It is common to have conflicts in the projects and conflicts would turn into disputes if not managed appropriately. Actually it is not odd to construction professionals that construction disputes are inevitable especially in the complex construction projects (Cheung and Yiu, 2006). The consequences of construction disputes include troubling progress of the project, deteriorating the relationship between contractors and the project owners, and leading to the overruns of budget and time (Iyer et al., 2008). In terms of cost of construction disputes, Love et al. (2010) stated that the direct cost of construction disputes could account for the contract value ranging from 0.5% to 5%, and the indirect cost would be in from of loss of productivity, stress from disputes, damage to reputation and loss of future work. Assuming the direct rework cost is equal to the direct cost of dispute, which means the cost associated with the disputes would account for, to some extent, l 0% of the total contract value.

Love (2012) stated that it has been widely accepted that the defective work and changes of scope are the main causes of construction disputes. A construction defect is generally defined as a defection in the design and workmanship which would result in failure of a component part of a building and causes damage to persons or property (Gashi, 2018). The defect in the construction industry could be caused by the design defect and the construction defect. The design defect is the result of a design professional's failure to reduce accurate and complete project design which is categorised as the design omission and the design error (Gashi, 2018). Additionally, construction defect includes latent and patent defect (Gashi, 2018). Latent defect means those unobvious defects that cannot be identified easily even via the comprehensive on-site inspection, whereas patent defects are already known or readily obvious based on reasonable inspection.

Therefore, it is necessary to investigate the causes of the disputes and to develop mitigation solutions to avoid them. Relevant, existing researches mainly focus on the analysis of the primary data, such as the research of Hwang et al. (2014), which uses the questionnaires to obtain the data, and the research of Farrington and Ledbetter (1992), whose data was derived from the interviews. The study of Cheung and Yiu (2006) used a fault tree to examine the causes of construction disputes in Hong Kong. In contrast, this research endeavour to trace disputes in legal cases instead of working with data that has primarily collected about dispute. This empirical study aims at creating insight on the occurrence of construction disputes through the lens of common legal disputes in the construction industry.

Construction Disputes

The causes of construction disputes could be various. Kilian and Gibson (2005) found that there are five factors contributing to the disputes, which are project management procedure, design error, inefficient contracting, site management and bidding miscalculations. Rhys (1994) lists management, culture, communication, design, tendering pressure, economics, contract, skill and law as the reasons behind construction disputes. Kumaraswamy (1997) claimed that the dispute could be divided into five common types including variations caused by the site condition, variations caused by the client changes, variations caused by the design errors, unforeseeable ground conditions and ambiguity of contract documents. Ashworth (2015) classifies causes of disputes from the perspective of key project stakeholders into six categories of general, client-related, consultant-initiated, contractor-produced, and subcontractor-triggered. Adriaanse (2005) stated that the quality of material and level of the skill, delays, variations, increase of cost, and the divergence of the interpretations of the contract provisions are main causes that contribute to construction disputes. Love (2002) stated that it has been widely accepted that the defective work and changes of scope are the main causes of disputes.

The research of Mitropoulos and Howell (2001) examined the development of construction disputes by analysing 24 cases of construction disputes in terms of the situation of the case the amount claimed and settled and the level of resolution. The result indicates that the planning and problem-solving ability are much more significant than the contractual terms on the prevention of complex and high-cost disputes.

Defective Construction Work

According to Barrett (2008) the term 'defect' has been firstly defined over one hundred years ago in a legal case in 1897 to be 'the lack or absence of essential elements to completeness'. In the case, a fence which supposed to set up between the operator and the machinery was missing, leading it to be defective.

Defect is defined as 'the non-fulfilment of a requirement related to an intended or specified use' by the Internal Organization for Standardization (ISO). Similarly, ISO defines 'the failure to fulfil a requirement' by using the word 'non-conformance'. Battikha (2008) stated that the non-conformance would occur when components of the project deviate from the defined requirements in the finished state of the project and lead to the decisions in terms of the acceptance and rectification. Another word that is similar to defect is ‘snag’. Sommerville and McCosh (2006) articulated that snags could be defined as the defects absorbed during the process of construction, which means they are corrected before completion of the project. Besides, the word 'post-handover defect' is defined as the defects that remain in the building after the completion and delivery of the building during the liability period, which would range from 12 months to 36 months (Forcada et al. 2012).

There are three main types of construction defects, including the failure of the materials and the work to achieve the acceptance level the failure of the materials and the work to remain the same as the specification and design brief, and the failure to complete the project. As for the completion of the work, it is likely to involve disputes if the construction requirements in terms of the specific quality of the work could not be achieved. The patent defects are the one which could be observable and visible. While for the latent defects, it is hidden and caused by the inadequacy of the materials (Mclean 2009).

In common law the obligation of the builders terminates after the completion of the construction work. Therefore, builders are allowed to leave the construction site and are no longer responsible for the future damage to the buildings, except for the damage that is caused before the completion of the work. Meanwhile the builders are allowed to terminate the insurance for the building after the completion. However, the builders should be responsible for the compensation for all the patent and latent defects that might be detected afterward. Because the defects might not emerge instantly but would be identified subsequently. These could also be related to a period called defects liability period. The period could range from 6 months to 12 months according to the contracts starting immediately after the building is completed by the builders. Besides, the liability period would be restart if any defects are identified during the original liability period. However, the total time span of the liability period should not exceed 2 years unless there is specific requirement stated in the contract (Barrett, 2009).

Methodology

This research implemented a qualitative approach through extraction of dispute data hidden in the legal case reports. The Australian legal databases, including Lexis Advance, Westlaw AU and Australian Legal Information Institute, was used to search for construction dispute cases related to the defective construction work over a twenty-year period starting from 1999 to 2019 in New South Wales. The research team has looked into 100 cases related to disputes in the construction industry concerned with defective construction work with a technical perspective in order to ascertain the root causes of the defective works behind the disputes.

Content analysis was deployed to analyse the data obtained from the law cases. The information in the cases was extracted and categorised with the description of the case situation and categorisation of the causes. The keywords ‘defect’ and ‘construction’ were used to identify cases, and each case was then examined in detail to determine the causation of the defective construction work. The disputes concerned with industrial, commercial and engineering construction projects were inspected.

The causes of the defect in the case study were laid into five categories, which are defective workmanship, communication issue lack of skill, contract issue, and external factor, to define the cause of the defective works in each dispute. Meanwhile, the type of the defect in the disputes was also divided into 3 different kinds namely the patent defect, latent defect, and the design error.

Discussion of Findings

This study successfully identified 100 dispute cases which are related to the defective construction works. It was noticed that the cause of the defective works, in some of the cases, had not been mentioned in the case record. In these instances, the parties merely to ask for the judgment to decide the party who should take the responsibility to the cost of the rectification. Therefore, the cause of the defect in those cases was unable to be identified and hence those cases were categorized into 'unknown' and were removed from the analysis of defect causes.

The result, including the causes of defects and the types of defect are shown in Figure 1 and 2. It is remarkable that the defective workmanship accounts for approximately 77% of the causes of defect in the disputes. The lack of skill and contract issue contribute around one-fifth of the defects, accounting for 11% and 8% individually. The remaining 4% of the defects are equally caused by the communication and external factor. As for the types of the defect, it is obvious that three-quarter of the defects are patent defect with approximately one-fifth of the defects are latent defect. The design error only accounts for a small portion of the defects with 6%.

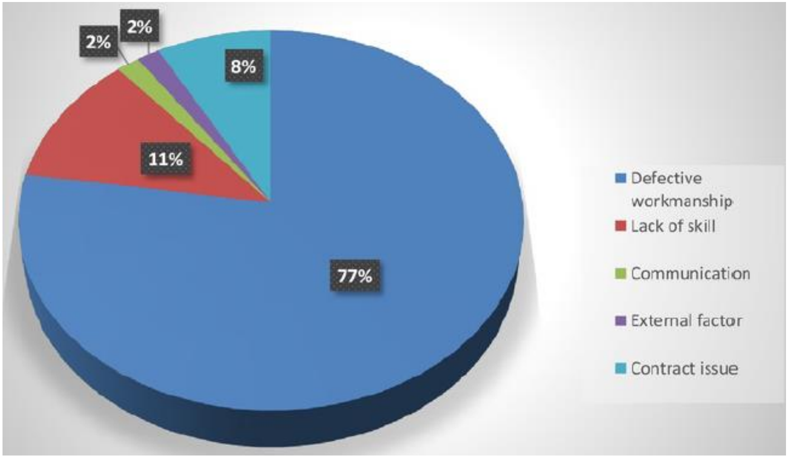


Figure 1: Causes of defect

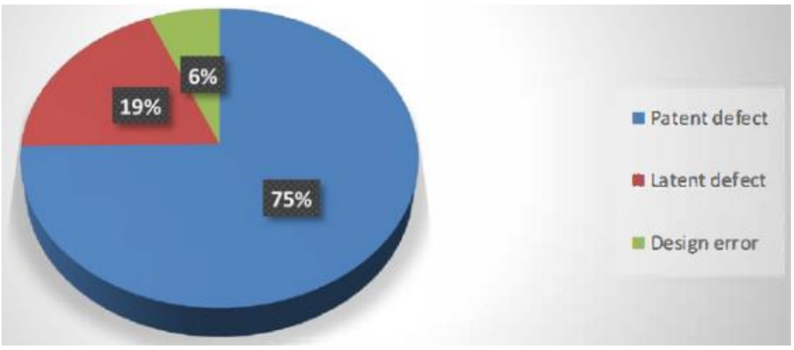


Figure 2: Types of defect

During the data collection process it was noted that a sizable number of cases were concerning licencing and registration issues, disciplinary proceedings, and qualification issues, which involved construction companies or builders and the authorities such as the Building Professionals Board and the NSW Fair Trading. The other types of the dispute cases are employment disputes which usually involve companies and employee's superannuation, worker's compensation and the long service leave.

According to the result of the research the defective workmanship is the biggest contributor to the defective construction works and the patent defect is the major type of the defective construction works.

Hence it is of great significance to project managers to reconsider the trade of between cheaper labour and the higher risk of defective works. The fact that majority of the defects were patent capable of being discovered by reasonable inspection, demonstrates the important role of effective supervision and inspection. Project management team is advised to take regular inspections seriously in order to detect the defects and to avoid disputes.

Factors such as building classification, size of the structure, use of performance solutions, experience of design and building team, and climate conditions have been considered to evaluate the risk associated with inspection of construction works. This study identified issues as simple of missing movement joints resulting litigation. Or, in regard to design, the mismatch between client’s need and what has been designed. In two cases for example, a pavement was designed and built that was not adequate for the kind of machinery the client planned to drive on the pavement. Improper classification of foundation material resulting in insufficient load bearing capacity or cracks in building elements due to reactive soil is another incident that could be avoided by more effective inspection.

Conclusion

Although there is a considerable amount of research and knowledge contributing to the study of dispute causation, legal disputes remain prevailing and hinder the process of construction, especially regarding the crucial costs. In order to improve the understanding of the causation factors underlying the legal disputes, this research was conducted. As a result, this research has identified that the defective workmanship as responsible for the majority of the defective construction works and the patent defect, which is detectable by reasonable inspection, accounts for a large portion of the type of the defective works.

This study provided project management team an insight of legal disputes initiated by defective work and recommended careful selection of the labour force as an immediate solution. Regular inspection and more comprehensive supervision of the construction process are also discussed to complement more rigorous recruitment. With the defective works being avoided, the potential disputes and the following economic loss could be significantly reduced.

References

Asln orth A 2012, *Contractual procedures in the construction industry*, 6th ed Harlow, England.

Adriaanse, J 2005, *Construction contract law: the essentials*, Basingstoke, Palgrave Macmillan.

Australian Bureau of Statistics 2015 Australian National Accounts: National Income Expenditure and Product, viewed 20 September 2018 <http://www.abs.gov.au/ AUS ST ATS/abs@.nsf/ProductsbyCatalogue/52AF A5FD696482C ACA25 768D002 lE2C7?0penDocument >.

Barrett, K 2008, *Defective construction work*, Chichester, West Sussex, UK.

Barrett K 2009. *Defective construction work: and the project team*, John Wiley & Sons.

Battikha, M 2008, 'Reasoning mechanism for construction nonconformance root-cause analysis', *Journal of Construction Engineering and Management*, vol. 134, no. 4, pp. 280-288.

Chan, E.H.W. & Suen H.C.H. 2005, 'Dispute resolution management for international construction projects in China', *Management Decision*, vol. 43, no. 4, pp. 589-602.

Cheung, S & Yiu, T 2006. 'Are Construction Disputes Inevitable?', *IEEE Transactions on Engineering Management*, vol. 53, no. 3, pp. 456-470.

Farrington J & Ledbetter W 1992 'Causes of quality deviations in design and construction', *Journal of Construction Engineering and Management*, vol. 118 no. I, pp. 34-49.

Forcada, N, Macarulla, M, Fuertes, A, Casals, M, Gangolells, M & Roca, X 2012, 'Influence of building type on post-handover defects in housing' *Journal of Performance of Constructed Facilities*, vol. 26 no. 4, pp. 43.

Gashi, E 2018 'Management of defective works in infrastructure projects' *International Review of Applied Sciences and Engineering*, vol. 9, no. l, pp. 73-80.

Hang B, Zhao, X & Goh, K 2014, 'Investigating the client-related rework in building projects: The case of Singapore', *International Journal of Project Management*, vol. 32, no. 4 pp. 698-708.

Iyer, K.C., Chaphalkar, N.B. & Joshi, G.A. 2008, 'Understanding time delay disputes in construction contracts', *International Journal of Project Management*, vol, 26, no. 2 pp. 174-184.

Kilian, J & Gibson G 2005, 'Construction Litigation for the U.S. Naval Facilities Engineering Command, 1982-2002 , *Journal of Construction Engineering and Management*, vol. 131, no. 9, pp. 945-952.

Kumaraswamy M 1997 'Conflicts, claims and disputes in construction', *Engineering, Conslntction and Architectural Management*, vol. 4, no. 2, pp. 95-111.

Love, P 2002, Influence of project type and procurement method on rework costs in building construction projects', *Journal of Construction Engineering and Management*, vol. 128, no. 1, pp. 18-29.

Love P Davis, P, Ellis J & Cheung S, 2010, 'Dispute causation: Identification of pathogenic influences in construction', *Engineering, Construction and Architectural Management*, vol. 17, no. 4, pp. 404-423.

Mclean, S 2009, Defective Construction Work', *Journal of Building Appraisal*, vol. 4, no. 3 p. 2

Mitropoulos P & Howell, G 2001, 'A Model for Understanding Preventing, and Resolving Project Disputes' *Journal of Construction Engineering and Management*, vol. 127, no. 3, pp. 223-23.

Rhys, J 1994, 'How constructive is construction law?', *Construction Law*, vol. 10 no. 1, pp. 28-38

Sommerville, J & Mccosh, J 2006, 'Defects in new homes: an analysis of data on 1,696 new UK houses', *Structural Survey*, vol. 24 no. 1, pp. 6-21.

BIM APPLICATIONS TO LEVERAGING LEAN PRINCIPLES IN MODERN CONSTRUCTION

Sandi Gozali[1], Payam Zekavat[1], Sungkon Moon[2], Liyaning Tang[1], Sherif Mostafa[3]

[1]School of Computing Engineering and Mathematics, Western Sydney University, Sydney, Australia

[2]School of Engineering, Swinburne University of Technology, Melbourne, Australia

[3]School of Engineering and Built Environment, Griffith University, Gold Coast, Australia

Abstract

This research aims to examine and model the synergy between Building Information Modelling (BIM) and lean principles in terms of attributes of modern construction methods. We present the pairing and reconciliation process as a system capable of optimising project total value and to minimize wasteful cost including financial, time, effort and materials. Multiple sources including scholarly publications, government guidelines and best practices were relied on to identify components of lean paradigms and features of BIM. A semantic matching was then conducted to formulate the interaction between BIM and lean. The developed model was then validated using cases borrowed from literature. The validation process comprised of testing applicability of the proposed model to the scenarios explained in selected publications. It was demonstrated that joint use of BIM and lean had the potential to overcome challenges mentioned in validation cases. As the result, BIM applications can leverage nine lean construction principles namely cycle time reduction, pull approach adoption, process visualisation for management, focus on project delivery, value for client, performance-based method selection, design efficiency, cooperative relationship, and eliminating waste. Millstone verifications through the course of formulating the synergy between BIM and lean were also conducted by referring to relevant government reports, documents and different forms of expert input. Our formulation depicted the mechanism through which the two novel processes of lean and BIM contribute to each other's efficiency.

Keywords

Building Information Modelling, Lean principles, Modern construction, Efficiency

Introduction

Nowadays, Building Information Modelling (BIM) is a trending technology in construction industry, as it can be used at planning, design, offsite manufacturing, and to monitor construction progress. Providing the virtual twin of the physical asset, BIM equips project team to identify more of potential issues in terms of design, construction and operation of the project. Enhanced understanding of the whole building lifecycle through integration of geographic information, geometry, properties and quantities of the building elements, cost estimation, project schedule, and material inventories, is also attributed to BIM (Bazjanac 2006). Accordingly, BIM is understood as a process rather than just an application. It means that BIM makes significant changes in the workflow as well as project delivery process (Hardin 2009). BIM as a process is consistent with the emerging concept of integrated project delivery as it provides a platform to integrate people, methods, and business structures and practices into a collaborative system in order to optimise the efficiency and reduce the waste of the entire project lifecycle (Glick and Guggemos 2009). The notion of waste reminds us of potential links to lean principles. Lean construction has the main goal of minimising waste (using less of everything) while satisfying customers' needs.

lean construction provides systems to minimise waste in human effort, materials and time by generating maximum value of cost efficiency (Howell 1999; Pinch 2005). These systems work by investigating the causes of waste, then using techniques and tools to remove those causes, and promoting the prevention of waste rather than solving the problem as the result of the effects of loss (Lapinski et al. 2006; Womack and Jones 2003). Five fundamental lean principals include: a) Client defines value of construction, b) the delivery value influences the value streams, c) the removal of waste influences the flows within work processes, d) the delivery of materials are not allowed until these materials are needed, e) pursuant of perfection via improvement of systems and processes is essential to be constantly revisited.

BIM seems suitable to be paired with lean principles, as both of them provide the systems that maximise construction quality by effectively minimising project cost and waste, and relaxing project's schedule. The main objectives of this research is to investigate and to define the relationship between BIM and lean principles related to construction industry and to show how both of them can be paired as a system to maximise the project value.

Overview of Covered Technology and Technique

BIM

Azhar (2011) examined BIM capability for purposes such as cost estimation, production of construction shop drawings, visualisation, design compliance review, construction sequencing, facilities management, collision detection, and forensic analysis. Eastman et al. (2008) emphasise improved information flow as the pathway through which BIM contribute to the betterment of project management processes. Controlling environmental data and whole-life costs is another key attribute of BIM (Construction Innovation 2007). In the same vein, Pikas et al. (2011) highlight building of the digital twin of the project and the value created by the constructability analysis. Kunz and Gilligan (2007) analysed BIM for its positive impact on project risk and suggested that adoption of BIM reduces project uncertainty and result in better risk distribution among all parties. Khemlani et al. (2009) add that sharing pain and gain among all parties can be arranged contractually. It is then reasonable to conclude that BIM offers the capacity to overcome significant problems faced by today's construction industries (Arayici et al. 2012).

Lean

Aziz and Hafez (2013) suggested that lean construction mainly aim at reducing waste of time, effort, and materials in order to produce the maximum feasible amount of value. Lean principles in construction target increased performance for the client at the project level (Tommelein & Ballard 1999). This contrasts the prevalent view that client values have been catered for in design and the project management effort must be dedicated to completion of project activities stemming from the design. The traditional focus on activities to assure reliable supply and meeting of milestones results in overlook of value-creation manifested in waste production (Houvilla et al. 1997). Lean attempts to preserve the excess capacity in the crew in order to manage their speed as needed. This diverts the attention from supply to work-front activities on site. It is important to note that lean doesn't overlook supply chain but operates to enhance cooperative relationships with the supply chain (Eriksson 2010). Not surprisingly, May (2005) proposes the following three models to pave the way for widespread adoption of lean: Model 1: focusing on eliminating waste, Model 2: focusing on partnering, and Model 3: focusing on structuring the project around lean thinking.

Interaction between BIM applications and lean principles

Sacks et al. (2009) provided examples to explain how BIM contributes to a 'pull flow' mechanism in order to reduce variability (one of lean principles) in construction stage. Therefore, in terms of lean construction principles, BIM enables visualisation of the construction processes and specifications.

Rischmoller et al. (2006) concluded that the Computer Advanced Visualization Tools contribute to waste reduction, flow improvisation, and better costumer value (based on a case study for over a four-year period). Those are the indications of synergy between BIM and lean construction principles. Gillian and Kunz (2007) stated that the use of Virtual Design and Construction can be considered to assist directly to the performance of lean construction principles. They demonstrated a lean project that utilised 3D models to save nearly $6 million. Koskela et al. (2002) test compatibility of BIM and lean from the perspective of empowering teams. Lean construction demands rapid feedback and facilitate team commitment. By using BIM, those demands can be addressed through complete and accurate information sharing of building lifecycle. Dave et al. (2013) mentioned that there are substantial synergies between lean construction and BIM.

Methodology

This study focuses on determining the relationship between BIM and lean principles in modern construction. Series of construction projects described in scholarly papers were explored to extract different elements of BIM and lean that are indirectly revealed in each report. A framework is then compiled to describe the relationship between the two. The framework is tested by referring to selected, official governmental records for its generality, objectivity and validity.

Cases and Results

The following nine case were used to extract attributes listed in Table 1. The produced list is then examined against BIM capabilities and lean principles to model possibility of co-existence and co-utilisation of BIM and lean for achieving/rectifying the outcomes/shortcomings identified within the context of different cases. The results of this analysis are presented in Figure 1.

- Case 1: A collection of nine major civil projects to study collaboration between client and contractor in United Kingdom construction industry (Bresnen and Marshall 2000).
- Case 2: Summary of an effort to implement Case-Based Reasoning (CBR) in construction management (Yau and Yang 1998)
- Case 3: A study on the causes of project delay and cost overruns in groundwater construction projects in Ghana (Frimpong et al. 2003)
- Case 4: An analysis of the operation of a large construction company to understand collaborative knowledge management (Dave and Koskela 2009)
- Case 5: Examination of a specific contract template in Hong Kong for its impact on effective partnership in railway projects (Bayliss et al. 2003)
- Case 6: Comparison of effectiveness of construction waste recycling between two building complexes (Mcdonald and Smithers 1998)
- Case 7: An overview of large construction projects in Vietnam (Long et al. 2003)
- Case 8: A reflection on organisational structure of six different construction projects for their appropriateness for dissemination of knowledge produced through the delivery of projects (Styhre et al. 2004)
- Case 9: An analysis of the issue of delay in construction projects in developing countries (AlSehaimi et al. 2013)

Table 1: Summary of selected projects and their attributes used for matching BIM and lean

Case No.	Focus of the case	Extracted outcomes of the project
1	Client-contractor relationship	Increased schedule efficiency Improved buildability of the design Enhanced responsiveness to the user requirements Improve familiarity with technical specifications and work environment Integrated teamwork Reduced cost Higher schedule efficiency Better chance of repeated business Long-standing relationship among core teams
2	Learning from experiences and re-implementation of them	Experience-oriented approach towards problems Improved cost and time estimation More comprehensive design review More effective selection of construction methods Enhanced risk analysis Improved administration of tendering process
3	Inefficiency	Management of inter-organisational relationships inducing contractors and suppliers Technical performance Construction material's price fluctuations
4	Collaborative knowledge management	Use of advanced communication technologies
5	Effective partnership	Improved cost and time efficiency Higher certainty around the project Better communication Awareness towards potential problems
6	Construction waste recycling	Reduced physical waste production Cost saving
7	Project efficiency in developing countries	Incompetency of project stakeholders Use of inappropriate tools and techniques Socially fragmented project environment
8	Intra-organisational learning	Facilitated exchange of information and experiences among heterogeneous groups Relying on learning by doing, communities practices, and personal contacts
9	Project delay	Ineffective control and planning Poor site management Manpower productivity and shortage of skills Poor coordination and communication Malfunctioning of Material procurement and supply chain

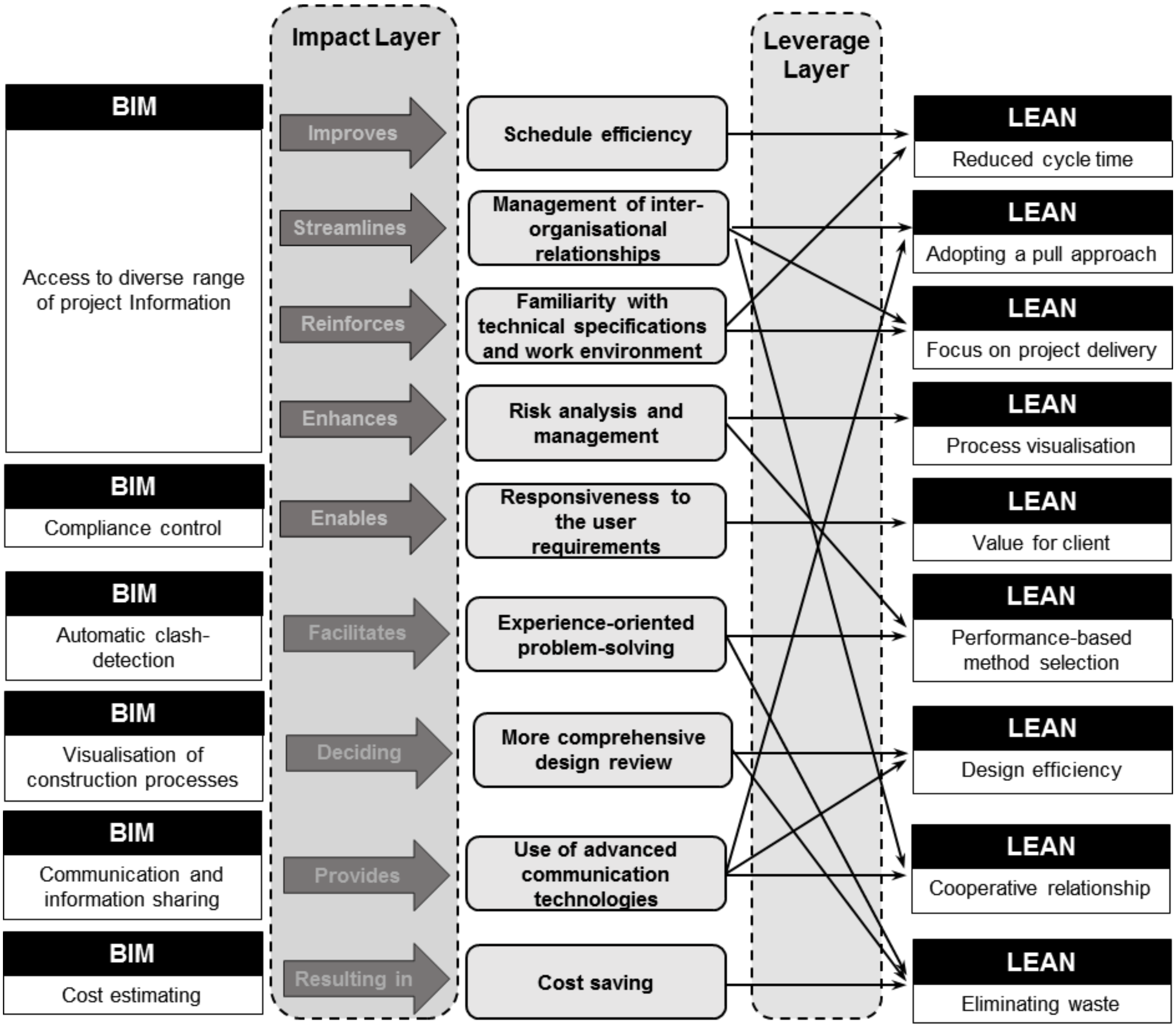
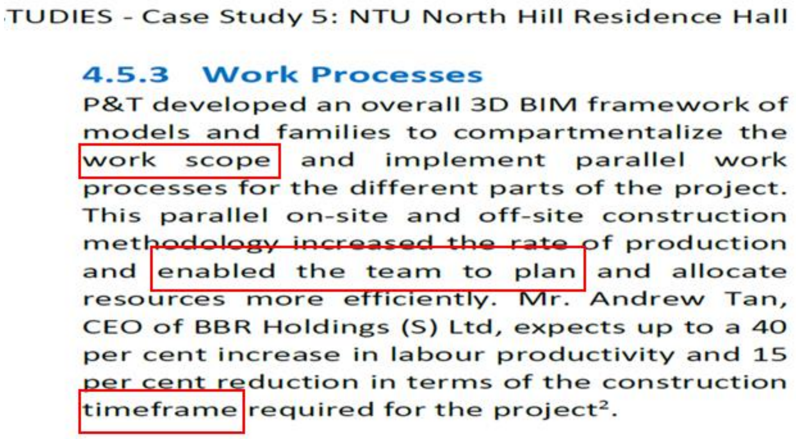


Figure 1: Impact path for co-utilisation of BIM and lean

Validation of Proposed Synergy Framework

This final stage of the research was undertaken to validate the identified synergy pathways between BIM and lean as depicted in Figure 1. Official governmental reports and expert opinions were referred to test the existence of links envisaged between BIM features and lean principles. For example, the cut-out from a guide on DfMA (Design for Manufacturing and Assembly) presented in Figure 2, readily supports the synergy pathway between access to project information — in this case, work scope for different parts of the project — and relaxation of construction timeframe through better work planning.


TUDIES - Case Study 5: NTU North Hill Residence Hall

4.5.3 Work Processes

P&T developed an overall 3D BIM framework of models and families to compartmentalize the work scope and implement parallel work processes for the different parts of the project. This parallel on-site and off-site construction methodology increased the rate of production and enabled the team to plan and allocate resources more efficiently. Mr. Andrew Tan, CEO of BBR Holdings (S) Ltd, expects up to a 40 per cent increase in labour productivity and 15 per cent reduction in terms of the construction timeframe required for the project[2].

Figure 2: Official guide on DfMA supporting a selected link between BIM and lean

Summary

BIM applications have been applied in many projects all over the world, and it is getting more popular as most projects are looking for more creative ways of deploying BIM. This study was an attempt to demonstrate that BIM adoption is likely to automatically reinforces lean principles. We produced a list of factors capable of differentiating high and poor performing projects by reviewing reports about various projects published in scholarly papers. Then an in-depth analysis was carried out to use those factors as mediators matching multiple BIM attributes to lean construction principles. It was shown that BIM adoption leverages nine lean construction principles including cycle time reduction, pull approach adoption, process visualisation for management, focus on project delivery, value for client, performance-based method selection, design efficiency, cooperative relationship, and eliminating waste. The model outlining the synergy between BIM and lean was validated by referring to official reports and expert opinion stated in various formats. Validation procedure for one of the many pathways was provided in this manuscript to demonstrate the possibility of validating the proposed model. The initial outcome of the validation was promising but a more extensive work on validation of the entire model is still ongoing.

References

AlSehaimi, A, Koskela, L & Tzortzopoulos, P 2012, Need for alternative research approaches in construction management: Case of delay studies, *Journal of Management in Engineering*, vol. 29, no. 4, pp. 407-413.

Arayici, Y, Egbu, CO & Coates, SP 2012, Building information modelling (BIM) implementation and remote construction projects: issues, challenges, and critiques, Journal of Information Technology in Construction, vol. 17, pp.75-92.

Aziz, RF & Hafez, SM 2013, Applying lean thinking in construction and performance improvement. Alexandria Engineering Journal, vol. 52, no. 4, pp. 679-695.

Azhar, S 2011, Building information modelling (BIM): Trends, benefits, risks, and challenges for the AEC industry, Leadership and management in engineering, vol. 11, no. 3, pp. 241-252.

Bayliss, R, Cheung, SO, Suen, HC & Wong, SP 2004, Effective partnering tools in construction: a case study on MTRC TKE contract 604 in Hong Kong, *International Journal of Project Management*, vol. 22, no. 3, pp. 253-263.

Bazjanac, V 2006, 'Virtual building environments (VBE)-applying information modelling to buildings', August, 29, pp. 2009.

Bresnen, M & Marshall, N 2000, Building partnerships: case studies of clientcontractor collaboration in the UK construction industry, *Construction management and economics*, vol. 18, no. 7, pp. 819-832.

Building and Construction Authority 2016, *BIM for DfMA (Design for Manufacturing and Assembly) Essential Guide*, viewed 10 April 2019, <https://www.corenet.gov.sg/media/2032999/bim_essential_guide_dfma.pdf>.

Dave, B & Koskela, L 2009, Collaborative knowledge management—A construction case study, *Automation in construction*, vol. 18, no. 7, pp. 894-902.

Dave, B, Koskela, L, Kiviniemi, A, Tzortzopoulos, P & Owen, RL 2013, Implementing lean in construction: lean construction and BIM.

Eastman, CM, Teicholz, P, Sacks, R, Liston, K & Handbook, BIM 2008, A Guide to Building Information Modelling for Owners, Managers, Architects, Engineers, Contractors, and Fabricators, John Wiley and Sons, Hoboken, NJ.

Erik Eriksson, P 2010, Improving construction supply chain collaboration and performance: a lean construction pilot project, Supply Chain Management: An International Journal, vol. 15, no. 5, pp. 394-403.

Frimpong, Y, Oluwoye, J & Crawford, L 2003, Causes of delay and cost overruns in construction of groundwater projects in a developing countries; Ghana as a case study, *International Journal of project management*, vol. 21, no. 5, pp. 321-326.

Gilligan, B & Kunz, J 2007, VDC use in 2007: significant value, dramatic growth, and apparent business opportunity, Technical Rep, no. 171, pp. 36.

Glick, S & Guggemos, A 2009, 'IPD and BIM: benefits and opportunities for regulatory agencies', Proceedings of the 45th ASC National Conference, Gainesville, Florida, Vol. 2, No. 4.

Hardin, B 2009, BIM and construction management, Wiley, Indianapolis, IN.

Howell, GA 1999, 'What is lean construction', Proceedings 17th annual conference of the international group for lean construction, Berkeley, CA, p. 1–10.

Huovila, P, Koskela, L & Lautanala, M 1997, Fast or concurrent: the art of getting construction improved. Lean construction, 20(2), pp.143-159.

Innovation, CC 2007, Adopting BIM for facilities management: Solutions for managing the Sydney Opera House, Cooperative Research Centre for Construction Innovation, Brisbane, Australia.

Khemlani, L 2009, 'Sutter Medical Castro Valley: Case Study of an IPD Project', AECBytes ''Building the Future'', Viewed 2 September 2018, http://www. aecbytes. com/buildingthefuture/2009/Sutter_IPDCaseStudy. html.

Kunz, J, & Gilligan, B 2007. 'Values from VDC/BIM use', viewed 2 October 2018, https://cife.stanford.edu/VDCsurvey.pdf

Koskela, L, Huovila, P & Leinonen, J 2002, Design management in building construction: from theory to practice, Journal of construction research, vol. 3, no. 01, pp. 1-16.

Lapinski, AR, Horman, MJ & Riley, DR 2006, 'Lean Processes for Sustainable Project Delivery', Journal of Construction Engineering and Management, vol. 132 no. 10, pp. 1083-1091, viewed 2 September 2018, https://doi. org/10.1061/(ASCE)0733-9364(2006)132:10(1083)

Long, ND, Ogunlana, S, Quang, T & Lam, KC 2004, Large construction projects in developing countries: a case study from Vietnam, *International Journal of project management*, vol. 22, no. 7, pp. 553-561.

Mcdonald, B & Smithers, M 1998, Implementing a waste management plan during the construction phase of a project: a case study. *Construction Management & Economics*, vol. *16*, no. 1, pp. 71-78.

Pikas, E, Koskela, L, Sapountzis, S, Dave, B & Owen, R 2011, Overview of building information modelling in healthcare projects.

Pinch, L 2005, Lean Construction, Construction Executive, vol. 15 no. 11, pp. 8-11.

Sacks, R, Treckmann, M & Rozenfeld, O 2009, Visualization of work flow to support lean construction, Journal of Construction Engineering and Management, vol. 135, no. 12, pp. 1307-1315.

Styhre, A, Josephson, PE & Knauseder, I 2004, Learning capabilities in organizational networks: case studies of six construction projects. *Construction Management and Economics*, vol. *22*, no. 9, pp. 957-966.

Rischmoller, L, Alarcón, LF & Koskela, L 2006, Improving value generation in the design process of industrial projects using CAVT, Journal of management in engineering, vol. 22, no. 2, pp. 52-60.

Tommelein, ID & Ballard, G 1999, Seventh Conference of the International Group for Lean Construction, Berkely, California: Lean Construction Institute, Varför är det den vanligaste, hur kan det förhindras.

Womack JP & Jones, DT 1996, Lean Thinking: banish waste and create wealth in your corporation, Simon and Schuster, NY.

Yau, NJ & Yang, JB 1998, Case-based reasoning in construction management, *Computer-Aided Civil and Infrastructure Engineering*, vol. *13*, no. 2, pp. 143-150.

WORK READINESS OF PROJECT MANAGEMENT GRADUATES WORKING IN CONSTRUCTION: A STUDY OF EMPLOYER PERSPECTIVES

Jessica Borg[1], Christina Scott-Young[1]

[1]School of Property, Construction & Project Management, RMIT University, Melbourne, Australia

Abstract

Undergraduate work readiness continues to gain increasing attention from employers and educators worldwide, yet remains a concept that is largely under researched. Within the context of the construction industry, there is an observed need for graduates who are able to successfully transition into and thrive within such a fast paced and dynamic industry. This research explores undergraduate work readiness within the context of the project management discipline, with the aim of ascertaining the perspective of industry employers regarding the work readiness of project management graduates working within the Australian construction industry. Qualitative in-depth interviews were conducted with eighteen employers of project management graduates. Research results illustrate that for employers of project management graduates working in the construction industry, work readiness constitutes i) empathic communication, ii) personality and passion and iii) construction knowledge. Findings also show that employers recognise that the responsibility for fostering work readiness is one that should be shared between university educators, project management students and themselves, suggesting a need for closer collaboration among the key stakeholders in project management education.

Keywords

construction industry, employer perspective, project management education, undergraduate work readiness, workplace transitions

Work readiness is a concept that though widely recognized as important, lacks a uniform definition. Work readiness is well recognized as being a key objective of education, and an essential component of performing well in the world of work. It is neither a concept that is industry nor discipline specific. Scholarly research defines work readiness as “the need for graduates to possess a range of generic skills and attributes, over and above their formal qualifications, that make them ‘prepared’ or ‘ready’ for both general and more specific workplaces” (Prikshat et al. 2018, p. 122). For employers, work readiness refers to the individual’s ability to make the successful transition into the workplace (Business Council of Australia 2016). With this understanding in mind, work readiness is defined as encompassing a mixture of values, behaviours and skills which facilitate a successful transition into the workplace (Business Council of Australia 2016). It is this definition which is adopted in this research.

Work ready graduates’ contributions to the workplace and industry in which they work extend past the period of transition into their work environment. It appears that industry is quick to recognise the importance of employing work ready graduates within their organisations, as employers across a number of industries continue to call for work ready graduates and advocate for the improvement of work readiness education for their future graduate employees (Cavanagh et al. 2015). There is a need for further investigation to better understand factors influencing undergraduate students’ transition into the workforce, to ensure that employers can recruit graduates who have the skills which their organisations need to succeed in the twenty-first (21st) century knowledge-based economy (Finch et al. 2013).

Work Readiness Requirements for Project Managers within the Construction Industry

There is a perceived gap in the extant literature with regards to how well the current supply side of project management graduates' competencies align with the demand side of employers' needs. On the demand side of the talent market, a tertiary qualification is viewed as a mandatory selection criterion for project management positions in certain companies, industries, and countries (Ahsan, Ho & Khan 2013; Gruden & Stare 2018). An Australian study of job advertisements for the five (5) largest industry employers of project managers found that many employers regard a university degree as an essential prerequisite, particularly in the construction, engineering and health industries (Ahsan et al. 2013). However, there is no research (Borg, Scott-Young & Turner 2017) which has specifically investigated the work readiness of graduates within the project management discipline, nor whether the work readiness levels of graduates meet the employers' requirements.

There is global concern that universities are producing graduates who do not possess the skills required by the industries of today and tomorrow (Pant & Baroudi 2008; Chipulu et al. 2013). From a review of the literature, it is apparent that employers' dissatisfaction with the work readiness of today's emerging graduates highlights two issues; i) that field specific knowledge and technical skills alone are not enough to label graduates work ready and ii) that graduates need to "develop certain capacities beyond their qualifications which would enable them to deal with the stressful nature of the work environment" (Masole & van Dyk 2016, p.70). Given the increasing number of emerging university graduates and the highly competitive nature of the labour market, the inability of graduates to meet the demand of the labour force is a pressing concern. The literature has identified a need for research which explores the transitions of university graduates from academia into the workforce (Holden & Hamblett 2007) as the transitioning of graduates from university into the world of work remains a subject which has been rarely researched (Wood, Psaros, French & Lai 2015). It is apparent from literature that the work readiness of graduates remains an issue that transcends across disciplines. Within the project management discipline, the work readiness of graduates who undertake project management programs poses a significant literature gap which would benefit from further investigation and exploration.

It is a well-known fact that the construction industry and the built environment sector as a whole, is in a constant state of change as a result of a number of variables including economics, labour resources, market forces, emerging technologies and government laws and regulations (Benhart & Shaurette 2014). As such, it is imperative that programs preparing students for work within the construction industry reflect the dynamic nature of the industry to ensure that the students emerge out of their degrees in a manner which prepares them for the workplace and its myriad of challenges (Ahmed et al. 2014; Benhart & Shaurette 2014). However, this requirement has been criticized due to the understanding that the diversity of the construction industry, makes it "impractical for the industry to have a single voice on their skills and labour requirements" (Amaratunga, Thayaparan & Malalgoda 2012, p. 3). This poses a challenge for higher educational institutions to address the requirements of the industry.

It is an expectation held by employers within the construction industry specifically, that graduates are expected to possess practical and theoretical knowledge as well as the ability to apply such knowledge to their work environment (Mills & Wingrove 2010). Work-readiness is an essential imperative for construction-related programmes (Mills & Wingrove 2010). Thus, the construction industry strongly calls for work ready students. Gauging exactly what skills and competencies are required by potential future employers is a task that literature has attempted to address globally across industries, including construction (Borg, Turner & Scott-Young 2017). The challenge predominantly lies in the attempt to pin down a set of skills and competencies which are constantly changing and being redefined. Within industries characterised by fast paced change such as the construction industry (Benhart & Shaurette 2014), the need for graduates who can thrive in the challenging industry is even more crucial. Conversely, it becomes more difficult to isolate exactly what skills and competencies graduates need to successfully succeed in such a dynamic industry.

The Employers' Voice in Graduate Work Readiness

Extant literature posits that work readiness is better realised through the collaboration of key stakeholders in education (Borg, Scott-Young & Turner 2019). It is therefore important to note that the employers cannot be merely perceived as the benefactors of university endeavours to produce work ready graduates. Research has found that "by better understanding the value employers place on employability factors, universities can design curricula based on the development of key skills that employers desire, and students can better position themselves in the marketplace" (Finch et al. 2013, p. 698). Yet, research reveals that many employers have unrealistic expectations of graduate skills and competencies and that they are i) infrequently involved with higher education institutions and ii) are seldom prepared to support graduates' transitions from university into the workplace (i.e. through induction, learning or structured career development systems) (Finn 2016; Hinchcliffe & Jolley 2011). It is an impossible task to expect universities to understand employers' desired values and attributes for their future employees without effective stakeholder engagement and communication between them.

Employers have a clear stake in graduate work readiness; the fact that they have something to lose (lack of work ready future employees) or gain (availability of work ready graduates who can contribute to the workplace) as a result of activities (i.e. the systems designed by universities to foster graduate work readiness) makes them an important stakeholder in graduate work readiness. Following Horton and Pilkington's (2014) classification of stakeholders, it can be asserted that in the context of graduate work readiness, employers can be classified as users as they are the end consumer of the work ready product (i.e. the work ready graduate/resource) (Borg, Scott-Young & Turner 2019). Upon graduation, the graduates will transition into the industry, serving as the employers' new recruits, thus contributing to the employers' organisations through the knowledge and work readiness specific skills gained at university.

Research Aim

The aim of this research was to ascertain the perspective of employers regarding the work readiness of project management graduates working within the Australian construction industry. Specifically, interviewees consisted of employers who recruited project management graduates from one of the highest ranked universities for employer reputation in Australia (Quacquarelli Symonds 2019). It was held that information collected would provide insight into how this particular university was preparing work ready project management graduates from the perspective of the employers themselves. Findings from this case may lend insights which could be valuable to other universities delivering such bachelor degrees.

Methodology

The purpose of the current research is aligned with the interpretivist/constructivist research paradigm, which suggests that it is essential that social action is analysed from the actor's standpoint (Tracy 2012). In alignment with this understanding, this research explores the concept of work readiness from the personal viewpoints and perspectives of construction industry employers of project management graduates. Stakeholder Theory, coupled with the underlying theoretical principles of the Resource Based View, the Shared Value Perspective and Matching Theory frames the aims and methodology of this research.

Data Collection and Analysis

The research entailed the use of semi-structured in-depth interviews to capture employer's individual voices and stories. The process involved is described as "a meaning-making partnership between interviewers and their respondents", indicating that in depth interviews are knowledge producing conversations (Hesse-Biber & Leavy 2006, p.128). When conducting research using in-depth interviews, the interviewer and the interviewee essentially co-create knowledge and meaning in an interview setting, thereby co-constructing reality. Thematic Analysis was selected as the method for analysing the data collected following the guidelines of Braun and Clarke (2006; 2013). In essence, inductive thematic analysis is a process of "coding the data without trying to fit into a pre-existing coding frame or the researcher's analytic preconceptions" (Braun & Clarke 2006, p.83). This does not mean that data is coded into "an epistemological vacuum" (Braun & Clarke 2006, p.85), as researchers are still influenced by their theoretical and epistemological commitments (Braun & Clarke 2006). However, in contrast to theoretical thematic analysis (whereby the analysis is considered to be more analyst driven), inductive thematic analysis has the strength of providing a richer description of the overall data set (Braun & Clarke, 2006).

Results

Sample – Demographic Profile

This study adopted purposive sampling of research participants. Organisations from which to recruit the participants were selected by reviewing the positions that were advertised to students at the selected university, within the last 1-5 years, via the university's database. Fifty-one organisations were identified and upon review of the types of projects they perform, 42 organisations were contacted. Out of these 42 contacted organisations, 18 participated in the research, corresponding to a participation rate of 43%. Eighteen interviews were conducted, ranging from 45 minutes to 1 hour in duration. Theoretical saturation was observed to have been reached at 16 interviews.

The interview participants were all project management professionals in middle management responsible for graduates in their employ. Twenty-eight per cent of participants were female and 72% were male. Participants were aged between 30 and 55 years of age and had been working within the project management discipline for periods ranging from 10 to 35 years. All interviewees had worked closely with project management graduates and their roles and interactions with and supervision of graduates, enabled them to reflect on the graduates in their employ. The roles of participants within their respective organisations varied, ranging from Head of Operations, Director, Associate Director, Senior Project Manager, Project Manager to Manager.

What Constitutes Work Readiness

Participants were asked to reflect on what they believe constitutes work readiness. When reflecting on what it means to be a work ready project manager within the construction industry, three major themes emerged: i) empathic communication, ii) personality and passion, and iii) construction knowledge.

Empathic Communication: The results revealed that employers looked for communication skills in their new recruits, specifically an ability to communicate ethically and empathetically with stakeholders in the industry. Employers considered that a work ready graduate would be one who has strong oral as well as written communication skills, but more than that, employers looked for graduates who could communicate with consideration of the other party's feelings and needs. Whenever employers referred to communication as a skill they consider that graduates should possess to be considered work ready, they did not merely refer to the graduate's ability to write or speak well (although these were mentioned and considered important). Employers linked effective communication with the ability to "build rapport with people" (Participant (P)11, female, 51 years old), "put yourself in others' shoes" (P7, male,46), "read emotions" and to "empathise" (P8, male, 43).

Personality and Passion: Personality (i.e. the general disposition of the graduates) was a key consideration from the perspective of the employers when employing graduates to work within their organisations. Employers took into consideration the personality of the individuals and their passion for the industry to assess not specifically their work readiness, but whether they were well suited to work within their organisation. In the participants' dialogue, personality and passion appeared to be intertwined. Participants used different terms for passion like ambition (P4-M-31; PG07-M-46). Results showed that employers deciphered one's personality from the articulation of one's passion for the industry. It was understood by employers that one's drive or passion for the industry would go a long way in determining whether the graduate in question would be a good personality fit within the organisation.

Construction Knowledge as a Function of Experience: For project management graduates entering the construction industry after graduation, employers considered knowledge of construction to be a key component of their work readiness. Participants considered that graduates should have an understanding of the construction industry, an appreciation of its many facets and a fundamental understanding of how things are constructed. Participants made note that graduates with work experience had a deeper understanding of the construction industry and therefore in the eyes of the employers, were considered to be more work ready than those graduates who had not worked in the industry while studying. Results indicated that employers noted that knowledge of the industry was more often than not a function of the graduates having previously worked within the construction industry. When referring to construction knowledge, employers were quick to point out that they referred to knowledge beyond that taught within the classroom.

Situations where Graduates were Well-prepared

Participants reflected on instances in which graduates had demonstrated their work readiness. The themes that emerged included i) professional presentation and communication and ii) application of technology.

Professional Presentation and Communication: There was agreement from participants that graduates were well prepared when it came to professional presentations and communications within a work setting, including leading meetings. Results revealed that the graduates impressed their employers when it came to their ability to lead meetings and communicate professionally, suggesting that their professional presentation and communication skills were beyond what was expected of a graduate.

Application of Technology: As observed by participants, an area of strength for graduates in the workplace was their ability to utilise technology. Employers made specific note of the graduates' abilities to utilise specific software such as Microsoft Project as well as a general competency and proficiency with computers. Participants recognised the graduates' skills with technology, appraising their ability to embrace technology within the workplace.

Situations where Graduates were Under-prepared

Participants reflected on situations which graduates had not been well prepared for or had not performed well in, contrary to what was expected by their employers. The themes that emerged included i) lack of confidence to ask for help (internal communications), ii) inability to respond to confrontational situations, iii) lack of basic construction knowledge and iv) inadequate professional writing ability.

Lack of Confidence to Ask for Help (Internal Communications): While the graduates' ability to present themselves professionally in their communication with external stakeholders was recognised by their employers, the results revealed that from the perspective of the employers, graduates lacked the confidence to speak up and communicate their concerns or ask for help, pointing to graduates being weak in communications within their own internal organisations and colleagues. The results revealed that employers observed that graduates lacked the confidence to ask questions and ask for help. Employers noted that this hindered the graduates' development as employers perceived the asking of questions as an essential element of professional skills.

Inability to respond to Confrontational Situations: Participants noted that graduates were often faced with confrontational situations they were not well equipped to handle, therefore pointing to a weakness in their work readiness. One participant (P2, male, 44) described how a graduate had been verbally abused by a construction worker on site and had been very upset afterwards, but had been unable to stand up for herself or talk to someone about what had happened. It was only much later, after being prompted by her supervisor, that the graduate had revealed the details of the confrontational situation. Her employer felt that she was not ready to respond to such a situation. Other participants spoke about confrontational situations, often describing them as the ‘nature’ of the industry. The carefree manner in which participants spoke about such incidents that one interviewee classified as “borderline bullying” (P14, male, 40) suggested that the employers expected graduates to be ready to respond assertively in such confrontational scenarios.

Lack of Basic Construction Knowledge: Participants felt that project management graduates entering the construction industry lacked what they perceived were the basics of construction, such as the ability to read drawings. Moreover, employers asserted that while the graduates may have an understanding of some construction elements, this knowledge was often not consolidated and graduates found difficulty in applying it to their work. Participants revealed that their expectations for graduates who had an understanding of basic construction principles were not being met. From the perspective of the participants, students were graduating without the knowledge their employers expected, and the employers had to adapt their expectations to suit. Employers noted that they are now having to teach graduates about the different roles in industry as graduates do not appear to possess this desired knowledge.

Lack of Professional Writing Ability: A key area of weakness for the graduates from the perspective of the employers was their professional writing ability which included their inability to write professional emails to clients, take minutes and an inability to write professional reports. The poor writing skills and ability to communicate professionally through written language was a common theme that emerged in the results. From the perspective of employers, the graduates were lacking sound professional writing abilities and “their writing ability, spelling, structure, grammar and presentation is certainly not improving” (P10, female, 40).

Advice for Graduates

Employers were asked to reflect on what the graduates could do to better prepare themselves for the transition into industry. The themes that emerged were i) to obtain work experience and ii) familiarise themselves with the industry.

Obtain Work Experience: From the perspective of the participants, gaining industry-relevant work experience was a key recommendation to graduates preparing to transition into the construction industry. While employers acknowledged that work experience relevant to the role the graduate was applying would be key, employers also revealed that they would view positively any experience related to the project management discipline. As an example, one employer even made reference to a recent graduate in his employ who had been working at her local hardware store while studying, saying that even though she did not have experience in project management, she had taken the initiative to find work somewhat related to the construction industry, within which she hoped to gain employment working as a project manager. Employers placed such a high value on work experience that if a graduate was to apply to work for their company and not have any experience related to the industry, then the employers would actually question that individual’s dedication and motivation. Findings suggest that graduates with no work experience will be at a disadvantage when they apply for work after graduation, with the employers themselves questioning their intentions and reasons as to why they did not work while studying. Working while studying therefore appeared to be an expectation of employers.

Familiarise Self with the Industry: Participants suggested that graduates should familiarise themselves with the industry prior to graduation. From understanding the nature of the work involved and work demands to having a clear direction on where they see themselves within the industry, participants suggested that graduates need to form a better understanding of the industry and what they are going into before they step into the role after graduation. Employers felt that graduates needed to have a better understanding of the different facets of the industry and work environments which they could potentially find employment in. For example, it was held that graduates need to have a better understanding of client side or construction side project management and what work within each different area would involve. Overall, the results indicated that from the perspective of their employers, project management graduates did not have a clear picture of the construction industry and the roles within which they were stepping into. Participants maintained that a better understanding of the nature and expectations within the role would aid the graduates in their transition to the industry.

Advice for Universities

Participants were asked to reflect on their thoughts on what the education sector was doing to prepare work ready graduates. The employers suggested areas that universities could focus on to better prepare graduates for the workforce. The following themes emerged: i) industry engagement, ii) embed practice, iii) literacy lessons and, iv) career coaching.

<u>Industry Engagement:</u> Participants suggested that universities could help better develop their graduates to be work ready through more engagement with industry partners and employers. Employers suggested that this can be done through hosting industry nights whereby the students can be introduced to members within the industry and use the opportunity to ask questions about the industry, thus familiarising themselves with industry expectations. Employers suggested that they would be happy to collaborate with the universities and assist in the education of the graduates, recognising that graduates who are work ready would have a positive impact within their organisations. An employer (P4, male, 31) revealed that his organisation had collaborated with the university by reviewing assessments or offering to come in and talk to the students, seeing it as an investment into their potential future employees.

<u>Embed Practice:</u> Employers advocated strongly for educators to teach content in a practical manner and to introduce work placements or industry practice into the curricula. This theme of ‘embed practice’ therefore can be split into two interrelated sub-themes: i) practical content and ii) practical experience. Employers suggested that educators should ensure that content taught within the program is up to date and relevant to what is being practiced in the industry. Participants acknowledged that the techniques in the industry are always changing and advocated for universities to ensure that content is kept up to date with the practical trends in industry. In reflecting upon how universities can embed practical knowledge into their teaching to ensure that graduates are prepared for the workplace, employers raised the integration of practical experience as key. Participants suggested that practical experience can be embedded within the curricula in a number of ways, including through i) work experience, whereby the graduates are given the opportunity to work while studying as part of their course requirements or alternatively, through ii) closer collaboration between universities and industry to make site visits and industry talks possible.

<u>Literacy Lessons:</u> Employers noted that graduates’ literacy skills were lacking and not meeting the industry’s expected standards. Participants advised that universities should focus on ensuring that graduates are competent in and equipped with the professional literacy skills required within the industry, such as writing emails, meeting minutes and reports. Participants were shocked by the lack of proficiency in literacy and identified this as a key area for universities to focus on.

<u>Career Coaching:</u> Participants suggested that universities focus more on educating their students on the various career opportunities, paths and trajectories that await them upon graduation. Employers have observed a lack of understanding of career opportunities for project managers amongst their graduates, suggesting that the graduates are not aware of the various roles within the industry as well as the differences between sectors such as client side or contractor side construction. Furthermore, participants suggested that project management graduates are educated on the various roles they could work in within the industry and the differences in roles and titles. They suggested that educating students on potential career opportunities and directions would help better prepare them for their future careers.

The Role of the Industry In the Graduates' Transition

Participants were asked about their role in the graduates' transitions and what they do to help new graduates assimilate into their respective organisations within the industry. The themes that emerged were i) mentoring and ii) training initiatives.

Mentoring: Participants revealed that within their organisations they had mentoring programs and initiatives which they believed assisted the students in their transition to the industry. Within the larger companies, mentoring was part of a structured graduate program, whereby typically a graduate would be paired with a previous graduate. Within the smaller organisations or organisations which did not have graduate programs, mentoring took on a more ad hoc approach and employers said that graduates would be around people with experience in the industry, to whom they were encouraged to ask questions.

Training Initiatives: Participants noted that training their graduates was important in assisting graduates to transition into the workplace, with employers acknowledging that they had a responsibility to provide this training. As per the mentoring initiatives, training regimes varied between structured programs to more ad-hoc approaches whereby graduates were trained by shadowing their senior colleagues and managers. The larger companies with graduate programs tended to have more structured training initiatives. Results revealed that smaller companies tended to have a more ad-hoc approach to training, whereby training was not necessarily part of a structured program. Graduates were considered to be in training when they were working under the supervision of senior colleagues.

Discussion

The findings show that employers identified empathic communication, personality and passion, and construction knowledge as components of work readiness in graduates working as project management professionals within the construction industry. This resonates with the findings of other scholars who argue that in addition to project-specific technical knowledge and skills, project practitioners also require a range of interpersonal or 'soft' competencies (Scott-Young & Samson 2008). By acknowledging empathic communication and personality and passion, alongside construction knowledge as components of work readiness, employers of project management graduates working within the construction industry also value the soft professional skills alongside the technical skills.

Moreover, in reflecting upon graduates who had successfully made the transition into their workplaces, employers felt that graduates were well prepared in terms of their professional presentation and verbal communication skills as well as in the application of technology. Conversely, employers acknowledged that graduates were not as well prepared when it came to having the confidence to ask for help, responding to confrontational situations, basic construction knowledge and professional writing ability. Essentially, the results suggest that the above-mentioned skills are what employers working in the discipline of project management within the Australian construction industry expect of their new graduate recruits. The literature shows that for project managers, soft skill competencies values by employers in other studies (not specific to construction) encompass; leadership, problem solving (Müller & Turner 2010; Hölzle 2010), communication (Skulmoski & Hartman 2010), emotional intelligence (EQ) (Müller & Turner 2010), social skills, negotiation skills, and professionalism (Skulmoski & Hartman 2010). Certainly, it is apparent that there are overlaps with the project management skills detailed in previous studies and the skills appraised by employers in the construction industry. For example, professionalism can be shown through professional presentations as noted by employers and the ability to respond to confrontational situations would entail the accompanying negotiation skills and emotional intelligence skills appraised in other studies.

It is interesting that basic construction knowledge was found to be lacking in project management graduates entering the construction industry, suggesting that the university degree may not have contextualised the project management theory within construction practice. It was also concerning that professional writing ability was found to be lacking in graduates; this can be considered a generic skill that is important across disciplines and not merely valuable to project managers working within the construction industry. The poor quality of two sets of skills observed in graduates (writing ability and basic construction knowledge) which from the perspective of the employers were seen to be basic requirements, suggests a disparity in what employers expect with what some universities are preparing their graduates for. Through the lens of Matching Theory, graduate work readiness results from the ability of the graduates to successfully exercise their knowledge and attributes, which can only be realised if their possessed knowledge and attributes match those required by their employers. Therefore, in looking at the results from a Matching Theory perspective, there appear to be elements of misalignment between some of the skills required by employers and those possessed by graduates.

This suggests that both employers and universities may benefit from open dialogue. This is in accordance with research recommendations that universities require input and support from industry in improving the graduates' education experience prior to their entry into the construction industry (Farooqi & Ahmed 2009). In effect, the findings showed that employers advocated for a stronger partnership with universities, believing that through better industry engagement, universities could establish better links between graduates and the industry. This is in alignment with the Shared Value Perspective of Stakeholder Theory, which posits that focusing on value creation for stakeholders fosters the ability to create win-win situations (Hickman & Akdere 2017). From the perspective of employers, having graduates who are work ready within their organisations would mean that their future employees are equipped with the skills and attributes that would enable them to make positive contributions to the organisations in which they work. Furthermore, employers whose graduate employees are work ready can expect higher levels of interaction and reduced staff turnover (Argyle 1989). It is essential that 'shared value' is reinforced among stakeholders (in this case, the universities and the employers), as a lack of alignment, coupled with possible limited understandings of stakeholder expectations, may lead to problems among the stakeholder groups (Balser & McClusky 2005; Nankervis et al. 2018). Recent research (Borg et al. 2019) has advocated for closer collaboration between key stakeholders in education, including between universities and employers, asserting that it "involves a major (but necessary) departure from the traditional educator-only approach to curricula design" (p.59).

Results show that employers in the construction industry placed a high value on work experience when recruiting graduates, with employers noting that if a graduate did not have any experience related to the industry, then this may negatively impact the application outcome. This is not surprising, given that literature shows that an increasing number of students are choosing to combine work and study prior to graduation, especially within the context of construction (Curtis & Williams 2002; Forsythe & Zou 2006; Lingard 2005; Mills et al. 2012; Moore & Loosemore 2014). The high proportion of students combining professional work and study prior to graduation may be the result of why graduates without any relevant work experience are considered outliers by employers.

Overall, the findings show that employers appear to recognise the value to be gained from having work ready graduates within their organisations. The literature on the Resource based View (RBV) of organizations defines resources as any organisational characteristic that can be a either a strength or a weakness (Wernerfetlt 1984) and from the perspective of employers, having access to a pool of work ready graduates from which they can recruit their future employees would constitute a strength. Work ready graduates are assumed to be able to make a successful transition into the employers' organisations (Business Council of Australia 2016; Caballero & Walker 2010), and thus, serve as valuable resources to employers soon after graduation. Graduates can be seen as rare (tangible) resources, given that only a certain number of students graduate from university per year. Through employing work ready graduates, employees can expect higher interaction in the workplace and significantly lower staff turnover rates (Argyle 1989), resulting in an organisation able to generate more profit. Essentially, work ready graduates serve as valuable resources to employers and enable them to gain a competitive advantage in terms of work performance.

Apart from the benefits to be gained by employing work ready graduates, employers recognised that they too have a part to play in helping nurture the graduates while transitioning into their organisations. Employers considered that they had a role in both mentoring and training the graduates. This is encouraging given that the construction industry is characterised by various challenges (Ahmed et al.

2014; Benhart & Shaurette 2014) and that when transitioning into the workforce, students often experience negative feelings including stress, pressure and bewilderment (Davis 2010; McNamara et al. 2011). Studies show that graduates are in need of support upon graduation and that a smooth transition into the work environment is interrelated with higher levels of interaction and mutual support in the workplace (Argyle 1989). Through mentoring, employers may help offer the much-needed support in the workplace, thus aiding graduates in making a smoother transition into industry.

Conclusion

This research serves as a critical step towards ascertaining the perspectives of employers with regards to project management graduates working within the construction industry. It is the first known study to explore work readiness from the perspectives of industry employers within the context of project management and construction, thus contributing to new knowledge and helping shed light on the topic of work readiness in an under researched area. In reflecting on the transitions of recent graduates in their employ, employers highlighted the areas of weakness and strengths in graduates' work readiness, suggesting ways in which graduates themselves can enhance their work readiness and serving as valuable feedback to universities preparing project managements students for careers in construction. Moreover, employers also recognised that they have a role in supporting the graduates in their transition into industry through mentoring and training initiatives. In addition, employers advocated for a stronger partnership between themselves and universities, recognising that graduate work readiness is the responsibility of more than one stakeholder group.

While the findings of this study cannot be generalised to apply to all employers in the construction industry with whom project management graduates seek employment, or to all universities that offer undergraduate project management degrees, the results can serve as a foundational step in beginning to understand graduate work readiness within the context of project management and construction. The next phases of this research will look towards ascertaining the perspectives of other stakeholders, including project management educators, students, alumni and professional bodies. In alignment with the shared value perspective framing this research, it is recommended that graduate work readiness can only be realised for the benefit of all stakeholders if there is active involvement of all stakeholders in ongoing and topical discussion.

References

Ahmed, S.M, Yaris, C., Farooqui, R.U. & Saqib, M. 2014, 'Key Attributes and Skills for Curriculum Improvement for Undergraduate Construction Management Programs', *International Journal of Construction Education and Research*, vol. 10, no. 4, pp. 240-254.

Ahsan, K., Ho, M., & Khan, S. 2013, 'Recruiting project managers: A comparative analysis of competencies and recruitment signals from job advertisements', *Project Management Journal*, vol. 44, no. 5, pp. 36–54.

Amaratunga, D., Thayaparan, M. & Malalgoda, C. 2012, *Bellcurve: Built Environment Lifelong Learning Challenging University Responses to Vocational Education: Lifelong University for the Built Environment*, Salford, UK.

Argyle, M. 1989, *The Social Psychology of Work*, 2nd Ed. Penguin: Wisconsin.

Balser, D., & McCluskey, J. 2005, 'Managing stakeholder relationships and non-profit organisational effectiveness', *Non-profit management and leadership*, vol. 15, no. 2, pp. 285–315.

Benhart, B. & Shaurette, M. 2014, 'Establishing New Graduate Competencies: Purdue University's Construction Management Curriculum Restructuring', *International Journal of Construction Education and Research*, vol. 10, no. 1, pp. 19-38.

Borg, J., Scott-Young, C.M. and Turner, M., 2019. 'Smarter Education: Leveraging Stakeholder Inputs to Develop Work Ready Curricula', In: Uskov., Howlett R., Jain L. (eds) Smart Education and e-Learning 2019. *Smart Innovation Systems and Technologies*, vol.144. Springer, Singapore, pp. 51-61.

Borg, J., Scott-Young, C. & Turner, M. 2017, 'Student Work Readiness: Evaluating A New Model', paper presented at the *European Academy of Management Conference (EURAM 2017),* Glasgow, Scotland, 21 - 24 June 2017.

Braun, V. & Clarke, V. 2013, *Successful qualitative research: A practical guide for beginners*. London: Sage.

Braun, V. & Clarke, V. 2006, 'Using thematic analysis in psychology', *Qualitative Research in Psychology*, vol. 3, no. 2, pp. 77-101.

Business Council of Australia 2016, *Being Work Ready: A Guide To What Employers Want, Business Council of Australia*, viewed 05 March 2017, <www.beingworkready.com.au>.

Cavanagh, J., Burston, M., Southcombe, A. & Bartram, T. 2015, 'Contributing to a graduate-centred understanding of work readiness: An exploratory study of Australian undergraduate students' perceptions of their employability', *The International Journal of Management Education*, vol. 13, no. 3, pp. 278-288.

Chipulu, M., Neoh, J.G., Ojiako, U., & Williams, T. 2013, 'A multidimensional analysis of project manager competences', *IEEE Transactions on Engineering Management*, vol. 60, no. 3, pp. 506 – 517.

Curtis, S. & Williams, J. 2002, 'The reluctant workforce: undergraduates' part ‐ time employment', *Education + Training*, vol. 44, no. 1, pp. 5-10.

Davis, G.J 2010, 'The perceptions of recent business graduates of the transition experience from the collegiate environment to the work environment', PhD Thesis, University of North Florida, Florida.

Farooqui, R.U. & Ahmed, S.M. 2009, 'Key Skills for Graduating Construction Management Students; A Comparative Study of Industry and Academic Perspectives', in Building a Sustainable Future, Construction Research Congress 2009. <http://ascelibrary.org/doi/abs/10.1061/41020%28339%29146%X >.

Finch, D.J., Hamilton, L.K., Baldwin, R. & Zehner, M. 2013, 'An exploratory study of factors affecting undergraduate employability', *Education & Training*, vol. 55, no. 7, pp. 681-704.

Finn, K. 2016, 'Relational transitions, emotional decisions: New directions for theorising graduate employment', *Journal of Education and Work*, vol. 30, no. 4, pp.419-431.

Forsythe, P. & Zou, P. 2006, 'Improving student satisfaction in undergraduate construction management studies', *Australian Universities Building Education Association Annual Conference*, Sydney, Australia July 2006.

Gruden, N., & Stare, A. 2018, 'The influence of behavioral competencies on project performance', *Project Management Journal*, vol. 3, pp. 98–109.

Hesse-Biber, S. and Leavy, P. 2006, *The Practice of Qualitative Research*. Thousand Oaks CA: Sage Publications.

Hickman, L. & Akdere, M. 2017, Stakeholder Theory: Implications for Total Quality Management in Higher Education, *4th International Conference on Lean Six Sigma for Higher Education*, May 25–26, 2017.

Hinchcliffe, G. W., & Jolley, A. 2011, 'Graduate identity and employability', *British Educational Research Journal*, vol. 37, no. 4, pp. 563–584.

Holden, R. & Hamblett, J. 2007, 'The transition from higher education into work: tales of cohesion and fragmentation', *Education + Training*, vol. 49, no. 7, pp. 516-585.

Hölzle, K. 2010, 'Designing and implementing a career path for project managers', *International Journal of Project Management*, vol. 28, no.8, pp. 779–786.

Horton, L., Pilkington, A. 2014, 'Rolling back from the power/interest matrix: A new approach for role based stakeholder engagement in projects'. *PM World Today*, vol. 111(v), pp. 3–4.

Lingard, H. 2005, 'Balancing study and paid work: The experiences of construction undergraduates in Australia', *Australian Journal of Construction, Economics and Building*, vol. 5, pp. 41-47.

Masole, L. & van Dyk, G. 2016, 'Factors influencing work readiness of graduates: An exploratory study', *Journal of Psychology in Africa*, vol. 26, no. 1, pp. 70-73.

McNamara, J., Brown, C., Field, R., Kift, S., Butler, D. & Treloar, C. 2011, 'Capstones: Transitions and professional identity', *2011 WACE World Conference*, Philadelphia.

Mills, A. & Wingrove, D. & McLaughlin, P. 2010, 'Exploring the development and assessment of work-readiness using reflective practice in construction education', *ARCOM Twenty Sixth Annual Conference*, England, 6-8 September, pp. 163-172.

Mills, A., Lingard, H., McLaughlin, P. & Iyer-Raniga, U. 2012, 'Pathways to Industry: Work Practices of Undergraduate Students in Construction Programs in Australia', *International Journal of Construction Education and Research*, vol. 8, no. 3, pp. 159-170.

Moore, P. & Loosemore, M. 2014, 'Burnout of undergraduate construction management students in Australia', *Construction Management and Economics*, vol. 32, no. 11, pp. 1066-1077.

Müller, R., & Turner, J. R. 2010. Attitudes and leadership competences for project success. *Baltic Journal of Management*, vol. 5, no.3, pp. 307–329.

Nankervis, A. Prikshat, V. & Dhakal, S. 2018, 'Mapping Stakeholders of Graduate Work-Readiness (GWR), in Dhakal, S. (ed.), *The Transition from Graduation to Work: Challenges and Strategies in the Twenty-First Century Asia Pacific and Beyond*, Springer, 2018, 31-42.

Pant, I., & Baroudi, B. 2008, 'Project management education: The human skills imperative', *International Journal of Project Management*, vol.26, pp. 124–128.

Prikhat,V., Nankervis, A., Priyono, S., Salleh, N., Connell, J., & Burgess, J. 2018, 'Graduate work readiness challenges in the Asia-Pacific region and the role of HRM', *Equality, Diversity and Inclusion: An International Journal*, vol. 37, no. 2, pp. 121-137.

Quacquarelli Symonds (QS), 2019, World University Rankings by Subject, viewed February 2019, <https://www.topuniversities.com/rankings/subject-rankings>.

Skulmoski, G. J., & Hartman, F. T. 2010, 'Information systems project manager soft competencies: A project-phase investigation', *Project Management Journal*, vol. 41, no. 1, pp. 61–80.

Tracy, S.J. 2012, *Qualitative Research Methods:Collecting Evidence, Crafting Analysis, Communicating Impact*, John Wiley & Sons, Incorporated, 2012.

Wernerfelt, B. 1984, 'A resource-based view of the firm', *Strategic Management Journal*, vol. 5, no. 2, pp. 171–180.

Wood, L.N., Psaros, J., French, E. & Lai, J.W.M. 2015, 'Learning experiences for the transition to professional work', *Cogent Business & Management*, vol. 2, no. 1, pp. 1-16.

A REVIEW OF CONSTRUCTION WASTE DATA AND REPORTING SYSTEMS USED IN AUSTRALIA

Shiyamini Ratnasabapathy[1], Srinath Perera[1], Ali Alashwal[1]

[1]School of Computing, Engineering and Mathematics, Western Sydney University, Sydney, Australia

Abstract

The construction industry is well recognised for the generation of a significant amount of waste which in turn has led the management of waste data as an important task of waste management. Waste data is essential not only for promoting effective waste management practices but also for the development and implementation of effective waste policies, legislations, and national standards. This paper aims to evaluate and understand the different waste data and reporting systems used in Australia. The outcomes of this study are based on the literature analysis of secondary data. The review revealed that most of the states and territories use a centralised waste data collection and reporting system and the use of such a system varies between states and territories due to the variation in waste definition, classification and estimation practices. This, in turn, hinders the development of effective waste management policies, relevant waste management programmes and as well as the establishment of domestic and international market platforms for recovered waste materials, attracting new circular business models. Consequently, the results inform the unyielding need to develop an efficient waste data management system. Blockchain as a decentralised data management technology could considerably improve the waste data management practices including waste data collection, reporting, and auditing and contribute to driving a shift towards the circular economy through circularity of waste information. Future research is aimed to develop a decentralised waste data management system as part of the development of a blockchain-technology based waste trading platform.

Keywords

Construction and Demolition Waste, Waste Data and Reporting, Waste Management, Blockchain, Australia

Introduction

Construction industry is well recognised for generating significant amount of waste arising from demolition, new construction, refurbishment and renovation activities, resulting in detrimental impact on the efficiency of the industry, health, and social life, environment and economy of the country (Arshad et al. 2017; Formoso et al. 2002; Manowong 2012). Subsequently, the industry and government to face challenges in terms of social, environmental and economic sustainability. In particular, the awareness of the environmental impact of Construction and Demolition (C&D) waste has been increasing and led to the development of Waste Management (WM) as an important function of project management (Shen et al. 2004) while there is an emerging focus on sustainable development in the built environment. Effective WM contributes to waste reduction and play a substantial role in sustainability drive with cost benefits (Arshad et al. 2017; John & Itodo 2013). WM is generally considered as a multidisciplinary activity, resulting in problems related to organisation, control, logistics, planning, recycling and disposal and requiring multi-criteria decisions at every stage of the project life cycle (Melare et al. 2017). Thus, the WM is going to be a very costly aspect of governance (Lamichhane 2017). In order to balance the impact on the environment and the cost effectiveness of each process, effective planning of waste management is critical. According to Lu & Yuan (2011), statistical waste data representing an accurate amount of C&D waste generated and its composition play a major role in understanding the need for waste reduction. Correspondingly, Yuan (2017), recognised that the accurate amount of waste generated and its detailed composition are key prerequisites in achieving effective C&D WM. Waste estimation including what and how much is of waste being generated and what is the appropriate destination for the waste (re-use or recycle or landfill) are fundamentals to any waste management strategic planning (Ilić & Nikolić 2016; Ojha 2011; Wu et al. 2014) and for the implementation of successful waste management system (Li et al. 2016; Paz & Lafayette 2016). As such up-to-date, accurate and detailed waste data and regularity of waste reporting could substantially contribute to better decision making to industry, waste management business and government (NWP 2018). This, in turn, helps waste management practitioners and businesses to make informed decisions towards sustainable development through minimization of waste (Moyano & Agudo 2013). Further, the government and the industry can benefit from the use of timely waste data in developing effective waste management plans and policies (NWP 2018; Yuan 2017).

In the Australian context, most of the data required for reporting purposes at both national and international levels are collected by the states and territories and then combined nationally. Collection, storage and reporting waste generation, recycling and disposal data varies between states and territories due to the variation in the way that the waste is classified and defined across the jurisdictions (SKM 2012). There are several issues and challenges with current underlying waste generation and resource recovery data arrangements in particular with the reporting obligations. Therefore, this paper aims to review the state of the art of waste data collection and reporting practices across different states and territories of Australia. A review of the current WM practices and waste data and reporting arrangements are presented to add the context to this study.

Methodology

This study is based on literature review and analysis of secondary data that are publicly accessible at the time of writing this paper. The databases used to collect the secondary data includes waste reports (E.g. National Waste Reports, Australian Bureau of Statistics), waste-related policies (E.g. National Waste Policy), legislations, acts prepared and administrated by the Environmental Protection Authority (EPA) of each jurisdictions of Australia and other state-specific authorities (e.g. Sustainability Victoria), reports prepared by private organizations (E.g. Hyder Consults Pty Ltd. and Sinclair Knight Merz Pty Ltd.). In addition, a comprehensive literature review from journal articles, conference proceedings, and other available web sources were carried out to determine the implications of waste data in streamlining waste management practices. Altogether 112 documents including reports, articles, discussion papers, and webpages were reviewed. The document analysis method was used to review the documents using the keywords 'waste data' and 'waste reporting'. The review provided the information on current waste data collection and reporting systems used in different states and territories, strategies related to waste data, obligations for waste data reporting and suggested programmes for improvements. Descriptive analysis was used to evaluate and demonstrate the secondary data collected from the documents.

Current status of the construction and demolition waste management

The construction industry in Australia is the second largest industry, which contributed 8.1% to the national GDP during the years 2017-18 (Master Builders Australia 2017). However, the industry is responsible for generating about 20.4 megatonnes of waste during the years 2017- 2018 only. This contributes to 30.5% of the total solid waste generated annually across different states of Australia (Pickin et al. 2018a). The C&D waste occupies 33% of landfill space for disposing of 33% of waste out of total waste generation. Waste generation is generally estimated as the combination of resource recovery (i.e. reusing, recycling and energy/other resources recovery) and disposal (Pickin & Randell 2017). Though it provides a clear definition of waste generation, not all waste generation can be readily measured and reported. This is because of some of the C&D waste, in particular, the mixed waste is still found in Municipal Solid Waste (MSW). Figure 1 shows the total waste generation, recycling, and disposal of core waste plus ash covering the year 2016-2017 from three core waste streams: Municipal Solid Waste (MSW), Commercial and Industrial (C&I) and Construction and Demolition (C&D). C&D

waste stream represents the second largest in volume in terms of waste generation, recovery, and disposal.

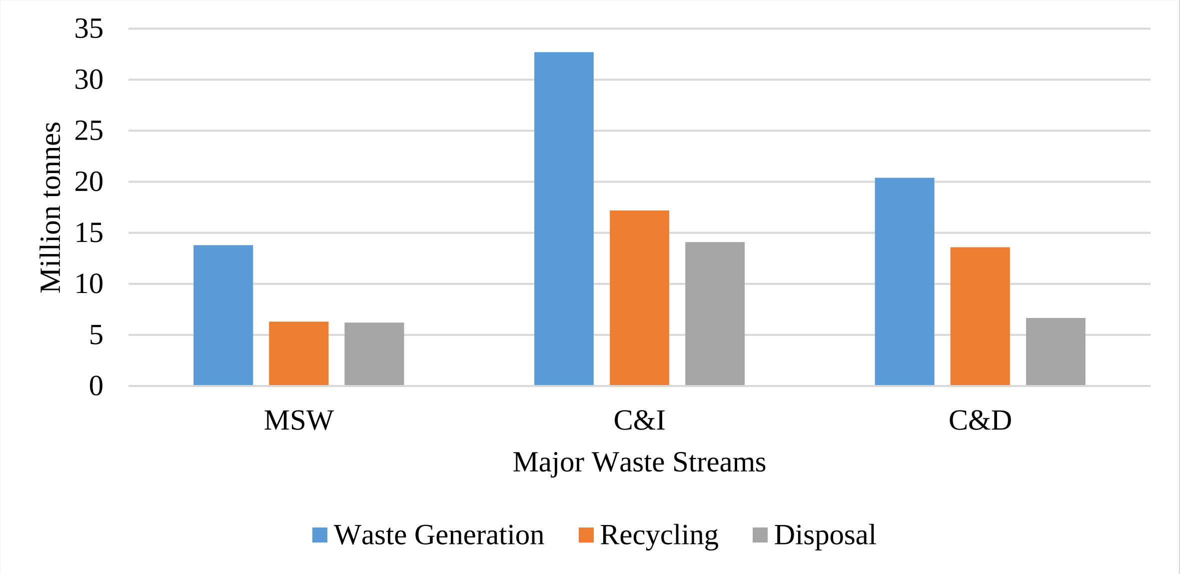


Figure 1: Waste generation, recycling, and disposal of the major waste stream in Australia.

(Data Source: National Waste Report, 2018)

The principle of managing waste according to the waste hierarchy is enshrined in relevant legislations or regulations in Australia and many waste policy targets and data collations are based on the various levels of the hierarchy (Waste Authority 2013). The management of waste from all major waste streams is controlled by the regulatory rules. These rules have been sanctioned by the legislature of the jurisdiction in which the waste is generated, administered and enforced by the relevant state or territory regulatory agency (SKM 2012). Most C&D waste is managed by the waste management services industry which typically involves the recovery of materials, recycling and disposal to landfill (Australian Burea of Statistics 2014). However, national industries are still facing waste data-related issues in various jurisdictions while the Australian government is directing efforts to coordinate the policies and regulations to ensure the consistency in national data and reporting, leading to rational and efficient WM.

Status quo of the waste data and reporting

The National Waste Report (NWR) annually presents the reports on national waste performance in terms of waste generation, resource recovery and fate for all three core waste streams. The core waste source streams include MSW, C&I and C&D. The report includes the primary waste management data comprising of waste generation, recycling, energy recovery and disposal from each waste stream. And the report was developed based on the data reported through the National Waste Data System (NWDS) reporting tool and National Waste Database of state and territory governments and industry associations (NWR, 2018). Waste reporting takes account of core data defined with the reference to the core waste source stream, management, and waste category and type. The primary waste performance indicators comprising of waste generation rate, recycling rate and the recovery rate in a given financial year are derived from these primary data sets (Pickin et al. 2018a).

The history of waste reporting

The very first effort on national waste reporting was made in 1990 with the target to measure the progress in implementing the 1992 *National Waste Minimisation and Recycling Strategy* (Pickin et al. 2018b, p. 112). The Department of the Environment and Energy (DEE) commissioned several snapshots of national waste quantities titled *Waste and Recycling in Australia*. Though the quality and comprehensiveness of data got improved over time, states and territories are still concerned about the transparency of the data transformations used to build a common national platform. The DEE released the first national waste report in 2010 using the data covering the year 2006-2007 followed by the release of National Waste Policy in 2009 and the second was in 2013 based on the data from 2010-2011. A 'method report' was commissioned in between these two reports to inform the type of waste data to be collected and the method of transformation of the collected data from each state and territory. Subsequently, a calculation workbook showing how the waste data from each state and territory has been transformed was released with 2013 NWR.

Further, a procedural document that defines the whole process and revised methods were developed in mid of 2015 and agreed by all states and territories. The revised method was implemented with the use of Microsoft Excel tool through which states and territories would enter their data and the data would be transformed to standardised output tables and charts. The third and fourth report was published in 2016 and 2018 respectively. To produce these reports, data were collected using the Excel tool. However, instead of generating a master workbook using Excel tool, a single flat database using Microsoft PowerBI was established to compile all the historical data and demonstrate the trend and so that users can have automated access to the data to carry out their own analysis and presentation (Pickin et al. 2018a).

Strategies for waste data and reporting

WM is always a challenging task as it is influenced by the community demand, government policies and programmes, technological development and market circumstances (NWR, 2018). Most jurisdictions use a strategy that guides government organisations and industries in improving waste management. While strategies mostly set targets for resource recovery or other waste performance indicators, some strategies have focused to improve the quality of data, data reporting, and waste data management systems across the jurisdictions. In particular, with the intention to promote resource efficiency through the application of circular economy principles, Strategy 13 on 'Data and Reporting' and Strategy 14 on 'Market Development and Research' have been developed. These strategies are closely linked with the principle of improving the waste information to facilitate innovation, guide investment and enable informed consumer decisions. Strategy 13 aims at providing continuous support to consumers and manufacturers to make more informed decisions by improving national data and reporting. While strategy 14 informs all governments and businesses the requirement to produce and report waste information which aims to improve existing markets and support the establishment of new markets for recycled materials at both national and international levels (NWP 2018, p. 16).

Current waste data and reporting systems between states and territories

For the purpose of waste reporting at both the national and international levels, most of the waste data required are collected by the states and territories and then combined together to make for the national level. According to NWR, 2018, the primary waste data which will be provided by all the states and territories will include the following data;

- Total amount (in tonnes) of waste disposed of landfill, disaggregated by source stream where known
- Total amount of imports and exports of landfill waste wherever known and significant
- The composition of waste to landfill in percentage terms, where local audits have been undertaken and are considered representative
- Total amount (in tonnes) of waste sent for recycling, disaggregated by material type and source stream where known
- Total amount (in tonnes) of waste to energy, disaggregated by material type and source stream where known.

States and territories across Australia use different waste data management systems which is mainly due to the difference in waste classification systems and their application in states and territories (Rajaratnam & Lamb 2011). Amongst other states and territories, New South Wales (NSW), Queensland (QLD), South Australia (SA) and Victoria (VIC) are using a central data management system to collect and report the waste data. Waste data reporting is currently mandatory in some jurisdictions, for example, NSW, whereas other states such as Western Australia (WA) has the plan to make data reporting mandatory in 2020 (Waste Authority 2019). For instance, the Environmental Protection Authority (EPA) of NSW has powered its waste regulatory framework to prepare quality reliable recycling and waste generation data by directing data collection and the use of weighbridges for waste recovery facilities (EPA NSW 2019b). This data will be reported through a simple online reporting tool called 'Waste and Resource Reporting Portal' (WARRP) which is a reporting tool designed to facilitate the submission of the Waste Contribution Monthly Report (WCMR).

According to EPA NSW (2019a), the fundamental difference between the landfill disposal data and recycling data makes a substantial variation in the quality of waste data that is publically available to industry, community, and the government. On the other hand, EPA collects recycling through voluntary surveys while disposal data is collected through land levy surveys. Consequently, the recycling data become incomplete and inaccurate due to poor response rates, inadequate record-keeping and a lack of weighing facilities. "These issues are exacerbated by some sectors of the waste industry that choose not to participate in the voluntary data surveys" (EPA NSW 2019a). However, EPA has changed the requirement from August 2015, based on which all the scheduled waste facilities which are not required to pay the waste levy will be required to report annually to EPA on the amount, type and destination of waste received and directed off-site. This data will be reported through WARRP.

In VIC, waste data portal is used to collect and store waste and recycling data from a number of sources. Sustainability Victoria's Waste Data Service produces a regular waste report, thus supporting data evidence-based. These data are used for well-targeted and planned waste projects and programs, thus strengthening and standardising existing waste and resource recovery data (Sustainability Victoria 2019). Where in QLD, a web-based system called, 'The Queensland Waste Data System' (QWDS) is used by the operators of all facilities to report on their waste data requirements. Operators who receive, sort, recycle, treat or dispose of waste, have the facility to log into QWDS using a secure login and enter the required information by following the user guide. The QWDS facilitates to provide up-to-date, reliable and secure information on waste management including waste recovery, recycling, and disposal activities in a secure and convenient manner (QLD Government 2019).

In the context of SA, Green Industries South Australia (GISA) has developed a web-based system called 'The Zero Waste Environment User System (ZEUS)'. SA's Waste Strategy of 2015-2020 aims to reduce the waste through the use of ZEUS which assists in monitoring, analysing and reporting the data (GISA 2019). As a web-based system, it allows automatic capturing, storage and reporting of waste recycling activity; waste (tonnes) to landfill by waste stream (MSW, C&I and C&D); litter; economic and environmental costs and benefit; infrastructure needs; and areas needing regulatory underpinning across SA (GISA 2019). GISA provides required training to local councils to use this system free-of-charge. ZEUS performed as a register for GISA for the Recycling Activity Survey conducted in 2015-2016 and National Waste Report published in 2016. In addition, it provides information to deal with illegal dumping and to undertake benchmarking of green industries in SA (GISA 2017). While ZEUS is being used for 10 years, it is being reviewed for its functionality to assess its capacity to deal with the business requirements, user interface to user-friendly access to new data capture requirements and accessibility from portable devices. As such it is could be considered as one of the efficient data management systems among other systems used in other states and territories.

In WA, spreadsheets are used to voluntary report the waste data in the annual local government waste and recycling census. Responsible entities including local governments, recyclers and regional landfill operators are required to use this spreadsheet. According to 2019-2020 waste authority business plan of WA, reporting of waste and recycling data become mandatory from 2019 and the current waste reporting arrangements are reviewed to meet the stakeholder's expectation and obligations. Subsequently, based on the amended Waste Avoidance and Resource Recovery Regulations 2008, a centralised online reporting system that improves data accuracy, timeliness and security will be introduced for mandatory waste data reporting in 2020 (Waste Authority 2019). As such, the Australian government continues to improve national data, and reporting on material flows, waste and recycling, including economic aspects and reporting indices (NWP 2018). However, a combined picture on underlying waste data and reporting arrangements of states and territories does not fully satisfy the combined requirements of Australia's key waste-related international reporting obligations (SKM 2012).

Issues with current waste data and reporting

There are considerable gap and issues with primary waste data and its quality which in turn hinder the required obligations for waste reporting and auditing. Data quality significantly shows a discrepancy both between the jurisdictions and between the different reporting pathways within each jurisdiction (Rajaratnam & Lamb 2011). Table 1 summarises the key issues with the current combined picture of data and reporting arrangements.

Table 1: Issues with current primary data arrangements

Key Issues	Description	Issues with current data arrangements
Transparency	Ability to verify the data output	- Data sets and outputs are not verifiable - Data systems do not provide a transparent description of their data method - Not publically available
Comparability	Possibility of comparison of data with same data generation methodologies	- Differences in waste definition and classification - Data system do not specify methods, input data and working - Lack of standardisation - Lack of cross-comparison on a like-for-like basis
Accuracy	Certainty in the data value	- Significant inaccuracies across many data sets and systems - Lack of independent, third-party audit and assurance of waste and recovery data
Completeness	all sources within state boundaries are identified and accounted for	- Gaps exist in current data arrangement in terms of major geographic, subject matter and material flows due to the differences in definitions, classifications and scope/boundary conditions around waste data across different systems - Difference between 'total waste' and 'waste dealt with by waste industry' hinders to satisfy the international obligation
Clarity	Data is understandable and accessible	- Fragmented nature of current data on waste and recovery - Combining the currently-fragmented data is significantly consuming time and resource costs - Lack of comprehensive, easily accessible and searchable combined data products. - Lack of transparency regarding methods, input data and workings.

Timeliness	Availability of up to date data as reporting occurs on a regular schedule	- Unavailability of some data set from some jurisdictions or data set produced only on a schedule (such as biennially) - Inability to meet annual reporting requirements due to the above reasons - Long-time lag (2-3 years) to release data set from the end of the reporting period, resulting in outdated data to users and inability to meet the reporting requirements
Traceability	Ability to trace the historical data	- Fragmented nature of current data on waste and recovery - Lack of comprehensive, easily accessible and searchable combined data products. - Lack of transparency regarding methods, input data and workings. - Data is not traceable to have regular monitoring and auditing

Data Source: Hardie et al. (2012);SKM (2012)

According to Canberra Business Champer (2014), there are considerable issues with those available data such as the usage of different measurement, different categorisation of the waste stream, and lack of capacity to measure accurately due to lack of weighbridges and estimation practices especially for mixed waste exacerbated by lack of staffing at waste management facilities. In order to improve the flow of waste information in the waste chain and reduce the impact from each waste stream, the stakeholders participating in waste management need to recognise the importance of collaboration to maintain a consistent and up-to-date waste data throughout the entire waste chain. Unavailability of such data makes the stakeholders stay abreast of the latest information and hinders to make decisions for future developments. As such, waste data management systems to be designed or improved should ensure that waste data required by the stakeholders throughout the waste chain is readily available when and where it is needed.

Subsequently, there is a pressing need to develop a reliable and consistent waste data management system that provides up-to-date waste estimation data with a high level of accuracy and transparency, readily available for analysing waste management performance at different levels such as project, local authority, state, national and international levels in a secured manner. Such data would in turn help to develop the waste management related policies and legislation for future developments. According to NWR 2018, the development of relevant methodology through research and development of best estimation methods '*based on transparent logic applied consistently over time*' would be useful to seal the major data gab. Besides, policies and legislations are to be developed to document these methods as a future national standard to make sure each jurisdiction use similar approaches in collecting and reporting waste data.

Although national reports such as Australian NWR, Australian Bureau of Statistics (ABS) are available on the composition of C&D waste, the accuracy of data on the volume and composition of C&D waste are not always publicly available and the issue is acute not only at the project level but also at both national and international level. Despite that, government/regulatory bodies have no access/channels to audit the WM data for the assessment of compliance requirements to streamline the WM (Ratnasabapathy, Perera & Alashwal 2019). Comparatively, the C&D waste industry has great potential to yield a significant volume of recovered material into the economy and environment by recycling, reuse or remanufacturing (Canberra Business Champer 2014). However, the recovery of resources from C&D waste is not being achieved at its maximum level due to poor processes and minimal environmental control by sector operators (NSW EPA 2017). Further, lack of actual data on the volume and composition of C&D waste, in particular in the regional areas, limits to extract the value of recovered material (Canberra Business Champer 2014). Apart from these, lack of easy access to accurate, reliable and transparent waste data for monitoring, reporting and auditing the C&D waste from conception to destination impedes the development of effective waste management practices (Ajayi et al. 2017; Paz & Lafayette 2016; Veleva, Bodkin & Todorova 2017). Subsequently, inconsistency in waste date reporting could limit the informed decision making on new bans placed by foreign countries on the import of waste.

The utilization of smart technologies such as Blockchain would provide a holistic solution to improve the alignment issues related to waste data collection and reporting obligations at both national and international levels. Blockchain is a decentralized transaction and data management technology (Wang et al. 2017). Smart contracts deployed on blockchain offer several benefits for the built environment including, disintermediation, trust & transparency, fast settlement, high accuracy, less risk, auditability, cost efficiency and the like (Arup 2019). Turk & Klinc (2017) acknowledged that blockchain as a database that is shared on a peer-to-peer network (Wang et al. 2017) can improve the records of construction onsite information such as construction logbooks, works performed and quantities of material as it provides reliability and trustworthiness of the information recorded. As such, distributed nature of blockchain and its distinct features including a high level of trust, transparency, immutability, and traceability can fundamentally change the traditional way of collecting, storing, replicating and tracing waste data throughout the waste chain, thus facilitating the auditing of waste management processes, while fulfilling the waste-related compliances. Blockchain can empower the communication between waste generators, waste consumers, society and governments/regulatory bodies without a central authority or external mechanism. Future research is aimed to develop a waste data management system through the development of a distributed ledger waste trading system.

Conclusions

Consistent and timely data of each fate of waste (generation, recovery, and disposal) with a high level of accuracy and transparency is crucial not only for evaluating and monitoring the progress of WM towards the resource recovery targets but also for the development and implementation of effective waste policies and national standards. The purpose of this study was to evaluate and understand the waste data and reporting management systems used in different states and territories of Australia. The findings revealed that most of the states and territories use a centralised waste collection and reporting system and there is an inconsistency in the use of such systems. This is because of the variations in waste definition, categorisation of waste materials and lack of capacity to accurately measure the waste due to lack of weighbridges and estimation practices. Inconsistencies in data reporting, in turn, hinders the development of effective waste management policies, relevant training programmes and as well as the establishment of domestic and international market structures for recovered materials, attracting new circular business models. The findings have practical implications for policymakers, waste management practitioners, government and regulatory bodies. The government should review regulations pertaining to waste data management and make sure they are implemented properly. Consequently, the results inform the pressing need to develop an efficient waste data management system to improve waste reporting and auditing. Such a system can be developed using Blockchain technology to ensure systematic and consistent data management. Blockchain as a decentralized data management technology could substantially contribute to improve the effective waste data management practices and drive a shift towards a circular economy through the circularity of waste information. High quality of waste information and development of secured markets for reusable and recycled waste materials could attract new circular business investments and develop targeted strategies to influence waste user behaviour. Future research is aimed to develop a decentralised waste data management system as part of the development of a blockchain technology-based waste trading platform, with the targets to improve resource efficiency and conserve natural resources.

References

Ajayi, S.O., Oyedele, L.O., Akinade, O.O., Bilal, M., Alaka, H.A. & Owolabi, H.A. 2017, 'Optimising material procurement for construction waste minimization: An exploration of success factors', *Sustainable Materials and Technologies*, vol. 11, pp. 38-46.

Arshad, H., Qasim, M., Thaheem, M.J. & Gabriel, H.F. 2017, 'Quantification of Material Wastage in Construction Industry of Pakistan: An Analytical Relationship between Building Types and Waste Generation', *Journal of Construction in Developing Countries*, vol. 22, no. 2, pp. 19-34.

Arup 2019, *Blockchain and the built environment*, London.

Australian Burea of Statistics 2014, 'Waste Account, Australia, Experimnetal Estimates , 2013', Australia, 3rd of November 2018, <http://www.abs.gov.au/ausstats/abs@.nsf/mf/4602.0.55.005>.

Canberra Business Champer 2014, *Building and Construction Waste Materials:Reduce, Reuse and Recycle -Opportunities and Strategies for the Capital Region*, Canberra Business Champer, Australia.

EPA NSW 2019a, *New reporting requirements for waste facilities*, Environment Protection Authority,NSW, Australia, viewed 13th August 2019 2019, <https://www.epa.nsw.gov.au/your-environment/waste/waste-facilities/waste-reporting/reporting-requirements-waste-facilities>.

EPA NSW 2019b, *The Waste and Resource Reporting Portal*, Environment Protection Authority,NSW, Australia, viewed 12th August 2019 2019, <https://www.epa.nsw.gov.au/your-environment/waste/waste-facilities/waste-reporting/waste-and-resource-reporting-portal>.

Formoso, C.T., Soibelman, L., De Cesare, C. & Isatto, E.L. 2002, 'Material waste in building industry: main causes and prevention.(Abstract)', *Journal of Construction Engineering and Management*, vol. 128, no. 4, p. 316.

GISA 2017, *Green Industries South Australia (GISA) 2016– 2017 Annual Review*, Green Industries SA, Australia, p. 20, <http://www.greenindustries.sa.gov.au>.

GISA 2019, *Business Plan 2018-19*, Australia.

Hardie, M., Khan, S., O'Donnell, A. & Miller, G. 2012, 'The Efficacy of Waste Management Plans in Australian Commercial Construction Refurbishment Projects', *Australasian Journal of Construction Economics and Building*, vol. 7, no. 2, pp. 26-36.

Ilić, M. & Nikolić, M. 2016, 'Waste management benchmarking: A case study of Serbia', *Habitat International*, vol. 53, pp. 453-60.

John, A.O. & Itodo, D.E. 2013, 'Professionals' views of material wastage on construction sites and cost overruns', *Organization, Technology and Management in Construction: An International Journal*, vol. 5, no. 1, pp. 747-57.

Lamichhane, M. 2017, 'A Smart Waste Management System using IoT and Blockchain Technology', Master thesis, ITMO University, Russia.

Li, Y., Zhang, X., Ding, G. & Feng, Z. 2016, 'Developing a quantitative construction waste estimation model for building construction projects', *Resources, Conservation and Recycling*, vol. 106, pp. 9-20.

Lu, W. & Yuan, H. 2011, 'A framework for understanding waste management studies in construction', *Waste Management*, vol. 31, no. 6, pp. 1252-60.

Manowong, E. 2012, 'Investigating factors influencing construction waste management efforts in developing countries: an experience from Thailand', *Waste Management & Research*, vol. 30, no. 1, pp. 56-71.

Master Builders Australia 2017, *2018 Pre-Budget Submission*, Australia.

Melare, A.V.d.S., Gonzalez, M.S., Faceli, K. & Casadei, V. 2017, 'Technologies and decision support systems to aid solid-waste management: a systematic review', *Waste Management*, vol. 59, pp. 567-84.

Moyano, P.M. & Agudo, A.R.-d.-A. 2013, 'Selective classification and quantification model of C&D waste from material resources consumed in residential building construction', *Waste Management & Research*, vol. 31, no. 5, pp. 458-74.

NWP 2018, *National Waste Policy (NWP) -Less Waste, More Resources* Australia.

Ojha, K. 2011, 'Status of MSW management system in northern India-an overview', *Environ Dev Sustain*, vol. 13, no. 1, pp. 203-15.
Paz, D.H. & Lafayette, K.P. 2016, 'Forecasting of construction and demolition waste in Brazil', *Waste Management & Research*, vol. 34, no. 8, pp. 708-16.
Pickin, J. & Randell, P. 2017, *Australian National Waste Report 2016* Australia.
Pickin, J., Randell, P., Trinh, J. & Grant, B. 2018a, *201811 Web - National Waste Report 2018 final*, Department of the Environment and Energy, Australia.
Pickin, J., Randell, P., Trinh, J. & Grant, B. 2018b, *Australian National Waste Report 2018* Australia.
QLD Government 2019, *Recycling and waste in Queensland*, 33, QLD Government,, Australia, viewed 12th August 2019, <https://www.qld.gov.au/environment/pollution/management/waste/recovery/data-reports/qwds>.
Rajaratnam, T. & Lamb, G. 2011, *Waste Classifictaions in Australia: A comparison of waste classifications in the Australian Waste Database with current jurisdictional classifications*, Australia.
Ratnasabapathy, S., Perera, S. & Alashwal, A. 2019, 'Assessment of Waste Generation and Diversion Rates in Residential Construction Projects in Australia', paper presented to the *CIB World Building Congress 2019*, Hong Kong, 17 – 21 June 2019.
Shen, L., Tam, V.W., Tam, C. & Drew, D. 2004, 'Mapping approach for examining waste management on construction sites', *Journal of construction engineering and management*, vol. 130, no. 4, pp. 472-81.
SKM 2012, *Review of Australia's international waste-related reporting obligations*, Sinclair Knight Merz Pty Ltd., Autralia.
Sustainability Victoria 2019, *Waste data portal*, Sustainability Victoria, Australia, viewed 13th August 2019 2019, <https://www.sustainability.vic.gov.au/Government/Victorian-Waste-data-portal>.
Turk, Ž. & Klinc, R. 2017, 'Potentials of Blockchain Technology for Construction Management', *Procedia Engineering*, vol. 196, pp. 638-45.
Veleva, V., Bodkin, G. & Todorova, S. 2017, 'The need for better measurement and employee engagement to advance a circular economy: Lessons from Biogen's "zero waste" journey', *Journal of Cleaner Production*, vol. 154, pp. 517-29.
Wang, J., Wu, P., Wang, X. & Shou, W. 2017, 'The outlook of blockchain technology for construction engineering management', *Frontiers of Engineering Management*, vol. 4, no. 1, pp. 67-75.
Waste Authority 2013, 'Waste Authority Communication on the Waste Hierarchy', viewed 3rd of November 2018, <https://engage.environment.nsw.gov.au/38561/documents/88957>.
Waste Authority 2019, *Waste Authority Business Plan 2019-2020*, Australia.
Wu, Z., Yu, A.T.W., Shen, L. & Liu, G. 2014, 'Quantifying construction and demolition waste: An analytical review', *Waste Management*, vol. 34, no. 9, pp. 1683-92.
Yuan, H. 2017, 'Barriers and countermeasures for managing construction and demolition waste: A case of Shenzhen in China', *Journal of Cleaner Production*, vol. 157, pp. 84-93.

A COST BENEFIT ANALYSIS OF RETROFITTING PUBLIC POLICIES ON ATLANTA RESIDENTIAL HOUSING

Arezoo Shirazi[1], Ali Bozorgi[2], Baabak Ashuri[3]

[1] School of Built Environment, Post-doctoral Fellow, University of Technology Sydney, Sydney, Australia

[2] Business School, Research Fellow, University of Sydney, Sydney, Australia

[3] School of Building Construction | School of Civil & Environmental Engineering, Associate Professor, Director, Economics of Sustainable Built Environment (ESBE) Lab, Georgia Institute of Technology, Atlanta, US

Abstract

The residential building sector has a major share in carbon emission and energy consumption. In the US, around 60% of the housing stock belongs to the owner-occupied sector. Since more than half of the existing building stock was built before the modern energy efficiency standards are taken place, there is a potential to reduce the energy consumption and greenhouse gas emissions in this sector, only by retrofitting the existing buildings. However, this goal cannot be achieved without a larger scale Cost Benefit Analysis (CBA) to develop and demonstrate market ready retrofit solutions/policies from both the government and the homeowner's standings. To this extend, the aim of the presented paper is to conduct a city-level CBA on the city of Atlanta which ranked 5th in producing GHG emissions among 100 US metropolitan areas while residential buildings sector is ranked 4th among other contributing sectors. To this end, a hypothetical public policy of retrofitting single-family residential buildings built before 1970s is proposed with the objective of reducing the regional energy consumption rate while calculating the upper bound of the tax to be proposed on the properties rejecting to renovate. The preliminary results of this CBA revealed that although retrofitting all the prior 1970s buildings won't be beneficial comparing to the status quo, the numbers are highly sensitive to the proposed discount rate as well as the percentage of the homeowners practically decide to retrofit. The sensitivity analysis showed that if only 30-40% of participants decided not to renovate and pay the tax, the CBA could be a positive Net Present Value (NPV) with a relatively low tax rate (less than \$0.5/sqft) implementation. Therefore, it is recommended to more accurately study the reaction of the homeowners to the policy before implementing the tax/subsidy rates while precisely observe the fluctuations of the market discount rate.

Keywords

Cost Benefit Analysis, Retrofitting Public Policies, Residential Housing, Decision Analysis

Introduction and policy definition

One of the major concerns in the emerging era of sustainable cities and urban resiliency is to reduce the overall energy consumption and associated environmental impacts. According to the 2018 US energy flow chart, the residential building sector accounts for more than 10% of the total US energy consumption (Lawrence Livermore National Laboratory, 2018). Since most of the existing residential building stock was built before the implementation of energy efficient codes and regulations in the US, there is a potential to reduce the energy consumption and consequential emissions in this sector, only by retrofitting the existing buildings. To this end, the authors chose Atlanta which was identified as one of the top producers of Greenhouse Gas (GHG) emissions among 100 US metropolitan areas (Markolf *et al.*, 2017), and assessed the implementation of a hypothetical public policy of retrofitting single-family residential buildings built before 1970s in this region. 1970s was chosen as the transition decade because the state of Georgia began to implement building restrictions on the residential construction to save energy starting from 1970s (Aroonruengsawat and Auffhammer, 2012).

Due to the data limitation, the Fulton county is selected to test and validate the policy implementation and the Cost Benefit Analysis (CBA). Fulton county is among one of the nine major counties that together, form the Atlanta metropolitan area. However, this county by itself, covers 90% of the City of Atlanta. The objective of the proposed policy is to reduce the regional energy consumption rate while calculating the upper bound of the tax threshold to be implied on the properties deciding not to renovate. The costs and benefits of implementing the proposed public policy is then compared with the status quo which is leaving the buildings as is.

CBA is a method for assessing the net benefits of a project or proposal relative to other alternatives, typically the status quo (Boardman, 2011). It is generally calculated by subtracting the monetary value of the total costs from the total benefits of the project or policy implementation practice. Most of the governments including the US and the Australian government are committed to the use of CBA to assess regulatory proposals in order to encourage better decision making.

The first step before conducting a professional CBA is to define the standings, meaning that whose benefits and costs should be included in the analysis. In this regard, the residents and the local government were identified as the standings for the proposed public policy. The next step is to identify the physical impact categories of the proposed policy, catalogue them as benefits or costs, and specify the measurement indicator of each impact category. A detailed explanation of the assumptions and ground rules used to perform the policy implementation are demonstrated in Table 1.

Table 1: CBA assumptions and ground rules

Numbers	Assumptions and ground rules
1	Local government pays for the subsidy and program administrations
2	Horizon of the project is selected to be 30 years based on the average replacement time for insulation materials (Athena, 2002)
3	Retrofit costs are averaged numbers from actual similar projects conducted in Atlanta (Jackson *et al.*, 2012)
4	Residents must pay tax if they don't retrofit
5	Residents will receive 20% of the renovation cost as a subsidy from local government based on a similar policy in Poland (Gerőházi and Szemző, 2016)
6	Retrofit options apply to all buildings including the attic/knee wall insulation and the foundation insulation (Jackson *et al.*, 2012)
7	People live in their homes during renovation period as it will happen zone by zone
8	10 cents per square footage is the monetary benefit of satisfaction for houses that retrofit
9	Local government will issue free renovation permit to those who retrofit
10	Discount rate assumed to be 8% based on the appropriate discount rate for residential real estate analysis in Atlanta
11	Electricity rate in Atlanta is $ 0.056582 per kWh based on the Georgia power declaration rates
12	52 kilograms of energy-related carbon dioxide per million Btu for Georgia is assumed based on the Energy Information Administration (EIA) 2018 report (US Energy Information Administration, 2018)
13	All construction and administration processes will happen in the first five years of the policy implementation project
14	Inflation rate is 2.13% based on the average inflation rate of Georgia in 2016 (Plecher, 2016)
15	Decisions of whether to retrofit or not will happen at the beginning of the policy implementation project

Benefits and costs impact valuation

The next step in conducting a CBA is to identify the impacts of the proposed policy on all the standings and categorize the impacts into costs or benefits. In the proposed policy, the benefits and costs of the standings were identified and presented in Table 2.

Table 2: Benefits and costs identified for the standings

Standings	Benefits	Costs
Residents	Potential saving on utility bills if retrofit Better living quality if retrofit	Cost of retrofitting
Local government	Tax revenue from those who do not retrofit Reduce regional CO2 emission	Provide subsidies on retrofit Program administration

In a CBA that analyses a change in government policy, all the associated costs need to be sum up and subtract from all the benefits resulting from the policy. Doing this requires that the values of all these benefits and costs are measured in monetary terms (Boardman, 2011). However, the most intuitively important impacts (e.g. environmental impacts) are sometimes difficult to value in monetary terms. In the following paragraphs, the models and secondary data sources used to monetize the identified impacts of the proposed public policy are discussed in detail.

Benefit 1: Savings on utility bills

The amount of annual energy savings after retrofitting were calculated as 11,300 BTU per square feet per year which is averaged on energy savings of similar case studies that took place in the region. The mentioned case studies were conducted by researchers at Oak Ridge National Laboratory (ORNL) in collaboration with Southface on comprehensive energy retrofits implementation on Atlanta dwellings (Jackson *et al.*, 2012). Additionally, the numbers were monetized using the $0.056582 per kWh electricity rates extracted for Atlanta from the Georgia Power webpage (Georgia Power, 2019).

Benefit 2: Reduction in carbon emissions

The average social cost of one ton of carbon dioxide emission is extracted as $20 from the shadow price values presented as valuation of impacts in the most referenced CBA textbook (Boardman, 2011). Additionally, the energy-related carbon dioxide emission is extracted as 52 Kg CO2 /MMBtu from the US Energy Information Administration (EIA) 2018 report (US Energy Information Administration, 2018). Using the mentioned numbers, the monetary value of carbon emission associated with the energy savings through retrofitting was calculated and used for the CBA study.

Benefit 3: Living satisfaction

This impact is valued and calculated completely based on pre-defined assumptions. As mentioned in Table 1, 10 cents per square footage assumed as the monetary benefit of satisfaction for houses that retrofit in every year. The idea is based on home-owner's expression of interest in saving energy and emissions for their society as well as the satisfactory feeling of living in an upgraded and more energy efficient house.

Benefit 4: Tax revenue

Since the proposed public policy is a hypothetical policy without any direct feedback from the government, the authors decided to keep the tax revenue as a variable and calculate the minimum revenue which the local government can expect from implementing the policy in order to receive zero net benefit. Therefore, this benefit is considered as a changing variable in the CBA study and further discussions around the feasible numbers are presented in the sensitivity analysis section.

Cost 1: Cost of retrofit

The cost of retrofitting was extracted and averaged from the same ORNL project (Jackson *et al.*, 2012) using case studies on houses built before 1970s in Atlanta which were renovated only for attic/knee and foundation insulation. Based on their results, the average of $4.7 per square feet is calculated for retrofitting the similar buildings in the region.

Cost 2: Subsidy costs

As mentioned in Table 1, based on similar policy adaptations in Poland (Gerőházi and Szemző, 2016), 20% of the retrofitting cost is assumed to be covered by the government as a subsidy to support the retrofitting policy. This will result in $0.94 per square feet of subsidy cost for the government.

Cost 3: Program administration costs

The administration cost of implementing the policy is calculated based on assumptions mentioned in Table 1. Particularly, the study considered the requirement of 10 people working fulltime on the average salary rate of $20/hr during the timeframe of the project which is assumed to be 5 years of continuous work for the complete implementation of the tasks.

Urban scale monetizing of the impacts

Finally, to convert all the monetized costs and benefits calculated previously into an urban scale analysis, the total number of single-family residential buildings in Fulton county including the buildings' footprint were extracted from various available data sources including the Zillow real estate (Zillow, 2019) as well as the Fulton county property tax (Fulton County Tax Commissioner, 2019) webpages. The results were then separated by the building's vintage for further urban-level CBA investigations. The data analysis revealed the total amount of 16,313,754 square feet of single-family residential buildings built only over 1970s (built between 1970 to 1979) and the total amount of 172,789,527 square feet of single-family residential buildings built before 1970.

In the next step after expanding the benefits and costs to an urban scale, the assumed inflation rate of 2.13% was used to monetize the total impacts throughout the whole life cycle of the project. This means that the benefits of retrofitting were assumed to be impactful over the 30 years of life cycle whereas the costs of the policy implementation were assumed to be distributed over the 5 years of the practical policy administration procedure.

Discounting and results

Most significant policies and projects have long term consequences that unfold over time. Therefore, it is essential to conduct an inter-temporal comparison of monetized impacts or discounting in a CBA study. Discounting is the adjustment of future impacts to a common metric. The general equation of discounting is presented in Equation 1. In this equation, Present Value (PV) represents the value today and Future Value (FV) represents the value at an interval "t" in the future. Additionally, "r" represents the interest rate in this equation.

$$FV = PV\,(1 + r)^t \qquad \textit{Equation 1}$$

Generally, for discounting in CBA studies, the Net Present Value (NPV) of different alternatives are calculated using Equation 2. For this purpose, each year must be separately discounted, and the total numbers are sum up to calculate the PV of the impacts.

Equation 2

$$NPV = PV(Benefits) - PV(Costs)$$

In this CBA case study, the discount rate of 8% is assumed based on the appropriate discount rate for residential real estate analysis in Atlanta. Using the assumed discount rate and taking all the ground rules mentioned in Table 1, the NPV of retrofitting every single-family residential building in the City of Atlanta turned into the negative number of ($102,782,318.43). This means that the costs of implementing this policy in a full urban-level scale significantly outweigh the benefits.

Sensitivity analysis

Although the initial proposed policy failed the CBA, it is important to notice that the CBA is only as good as the assumptions and ground rules. There are several variables and unknowns that might critically change the results including technology changes, operating environment as well as consumer preferences. For this reason, there may be considerable uncertainty involved in both the predicted impacts and the appropriate monetary valuation of each unit of the impact. To this end, sensitivity analysis is used in CBA studies to deal with such uncertainties.

One of the main uncertainties involved in the proposed public policy is the reaction of the homeowners to the policy. Although the current CBA study considered that everyone will retrofit their old houses, it is not the case in real world scenarios. To reflect this in the analysis, the authors considered various percentages of homeowners who practically accept to renovate. Hence, the authors re-ran the CBA multiple times with different portions of people accept to retrofit, considering the tax revenue as a variable and the NPV to be zero. The results are shown in Table 3. In this table, the "proportion retrofitted" represent the percentage of the homeowners with houses built before 1970s, who decide to retrofit their buildings.

Table 3: Sensitivity analysis on percentage of homeowners accept to retrofit

Portion Retrofitted	Total (retrofitted) sqft	Remaining (taxable) sqft	Tax Revenue ($/sqft)	NPV
Status quo	-	-	-	0
10% retrofit	17,278,952	155,510,574	0.08	0
20% retrofit	34,557,905	138,231,621	0.16	0
30% retrofit	51,836,858	120,952,668	0.26	0
40% retrofit	69,115,810	103,673,716	0.41	0
50% retrofit	86,394,763	86,394,763	0.60	0
60% retrofit	103,673,716	69,115,810	0.90	0
70% retrofit	120,952,668	51,836,858	1.40	0
80% retrofit	138,231,621	34,557,905	2.39	0
90% retrofit	155,510,574	17,278,952	5.36	0

All built before 1970	172,789,527	0	0	(102,782,318)

Based on the results in Table 3, the tax revenue increases linear, as the percentage of participants in the retrofit plan increases. The reason behind that is the increasing cost of retrofitting (by providing subsidies) impose higher monetary pressure on the government and therefore, the government must increase the taxes in order to compensate the additional cost and keep its NVP on zero. In the extreme case of 90% retrofit, the government would be left with only 10% of the houses for taxing. Considering an average house with 1200 square feet area, the homeowner is required to pay the approximation of $6000 if decided not to retrofit. It is obvious that for less volume of householders decided to retrofit, the tax rate decreases.

In another scenario, it is of interest to study the effectiveness of the imposed policy, if buildings from different vintage are targeted. In this sensitivity analysis, it is assumed that every targeted household participates in the retrofit plan. The results are summarized in Table 4. The results showed that for all scenarios, the NPV is still negative. It is also noted that there is a significant jump in the value of NPV from1960 to 1950, as well as from 1930 to 1920, that worth further analysis. For instance, due to the huge increase in the total square footage of the buildings built during 1920s and 1950s, it worth imposing more detailed policies considering the exact vintage of the building.

Table 4: Sensitivity analysis on imposing policy based on building vintage

Policy to retrofit	Total sqft	NPV
Built < 1970	172,789,527	(102,782,318)
built < 1960	138,157,814	(82,527,152)
built < 1950	74,743,028	(45,437,533)
built < 1940	54,805,757	(33,776,755)
built < 1930	37,210,979	(23,486038)
built < 1920	8,812,742	(6,876,666)
built <1910	3,362,196	(3,688,787)

Another uncertainty involved in the proposed CBA, is the exact amount of discount rate at the time. It is of interest for the policy maker to find out the break event point for the discount rate, to make the renovation decisions economically feasible. In this essence, the next set of sensitivity analysis runs by altering the discount rate. The results are summarized in Table 5. The analysis is performed representing the case in which all buildings decide to retrofit. The results revealed that for discount rates of 6.5% or lower, the retrofit is an economically feasible option, but if the discount rate is 7% or above, the incurred cost outperforms the gained benefits.

Table 5: Sensitivity analysis

Policy to retrofit	Discount Rate	NPV
Built < 1970	8%	(102,782,318)
Built < 1970	7.5%	(71,340,889)
Built < 1970	7%	(36,623,839)
Built < 1970	6.5%	1,737,450
Built < 1970	6%	44,157,835
Built < 1970	5.5%	91,104,746
Built < 1970	5%	143,105,469

Conclusion and discussion

In this paper, the authors conducted a CBA on a hypothetical public policy to better understand the larger scale economic aspects of a retrofit plan devised on an urban level. Based on the proposed policy, all the single-family residential buildings of before 1970s, must either participate in the program and retrofit the house or pay additional taxes on rejecting the policy. Due to the time difference between the incurred costs and the gained benefits, the NPV technique is used to evaluate different items on an indifferent basis.

The results of this analysis revealed that although the initial proposed policy is not economically feasible, a proper tax rate implementation along with a feasibility study of the actual number of homeowners decide to participate, could significantly change the outcome. Additionally, as it is shown in the discount rate sensitivity analysis, the results are highly dependent on the discount rate. Hence, it is highly recommended to make sure to remove any potential uncertainty from the discount rate variable. Therefore, with a precise estimation of discount rate and number of households willing to retrofit, this policy could achieve its highest NPV, by correct assignment of the tax rates for those who won't retrofit.

On the other hand, it is anticipated that the best solution is to prepare a survey among targeted households and have an estimation of the portion of the participating households who will decide to renovate. The results of the sensitivity analysis showed that if only 30-40% of participants decided not to renovate and pay the tax, this could be a positive NPV with a relatively low tax rate (less than $0.5/sqft) implementation.

From practical perspective, it can be discussed that the retrofit option is associated with some discomfort during the renovation operations. The discomfort directly depends on the level of renovation, time of the year, etc. On the other hand, once the renovation is finished, the tenants will enjoy the renovated building (partially or fully), which lasts longer than the renovation period. Considering both comfort/discomfort and economical analysis, it is recommended for the governmental body and policy making firms to deliver appropriate information, along with economical incentives, to the home owners to expect higher participation rate in retrofit plan in the community.

References

Aroonruengsawat, A. and Auffhammer, M. (2012) 'The impact of state level building codes on residential electricity consumption', *The Energy*. Available at: http://search.proquest.com/openview/8c305c18860372599d68771e8b746409/1?pq-origsite=gscholar&cbl=48483 (Accessed: 13 June 2017).

Athena (2002) *Maintenance, repair and replacement effects for building envelope materials*. Ottawa. Available at: http://www.athenasmi.org/wp-content/uploads/2011/10/2_Maintenance_Repair_And_Replacement.pdf (Accessed: 2 May 2018).

Boardman, A. E. (2011) *Cost-benefit analysis : concepts and practice*. Prentice Hall.

Fulton County Tax Commissioner (2019) *Fulton County Tax Commissioner | Property taxes*. Available at: https://www.fultoncountytaxes.org/property-taxes/search-for-tax-bill.aspx (Accessed: 30 August 2019).

Georgia Power (2019) *Home | Georgia Power*. Available at: https://www.georgiapower.com/ (Accessed: 30 August 2019).

Gerőházi, É. and Szemző, H. (2016) *National subsidies for renovation of multi-family buildings in Poland - REELIH - Residential Energy Efficiency for Low-Income Households*. Available at: https://getwarmhomes.org/national-subsidies-for-renovation-of-multi-family-buildings-in-poland/ (Accessed: 27 August 2019).

Jackson, R. K. *et al.* (2012) *Advancing Residential Retrofits in Atlanta*. Oak Ridge National Laboratory.

Lawrence Livermore National Laboratory (2018) *Energy Flow Charts: Charting the Complex Relationships among Energy, Water, and Carbon*. Available at: https://flowcharts.llnl.gov/ (Accessed: 27 August 2019).

Markolf, S. A. *et al.* (2017) 'An integrated approach for estimating greenhouse gas emissions from 100 U.S. metropolitan areas', *Environmental Research Letters*, 12(2), p. 024003. doi: 10.1088/1748-9326/aa5731.

Plecher, H. (2016) *Georgia- inflation rate 2024 | Statista*. Available at: https://www.statista.com/statistics/441482/inflation-rate-in-georgia/ (Accessed: 27 August 2019).

US Energy Information Administration (2018) *EIA - Annual Energy Outlook*. Available at: https://www.eia.gov/outlooks/aeo/ (Accessed: 27 August 2019).

Zillow (2019) *Zillow: Real Estate, Apartments, Mortgages & Home Values*. Available at: https://www.zillow.com/ (Accessed: 30 August 2019).

A LITERATURE REVIEW OF WASTE PREDICTION MODELS IN CONSTRUCTION PROJECTS

Ali M. Alashwal[1]

[1]School of Computing Engineering and Mathematics, Western Sydney University, Kingswood, Australia

Abstract

Construction waste prediction and quantification contribute to effective waste management. Waste prediction enables information and data utilization at the early stage of the project to minimise waste during subsequent stages. However, waste prediction and estimation have gained less attention among researchers. The purpose of this paper is to review the available papers on waste prediction and evaluate current prediction models. Based on the review, waste prediction models can be divided into macro and micro models. The macro models use project-level data to predict waste at a city or country level, while the micro models use data to predict waste generated during construction and demolition stages. The focus of this paper is on the micro models. Most of the existing studies are theoretical-based and use descriptive analysis of waste data. The common models of waste prediction, which are evaluated in this paper are linear and regression models, S-curve and Artificial Neural Network model, Big Data framework, and designing-out waste. The outcome of this paper provides an insight into main prediction models, limitations of these models, and factors influencing accurate waste predication.

Keywords

Construction, waste estimation and quantification, waste analytics, waste management

Introduction

Regardless of the social and economic benefits of construction projects, their negative impact on the environment cannot be ignored. Waste generated from construction-related activities accounts for approximately 20-35% of all waste worldwide (Lu et al. 2016; Solís-Guzmán et al. 2009). Construction waste is occupying a large landfill area (Yuan & Shen 2011), which is expanding every year. In addition, construction waste may include toxic and hazardous substances that have a serious impact on the ecological system. Different waste materials are generated during different stages of building projects such as excavation, renovation, demolition, and decoration. Construction waste consists of inert material (e.g. soil, sand, rocks, concrete, aggregates, plaster, bricks, masonry, glass, and tiles); non-inert material (e.g. drywall/gypsum, metals, wood, paper, cardboard, packaging, and plastic); and hazardous materials (e.g. paint, acids, bases, and explosive and violent chemical reaction materials when exposed to air or water) (Bakshan et al. 2015; Shang et al. 2013).

In order to reduce the negative impact of construction work, there is a need for more effective waste management strategies (Shang et al. 2013). One of the main approaches of waste management is the prediction of the amount and type of construction waste. Waste prediction is the cornerstone of waste management, which can facilitate project planning and the decision-making process. The main purpose of waste prediction is to provide accurate information to facilitate decision-making during project design (Lu et al. 2016). Waste minimisation through design, or known also as designing out waste, is argued to be the future of waste management and research (Bilal et al. 2016).

To understand how waste prediction has been addressed in the literature, a search on the Web of Science database was conducted on 25 March 2019 using the keyword "Construction Waste". The result of the search revealed 1,433 publications in this area. It was noted that the number of publications in this area has increased steadily since 2010. A text mining analysis was conducted on these publications. The result revealed that construction waste can be divided into two distinct areas, namely Waste Management and Construction Material as shown in Figure 1. Waste Management includes topics such as factors, approaches, issues, implementation, practices, design methods, and reduction of construction waste. Questionnaire survey is the main research method used in this area. On the other hand, Construction Material includes topics such as concrete, product, property, plant, aggregate, brick, fly ash, road, and soil. Experimenting is the main research method used in this area. Waste prediction or forecasting did not appear as a distinct area in the literature. It appeared vaguely, however, under the Waste Management area. This indicates the need to conduct more research in waste prediction and estimation.

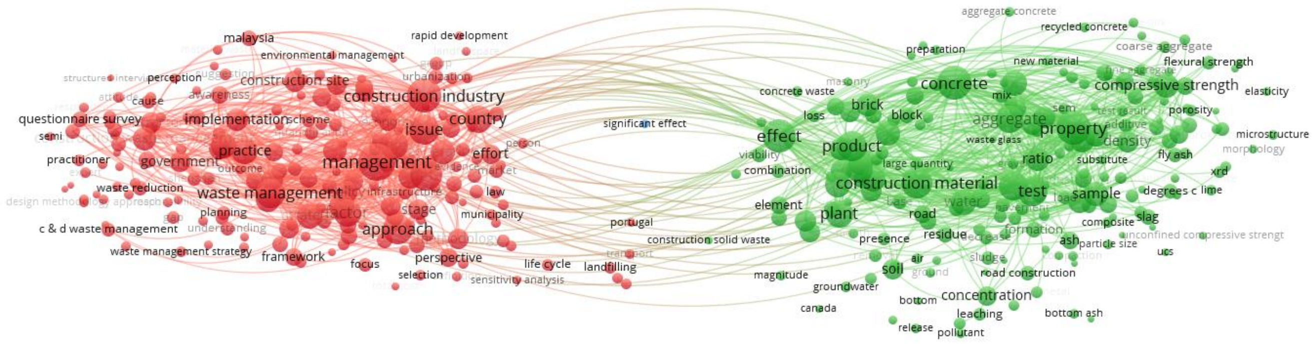


Figure 1: Classification of research on construction waste (developed by the author using VOSviewer text mining)

Most of the existing studies on waste estimation and prediction are based on descriptive analysis of building waste data or theoretical model (Bakshan et al. 2015; Bossink & Brouwers 1996; Goktepe & Yetilmezsoy 2016; Mah, Fujiwara & Ho 2016; Noori, Karbassi & Sabahi 2010; Paz & Lafayette 2016; Sáez et al. 2018; Solís-Guzmán et al. 2009; Song, Y et al. 2017). There is still a limitation of studies that are based on analytical-based models for waste prediction in construction projects.

The main purpose of this paper is to review the available studies on waste prediction in construction. This paper focuses on prediction models at the project level. Waste prediction at the project level is needed for many reasons. Different construction waste disposal charging schemes have been enacted in many countries (Lu et al. 2016) including Australia. Contractors are charged with a levy for waste disposal in the landfill. Usually, contractors put the levy in their bids so the extra cost will eventually be transferred to the client. During the course of the project, contractors need to collect information regarding the amount of waste to be generated as a result of different construction activities. For instance, contractors need to know the size of roll-off containers, the best form of external and internal transport, and all the waste logistics (Lu et al. 2016) cited (Nagalli 2013). In addition, waste estimation provides a methodology to benchmark actual waste generation and helps to develop the Waste Management Plan (Lu et al. 2016). It can be used to create a baseline in which waste management can be monitored and controlled. Furthermore, waste prediction is required to develop appropriate waste interventions. Lastly, waste prediction can facilitate knowing what is being generated (qualitative data), how much is being generated (quantitative data), and what is the appropriate destination for this material (Paz & Lafayette 2016).

This paper will evaluate the common models used for waste prediction at the project level and assess their strengths and limitations. In addition, the review will enable the identification of factors influencing waste prediction as well as directions for future research in this area. The next section provides an overview of waste quantification methods in construction followed by the research method used to collect and review previous papers.

Waste Estimation and Quantification Methods

According to Wu et al. (2014), waste estimation methods can be divided into site visit method, waste generation rate method, lifetime analysis method, classification system accumulation method, variables modelling method, and other methods such as fixed percentage of purchased materials. Lu et al. (2016) indicated these methods and explained that waste quantification can be conducted as a post-mortem of completed or ongoing projects (i.e. onsite investigation and analysis of waste disposal records or material flow). Chen and Chang (2000) mentioned traditional forecasting models such as geometry average method, saturation curve method, least-squares regression method, and the curve extension method. These methods are designed based on the configuration of semi-empirical mathematical models (cause-effect or trend extension structures). The non-traditional methods (semi-structured techniques for uncertain environments) include fuzzy forecasting and grey dynamic modelling. Waste quantification can be conducted as a post-mortem of completed or ongoing projects (i.e. onsite investigation, analysing waste disposal records or material flow) (Lu et al. 2016). Mah, Fujiwara and Ho (2016) mentioned some methods of construction waste estimation including on-site estimation (using hand-sorting or machinery-based-sorting), waste generation quantity, waste disposal quantity, and records of waste flow and waste disposal. The estimated waste can be quantified through different means such as waste amount (measured by volume, weight, size of waste bin, or waste truck trips), waste material density, and floor area of the project (Kourmpanis et al. 2008; Mah, Fujiwara & Ho 2016). Bakshan et al. (2015) identified the limitations of different estimate quantities methods as shown in Table 1.

Table 1: Limitations of construction and demolition waste estimation methods (adapted from Bakshan et al. 2015; Mah, Fujiwara & Ho 2016)

Method/Model	**Limitations**
Actual quantification on-site (e.g. sorting and weighing construction waste)	Costly, time-consuming, and require a high degree of manpower and machinery
Visual observation	Depends on experience of observer, provides approximate data, and not sufficient for developing detailed waste planning strategies
Constructed area (e.g. CW in m^3 or kg = GFA ×WI)	No categorization of waste materials, depends on availability of database and requires continuous update, index might be context-relevant
Building components (i.e. components index)	Requires labour-intensive measurement and update, might interfere with normal site activities
Material flow analysis approach (e.g. CW= M×wc,…)	Construction guides -external source- to estimate average material discarded during construction rely on industry surveys, accuracy of estimation depends on accuracy of the surveys
Construction database (e.g. budget record analysis from several construction projects)	Database may not be applicable to other regions or projects in other regions
Forms of physical layout (stockpiled, gathered, scattered, and stacked forms – e.g. in the case of stockpiled waste, the volume is estimated using the equation of the pyramid volume)	Provides rough data, which is not enough for detailed waste planning strategies
Software accounting tools (e.g. SMARTWaste, which relies on data obtained from the UK construction industry)	Limited application to certain regions or countries, where the industry has similar characteristics to the UK construction industry

Research Method

A review of the literature is used in this study to identify and evaluate previous waste forecasting models. The research papers were primarily searched through Scopus, Google Scholar, and Web of Science. Apart from that, the Western Sydney University library website was used to search and download most of the collected papers. As construction and demolition waste is a prominent area among many researchers and practitioners, much research work is being contributed to the knowledge base every day. Thus, limiting the search to a specific topic was challenging due to the availability of literature in abundance, which might result in unnecessary information being generated. Considering this effect, the keywords used for the search were strictly limited to "Construction and Demolition Waste", "Waste Forecast", "Waste Prediction" "Forecast Model" and "Waste Prediction Model".

Notwithstanding the limitations of the keywords, a large number of papers were found. The papers were screened and filtered to include 70 papers on construction and demolition waste. These papers are distributed as follows; 23 papers were on "Waste Estimation and Quantification", 18 papers were on "Waste Management", 17 papers were on "Waste Forecasting / Prediction Models", 8 papers were on "Designing out Waste", and 4 papers were on "Waste Generation Rate / Index". It was noted that the term "Model" was used in various facets in the topic such as, "Waste Estimating Models", "Waste Quantification Models", "Waste Management Models", "System Dynamic Models" and "Waste Generation Index Models" apart from "Waste Forecast Models" and "Waste Prediction Models". The selected papers were screened further to decide on the most relevant papers for this study. Therefore, 21 papers on "Waste Estimation", "Waste Forecasting", and "Waste Prediction Model", were subject to critical evaluation. Apart from the waste prediction models, those were predominantly based on waste generation data at the construction stage, the analysis was extended to evaluate some papers on designing out waste. The evaluation was based on studying the purpose, methods, outcomes, model characteristics, process, data type and source, variables, and limitations of waste prediction methods or models.

Findings and Discussion

Overview

Table 2 shows the studies reviewed in this paper. Based on prediction model outputs or applications, these studies can be classified into macro and micro prediction models. The macro-level models used project-based data to predict waste generated from the project to estimate waste at a city, region, or country level. While the micro-level studies used construction project data to predict waste during different stages of the project. This study focuses on the micro-level prediction and, therefore, 13 papers were evaluated in more details as shown in the following section.

Table 2: Previous studies on waste estimation and prediction (macro- and micro-level application)

Reference	Context	Project Type	Waste Type	Model	Main Outcomes
Macro-Level Models (City, Region, or Country based on Project Data)					
(Shang et al. 2013)	Waste prediction	Building projects	Decoration solid waste	Grey Prediction Model – GM (1, 1)	Prediction of amount of waste during 2012 – 2016.
(Goktepe & Yetilmezsoy 2016)	Waste estimation & quantification	Construction projects	Construction, demolition and excavation waste	Previous model (Fatta et al. 2004) on waste density and generation rate	Recommendations for further studies in establishing more accurate and reliable waste quantification model.
(Coelho & de Brito 2011)	Waste quantification	Construction projects	Construction and demolition waste	Mathematical model and probability	Estimated construction waste = 400 kg person^{-1} year^{-1}
(Song, Y et al. 2017)	Waste prediction	Building projects	Construction and demolition waste	Gray Method – Support Vector Regression (GM-SVR)	Amount of waste based on annual total area of construction (ATAC).

(Wu, Fan & Liu 2015)	Waste prediction	Building projects	Construction and demolition waste	Gene Expression Programming (GEP)	Trend of construction and demolition waste generation and its relationship with influential factors.
(Song, Z, Li & Huang 2015)	Waste prediction	Building projects	Construction and demolition waste	ARIMA	Construction and demolition waste output prediction for 2015 – 2020.
(Seo & Hwang 1999)	Waste estimation	Building projects	Construction and demolishing waste	Statistical model	Estimation of building life span, floor area to be constructed, and building floor area to be demolished.
(Wang, Wang & Shi 2016)	Waste prediction	Building projects	Construction and demolition waste	Gray Verhulst prediction model	Annual total construction and demolition waste output.
Micro-Level Prediction (Construction Project)					
(Bakshan et al. 2015)	Waste estimation	Building projects	Construction waste	Simple linear equations model	Estimated waste as kg/m^2 of built-up area based on different materials.
(Solís-Guzmán et al. 2009)	Waste estimation	Residential buildings	Construction and demolition waste	Simple mathematical quantification model	Waste categorization based on materials and sources of waste generation.
(Sáez, Porras-Amores & del Río Merino 2015)	Waste quantification	Retrofitting of residential buildings	Construction and demolition waste	Linear regression model	Type of retrofitting work generates waste.
(Sáez et al. 2018)	Waste estimation	Retrofitting buildings	Construction and demolition waste	Theoretical method	Waste generation = between 2.46 and 65.24 kg/m^2 and 0.012 - 0.008 m^3/m^2
(Mah, Fujiwara & Ho 2016)	Waste estimation (Waste Generation Rate)	High rise buildings	Construction and demolition waste	Simple mathematical quantification model	Waste generation rate of conventional construction method = 9.88t $100/m^2$, mixed-construction method = 3.29 $t100/m^2$, and demolition projects = 104.28 t $100/m^2$
(Lu et al. 2016)	Waste generation forecasting	Building projects	Construction waste	S-curve model and Artificial Neural Network (ANN)	Amount of waste generated during project execution stage.
(Bossink & Brouwers 1996)	Waste quantification and waste source evaluation	Housing projects	Construction waste	Simple mathematical quantification model	80% of waste is attributed by the use of stone tablets, piles, concrete, sand-lime elements, and roof tiles. These materials cause 67% of the total cost of waste. 9% of the total purchased materials end up as waste.
(Paz & Lafayette 2016)	Waste estimation	Residential projects	Construction and demolition	Waste generation rate for a different type of construction work and regression analysis	Software system and waste estimation indexes. Waste estimation based on build area is the most suitable method for calculating waste generation.
(Bilal et al. 2016)	Designing-out waste (waste minimisation)	Construction projects	Construction waste	Big Data architecture based on literature review and preliminary analysis	Conceptual framework. Construction waste data requires iterative algorithms, compute-intensive tasks, and near real-time visualisation.
(Ajayi & Oyedele 2018)	Designing-out waste	Construction projects	Construction waste	Structural Equation Modelling (SEM)	Five design measures to minimise waste: design process, organic design, design document, design for standard,

					and design for modern methods of construction.
(Lu et al. 2017)	Designing-out waste	Construction projects	Construction waste	BIM	Prototypical framework for computational application of BIM in construction waste management.
(Akinade et al. 2018)	Designing-out waste	Construction projects	Construction and demolition	BIM	BIM functionalities and how to use them to improve the existing waste management tools and the expectations of stakeholders on BIM as a waste management tool.
(Llatas & Osmani 2016)	Designing-out waste	Housing projects	Construction waste	Building Design Waste Reduction Strategies (Waste ReSt) model	Correlations between various design variables and their impact on onsite waste reduction.

Prediction Models – Project Level

Project level (micro-level) waste prediction facilitates more focused and effective waste management at different stages of the project. In this regard, different studies have been conducted in different countries using different methods and models. The following is an overview of project-level prediction studies and their limitations.

Bakshan et al. (2015) surveyed 28 construction projects to quantify waste generated from different streams during different stages of construction projects in Lebanon. The total waste generation rate was calculated as the sum of waste generation for streams plus waste generation rate of other waste such as packaging and paint waste materials. The waste generation rate was estimated as 38–43 kg/m^2 with masonry and concrete constituting more than 60% of the total waste followed by wood, tile, steel, and plaster. As the authors stated, this study can be used also to determine the amount of waste generated at the country level. A limitation of this study is to estimate the amount of other waste based on previous studies, not actual quantification.

Solís-Guzmán et al. (2009) developed a model to estimate the waste volume expected to be generated in new construction and demolition dwelling projects in Spain. The model enabled waste estimation as three main sources or streams, namely, demolishing, wreckage, and packaging waste. Based on the bill of quantities of 100 projects and construction costs database, the waste amount was determined. A case study of two projects was then used to estimate waste based on the same database. The authors predicted 320m^3 excavated soil and 172.20m^3 mixed waste (including packaging). A limitation of this study is the use of a database for waste estimation not based on actual quantification. The case study was not used to validate the results rather generate another estimation based on the same database.

Sáez, Porras-Amores and del Río Merino (2015) proposed to quantify waste generated in retrofitting of residential buildings by considering the total floor area and the number of units. The study identified seven most common works conducted in the vertical envelope to quantify waste. Recorded data of two pilot construction sites were used to obtain waste generation ratios. The developed model has 1% - 10% mean deviation compared with other models in the literature. The authors noted the influence of good management of team and practices to minimise waste. In a similar study, Sáez et al. (2018) quantified waste generation in the same context (i.e. common works in the retrofitting of the vertical envelope to improve energy efficiency). They found that the generation ratio of construction and demolition waste varies between 2.46 and 65.24 kg/m^2 and between 0.012 and 0.008 m^3/m^2. A limitation of these studies is the reliance on a small number of projects to generate waste generation ratios.

Mah, Fujiwara and Ho (2016) developed a method for estimating waste generation rate of construction and demolition works using a case study of 11 projects across Malaysia. Data were collected through document reviews such as waste management plan, contractor claim, bill of quantities, and waste composition. Periodic site observations and interviews were conducted as primary data collection (sampling, measurement of waste bin size, and interviews). The results indicated that conventional construction method has a waste generation rate of 9.88t 100/m^2, mixed-construction method has a waste generation rate of 3.29 t 100/m^2, and demolition projects have a waste generation rate of 104.28 t 100/m^2. A limitation of this study is the usage of previous studies to estimate the waste generation rate. In addition, waste material density was projected from the average of data gathered from developed countries (Australia, New Zealand, and Japan).

Lu et al. (2016) developed an S-curve model to forecast the accumulative waste generated during the execution of high-rise building projects in Hong Kong. The authors benefited from the huge records of data of waste and characteristics of 138 projects to select the best formula of the S-curve. Then they used the artificial neural networks (ANN) to link four characteristics of the projects (duration, public-private nature, location, and value) with the S-curve formula to determine its parameters. The authors used a robust methodology to develop the model, however, the result is difficult to generalise. The authors suggested that this model would be used with extreme caution in applying types of projects other than for which it was developed, other contexts, with different project management methods and with new materials and modern techniques.

Bossink and Brouwers (1996) attempted to quantify waste after the introduction of the waste reduction policy in the Netherland. They used a case study of 5 housing construction projects to record and sort waste materials. The results showed that the largest sources of waste are stone tablets, piles, concrete, sand-lime elements, and roof tiles. The ratio of purchased materials to total waste was between 1% to 10%. The author noted that using a particular type of material contributes to the increasing cost of the waste. The authors also identified the causes of waste in each type of material. For example, the causes of waste for the stone tablets are cutting, shaping, low quality, over order, and storage of the tablets. This study extended the list of sources and causes of waste and highlighted that great amount of waste can be related to both design and operation activities.

Paz and Lafayette (2016) developed software of waste management in construction sites using waste generation indicators. They collected data from 19 sites to estimate waste in three methods, namely, build area, duration of the work, and the number of floors. The amount of waste generated from each project was determined for different types of work including foundation, structure, and finishing. The system was validated in 12 construction sites. The result confirmed that waste estimation using build area is the best compared with the other two methods. Waste estimation based on the number of floors has a great performance for small projects. A limitation of this study is the number of projects used to estimate waste is small to generate sufficient data about each work type (i.e. finishing and structure).

Bilal et al. (2016) proposed Big Data architecture for waste estimation and management. They used the literature review to develop five design principles to minimise waste including design for reuse and recovery, design for resource optimisation, design for off-site construction, design for resource efficient procurement, and design for the future. Then, they collected waste data from 900 selected construction projects from a waste management facility company in the UK. Preliminary results presented using different plots and graphs. The most common waste material includes light mixed and compatible waste, mixed construction waste, and mixed inert waste indicating that waste segregation is not commonly used in construction. Recycled waste includes soil, inert waste, concrete, metal, paper, rubber, etc. A small amount of general mixed and other waste, timber, plasterboard, brick, hazardous waste is sent to landfill. The amount of waste during the studied period generated across the UK were also presented. A limitation of this study is that designing out waste was not covered in the empirical results. The framework is yet to be validated and to determine how it influences decision making during the design process.

Other studies concern about the role of design in waste estimation and minimisation include (Ajayi & Oyedele 2018; Akinade et al. 2018; Llatas & Osmani 2016; Lu et al. 2017). These studies used Building Information Modelling (BIM) and other approaches to determine factors, measures, and strategies that can be adopted to minimise waste during construction and demolition stages. For example, Ajayi and Oyedele (2018) used Structural Equation Modelling to identify main factors affecting designing out waste including the design process, organic design, design document, design for standard, and design for modern methods of construction. Akinade et al. (2018) highlighted BIM functionalities and how to use those functionalities to improve the existing waste management tools and stakeholders' expectations. Increased efforts are made from recent years to understand the possibility of employing construction waste management measures at the design stage by predicting possible waste outcomes, thereby facilitating designing out waste with effective design measures. Inevitably designing out waste is regarded as cost-effective, flexible, and one of the most effective among waste management strategies (Akinade et al. 2018) at the project level. 'Waste Analytics' is regarded to be more effective for optimising building design for waste management (Bilal et al. 2016). Waste Analytics, compared with Waste Intelligence, allows proactive estimation of waste arising from building design, which facilitates design optimisation (Table 3). This approach also allows advanced analytical tools (such as time series analysis) to forecast waste and prescribe the best course of action to pre-emptively minimise construction waste (Bilal et al. 2016).

To summarize, most of the studies used previous indexes to estimate construction waste. Some studies are in the development stage and produced conceptual or theoretical models. Waste analytics studies are scarce. This could be mainly due to a lack of waste data at the project level and the fact that each project is unique, making result generalisation extremely difficult. All the reviewed studies have their inherent limitations due to the uniqueness of project characteristics and project operating environments. Designing out waste is an important area of application of waste estimation. However, studies on designing out waste have also some limitations, requiring findings to be used with care and with appropriate adjustments to suit specific projects with different characteristics and operating environments. Considering all these limitations, understanding factors affecting accurate waste estimation and prediction is important. The following section highlights factors affecting waste prediction from the literature in this area.

Table 3: Waste intelligence versus waste analytics (developed based on Bilal et al., 2016)

Waste Intelligence	**Waste Analytics**
Deal with waste after it happens	Deal with waste before it happens
Concerns about reports, dashboards, and queries on small amount of current and past waste data	Able to analyse separate and huge datasets to discover trends and correlations in different delivery process including design, procurement, material, and supply-chain
To answer close-ended questions (e.g. site waste generated)	Concerns about holistically designing out construction waste
To understand how a particular design strategy generates waste	Data-driven decision-making at the design stage
Provides users with hindsight (static) on waste management activities	Provides users with insight on waste management activities
Adopt waste estimation and quantification methods such as waste generation rate and waste index.	Adopt waste estimation methods and 'new' tools such as Big Data and BIM

Factors Influencing Waste Prediction

Construction waste generation is mainly influenced by project characteristics such as duration, construction method, value, location, project type, and client type (e.g. private or public) (Lu et al. 2016). Moreover, based on many other factors external to the project environment such as the geographical location, governance, and socio-economic conditions, each project's operating environment has become unique and different from each other. Thus, accurate prediction of construction waste has become extremely difficult due to different conditions and factors. Table 4 shows factors affecting waste prediction, which can be categorized into internal factors (such as project characteristics) and external factors (such as country's rules and regulations). The table provides a comprehensive list of factors but requires validation through an empirical study to refine these factors based on project type and context. The identified factors, which influence waste generation, amount, density, and type, were extracted from the literature as follows:

1. The factors are used as variables in the waste prediction models;
2. The factors are suggested by the research studies to be considered in future research;
3. The factors are identified as limitations of the previous studies; and
4. Previous studies believed that a particular factor or factors would affect waste reductions.

Table 4: Factors affecting construction waste estimation

No.	Factors	Details / Examples	References
Internal Factors			
1.	Waste Classification	Construction, demolition and decoration waste (e.g. residential area of high-level decoration produces more timber waste)	(Shang et al. 2013)
2.	Project Type	Building, roads, bridges etc.	(Ajayi & Oyedele 2018; Bakshan et al. 2015; Lu et al. 2016; Mah, Fujiwara & Ho 2016)
3.	Construction Method		(Lu et al. 2016; Mah, Fujiwara & Ho 2016)
4.	Building Type	Residential, commercial, office, hospitals etc.	(Llatas & Osmani 2016; Lu et al. 2016; Seo & Hwang 1999; Song, Y et al. 2017; Song, Z, Li & Huang 2015; Wang, Wang & Shi 2016)
5.	Building Life Span	Building life span influenced by economic, social, and technological conditions of the building	(Seo & Hwang 1999)
6.	Project Size	Building or project size such as number of floors, high-rise etc.	(Lu et al. 2016; Mah, Fujiwara & Ho 2016; Paz & Lafayette 2016; Seo & Hwang 1999)
7.	Building Structure	Types of structure, including brick-concrete, frame, frame-shear, modular type, etc., produce different types of waste	(Lu et al. 2016; Seo & Hwang 1999; Shang et al. 2013; Song, Y et al. 2017; Zhao, Leeftink & Rotter 2010)
8.	Waste Components	Type of waste such as brick, mortar, concrete, package material, roofing material, steel, wood, etc.	(Lu et al. 2016; Seo & Hwang 1999; Song, Y et al. 2017; Wang, Wang & Shi 2016)
9.	Waste Generation Rate and Waste Intensity	Measured in ton/m^2	(Ajayi & Oyedele 2018; Lu et al. 2017; Paz & Lafayette 2016; Seo & Hwang 1999; Song, Y et al. 2017; Song, Z, Li & Huang 2015; Wang, Wang & Shi 2016)
10.	Ratio of Material Loss	Breakage, damages or discarding during construction	(Seo & Hwang 1999)
11.	Project Location		(Bakshan et al. 2015; Lu et al. 2016)
12.	Building Class	Luxury, medium quality, low cost	(Shang et al. 2013)
13.	Stage of Project and Construction	Project stage includes design, construction, etc. and construction stage includes: initial, finishing etc.	(Ajayi & Oyedele 2018; Akinade et al. 2018; Lu et al. 2016; Lu et al. 2017; Paz & Lafayette 2016)
14.	Standardization	Extent of standardization use	(Ajayi & Oyedele 2018)
15.	Client Type	Public private nature	(Lu et al. 2016)
16.	Project Duration		(Lu et al. 2016; Paz & Lafayette 2016)
17.	Construction Management	Efficient use of construction management including procurement method	(Paz & Lafayette 2016)
18.	Minimisation Strategies	Waste minimisation strategies during the design stage	(Ajayi & Oyedele 2018; Akinade et al. 2018; Llatas & Osmani 2016)
19.	New Technology	Extent of new technology use such as lightweight materials and modern method of construction	(Ajayi & Oyedele 2018; Akinade et al. 2018; Llatas & Osmani 2016; Lu et al. 2016)
20.	Prefabrication	Extent of prefabrication use	(Llatas & Osmani 2016; Lu et al. 2016)
21.	Floor Area	Gross floor area or build-up area for construction, demolition, decoration. Build up area for general work.	(Paz & Lafayette 2016; Seo & Hwang 1999; Song, Y et al. 2017; Song, Z, Li & Huang 2015; Wang, Wang & Shi 2016; Wu, Fan & Liu 2015)
22.	Building Height	Number of floors (especially for small sites)	(Lu et al. 2016)
23.	Project Value	Gross value of construction work or contract sum	(Lu et al. 2016; Wu, Fan & Liu 2015)
24.	Building Design	Design for modern methods of construction, waste-efficient design process, design for standardisation, and waste-efficient design document	(Ajayi & Oyedele 2018; Lu et al. 2017)

External Factors			
25.	Charging Schemes	Waste charging schemes in state or country	(Wu, Fan & Liu 2015)
26.	Rules and Regulations	Policies, standards and laws on waste and environmental protection	(Llatas & Osmani 2016; Mah, Fujiwara & Ho 2016; Wu, Fan & Liu 2015)
27.	Extent of Recycling		(Llatas & Osmani 2016)
28.	Economy	Socio Economic Environment	(Llatas & Osmani 2016; Mah, Fujiwara & Ho 2016)
29.	Income Group	Low income, medium income, etc.	(Shang et al. 2013)
30.	Gross Domestic Product	GDP	(Wu, Fan & Liu 2015)
31.	Town Planning		(Seo & Hwang 1999)
32.	Location	Geographical location of project in province, country etc.	Most studies (prediction is done for a particular geographical location).
33.	Weather / Disasters		(Mah, Fujiwara & Ho 2016)
34.	Technology, labour, and resources	Availability of technology and resources in the country	(Mah, Fujiwara & Ho 2016)

Conclusion

Studies on construction waste prediction and estimation are limited. This study attempted to distinguish between two types of research studies based on application areas of the estimation models, which are macro-level and micro-level. The first type of studies used construction data and waste rate to determine the amount of waste expected to be generated by all construction projects in a certain region or country. The second type of studies used project parameters such as build area and number of floors to quantify the amount of waste and determine waste streams. This paper focused on the second type of studies and highlight their contributions and limitations.

As can be observed from this paper, the terms waste estimation, waste quantification, and waste prediction have been used interchangeably in the literature. In fact, there are some differences between these terms. Waste estimation concerns about determining waste at the project level based on the type of construction work. Waste quantification is closely related to waste estimation but it is applied mainly to determine waste materials or streams. While, waste prediction is commonly used in studies concern about waste forecasting at the city, province, or country level.

The estimation of waste at the project level is not easy due to several internal and external factors such as project location, type, construction methods, construction materials, project size, and the operating environment. More studies are needed to determine significant factors affecting waste estimation. On the other hand, the lack of reliable and complete data can be one of the challenges to develop comprehensive waste estimation outputs. Therefore, it is recommended to developing methods to easily trace and record waste generated in construction projects. One area that can benefit from waste estimation at the project level is designing out waste to minimise waste during the construction and demolition stages. Designing out waste and waste data analytics are two areas of research that will receive more attention in the near future. Designing out waste will become possible due to the availability of analytical tools such as Big Data and Artificial Intelligence as well as the increasing utilization of data management and design platforms such as cloud computing and BIM.

Acknowledgement

This research was supported by the Start-up Research Fund, Western Sydney University.

References

Ajayi, SO & Oyedele, LO 2018, 'Critical design factors for minimising waste in construction projects: A structural equation modelling approach', *Resources, conservation and Recycling*, vol. 137, no. 2018, pp. 302-13.

Akinade, OO, Oyedele, LO, Ajayi, SO, Bilal, M, Alaka, HA, Owolabi, HA & Arawomo, OO 2018, 'Designing out construction waste using BIM technology: Stakeholders' expectations for industry deployment', *Journal of Cleaner Production*, vol. 180, pp. 375-85.

Bakshan, A, Srour, I, Chehab, G & El-Fadel, M 2015, 'A field based methodology for estimating waste generation rates at various stages of construction projects', *Resources, conservation and Recycling*, vol. 100, pp. 70-80.

Bilal, M, Oyedele, LO, Akinade, OO, Ajayi, SO, Alaka, HA, Owolabi, HA, Qadir, J, Pasha, M & Bello, SA 2016, 'Big data architecture for construction waste analytics (CWA): A conceptual framework', *Journal of Building Engineering*, vol. 6, pp. 144-56.

Bossink, B & Brouwers, H 1996, 'Construction waste: quantification and source evaluation', *Journal of construction engineering and management*, vol. 122, no. 1, pp. 55-60.

Chen, H-W & Chang, N-B 2000, 'Prediction analysis of solid waste generation based on grey fuzzy dynamic modeling', *Resources, conservation and Recycling*, vol. 29, no. 1-2, pp. 1-18.

Coelho, A & de Brito, J 2011, 'Generation of construction and demolition waste in Portugal', *Waste Management & Research*, vol. 29, no. 7, pp. 739-50.

Fatta, D, Papadopoulos, A, Kourmoussis, F, Mentzis, A, Sgourou, E, Moustakas, K, Loizidou, M & Siouta, N 2004, 'Estimation methods for the generation of construction and demolition waste in Greece', in MC Limbachiya & JJ Roberts (eds), *The International Conference on Sustinable Waste Management and Recycling: Construction Demolition Waste*, Kingston University - London, p. 405.

Goktepe, F & Yetilmezsoy, K 2016, 'Construction and Demolition Waste Quantification Methods in Istanbul', *Fresenius Envrionmental Builletin*, vol. 25, no. 11, pp. 4753-9.

Kourmpanis, B, Papadopoulos, A, Moustakas, K, Stylianou, M, Haralambous, K & Loizidou, M 2008, 'Preliminary study for the management of construction and demolition waste', *Waste Management & Research*, vol. 26, no. 3, pp. 267-75.

Llatas, C & Osmani, M 2016, 'Development and validation of a building design waste reduction model', *Waste Management*, vol. 56, pp. 318-36.

Lu, W, Peng, Y, Chen, X, Skitmore, M & Zhang, X 2016, 'The S-curve for forecasting waste generation in construction projects', *Waste Management*, vol. 56, pp. 23-34.

Lu, W, Webster, C, Chen, K, Zhang, X & Chen, X 2017, 'Computational Building Information Modelling for construction waste management: Moving from rhetoric to reality', *Renewable and Sustainable Energy Reviews*, vol. 68, pp. 587-95.

Mah, CM, Fujiwara, T & Ho, CS 2016, 'Construction and demolition waste generation rates for high-rise buildings in Malaysia', *Waste Management & Research*, vol. 34, no. 12, pp. 1224-30.

Nagalli, A 2013, 'The sustainability of Brazilian construction and demolition waste management system', *The Electronic Journal of Geotechnical Engineering*, vol. 18, pp. 1755-9.

Noori, R, Karbassi, A & Sabahi, MS 2010, 'Evaluation of PCA and Gamma test techniques on ANN operation for weekly solid waste prediction', *Journal of Environmental Management*, vol. 91, no. 3, pp. 767-71.

Paz, DH & Lafayette, KP 2016, 'Forecasting of construction and demolition waste in Brazil', *Waste Management & Research*, vol. 34, no. 8, pp. 708-16.

Sáez, PV, Astorqui, JSC, del Río Merino, M, Moyano, MdPM & Sánchez, AR 2018, 'Estimation of construction and demolition waste in building energy efficiency retrofitting works of the vertical envelope', *Journal of Cleaner Production*, vol. 172, pp. 2978-85.

Sáez, PV, Porras-Amores, C & del Río Merino, M 2015, 'New quantification proposal for construction waste generation in new residential constructions', *Journal of Cleaner Production*, vol. 102, pp. 58-65.

Seo, S & Hwang, Y 1999, 'An estimation of construction and demolition debris in Seoul, Korea: waste amount, type, and estimating model', *Journal of the Air & Waste Management Association*, vol. 49, no. 8, pp. 980-5.

Shang, C, Yang, Y, Yin, Z, Li, Y & Liu, L 2013, 'Prediction and Analysis on the Amount of the Construction Decoration Waste in Haikou, Hainan Province', paper presented to ICCREM 2013: Construction and Operation in the Context of Sustainability.

Solís-Guzmán, J, Marrero, M, Montes-Delgado, MV & Ramírez-de-Arellano, A 2009, 'A Spanish model for quantification and management of construction waste', *Waste Management*, vol. 29, no. 9, pp. 2542-8.

Song, Y, Wang, Y, Liu, F & Zhang, Y 2017, 'Development of a hybrid model to predict construction and demolition waste: China as a case study', *Waste Management*, vol. 59, pp. 350-61.

Song, Z, Li, Y & Huang, Z 2015, 'Analysis and Forecast of Construction Waste Based on ARIMA Model', in *5th International Conference on Civil Engineering and Transportation*.

Wang, Q, Wang, S & Shi, D 2016, 'The GM (1, 1) Model and Verhulst Forecast Model in the Application of Construction Waste Output Prediction: Taking Shenyang as an Example', in *ICCREM 2016: BIM Application and Off-Site Construction*, American Society of Civil Engineers Reston, VA, pp. 415-21.

Wu, Z, Ann, T, Shen, L & Liu, G 2014, 'Quantifying construction and demolition waste: An analytical review', *Waste Management*, vol. 34, no. 9, pp. 1683-92.

Wu, Z, Fan, H & Liu, G 2015, 'Forecasting Construction and Demolition Waste Using Gene Expression Programming', *Journal of computing in civil engineering*, vol. 29, no. 5, p. 04014059.

Yuan, H & Shen, L 2011, 'Trend of the research on construction and demolition waste management', *Waste Management*, vol. 31, no. 4, pp. 670-9.

Zhao, W, Leeftink, R & Rotter, V 2010, 'Evaluation of the economic feasibility for the recycling of construction and demolition waste in China—The case of Chongqing', *Resources, conservation and Recycling*, vol. 54, no. 6, pp. 377-89.

SUPPLY CHAIN OF PREFABRICATED HOUSING CONSTRUCTION: A CASE STUDY OF NEW ZEALAND

Nishadi Sooriyamudalige[1], Niluka Domingo[1], Paul Childerhouse[1], Wajiha Shehzad[1]

[1]School of Built Environment, Massey University, Auckland, New Zealand

Abstract

It is believed that prefabrication will be the success factor for construction productivity growth (Construction 2011; Kamali & Hewage 2016; PrefabNZ 2014; Shahzad, Mbachu & Domingo 2015). However, in New Zealand, it has a lower uptake due to many challenges, including a lack of integrated supply chain specifically in prefabricated housing construction. Therefore, this paper aims to review the current supply chain of prefabricated housing elements, specifically in modular bathroom manufacturing. Further, the issues associated with the supply chain of modular bathroom manufacturing is explored.

The paper is based on the analysis of twelve interviews conducted with the prefab experts in New Zealand housing construction sector. The processes and the networks of the participants in the supply chains of New Zealand prefabricated house elements are formed temporarily for a particular project and discharge after the project. Ad-hoc relationships, poor planning and scheduling, transportation of volumetric modules, miscommunication and customisation are a few major challenges in the manufacturing process of prefabricated house elements. However, proper supply chain practices would enhance the inefficiency across the supply chains in prefabricated house elements.

Keywords

Housing; Prefabrication; Modular prefabrication; Supply chain; New Zealand

Introduction

New Zealand housing construction sector is struggling to achieve the balance between supply and demand with inadequate traditional construction methods (Housing affordability inquiry 2012; PrefabNZ 2014). Productivity and quality issues within the industry are creating a more challenging environment for the builders (Mbachu, Egbelakin, Rasheed & Shahzad 2017; PrefabNZ 2014). There is a rising consensus towards the adoption of more innovative technologies like modular prefabrication (Lessing, Stehn & Ekholm 2015).

Prefabrication is one of the potential solutions to most of these problems associated with the housing construction in New Zealand (PrefabNZ 2014; Shahzad, Mbachu & Domingo 2015). It is one of the ways to improve quality and accessibility to architectural designs to housing construction (Bell 2012). The notion of prefabrication extensively offers numerous benefits to all stakeholders in the construction cycle (Blismas & Wakefield 2009). From an economic point of view, this is used to achieve economies of scale in production (MBI 2010). Compared with the manufacturing supply chain, the key difference becomes assembling the product on-site, and a higher degree of the supply chain is finalized during the production (Stroebele & Kiessling 2017). Primarily, the prefabrication construction supply chain consists of four stages; (i) design approval, (ii) manufacturing of modules/components off-site, (iii) transportation of modules to a final destination and (iv) assembly of modular units to form the finished building (MBI 2010).

Even though prefabrication offers numerous benefits, the usage and the uptake of it in New Zealand is quite low (Page 2014; PrefabNZ 2014). As Burgess et al. (2013), mentioned, 17 percent of all construction taking place in New Zealand is prefabricated, with a huge potential of almost double the uptake of prefabrication in the next few years. Mainly, prefabricated timber wall panels, roof frames, joinery and windows are used for housing construction in New Zealand (PrefabNZ 2014). According to the report of PrefabNZ (2014), the usage of prefabrication for non-residential buildings and residential buildings is 11 percent and 37 percent, respectively. This lower uptake and usage is caused by a number of issues and most prominently, collaborative approach thorough out the supply chain is identified as one of the challenging areas for the uptake of prefabrication in New Zealand (PrefabNZ 2014).

Prefabrication housing construction is more likely to be challenging compared to the conventional practices and therefore requires greater attention in integrating prefabrication into off-site construction (Pan, Gibb & Dainty 2012). Integration of the entire construction processes at the organisational level is an important aspect to achieve substantial growth in the uptake of prefabrication in house building (Pan et al. 2012). Integration of the key business functions across the supply chain can provide benefits resulting from the reduction in cost and time taken to produce an order (Power 2005).

The process of integration is not a simple task. To integrate, identifying appropriate processes link with the supply chain member is an important aspect (Lambert, Cooper & Pagh 1998). It begins with product design and includes all the activities leading to the ultimate sale of the product and drives by the integration of information, coordination of resources and management of supply chain relationships (Handfield & Nichols Jr 1999). Even though supply chain integration offers the potential to improve efficiency and effectiveness, there are challenges link with implementation. These challenges can be classified, challenges for supply chain integration can be classified into three categories; technical, managerial and relationship (Awad 2010). Supply chain integration is one of the hardly discussed matters in the construction industry due to its one-off project focus nature (Doran & Giannakis 2011). However, the construction industry needs to integrate its processes and products to ensure the value of the product (Construction 2011).

The construction industry in New Zealand is taking very little advantage of prefabrication in housing construction due to inefficiencies in its supply chain (PrefabNZ 2014). Supply chain integration can mitigate the barriers through effective engagement of the members of the supply chain and a clear focus upon the alignment and integration of the processes (Doran & Giannakis 2011). This paper, therefore, focuses on identifying barriers and challenges in the supply chain of modular bathroom manufacturing which is one of the commonly used types of prefabricated elements in housing construction.

First, the paper draws a background picture of the concept of supply chain management, prefabricated housing construction and the nature of the New Zealand prefabricated housing sector based on the literature. The paper presents the nature of the prefabricated housing construction based on the opinions of the industry practitioners. The nature of the supply chains and the participants are demonstrated in the paper. A comparison of the theoretical aspects and industry practice is drawn. Further, the issues in the supply chain of modular bathroom pods are demonstrated.

Methodology

The success of a well-organised supply chain will depend upon proper planning and controlled management system (Cooper, Lambert & Pagh 1997). To structure the supply chain process and the network between participants, the theatrical aspects and practical scenario in New Zealand prefabricated housing construction must be examined. The study first provides a background idea of the Supply Chain Management (SCM) concept the nature of the prefabricated housing construction and prefabricated housing construction in New Zealand. For the data collection, the manufacturing process of modular bathroom pods is selected as it is commonly used in the prefabricated construction. On the other hand, examining the whole building manufacturing is not realistic as in New Zealand, modular homes are not the common choice (PrefabNZ 2014). However, the actual supply chain processes and networks in the prefabricated housing supply chain in New Zealand were examined to get an idea. As per further, the issues associated with the supply chains of modular bathroom pods were investigated.

Therefore, twelve semi-structured interviews were carried out among industry experts who are engaged in prefabrication housing construction. Purposive sampling method was used as the sampling techniques as it facilitates capturing participants, appropriate to the study based on the researcher's own knowledge and opinion. These include architects, developers, subcontractors, contractors and sub-contractors. Based on the findings, the supply chain of the New Zealand prefabricated house building and the process of bathroom pods manufacturing is illustrated, and further, the issues in the supply chain of bathroom pods manufacturing are identified and categorised.

A comparison between the actual and the theoretical supply chains of the prefabricated housing construction is drafted under the discussion section. The conclusions were drafted based on the findings from the literature review and the data collection through semi-structured interviews.

Findings and discussion

The attention for prefabrication is resurging in the New Zealand housing construction industry driven by its benefits. Prefabrication construction in New Zealand is classified into five types: component-based prefabrication, panelised prefabrication, modular prefabrication, whole building prefabrication, and hybrid prefabrication (Shahzad 2016). Amongst, component-based prefabrication and panelised prefabrication are the commonly used types of prefabrication in house building. This is similar to the literature findings where, PrefabNZ (2014) highlighted prefabricated timber walls, roof frames, joinery and windows as mainly used types of prefabrication in housing in New Zealand. Besides, participants admit that there is a current trend towards the construction of modular homes and container homes to provide the solutions for the crisis of the affordable house in New Zealand. However, the demand for modular and container homes remains controversial.

New Zealand housing construction industry is criticised for time delays, less productivity, quality variations, less innovation and high cost in construction (PrefabNZ 2014; Building Industry Federation of New Zealand (BIFNZ 2013; CHRANZ 2011). Therefore, participants were asked about their opinion on mitigating these issues by using prefabrication. Overall, the participants' opinions indicate that prefabrication enables low-cost houses through improving efficiency. Off-site manufacturing under controlled and highly automated environment facilitates high-quality houses. This is identical to the literature sources, which endorse the product standardisation to improve productivity and quality in housing construction (Hines 2012; MBI 2010; Gann 1996).

Even though prefabrication could elevate New Zealand housing construction, the uptake of it is criticised in the literature. Literature sources further disclose the reasons for this situation in New Zealand. Participants agreed with the low-level of usage of prefabrication in New Zealand house building.

The process of the prefabricated house building was revealed to be very complex and unique across each project. As the prefabricated house building process is not a standardised one, the key stages and key stakeholders of the prefabricated house building are examined to identify the interfaces followed by the issues in the process. Figure 1 was developed based on the interviews and the observations made from the site visits. Most of the identified stages are primarily sequential except the off-site manufacturing and site preparation and foundation. However, there can be slight changes to the developed process based on the type of prefabrication used to construct the house. The supply chain can divide into two main parts, the pre-assembly and the construction site, which has different demands on the supply chain. The pre-assembly involves purchasing, materials handling, supplier involvement, transportation and supply patterns etc. Activities on the construction site have the structure of the final assembly, and the deliveries of elements and components must be thoroughly planned where Just In Time is implemented in close relationship with component and element suppliers.

It is recognised, that design and planning stage are key milestones of the prefabricated housing construction as it involves-design freezes, cost planning, methods of procurement and project planning and scheduling. Designers have to identify the parameters and basic requirements in designing prefabricated houses to get approvals and to minimise the complications in the construction stage.

Getting the building consent is discussed as one of the time consuming and an important milestone in the process. A well-developed supply chain management system must involve all parties of the process, such as developer/builder, designer, manufacturer, material suppliers, distributors and clients and information sharing as the developed process.

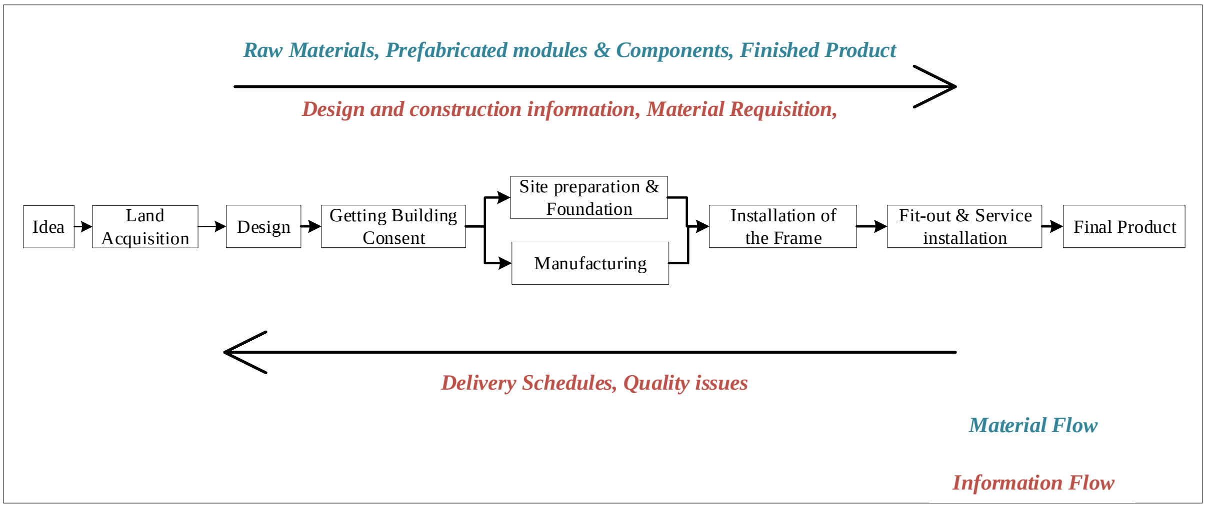


Figure 1: Supply chain of prefabricated housing construction

The modular bathroom manufacturing process

Generally, application of prefabrication differs from project to project depending on the scale and unique nature of each project. In New Zealand, wall panels and modular bathroom pods are commonly used types of prefabricated elements in house building. Modular bathroom pods are mass-produced under controlled manufacturing conditions and delivered to the project site based on the schedules. These are inherently beneficial to achieve tight deadlines, minimal site impact and generally used in repetitive structures like apartments.

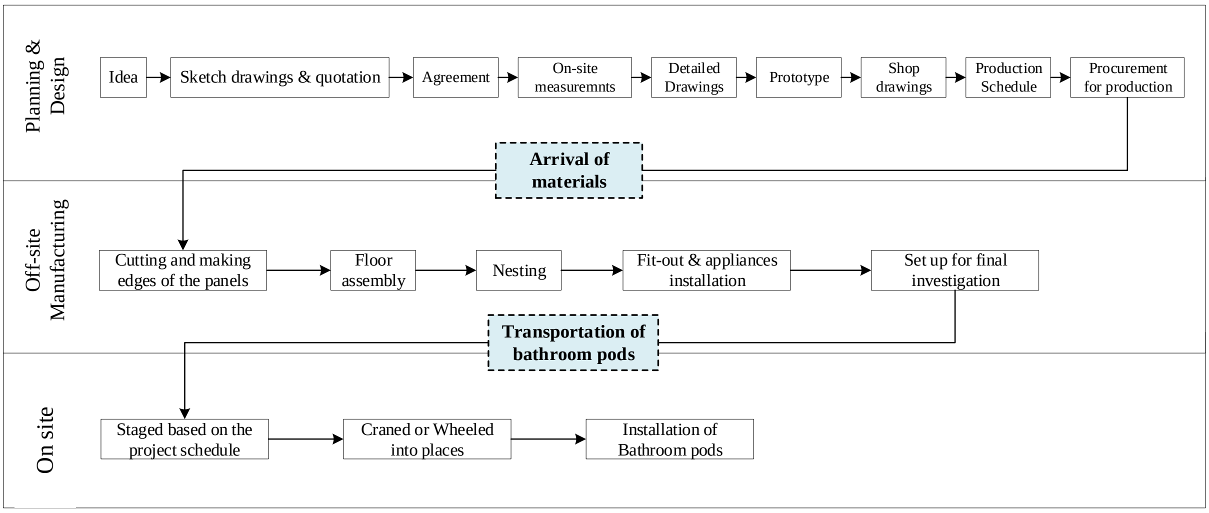


Figure 2: Modular bathroom pods manufacturing process

The modular bathroom manufacturing process can be mainly divided into three stages as planning and designing, off-site manufacturing and onsite assembly. Generally, the module manufacturer is the accountable person for these three stages. The process starts with the client's initial requirement and extends to detail design and planning, production and onsite assembly. Material procurement and handling and delivery of the bathroom pods require greater attention in order to prevent delays and disruptions in the process. To improve the production process of house building, barriers in bathroom manufacturing were considered in the interviews.

Barriers in the supply chain of modular components

The identified main causes for the supply chain of the bathroom can be divided into three main categories as we discussed earlier: managerial, technical and relationship-wise. The interviews further indicate few barriers for the supply chain in prefabricated these elements that are external to the organisation.

Managerial Barriers

Inadequate project planning and scheduling

As noted, the lack of project planning and scheduling seems to be a major internal barrier in both manufacturing processes. Compared to traditional construction, prefabrication requires a proper management system from start to end to avoid delays and to achieve customer satisfaction. Jonsson (2014); Kamali and Hewage (2016) and Jaillon and Poon (2008) also discussed the importance of having a proper project planning system for prefabrication construction. Early design freeze and less flexibility for changes in prefabrication, improve the requirement of a proper plan with schedules to eliminate complications (Jaillon & Poon 2008). However, in New Zealand, most of the prefab manufacturing companies are not using proper project planning tools to schedule their work. This has created delays and cost overruns in the industry.

Inadequate performance measurement systems

Prefabrication is about improving efficiency in the construction. Performance measuring and evaluations are required to develop the processes. Real-time performance measurements are beneficial for product development, efficiency improvements and decisions making. However, performance measurement and follow-ups in the manufacturing process are not properly conducted within the factories. In New Zealand, most of the manufacturing companies are operated with less automation. Most of the companies are operated based on a project basis and try to achieve a particular project within the time frame.

Inconsistent goals within the company

Goal setting is an important component of a business to gain competitive advantages through achieving targets and improving performance. In prefab manufacturing companies in New Zealand, are not seems to be interested in setting up short-term and long-term goals. Stakeholders of the supply chain process of prefabrication are having their own goals for career development rather than having common goals. Different perspectives of the participants of the process and inconsistent goals within the company create poor collaboration and coordination issues. This ultimately results in cost and time overruns and poor quality work.

Lack of knowledge in consumer demand

A clear idea of the market demand and its trends is necessary to ensure that the companies are getting sufficient work for survival and growth within the industry. Market investigations and surveys are needed to forecast consumer demand and demand trends in the market. However, among the interviewees, only one company had a database for customer demand evaluation, and most of the other participants pointed out it as a barrier.

Lack of understanding of SCM

As noted, prefab manufacturing companies are not using manufacturing concepts to improve their efficiency. Some of the participants of the interviews are aware of Lean Principles and using it to minimise the waste. However, the concept of SCM is not using in most of the companies.

Technical Barriers

Lack of information sharing

Effective and efficient means of coordination and communication is needed to throughout the whole process of delivering a prefabrication building, including project planning, procurement, supply chain scheduling, assembling and construction, and delivery (Kamali & Hewage 2016). To deliver the project in time, the communication between the participants of the construction process must be standardised (Stroebele & Kiessling 2017). As noted, manufacturing companies are not using any standardised information-sharing systems to share information openly. E-mails, phone calls, face to face talks, meetings are used to communicate and share information. However, open and reliable information sharing is not visible in New Zealand.

Lack of technology and automation

Lack of using technology and reluctant to innovation is a common phenomenon in the New Zealand construction industry. The process of prefabrication requires accurate and reliable information. Modern technologies facilitate effective means of handling updates and changes in the manufacturing process and indicate real-time performances. Use of extensive modern IT tools and automated machinery provide solutions for information and data exchange and performance and efficiency problems in the industry (Lessing 2015). However, the usage of modern information and communication technologies in the New Zealand construction industry appears to be at a very low level. This reflects the following comment made by a participant.

"Technological barriers in 3D scanning, modelling and 3d dimensioning and that sort of things are quite new in New Zealand. So it's going to take a few years to use those together – (P-03").

However, It was noted that few companies use technologies like Building Information Modelling (BIM) for their productions.

Transportation of modules

Transportation is one of the significant stages in the prefabricated housing construction. Most of the component of the house is manufactured in a factor; delivery of those into the site should receive significant attention. As New Zealand's landscape is hilly and transportation of heavy modules across the country is quite a challenge, and thereby, transportation incurs a significant cost. This is emphasised by the following statement.

"New Zealand's geography means that we are inevitably going to have a large transport component-(P-10)".

"In New Zealand, the land is very heavy and skinny. Therefore, transportation is difficult, and it takes a significant amount of money to transport heavy modules- (P-03)."

Relationship Barriers

Lack of long-term partnerships

Suppliers and clients are engaged in informal basis without forming contracts. This will creates conflicts in finding trustworthy and cooperative suppliers and clients and further organisations have to waste time and effort in tendering for the selection of suppliers. Long-term relationships facilities co-operation among the parties and ultimately leads to quality improvements with time and cost savings.

Lack of trust among the stakeholders

Stakeholders in the supply chain of prefabricated modular components manufacturing seem to be engaged based on a project basis and discharge when a particular project is completed. This hinders the opportunity for gaining trust among the stakeholders. In the meantime, most of the operational workers engaged in the organisation temporarily and left the company when they found better jobs. Therefore, trust among the stakeholder has become one of the major concerns in building long-term stable relationships to integrate the business functions.

In addition to the aforementioned internal barriers, few external barriers are indicated within the interviews: the scale of the New Zealand market, undercapitalised companies, anti-competitive behaviour and the lack of education about the benefits of prefabrication.

Conclusion

Prefabrication can be used as an innovative approach to improving productivity and to address the growing demand for houses in New Zealand. It can further improve the productivity of the construction industry. The concept of the prefabricated housing construction is shown to be a complex process as it requires proper planning and structuring the process from start to end of the project. And also it requires proper management in between the site construction and off-site manufacturing and in delivering the volumetric modules to the onsite at the specific time. Delays in delivering will cause problems to drag the delivery time of the project while early delivery of the modules generates a cost for storage facilities. Therefore, proper supply chain management over the process is a prerequisite.

On the other hand, according to literature, manufacturing concepts are constantly emerging in the construction industry to improve efficiency. In New Zealand, prefabricated housing construction has gained much attention to overcome the issues associated with the sector. However, due to product standardisation, the customer demand for prefabricated houses are quite low. And lack of proper planning and control management over the whole building construction are issues which drag down the uptake of prefabrication in housing construction. This research aims at identifying the current nature of the supply chains in prefabricated housing construction.

According to industry opinion, there are no standard supply chain structures in the industry. It is ad-hoc in nature and depends upon the nature and the procurement method of the project. Thereof, developing a supply chain structure to match the industry need is one of the main tasks of the paper. Based on the developed structure, it is easy to identify the main stages and relationships of the process. Some of the relationships are independent, and some of them are dependable. For example, site construction is depending upon the transportation of modules to onsite. Likewise, the whole process is staked and depending upon each of the activities.

The supply chain management is required to overcome these barriers through an integration mechanism. Further, Industry needs to rectify the current situation of the prefabricated housing element manufacturing to provide the solutions for the housing construction sector as it's the common type of prefabrication used in the sector.

References

Anonymous. 2012. *Housing affordability inquiry*. New Zealand: The New Zealand Productivity Commission.

Awad, D. 2010. A broader view of the supply chain integration challenges. *Int. J. Business Performance and Supply Chain Modelling*, 2.

Blismas, N. & Wakefield, R. 2009. Drivers, constraints and the future of offsite manufacture in Australia. *Construction innovation*, 9**,** 72-83.

Construction, M. H. 2011. Prefabrication and modularization: increasing productivity in the construction industry. *Smart Market Report*.

Cooper, M. C., Lambert, D. M. & Pagh, J. D. 1997. Supply chain management: more than a new name for logistics. *The international journal of logistics management,* 8**,** 1-14.

Doran, D. & Giannakis, M. 2011. An examination of a modular supply chain: a construction sector perspective. *Supply Chain Management: An International Journal,* 16**,** 260-270.

Fellows, R. F. & Liu, A. M. 2015. *Research methods for construction*, John Wiley & Sons.

Handfield, R. & Nichols Jr, E. 1999. Introduction to. *Supply Chain Management, Prentice Hall, Englewood Cliffs, NJ*.

Lambert, D. M., Cooper, M. C. & Pagh, J. D. 1998. Supply chain management: implementation issues and research opportunities. *The international journal of logistics management,* 9**,** 1-20.

Lessing, J., Stehn, L. & Ekholm, A. 2015. Industrialised house-building–development and conceptual orientation of the field. *Construction Innovation,* 15**,** 378-399.

Mbachu, J., Egbelakin, T., Rasheed, E. O. & Shahzad, W. M. 2017. Influence of key role players on productivity outcomes in the residential building lifecycle. *Journal of Engineering, Design and Technology,* 15**,** 528-551.

Power, D. 2005. Supply chain management integration and implementation: a literature review. *Supply chain management: an International journal,* 10**,** 252-263.

Prefabnz. 2014. *Prefb roadmap: A way forward for prefabrication in New Zealand (2013-2018)* Wellington, New Zealand PrefabNZ.

Saunders, M., Lewis, P. & Thornhill, A. 2009. Research Methods for Business Students (5th edn). Pearson Education.

Shahzad, W. 2016. *Comparative analysis of the productivity levels achieved through the use of panelised prefabrication technology with those of traditional building system.* PhD, Massey University, New Zealand.

Stroebele, B. S. & Kiessling, A. J. 2017. Impact Analysis of Complexity Drivers in the Supply Chain of Prefabricated Houses. *Journal of Management and Strategy,* 8**,** 1.

'BLT' IS NOT A SANDWICH: LEARNING & TEACHING EMERGING BUILDING PROCUREMENT METHODS; AUSTRALIAN, ASIAN AND EUROPEAN PERSPECTIVES

Guillermo Aranda-Mena[1], Paulo Vaz-Serra[2]

[1]School of Property, Construction and Project Management, RMIT University, Melbourne, Australia

[2]Constrution Management, Faculty of Architecture, Building and Planning, University of Melbourne, Australia

Abstract

A clear understanding of procurement methods for built environment professionals is paramount. The current building process continues to evolve for both, governments and private sector clients and in cases also for combined public-private concessions. Over the last 25 years clients have become more knowledgeable on procurement, project finance and construction delivery mechanisms. Some institutional clients have evolved to become industry experts, in other cases contractors have become project investors such as in Public-Private Partnerships (PPPs) or Build-Lease-Transfer (BLT). As building and construction procurement methods continue to change it is then paramount to bring this knowledge into Master and Higher Education programs related to the built-environment. It is important to clearly understand the emerging procurement methods and mechanisms to successfully deliver and operate projects including building with quality, stakeholder engagement, risk sharing, owner life-cycle operations and project financing strategies. It is important is to learn how to identify key project attributes before selecting a procurement route. This matching exercise is explained in the paper utilising six techniques. This paper then discusses on learning and teaching procurement as experienced by the authors with experiences in Australia, Asia and Europe in particular with research and teaching to Master and Honours students in architecture, engineering, building operations and construction management.

Keywords

Building Procurement, Decision-Making, Value for Money, Project Life-cycle

Introduction

Learning & Teaching building procurement methods to built environment professionals is paramount. In the last three decades considerable attention and research has been done in construction procurement methods (Naoum & Egbu, 2016). The construction industry was identified as an example of market failure, contracting arrangements generating excessive transaction costs and poor client satisfaction (Sweeny, 2009). Sweeny in his research found that the current industry model is not operating to deliver projects outcomes to achieve accurately customer needs and expectations in a consistence way. In addition, a survey prepared by the Chartered Institute of Buildings in 2010 (CIOB, 2010), revealed that for 77% of the respondents see clients as not sufficiently knowledgeable about procurement in the construction industry, which often leads to poor leadership and advice being taken from a client perspective and results in potential project short comes such as over-budget, outside of timeframes and poor construction standards with resulting building defects and quality short comes (CIOB, 2010). Much of the concern for construction quality has exacerbated in recent years, in particular with flagship projects being on the spotlight such as the disastrous fires of the Glenferrie Tower in the UK (2017) and the Lacrosse Tower, Melbourne (2014) and more recently the disputes on urgent structural rectification of the Opal (2018) and the Mascot (2019) towers in Sydney.

From an industry perspective, construction professionals view procurement as crucial to the timely delivery of project both, on budget and to high quality standards. The same survey (CIOB, 2010), revealed that for 87% of respondents believed that good procurement is synonymous of a successful project. The same survey identified that 65% of the construction short comes were due the wrong used of delivery methods (CIOB, 2010). Considering that 93% of respondents have been involved in projects that overran in terms of cost is it worth considering their views as 57% of those projects believed that the chosen procurement method directly contributed to the cost overruns. Similarly, 94% have been involved on projects that overran in terms of time. Of those, 49% believe the chosen procurement method directly led to the time overruns.

If looking at the above, the link of procurement methods and project outcome is clear. Two questions remain open: which are those procurement methods are available? and how to select the right fit? In the view of the authors those two questions in combination require further investigation and more importantly, adoption by industry and client organisations. This paper deals with the second aspect. This is to say that Learning & Teaching and learning construction procurement by various project stakeholders is paramount in the improvement of construction quality.

Some authors recognised the importance of the procurement selection criterion and identified that it often tilts towards risk aversion or preventions rather than best overall outcomes, thus identifying best value for money solution for overall project lifecycle (Edwards et. al, 2014). More often than not, the industry seems to make key decisions based on ‘gut-feeling’ rather than applying rational thinking and decision-making, Sweeny (2009) highlighted that a significant percentage of industry key decision-makers did not make appropriate criterion for selecting the best method, ie. they have stayed in a comfort-zone selecting procurement methods previously utilised. Alan Turner (1997) developed a table with four traditional methods and using nine criterion and questions that could be applied for procurement method selection resulting in an objective and rational decision.

However, a problem identified in the literature is the overwhelming use of jargon and terminology that also changes in relation to countries and geographic jurisdictions such as economic zones or states within countries. Klein, R. (RIBA, 2018) mentioned that in his experience, over 95% of sub-contracts and sub-sub-contracts are amended standard contracts or bespoke contracts. In 30 years of dealing with contractual and legal issues in the industry, I can only recall one example of the use of an unamended sub-contract. In other words, even if the principal contractor is set away from a cost + contract such as an alliance contract, subcontractors and the overall supply chain is still pretty much business as usual. This calls for deeper education for client and industry bodies and representatives of various suppliers of professional services.

Soup of letters: building procurement methods

The process for selecting the most suitable procurement delivered method has been studied since 1985 with the NEDO report (NEDO, 1985) and after that several methods have been used and research to adjust the methods with the specify requirements of projects and clients (Skitmore & Martin, 1988; Franks, 1990; Turner, 1990; Kumaraswamy & Dissanayaka, 1998; Alhazmi & McCaffer, 2000; Chueng et al. 2001; Morledge & Smith, 2013; Naoum & Egbu, 2016; Bugrov & Bugrova, 2018). Grimsey and Lewis further reviewed methods such as Public-Private Partnership by carefully describing what is a PPP, and what not (2014) the paper contains a raft of abbreviations and acronyms ranging from BLT (Build-Lease-Transfer) to BOO and BOOT (Build-Own-Operate and Transfer).

The authors now reflect on the lessons of teaching procurement methods in higher education with Construction Management Honours and Master programs delivered in Europe, Asia and Australia. The vision is to educate construction professionals at a deeper level on the clear understanding of how projects come about and what are the contractual relationships, which place them on a launching platform for success. Value management workshops identifying core project attributes and procurement method identification are some of the teaching techniques applied (Aranda-Mena 2016). The premise is that there is no good nor bad procurement method but the challenge is on identifying the right fit based on project attributes. For over a decade all cases have been real construction scenarios with industry speakers brought on board (Aranda-Mena et. al. 2013).

Procedure: Teaching and learning procurement methods in a period of twelve weeks in lectures of two to three hours plus weekly tutorials. Industry guest speakers are often invited due to the pragmatic nature of the subject, students of construction management and engineering highly value direct industry insights and hands-on workshops during tutorials. The aim is to develop a clear understanding on each of the procurement methods and students are asked to set up packages for a building or infrastructure project so lessons learnt are put into place from day one. The methods presented here below encourage students not only to apply established procurement routes but also to compare with emerging ones based on best project outcomes. The three first methods on construction procurement are thought by the second co-author and the last two, on infrastructure procurement, by the lead co-author.

Selecting a procurement route: Alan Turner (1997)

Turner, A (1997) develop a methodology to help clients to select the best procurement route following the recommendation of the NEDO' report (NEDO, 1987). He started the process with the first seven steps for medium-large projects: (1) selecting an in-house project executive; (2) Appointment of a principal adviser; (3) Care in deciding the client's requirements; (4) Timing the project realistically; (5) selecting the best procurement path; (5) Choosing the organisations to work with the client (7) Designation a site or building. Based on 12 case studies he tested the application of the NEDO report "Thinking about Building" and introduced developed a table with nine criterion for four traditional methods, not including private finance: Traditional, Design and Build Management and Design and manage

His strategy was to start with the context, understand the client characteristics based on Masterman and Gameson (1994) suggestions and project, and use the NEDO table suggestions to access the Procurement Assessment Criterion (PAC) (See Table) following an analysis of the results looking at the different Procurement Arrangement Options (PAO).

As point of departure, client and project particulars are explained and workshopped during class. Alan suggested an initial understanding of the balance of priorities between what he called Product, Price and Programme. The product is usually referred to quality, performance or complexity. The price is usually referred to costs, cost certainty, or flexibility in target. The programme is time, early start, early completion, important milestones. See in figure 2, an example of a project with a balance of priorities where the programme is more relevant for a client.

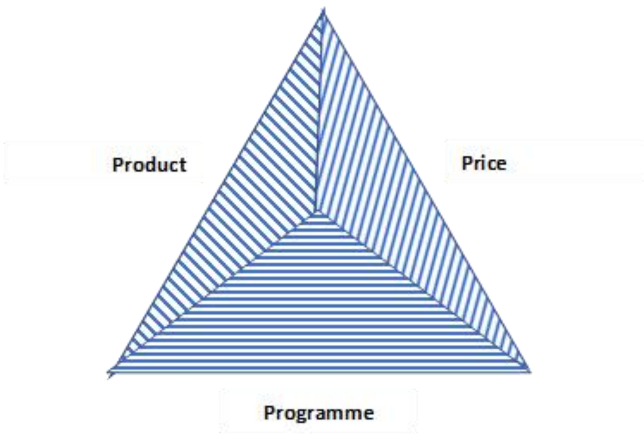


Figure 1. Example of balance between programme, product and price (based on Alan 1990)

The following Table 1 Provides and example of underlying project criteria and project attributes. The clear understanding of project nature can then be linked to a procurement method or methods such as in cases when projects are packaged under various modes looking at ‘value for money’ outcomes.

Table 1: Adapted from Alan (1990) and NEDO (1987)

Combined Procurement Assessment Criteria and Identifying Project Priorities

Criteria	Sub-criteria		Procurment method								
			Traditional		Design and Build			Management		Design and Manage	
		Criteria (0 or 1)	Sequencial	Accelerated	Direct	Competitive	Develop and Construct	Management contracting	Construction Management	Contractor PM	Consultant PM
Timing	Crucial	0		0	0			0	0	0	0
	Important	0		0	0	0	0	0	0	0	0
	Not as important as other factors	0	0								
Variations	Yes	0	0	0				0	0	0	0
	Definitively not	0			0	0	0				
Complexity	Yes	0	0	0				0	0	0	0
	Moderately so	0		0	0	0	0	0	0	0	
	No, just simple	0			0	0					
Quality level	Basic competence	0			0	0					
	Good but not special	0	0	0	0	0	0	0	0	0	0
	Prestige	0	0	0				0	0		
Price certainty	Yes	0	0		0	0	0	0		0	
	Target plus or minus will do	0		0					0		0
Competition	Certainly for all construction work	0	0			0	0	0	0	0	0
	Construction and Management teams	0	0				0	0			
	No, other factor are more important	0			0						
Responsibility	Can manage separate firms	0	0	0				0	0		
	Must have only one firm for everything	0			0	0	0			0	0
Risk avoidance	No, prefer to retain risk and therefore control	0							0		0
	Prepared to share agreed risks	0	0	0				0			
	Yes	0			0	0	0			0	
		Total	Σ	Σ	Σ	Σ	Σ	Σ	Σ	Σ	Σ

For teaching proposes the four Procurement Methods show in the above Table 1 are used in an individual assignments. Students need to clearly understand client requirements and project characteristics (including expectations) and then to use table to compare and run the best matching factor. The NEDO / Alan table also provide an effective way to investigate existing projects/case studies in order to evaluate other potential outcomes to the one reported by the client or project team. This method helps students to justify what and why they recommend specific procurement modes. This method combines quantitative data and qualitative assessments as well.

Selecting a procurement route: Sean Sweeny (2009)

Sweeny (2009), demonstrated the importance of using transaction cost economics (TCE) theory for project delivery approaches in large and complex projects rather than use current ‘market contracting’ perspective. Sweeney studied twelve different procurement methods: Lump-Sum; Guaranteed Maximum Price (GMP), Cost reimbursable; Measure and value/schedule of rates; Design and Construct (D&C); Construction Management, Managing Contractor; Fast track; Negotiated; Project Alliance; Public-Private Partnerships (PPP). Sweeny recommended organisations to six steps to approach his methodology: (1) Identification of project characteristic, (2) Development of a Procurement delivery project performance criterion, (3) weighting the criterion against the specific needs of the project, Client’s Criterion Preference Score (CCPScore) (see table 2), (4) Assessment and scoring of the same criterion across a wide range of PDM’s to generate ‘utility factors’ for each criterion for each PDM (see table 3), (5) Scoring each PDM using the utility scores noted in 4 and multiply these by the weightings developed on 3, (6) ranking each PDM by the resultant score to identify the PDMs most likely to suit the needs of the project (see table 4).

Table 2 – Identify client's criterion preference score (Adapted from Sweeney 2009)

	Criterion 1	Criterion 1	Criterion 1	…
CCPSCore	A%	B%	C%	…

Table 3 – Example of raking of each criterion for each PDM (1-10) to generate CCPScores (Sc 1-Sc10) (Adapted from Sweeney 2009)

Criterion	*PDM 1*	*PDM 2*	*PDM 3*	*PDM 4*	*…*
Criterion 1	Sc.1	Sc.6	Sc.4	Sc.9	…
Criterion 2	Sc.5	Sc.3	Sc.5	Sc.2	…
Criterion 3	Sc.6	Sc.9	Sc.7	Sc.5	…
…	…	…	…	…	…

Table 4 – Final results combining raking of criterion of each PDM with criterion score for client (Adapted from Sweeney 2009)

Criterion	*CCPSCore*	*PDM 1*	*PDM 2*	*PDM 3*	*PDM 4*	*…*
Criterion 1	A%	A% x Sc.1	A% x Sc.6	A% x Sc.4	A% x Sc.9	…
Criterion 2	B%	B% x Sc.5	B% x Sc.3	B% x Sc.5	B% x Sc.2	…
Etc.	..	…	…	…	…	…
Total	∑100%	∑	∑	∑	∑	

Sweeny (2009) identified 30 main project performance criterion consolidated in 11 generic ones. An example criterion would be: Quality, funding rigidity, program speed, scope rigidity, risk transfer, complexity in client, need for contractor involvement in design, flexibility, operational perspective to the design, innovation and value creation, transaction economy. This method is used in workshops with the students, and in groups of 4 or 5 students are requested to look at different case studies. Firstly, each group needs to identify between 5 and 7 criterions by which to select preferred PDM for their project. Each criterion should reflect their Client's preferences and be expressed as clearly as they can. e.g. Cost - their preference that the selected PDM can control cost growth risk throughout the progress of the project. Spend some time thinking and discussing what your Client's criterion may be.

Then the students are expected to produce an agreed list of Client criterion for a given project. Secondly, each group splits into two. The smaller number of the group ranks or scores each criterion in terms of relative preference over the other agreed criterion. Should end up with each criterion having a numeric score (or %) which shows it relative ranking in relation to the other criterion. Call this the Client's Criterion Preference Score (CCPScore). The larger part of the group takes the Client criterion and assesses each of the PDMs against the list of criterions. I.e. for each PDM produce a score (say 1-10) which notes that PDM's specific ability to provide or meet the demand of each specific client criterion. Finally, each group review scores, discuss and report recommendation to the full class.

Selecting a procurement route: Morledge & Smith (2013)

Morledge & Smith (2013) in the second edition of the book Building Procurement developed a methodology, including NEDO (1998) and Skitmore and Marsden (1988). Using the same methodology that Alan for client characteristics, Morledge & Smith introduced the component dynamic of the process and a typical balance for main types of clients. Owner-occupier clients may emphasise occupation and value certainty; developers, price and rapidity; and investor clients, design and speed.

In addition, the authors, adapted the method of scoring utility factors developed by Fellows and Langford (1980) to rank the criterion for each procurement method (See columns (a) in table 5). In other to link client and project's particular with these utility factors, the authors proposed a client's priority (P) raking between 5 to 1 (From 5 Essential to 1 Do Without). Each client's priority will be multiplied by the utility score to obtain a score, the final results will be adding all the scores by each column.

Table 5: Identifying client's priority. Adapted from Morledge & Smith (2013)

Client's Priority		Procurement Method																	
	P= 5 to 1	Traditional				Design and Build						Management				Design and Manage			
		Sequential		Accelerated		Direct		Competitive		Develop and Construct		Management contracting		Construction Management		Contractor PM		Consultant PM	
		(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
Timing	P1	10	(a)xP1	50	(a)xP1	100	(a)xP1	90	(a)xP1	60	(a)xP1	100	(a)xP1	100	(a)xP1	90	(a)xP1	80	(a)xP1
Cost	P2	90	(a)xP2	40	(a)xP2	100	(a)xP2	100	(a)xP2	90	(a)xP2	20	(a)xP2	20	(a)xP2	30	(a)xP2	20	(a)xP2
Flexibility	P3	100	(a)xP3	90	(a)xP3	30	(a)xP3	30	(a)xP3	40	(a)xP3	80	(a)xP3	90	(a)xP3	60	(a)xP3	70	(a)xP3
Complexity	P4	40	(a)xP4	20	(a)xP4	20	(a)xP4	10	(a)xP4	40	(a)xP4	100	(a)xP4	100	(a)xP4	70	(a)xP4	80	(a)xP4
Quality	P5	100	(a)xP5	60	(a)xP5	40	(a)xP5	40	(a)xP5	70	(a)xP5	90	(a)xP5	100	(a)xP5	50	(a)xP5	60	(a)xP5
Price Certaint	P6	40	(a)xP6	50	(a)xP6	100	(a)xP6	90	(a)xP6	90	(a)xP6	40	(a)xP6	30	(a)xP6	100	(a)xP6	80	(a)xP6
Responsibilit	P7	30	(a)xP7	30	(a)xP7	100	(a)xP7	100	(a)xP7	70	(a)xP7	60	(a)xP7	90	(a)xP7	100	(a)xP7	90	(a)xP7
Risk	P8	30	(a)xP8	30	(a)xP8	80	(a)xP8	100	(a)xP8	70	(a)xP8	30	(a)xP8	10	(a)xP8	100	(a)xP8	80	(a)xP8
	Results		∑		∑		∑		∑		∑		∑		∑		∑		∑

(a) Utility, (b) Score

Selecting a procurement route: Grimsey and Lewis (2004 and 2014)

The Grimsey triangle is a method currently public infrastructure procurement. The use of the tool is set in a workshop environment where students need to assess and think on a particular project attributes from various stakeholders and professional disciplines thus bringing best Value for Money outcomes. Overall, it is important to understand where a particular project sits in relation to five axes including: time to market, value for money, risk transfer, innovation and flexibility for change (See Fig. 2).

A workshop discussion takes place where participants rank the project according to the above 5 dimensions and then drawn on a two-dimensional plot. Then, a second layer where various procurement methods are objectively located in relation to the 5 dimensions is shown. The findings are discussed across main stakeholders and a decision is made. Full explanation of the method is beyond the scope of this paper however, figure 3 illustrates the relationship of the 5 dimensions of project expectations and the qualities of various procurement methods.

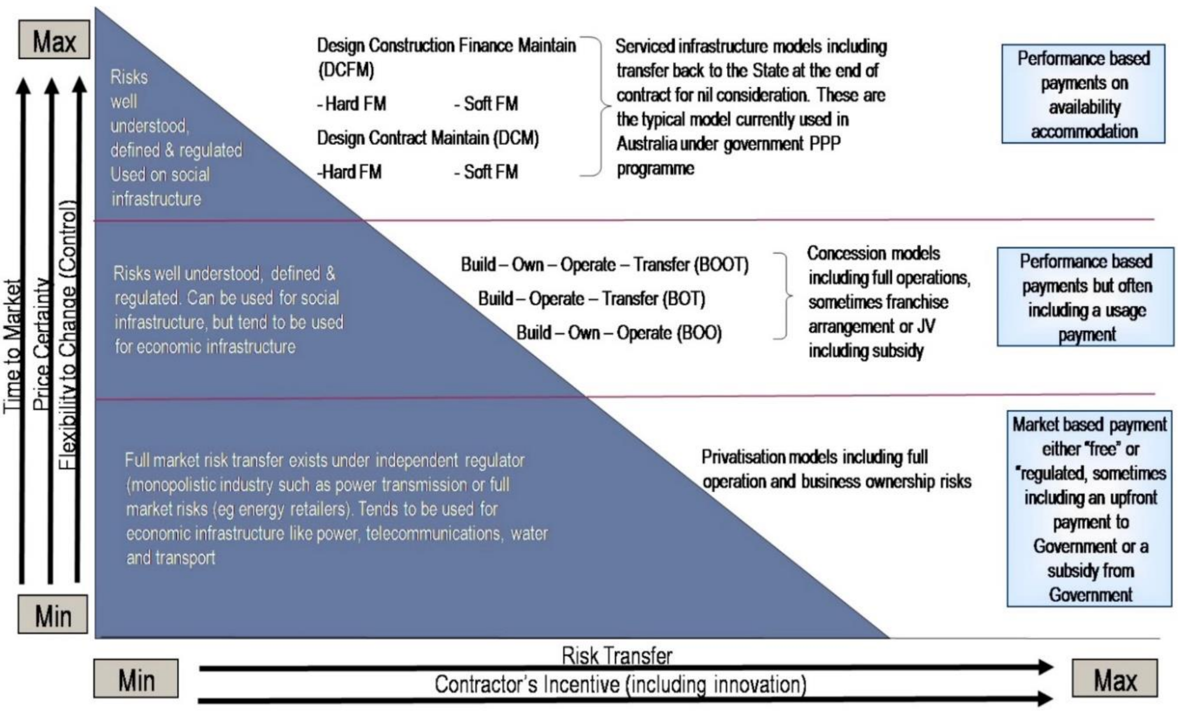


Figure 2: Triangle with five dimensions on project attributes (Grimsey and Lewis 2004)

Selecting a procurement route: Richard Foster

The Foster approach closely aligns to the one set by Partnerships Victoria, Australia for infrastructure procurement, the method looks to further investing the business case if a project is being proposed as a Public-Private Partnership. This is important to further investigate as the PPP route creating a business plan and market appetite if private sector project financing is a viable route. The full procedure aims to identify value for money and a clear business case for the client (not for the contractor but for the client which in the PPP model is a public organisation or entity such as hospital for instance).

Learning & Teaching procurement: reflections

The process of teaching procurement methods should always start by a thorough understanding of project attributes which could escalate into high risk such as price, design/construction quality, time, resources (material, labour and equipment), coordinating subcontractors (or trade contractors) amongst other. This first approach of basic methods leads towards more modern methods, using collaborative methods of sharing risks for construction (alliancing), and using external partners to finance the project (BOT) and to finance and operate (BOOT, PPP, PFI) which usually include the traditional methods as sub-procurement. In addition, looking at procurement methods internationally, language and cultural issues need to be better understood.

If reflecting on regional and national differences, this paper discusses on the need for procurement courses to cater for such contextual differences. Harmonisation on standards across European member states helps and comparison with Australia is important when teaching international students. In the case of Asia ISO standards apply. Procurement methods or process to deliver projects have different names in different countries. As an example, in Portugal the term Procurement does not have a direct translation, the different methods of contracting are identified by "code of contracts" or "work contracts" used in Portuguese legislation and standards forms of contracts. An example is a typical construction management system that in Europe is the designation for the management method where the client takes on the contractual role and construction or project manager provides the active role of managing the separate trade contractors. In comparison the UK and Australia, the label (name) of some procurement methods differ however the methods remains the same for example Private Finance Initiative versus Public-Private Partnership. Other examples on label changes across jurisdictions are two management methods: Construction Management and Management contracting in Europe (UE) and UK Construction Management methods means that the client contract the trades (thus liable). In Australian the same name alludes to the main contractor subcontracting all trades (see table 6). Also, in Australia is common to use the terminology such as design and construct or design and build, with or without novation of the design consultant, which is not the case in other jurisdictions.

Table 6: Comparative table on construction management roles and methods from client perspective.

Names of procurement delivery methods in UE versus Australian for Management Methods:		
Management Methods	UE (EC-LLC, 2012)	Australia (Australian Standards)*
Client liable for Design consultants and Trades packages hiring a consultant to act as PCM to help on the performance	Construction Management (Consultant)	AS 4915-2002 Project Management (General conditions) *[This contract is between the client and the consultant]*
Client liable for Design consultants and Trades packages hiring a contractor to act as PCM to help on the performance	Construction Management (Contractors)	Could amend a variety of AS contracts depending on whether the individual contractor is doing design work *[These contracts are between the client and the contractors]*
Client liable for Design consultants and hire a contractor to act as a PCM and to be liable for Trades packages	Management contracting	AS 4916-2002 Construction Management (General conditions) *[This contract is between the client and the consultant]*
Client hires a consultant to act as PCM to be liable for Design consultant and Subcontractors' work	Design and Manage (Consultant)	AS 4904-2009 Consultants agreement (Design and Construct) *[This contract is between the client and the consultant]*
Client hires a contractor to act as PCM to be liable for - Design consultant and - Subcontractors' work	Design and Manage (Contractors)	Could amend a variety of AS contracts depending on whether the individual contractor is doing design work

* Note: The Australian Standard contracts do not necessarily correspond perfectly to the UE delivery methodology; they will typically require scrutiny and amendment.

Reflections on learning and teaching: Southeast Asia and Australia. All course offerings are part of the same Honours Bachelor of Science in Construction Management under the following course subjects: Advanced Construction Management, Construction Planning and Design 3 and Construction Specialisation. The approach is by preparing an Expression of Interest (EOI) report for an infrastructure project often on the area of health such as a hospital or transportation such as a train or metro line including stations. At the early project stages students need to develop a procurement plan in which they look at an overall value for money (VfM) proposition such as sub-packaging projects. For example, when taking a project such as the North-West Rail Link in Sydney, they had to identify aspects of the project, which could be delivered under Traditional, Alliancing, Design, and Build or Public-Private Partnership (PPP) contract types, then they had to develop a full EOI for the project proposal including all procurement project packages. Client organisations (or industry presenters) representing the Government provide the project brief. The difference between Australian and Asian offerings is the contextual and cultural difference. All case projects tend to be located in Australia however Asian teams often creating more diverse and interesting international industry consortium as they set up their Joint Venture (JVs) or Special Purpose Vehicles (SPVs), also the outlook for schematic/conceptual designs tends to be more creative and well represented by the Asian students (in particular Singaporean students who often develop sophisticated 3D visualisations in BIM platforms).

Student feedback and experience over the years indicates that the value on delivering a class in this mode relies on industry engagement and proximity with real (professional) life scenarios including call for expressions of interest (EOIs) made for real by Government departments of health or transport. Also, attendance by key industry players as guest speakers and tutorials delivered in workshop style with activities like those from practice (often attended by industry as well). A final aspect of real-life experience includes end of semester presentations to an industry panel (which sets questions, examines and provides feedback at the end of semester). In this way, industry engagement works both ways.

Applying lessons and future directions

Both co-authors are looking to further engage on the delivery of their courses, not only engaging with industry but collaborating across universities and disciplines. As next step, the authors are looking to work across countries and institutions offering thus shared experiences and lessons from various contextual and cultural background across European, Asian and Australian experiences. This somehow is seen as a virtual study tour in which, for instance, Singaporean students are briefed by Melbourne students acting as client organisation for a project development in Australia and vis-a-versa, Melbourne students briefed by Singaporean students acting as client organisation for a project development in South-east Asia. Technical and strategic thinking develops as students are immersed in different cultural, economic and legal context, not just across countries and programs but also disciplines forcing them to collaborate and ultimately learn. This Learning & Teaching mode and model has also attracted industry interest to be applied/delivered inside client and construction organisations as part of their Continued Professional Development (CPD). Finally, both co-authors are in the process of preparing research grant applications to further academic and industry domain knowledge on procurement.

References

Alhazmi, T and McCaffer, R. (2000) Project Procurement System Selection Mode. Journal of Construction Engineering & Management, 126(3), 176-84.

Aranda-Mena, G. (2016) 'Four value propositions for architecture education', in Proceedings of the 50th International Conference of the Architectural Science Association 2016, Adelaide, Australia

Aranda-Mena, G., D'Amico, V. and Vines, M. (2013) Innovative ways for learning and teaching PPPs', in Proceedings of the 2013 International Conference on Public Private Partnership. UK.

AS 4904 (2009). Consultants agreement – Design and Construct. Australian Standards

AS 4915 (2002) Project Management – General conditions. Australian Standards
AS 4916 (2002) Construction Management – General conditions. Australian Standards
AS 4917 (2003) Construction Management trade contract – General conditions. Australian Standards
Bugrov, O. & Bugrova, O. (2018). Formalization of selection of contract-organizational project delivery strategy. Eastern-European Journal of Enterprise Technologies, 6, 28-40.
Cheung, S, Lam, T, Leung, M and Wan, Y. (2001). An analytical hierarchy process-based procurement selection method. Construction Management and Economics, 19(4), 427-37. doi:10.1080/01446190130013240l
CIOB (2010). A Report Exploring Procurement in The Construction Industry. The Chartered Institute of Building.
EC-LLC (2012) Manual "procurement strategy in construction". Leonardo da Vinci ToI Train-To-Cap. European Commission under the Lifelong Learning Programme. Project no. 2010-1-PL1-LEO05-11469
Fellows, R.F. and Langford, D.A. (1980). Decision theory and tendering. Building Technology and Management October 36-9.
Foster, R. (2014) Mechanisms to Promote Good Design Outcomes in Social Infrastructure Public-Private Partnerships In Giorgino, Aranda-Mena and Monda: Innovation in Public Finance Conference Book of Proceedings. PoliFinance Publishing Ltd. 2014 ISBN: 978-1-910069-003
Franks, J. (1990), Building Procurement Systems – A Guide to Building Project Management. Chartered Institute of Building, Ascot, UK.
Grimsey, D. and Lewis, M (2014) What is a PPP, and what is not. In Giorgino, Aranda-Mena and Monda: Innovation in Public Finance Conference Book of Proceedings. PoliFinance Publishing Ltd. 2014 ISBN: 978-1-910069-003
Grimsey, D. and M. Lewis (2004), Public Private Partnerships: The Worldwide Revolution in Infrastructure Provision and Project Finance, Edward Elgar, Cheltenham.
Kumaraswamy, M. M and Dissanayaka, S. M. (1998). Linking procurement systems to project priorities. Building Research & Information, 26(4), 223-38. doi:10.1080/096132198369832
Lewis, J A, Odeyinka, H and Eadie, R (2011) Innovative construction procurement selection through an artificial intelligence approach. In: Egbu, C. and Lou, E.C.W. (Eds.) Procs 27th Annual ARCOM Conference, 5-7 September 2011, Bristol, UK.
Masterman, J. & Gameson, R. (1994). Client characteristics and needs in relation to their selection of building procurement systems. East meets West, 221-228. CIB REPORT, 79-79
McCann, S., Aranda-Mena, G. and Edwards, P. (2014) 'Delivering value-for-money in the operating phase of public private partnerships: interview findings', in International Public Management Review, International Public Management Network (IPMN), Gallen, Switzerland, vol. 15, no. 2, pp. 91-110 ISSN: 1662-1387
Morledge, Roy, and Adrian Smith (2013). Building Procurement. Second edition. John Wiley & Sons, Incorporated, 2013. ProQuest Ebook Central, docID=1120899.
Naoum, S. G., & Egbu, C. (2016) Modern selection criterion for procurement methods in construction: A state-of-the-art literature review and a survey. International Journal of Managing Projects in Business, 9(2), 309-336.
NEDO (1985). Thinking about Building. National Economic Development Office, HMSO, London.
Ng, T., Luu, D. & Chen, S. (2012). Decision Criterion and Their Subjectivity in Construction Procurement Selection. Construction Economics and Building, 2, 70-80
RIBA (2018), Fourth NBS National Construction Contracts and Law survey report, Royal Institute of British Architects. RIBA Enterprises, UK https://app.lms.unimelb.edu.au/bbcswebdav/pid-7568646-dt-content-rid-63681917_2/courses/ABPL90327_2019_SM2/nbs-national-construction-contracts-and-law-report-2018.pdf
Skitmore, M. & Marsden, D. (1988) Which procurement system? Towards a universal procurement selection technique. Construction Management and Economics, 6(1), pp. 71-89.
Sweeny, S. (2009) Addressing Market Failure: Using Transaction Cost Economics to Improve the Construction Industry's Performance. PhD Thesis. University of Melbourne
Turner, E. A. (1990) Building Procurement. Macmillan Education LTD. London. UK. ISBN 0-333-52286-9

EXPLORING THE LEVELS OF COMPLIANCE TO UNIVERSAL ACCESS PARAMETERS AT SOUTH AFRICAN HIGHER EDUCATIONAL INSTITUTIONS: EXPERIENCES AT DOORNFONTEIN CAMPUS OF THE UNIVERSITY OF JOHANNESBURG

Nischolan Pillay[1], Trynos Gumbo[2]

[1] Town and Regional Planning/ Engineering and the Built Environment,University of Johannesburg, Johannesburg, South Africa

[2] Town and Regional Planning/ Engineering and the Built Environment,University of Johannesburg, Johannesburg, South Africa

Abstract

Universal access to public buildings is a basic human right that everyone must enjoy regardless of age, nature of ability and many other parameters. South African national universities are part of public institutions that are regulated by national standards that set out rules and regulations for access by all citizens and the institutions' staff members, students and visitors. The University of Johannesburg inclusive have been making several concerted efforts to improve the accessibility of their buildings over several decades. What remains to be known however is the successes that have been made in ensuring that their buildings are accessible to their students and other stakeholders. This work therefore investigates the level of compliance by the Doornfontein Campus of the University of Johannesburg to universal access system parameters. The work adopted the case study research design and applied the qualitative research approach where semi-structured interviews were conducted to gather rich data that was used to develop themes that explain the state of compliance to universal access. Research findings reveal that the Doornfontein campus is partially compliant to the national standards, rules and regulations of universal access. A lot still needs to be done to administrative and security buildings and others.

Keywords

Universal Access, Compliance, Educational Institutions, Disability, Inclusive Design, Parameters

Introduction

In 1994 South Africa gained its democratic independence from the apartheid government, giving all people of South Africa freedom as detailed in the Bill of Rights. This important milestone finally gave the people of the country the privilege to attain their goals and aspirations in whatever form it appropriated, albeit within the law of the land. The constitution implemented non-discrimination of any person within the republic regardless of race, colour, creed, gender, class, caste, sexual orientation, disability or any other form of inequity (South Africa, 1996). It was imperative that discrimination in all forms be abolished from all aspects of South African life, consequently it is important to note the spatial injustices of the past. Spatial Injustice can occur at several different levels, from macro to micro planning. For the purposes of this research, Micro Spatial Injustice or Architectural Discrimination will be observed through the lens of Universal Design of Infrastructure in higher learning institutions. Public institutions must provide the adequate accessibility for all users to be truly spatially just and non-discriminatory. This paper explores the Levels of Compliance to Universal Access Parameters at South African Higher Educational Institutions, case in point: The University of Johannesburg's Doornfontein Campus. This research will begin with a review of literature from national and international authors to provide a reference to universal design in higher educational institutions. The study will then introduce the various approaches and research design that was facilitated to gather results, to conclude a discussion will be formed around the research findings with reference to the literature review.

Literature Review

This literature review takes a critical approach to investigate the spatial justice and architectural discrimination in terms of International and National Standards with reference to access for people with disabilities. The review will looks at accessibility to space at a micro planning (Building) level to critique existing policies and implementations in terms of space access for persons with disabilities as experienced globally and expressed in various literature sources.

Spatial Justice

The term Spatial Justice is the formation of two words: *Spatial* being a space-based concept or referring to geographically defined region and *Justice*, which is strongly based in the laws as being a theory by which fairness, is administered. According to Soja (2009,p.1) the term Spatial Justice is often shied away as a specific occurrence and social justice is used to explain the phenomenon of spatial (in)justice in a geographic location, however he believes that the term spatial justice comes with a specific dispensation of relating directly to the spatial agenda. Alternatively Marcuse (2009, p.3) states that spatial justice is a derivative of social justice, in a physical location, making it a sub agenda of social justice. It can be argued that spatial justice occurs socially first rather than in a location, it is society that forms the injustices before space can be placed into the phenomenon of spatial justice. The two authors' views towards Spatial Justice, confirm that the concept of space is introduced into the broader discussion of social justice making it relevant in discussions of future planning strategies, however the question remains topical, how can space be unjust? Spatial justice theories reveal the truths of past planning practices in the sense of equality; According to Soja (2009, p.2):

"*Spatial (in)justice refers to an intentional and focused emphasis on the spatial or geographical aspects of justice and injustice. As a starting point, this involves the fair and equitable distribution in space of socially valued resources and the opportunities to use them."*

It is evident from Soja's framework that spatial justice is inextricably linked to space and geographies making it crucially important to understand that spatial justice is topical and cannot be discussed with the exclusion of space. It may seem that space has a major bearing on spatial justice, but what forms the injustices of space? Marcuse, (2009) proposes that spatial (in)justice is causal in nature and it cannot be delinked from social justice which is the leading factor in spatial (in)justice, he goes on to state:

"*Spatial remedies are a necessary part of eliminating spatial injustices, but by themselves insufficient; much broader changes in relations of power and allocation of resources and opportunities must be addressed if the social injustices of which spatial injustices are a part are to be redressed."*

Marcuse believes spatial (in)justice lies solely and is a derivative of social injustice. It remains clear that Marcuse's framework revolves around a derivative principle. Marcuse and Soja both have critical frameworks around spatial justice, consequently both authors have similar opinions on unfair distribution of resources and segregation. With both the authors views a general idea of spatial justice is formed, however how can spatial justice be applied to a micro-space (Buildings)? The next section will investigate Architectural Discrimination in buildings with reference to the frameworks of universal design.

Architectural Discrimination

South Africa has a rich history that is painful to some in the form of social and spatial segregation. The Constitution of South Africa sought to right the wrongs of the past by giving all the people of the land a free and fair society that they can participate in (South Africa, 1996). In this sentiment, focus is brought mainly to cities, towns, urban areas etc. According to Schindler (2015,p.1934,1942) architecture serves as a function of regulation, potentially allowing it to dictate the use or exclusion of certain people. However Nicol et al (2000, p.36) states that architects themselves often design buildings in their experiences and refute the experience of others. Following on from Spatial Justice, architectural discrimination is similar in nature, proving that both spatial and social issues are inherent in theory. It is incumbent that buildings provide equal access and use to everyone.

Universal Design

Approximately 15% of the world's population has some form of disability and around 2-4% suffer from debilitating disabilities (WHO, 2011, p.27). In South Africa, the statistics are lower, however the number of people with disabilities is a staggering 7.5% of the population (Lehohla, 2011, p.25). According to Goldsmith (1967, p.vii) the term "*disable"* can take on many forms for e.g. the medically disabled as deduced by a physician viz. physical or cognitive or the uncommon terms of economic disability, social disability and the more common; architectural disability. Mace et al. (1985, p.4) defines *"disable"* as "*any physical or mental impairment that substantially limits one or more of the major life activities of an individual, a record of such an impairment, or being regarded as having such an impairment".* Similarly, The South African Human Rights Commission (SAHRC 2017, p.6) states that disability is an evolving concept and includes but not limited to people with long term physical, mental, intellectual and sensory disabilities, of which when encountered with physical barriers hampers their ability to participate in society on an equal basis. According to Nugent (1961, p.51) one of the biggest problems facing physically disabled people are public buildings and facilities that prohibit the full use of the facility. Nugent (1961, p.51) further goes on to state that due to architectural barriers, limited access, use and social engagement occurs preventing the physically disabled from reaching their aspirations, exercising their skills and developing their talents. As radical as it seemed in the early days of barrier free design, it was the beginning of a new movement viz. *"universal design".* In the early 70's architects started to become more involved in the movement of universal design, rather than barrier free design. Ronald Mace, an architect who was disabled, coined the term *"Universal Design"*, Mace et al (1985, pp.4-6) conceptualizes universal design as a diverse arena that is not limited to people with physical disabilities, but people with all types of disabilities and the caregivers, family and others directly associated with PWD's. Similarly the Architect Michael Bednar stated that the functional capacity of humans is enhanced when barriers are removed and theorised a more broader outlook beyond accessibility be implemented, something that was more "universal" in its approach (Bednar, cited in IHCD, 2016). Universal design is distinguished as being a holistic approach to the design of environments that caters for everyone, not only the disabled. In 1997 The Centre for Universal Design (1997) advocated seven principles of Universal Design as a guide for implementation in Buildings, Product Designs, Environmental Designs etc. These guidelines have been implemented all over the world (Mcguire, Scott, Shaw, 2006, p.167, IHCD, 2016). The following principles were promulgated by the Centre for Universal Design (1997):

Table 1: Principles of Universal Design

Principle	Title	Description
One	Equitable Use	The design is useful and marketable to people with diverse abilities.
Two	Flexibility in Use	The design accommodates a wide range of individual preferences and abilities.
Three	Simple and Intuitive Use	Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.
Four	Perceptible Information	The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.
Five	Tolerance for Error	The design minimizes hazards and the adverse consequences of accidental or unintended actions.
Six	Low Physical Effort	The design can be used efficiently and comfortably and with a minimum of fatigue.
Seven	Size and Space for Approach and Use	Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.

Source : Centre for Universal Design (1997), Modified

The Principles of Universal Design for the first time, created a holistic approach to human centred design rather than dealing specifically with physical disability. The seven principles are an easy to follow guide that relates directly to all spheres of the environment and products humans find themselves interacting with. According to Story (1998, p.7) the principles of universal design can be used to guide design decisions, to make an evaluation of new and existing designs and to teach students and practitioners the concepts of universal design and how to achieve the level of full compliance. Furthermore Mace et al (1985, p.1) state that the intention of universal design principles is to design all buildings, products and exterior spaces to be used by everyone to the greatest extent. The authors believe that the conceptualization of a universal design framework is paramount to the successes of a building, product or environment.

Universal Access Parameters in Buildings

With the need to think more universally, many regulations and by-laws were introduced the world over to implement the principles of universal design in the various professions. These parameters make it somewhat easier to implement the universal principles of design.

Signage

The ability to manoeuvre oneself in a complex public building lies greatly in the reading of signage. According to McGuire et al (2006, p.168) signage can assist people who cannot read and is helpful for non-English speaking users. From McGuire et al, it can be understood that signage is a universal language that must be understood by everyone, including crossing the language barrier. Furthermore Passini (1996, p.319) insinuates unintelligible signage can be rather unpleasant to users and changes their attitudes to the setting, also the setting can never be truly appreciated in a spatial sense if it is hard to manoeuvre due to lack of signage. It becomes distinct that signage must be clear, concise and speak to everyone, therefore it must be universal in its design. According to the SANS 10400 (2011, p.9) facilities in a public building that are specifically designated for people with disabilities must be clearly indicated by means for the international symbol for access. The regulations set out in the SANS 10400, Part S are similar to those set out both in the Hong Kong, Australian and British Standards (Hong Kong Government, 2008, pp.73-77,Australian Government, 2010, Braile and Tactile sign specification section, para 2). It can be argued that all the regulations set out the basic requirement, however some are more detailed than others.

Parking for the Disabled

Parking for the disabled has become very important in all countries who serve to provide equal rights to all members of the public. The SANS 10400, Part S, Section 4.3-Parking portrays the deemed to satisfy rules for the implementation of disable parking in buildings. According to SANS 10400 (2011, p.10) in a building where people are employed, at least one parking bay must be for PWD's, the regulations go further to state the direct relationship between parking bays and building sizes. The regulations also make mention of parking sizes, a disabled parking bay must have a minimum depth of 4500mm and a minimum width of 3500mm. Similarly, International regulation promulgates the same regulations with slight variation, but in essence the same minimum standards (Hong Kong Building Department, 2008, pp17-27, HM Government, 2015, p.19, Australian Government, 2010, Accessible carparking section, para 1).

Circulation in and around buildings

An important aspect of universal design includes the design of circulation in and around buildings, so much so that the SANS 10400, Part S has a special section for it viz. Section 4.4 External and internal circulation. According to the SANS 10400 (2011, p.11) all circulation routes must be design to be wide enough to allow for a self-propelled wheel chair. Furthermore, the SANS 10400 also gives a detailed list of regulations for clear access which will be discussed further in the empirical findings. The regulations for circulation and access in buildings is similar to regulations adopted in Hong Kong, England and Australia (Hong Kong Government, 2008, pp 22-27, HM Government, 2015, pp.16-19, Australian Government, 2010, Access to buildings section, para 1).

Doors and Door Furniture:

Doors form one of the biggest barriers for PWD's, however it is possible to create accessible spaces with doors that cater for all. The SANS 10400, Part S dedicates section 4.6 to doors and door furniture. The SANS 10400 (2011, p.14) states the minimum dimensions required for doors and doorways. Notwithstanding the minimum dimensions for doors, the SANS 10400 takes the regulation further by implementing rules for circulation that incorporate barrier free design and the use of doors for PWD's (2011, p.15). The SANS 10400, Part S has similar standards to those of International countries, it can be affirmed that the regulations are universal (Hong Kong Government, 2008, pp.55-60, HM Government, 2015, pp.24-35, Australian Government, 2010, Access to buildings section, para 4). One of the more overlooked design elements in universal design spectrum is door furniture (Ironmongery), the SANS 10400, Part S, section 4.6.2 makes specific mention of door handles. The regulations state the minimum dimensions, tactility and types of handles suitable for PWD's.

Vertical Travel:

One of the most important regulations in the SANS 10400, Part S is change in levels and ramps. PWD's like everyone else should be afforded the opportunity to use any building to its maximum extent. The SANS 10400, Part S implements various regulations in vertical movement. The first instance of change in level is the minimal changes in horizontal surfaces, this includes the threshold from outside to inside as stated in section 4.7 of the SANS 10400, Part S (SABS, 2011). The regulations further state the parameters for ramps in buildings in section 4.8. The use of ramps is not a necessity, however it does make vertical travel easier for all users (SABS, 2011). The international standards of Hong Kong, England and Australia have similar conditions for the use of ramps (Hong Kong Government, 2008, pp.27-31; Australian Government, 2010, Ramps section, para 1; HM Government, 2015, p.37). Vertical access in relation to universal design in buildings are not limited to ramps, the regulations include the use of elevators and stairs. Part S, section 4.9 deals specifically with universal principles for the design of stairs to allow for all users to be comfortable in transit on a stair, the regulation also includes the principles for the design of handrails for use in stairwells and ramps (SABS, 2011, p. 19).

Toilet Facilities for PWD's
For a person with a disability, a normal toilet setting does not allow for the anthropometric, full usage of the facility. The SANS 10400. Part S, section 4.12 makes specific provision for the implementation of toilets for PWD's. According to the regulations, where the Part S may be applied, the first wheelchair accessible toilet must be unisex in nature and provide access to abled and disabled users, the regulations further go on in detail proving more regulations around the design and implementation of wheel chair accessible toilets (SABS, 2011).

Auditoriums
According to the SANS 10400, Part S (2011, p. 23) auditoriums must make provision for PWD's that use a wheel chair, furthermore the regulations promulgate other important regulations to be applied when designing auditoriums for universal purposes. The Hong Kong regulations for universal design state similar regulations regarding the design of auditoriums, (Hong Kong Government, 2008, pp.11-15), however no mention is made in the other guidelines of universal access to auditoriums. The SANS 10400, Part S is very comprehensive in terms of the application of universal design principles. It is important that the deemed to satisfy rules are implanted in all buildings not only to allow for the disabled but to allow easy access for everyone.

Research Methodology

This paper is multidisciplinary as it involves the study of spatial designs as well as the experiences of the students with disabilities at the Doornfontein campus of the University of Johannesburg. The first focus is more design oriented an aspect that falls within the architecture discipline whilst the second aspect is more social related as it focuses on life experiences of students within the campus. Due to the multidisciplinary nature of the research; the work adopted a case study research design where spatial and qualitative research approaches were applied. An inspection of the facilities and building designs were investigated to determine their level compliance to universal access system parameters. In addition, semi-structured interviews were conducted to gather rich data from research participants, particularly students with disabilities as well as personnel working in the operations department that is tasked with the responsibility to plan, development, manage and make necessary recommendations for alterations and adjustments of buildings and facilities to accommodate all the stakeholders of the university regardless of their state of ability or disability. The work used mostly content analysis to gather information from the gathered data. The responses were gleaned to derive meaning from the responses, which were used to develop categories, and then key themes that emerged from the study. The themes were used to reveal the nature of experiences of students with disabilities within the campus and determine the level of compliance of the campus to universal access and use system parameters. Initially, extensive literature was reviewed to highlight the state of research on universal access and use system parameters and developments as well the current concerns and gaps that still need to be filled within this area of study.

Research Analysis & Results

Research findings reveal that the Doornfontein campus is partially compliant to the national standards, rules and regulations of universal access. Although efforts have been made in the last few years to improve access by people with disabilities to some buildings and facilities other spaces of importance are still not accessible and therefore cannot be used by students with disabilities. It was also observed that compliance to access is not enough, as universal access does not end at access between two spaces or levels.

Spatial Justice and Architectural discrimination
The work reveals that spatial justice and architectural inclusion are reasonably observed and fulfilled within the Doornfontein campus of the University of Johannesburg. However, several places are spatially presented and provided in such a way that students with disabilities cannot access them. The same applies to the architectural presentation of some buildings and spaces, which discriminate some students with disabilities for example, the physically disabled students. The spatial injustice and architectural discrimination and concerns play out at the campus exactly the way they are highlighted by both Soja (2009) and Schindler (2015). There is therefore need to ensure that spatial planning and layouts within campuses respond to the needs of people with disabilities. The personnel of the university that were interviewed indicated that several have been made to improve the accessibility of the campus in the past decade since them incorporation of the former Witwatersrand Technikon campus within the University of Johannesburg. More programmes have been lined up to improve the accessibility and use of the campus by the people with disabilities and these will be achieved conscious and responsible spatial planning and architectural inclusion.

Universal Design
The research work completed at the University of Johannesburg's Doornfontein Campus included the Administration Block and Library and reveal that the buildings are partially compliant to the universal principles. The following table gives an indication of the compliance levels to the universal principles:

Table 2: Levels of Compliance-Administration and Library Complex in respect of Universal design.

Principles	**Administration Block Compliance level**	**Library Block Compliance level**
Principle 1: *Equitable Use*	40%	100%
Principle 2: *Flexibility in Use*	40%	80%
Principle 3: *Simple and Intuitive use*	60%	90%
Principle 4: *Perceptible Information*	60%	90%
Principle 5: *Tolerance for Error*	40%	100%
Principle 6: *Low Physical Effort*	70%	90%
Principle 7: *Size and Space for Approach and Use*	80%	90%
Overall Compliance	**55.71%**	**91.4%**

Source: Authors

The above table summarizes the results from investigative study of the two buildings applying the universal design principles. The results show that the administration block has many challenges when the universal design principles were applied. The building has issues of access and travel between floors, furthermore the rigid design does not allow for flexible space. The administration block is not well sign posted and way finding becomes an issue. The building in some cases requires high level of physical effort especially were floor finishes change level and access doors that open inward in the direction of travel making it difficult to access. The administration building is rated at 55.71%, proving that it still has challenges that must be resolved to allow PWD's to use the space well.

The library complex however complies at a high level. Access to the facility is well designed and easily identifiable. The spaces are flexible and allow for freedom of movement and change. The library complex is well signposted and is intuitive for users. In terms of low physical effort and tolerance for error, the building performs well and is easily usable in terms of physical effort. The overall level of compliance is 91.4%, proving it is well designed and applies the universal principles well.

Universal Access Parameters in Buildings

The initial research study focused on investigating the administration and library in terms of its compliance with the SANS 10400, Part S regulations. The following table gives an indication of the compliance with regards to the national regulations:

Table 3: Levels of Compliances- Admin Block and Library Complex in terms of SANS 10400, Part S

Regulation	Administration Block Compliance level	Library Block Compliance level
Signage	60%	100%
Parking for the Disabled	100%	100%
Circulation	70%	80%
Doors and Door Furniture	50%	80%
Vertical Travel	60%	100%
Toilet Facilities	100%	100%
Auditoriums	N/A	100%
Overall Compliance	**73.3%**	**94.2%**

Source: Author

The administration block is partially compliant with the regulations. The building includes some aspects of signage but is not well posted, effort must be made to add in additional signage. Parking for PWD's is fully compliant and two parking bays are provided. The circulation in the building works to some extent and passage ways are wide enough to allow for wheelchair access, furthermore it was noticed that all doors are the minimum dimension of 750mm although the door handles are not fully compliant and include sharp edge and are vertical in nature making it more difficult to get a firm grip. In terms of vertical travel, the building complies with the minimum requirements, however provision must be made in the building for vertical travel when the lift is not in operation. The toilet facilities that the building incorporates are 100% compliant in terms of the regulations. The overall rating of the building in terms of compliance is rated at 73.3%, recommendation is made to the university officials to update the building in terms of the SANS 10400. Part S. The library complex is highly compliant with the regulations, Signage is well posted and easy to read. The library also incorporates two disabled parking bays making it 100% compliant. The circulation in the building works well, however in some areas some barriers exist but are completely movable. Doors and door furniture comply however some doors are not the minimum dimension of 750mm and some door handles are of the vertical format making it hard to grip and open a door. Vertical travel, toilet facilities and auditoriums are 100% compliant and meet the minimum requirements of the SANS 10400. The library complex is rated at 94.2% and will require minimal changes for a full 100% compliance.

Experiences of Students with Disabilities

The students that were interviewed indicated that they have different experiences of the campus depending on the buildings and spaces they intend to access and use. Generally, there was satisfaction with the access of most of the lecture rooms within the bigger buildings of the campus that are John Orr Building and the Perskor. However, it was revealed that sometimes it is easy to access the building but not all the rooms within the buildings or in some instances not all the facilities within the room. A case in point are lecture rooms that are have seats that are vertical raked and slanting. It becomes difficult either to access the top seats or to participate in classes whenever the lecturers request students to come down and demonstrate on the boards. Concerns were raised about the newly acquired building that is currently being used a test venue by the university and lecturers that has no ramps and functional lifts, making it difficult for students with disabilities to access and use the venues. The situations inconvenience not only the students but also the lecturers who have no luxuries of choosing tests venues due to shortages of spaces within the campus. The students also highlighted that besides unfriendly lecture rooms that they use on a daily basis they also face difficulties with some of the toilets that do not have provisions for students with disabilities creating serious inconveniences to the students as they struggle to help themselves when nature calls. Serious concerns were raised about the administrative and security buildings as well as others that provide essential services on day to day to students. These buildings have no ramps and the lifts where they are provided, are either not reliable functionally such that they can be used at the student's risk or always broken such that they cannot be used at all hence it leaves the students with disabilities stranded as they fail to access the essential services. Although parking at Doornfontein campus is a problem for all stakeholders, it becomes a nightmare for students with disabilities, as there are very few appropriate slots, if any in most spaces.

Research Contribution

This work provides the much-needed up to date information on the level of compliance to universal access system parameters by universities in South Africa, of course using the Doornfontein campus as the case of study. Although the results may not reveal what is currently obtaining in all the campus, the work assists in highlighting some of the current designs that are still common in our universities today and therefore points to the actions that are needed by the universities and the government at large. The paper also highlights the experiences by students with disabilities and other stakeholders as they navigate campuses of South African universities. Although the experiences may not be the same in all campuses within South Africa, the highlights assist in sending the correct messages to universities managers and as a result push them to take action and check the state of their infrastructure and give audience to people with disabilities who access and use their campuses.

Research Limitations

The researchers obtained consent from the students with disabilities before they could provide responses to questions. However, the campus has very few students who have disabilities that could be interviewed and be requested to share their experiences as they use the campus. The multi –campus system meant that senior management staff that are responsible with affairs at campuses are mobile and, in most cases, have tight schedules thus making it difficult to meet them to exhaust the research.

Discussion & Concluding Remarks

This study has demonstrated that the Doornfontein campus of the University of Johannesburg is relatively accessible to people with disabilities, particularly students that are enrolled and studying towards the various diplomas and degrees that are offered by university. What is commendable is the provision and proper maintenance of ramps and lifts for use by students with disabilities to access lecture rooms, the library and rooms of convenience. However, not all buildings and rooms are accessible to students with disabilities for example the administration building that has all the facilities and services such as registration and queries, finance other necessary facilities is not readily accessible, as there are no ramps and the lift that service the building is too small and not reliable as it experiences constant breakdowns. There is need for great efforts to ensure that clients of the university, particularly students with disabilities are able to access and use the facilities. Sometimes access is provided and therefore possible but some students with disabilities may not use some facilities after accessing them. A case in point is the structure and set up in some lecture venues that are raked. This makes sitting by people with disabilities very difficult thus affecting concentration during lectures. The paper concludes by recommending that since universal access is a more intimate nature of ergonomic and anthropometrical design of spaces in which everyone can use the space in a wide range of situations; there is consequently a need to ensure access of everyone, particularly people with disabilities hence this needs to be addressed to allow for equality in accessibility. This will facilitate the full functionality of the university's campuses in line with the principles of universal design.

South Africa has implemented regulations to ensure that every citizen is able to access buildings with ease. According to The South African National Standards for Buildings (SANS 10400), Part S; Facilities for Persons with Disabilities: all buildings must be accessible at a macro and micro level, i.e. access must be provided to enter the site without obstruction and access must be provided to enter and manoeuvre within all spaces with the right to gain entry and use all spaces. Following on from the compliance set out in the SANS 10400, Part S it is crucial to note that not all public buildings comply with the regulations. It is however, evident that older public buildings are now being retrofitted to comply with the regulations set out in the SANS 10400, Part S. It is incumbent that public buildings serve every user, this has become particularly evident at higher learning institutions where students with physical disabilities are enrolled to study. Although efforts have been made in the last few years to improve access by people with disabilities particularly to its lecture venues, library; very little has been done to the administrative and security buildings as well as others that provide essential services on day to day to students. It was also observed that compliance to access is not enough, as universal access does not end at access between two spaces or levels. Efforts need to be made to ensure that clients of the university are able to use the facilities after accessing them. A case in point is the structure and set up in some lecture venues that are raked. This makes sitting by people with disabilities very difficult thus affecting concentration during lectures. The paper concludes by recommending that since universal access is a more intimate nature of ergonomic and anthropometrical design of spaces in which everyone can use the space in a wide range of situations; there is consequently a need to ensure access of everyone, particularly people with disabilities hence this needs to be addressed to allow for equality in accessibility. This will facilitate the full functionality of the university's campuses in line with the principles of universal design.

References

Australian Government (2010) *Disability (Access to Premises-Buildings) Standards 2010*. Australia: Disability Discrimination Act 1992.

Centre for Universal Design (1997) *The Principles of Universal Design, Raleigh: North Carolina State University, Center for Universal Design.* Available at: https://projects.ncsu.edu/design/cud/about_ud/udprinciplestext.htm (Accessed: 22 April 2018).

Chamberlain, C. (2015) *Tim Nugent a pioneer in changing life for people with disabilities | Illinois, Illinois News Bureau*. Available at: https://news.illinois.edu/view/6367/277535 (Accessed: 22 April 2018).

Goldsmith, S. (1967) *Designing for the Disabled: The New Paradigm*. London & New York: Routledge.

HM Government (2015) *Access to and use of buildings, Access to and use of Buildings*. England and Wales: The Building Regulations 2010.

Hong Kong Government (2008) *Design Manual-Barrier free access 2008*. Hong Kong: Design Manual Barrier Free Access 2008.

IHCD (2016) *History of Universal Design | Institute for Human Centered Design (IHCD), Institute for Human Centered Design*. Available at: https://humancentereddesign.org/universal-design/history-universal-design (Accessed: 22 April 2018).

IPC (2015) *Tim Nugent, US 'father of accessibility' dies age 92, Official website of the Paralympic Movement*. Available at: https://www.paralympic.org/news/tim-nugent-us-father-accessibility-dies-age-92 (Accessed: 22 April 2018).

Mace, R. L., Hardie, G. J. and Place, J. P. (1985) *Accessible Environments : Toward Universal Design*.

Marcuse, P. (2009) ‘Spatial Justice : Derivative but Causal of Social Injustice’, *Justice spatiale/Spatial justice*, (1), pp. 1–6. doi: 10.4000/books.pupo.420.
Mcguire, J Scott,S Shaw, S. (2006) ‘Universal Design and Its Applications in Educational Environments’, *Remedial and Special Education*, 27(3), pp. 166–175.
Nicol, D. and Pilling, S. (2000) *Changing Architectural Education: Towards a New Professionalism*, *Ebook*. doi: 10.1017/CBO9781107415324.004.
Nugent, T. (1961) ‘Conference of The Building Research Institute, Division of Engineering and Industrial Design, Washington D.C’, in *Design of Buildings to Permit Their Use by the Physically Handicapped.* Washington D.C: National Academy of Sciences, National Research Council, Washington D.C.
P.Lehohla (2011) *Profile of persons with disabilities in South Africa*.
Passini, R. (1996) ‘Wayfinding design: Logic, application and some thoughts on universality’, *Design Studies*, 17(3), pp. 319–331. doi: 10.1016/0142-694X(96)00001-4.
SABS (2011) *SANS 10400-S : 2011 SOUTH AFRICAN NATIONAL STANDARD The application of the National Building Regulations Part S : Facilities for People with Disabilities*. Pretoria: SABS Standards Division.
SAHRC (2017) *Research brief on disability and equality in south africa*.
Schindler, S. B. (2015) ‘Architectural Exclusion : Discrimination and Segregation through Physical Design of the Built Environment’, *The Yale Law Journal*, 1934.
Soja, E. W. (2009) ‘The city and spatial justice’, *Justice Spatiale Spatial Justice*, 1, pp. 1–5.
South Africa, J. and C. D. (1996) *Constitution of the Republic of South Africa*, *The Constitution OF THE REPUBLIC OF SOUTH AFRICA*. doi: 10.1017/S0021855300011499.
Story, M. F. (1998) ‘Maximizing Usability: The Principles of Universal Design’, *Assistive Technology*, 10(1), pp. 4–12. doi: 10.1080/10400435.1998.10131955.
WHO (World Health Organization) (2011) ‘World report on disability 2011’, *American journal of physical medicine rehabilitation Association of Academic Physiatrists*, 91, p. 549. doi: 10.1136/ip.2007.018143.

CONCEPTUAL FRAMEWORK TO ADDRESS THE EMPLOYER- CAUSED DELAY FACTORS: A CASE STUDY

Mohammad Tawfiq Barqawi[1], Heap-Yih Chong[1], Emil Jonescu[1]

[1] School of Design and Built Environment, Curtin University, Perth, Australia

Abstract

Delay in construction projects remains a challenging issue. Previous studies in construction delay have attempted to address the delay problem by proposing frameworks with different types, contents, and methodologies. However, limited studies have investigated an employer- caused delay factors, their relevant success factors and their effects in details. Hence, this paper aims to develop a conceptual framework to address the employer-caused delay factors based on in-depth literature analysis, and subsequently validate it using a case study from one of the major building projects in the Middle East. The framework articulates almost all possible construction delay caused by the employer in the previous studies. It also suggests the tools available to address and mitigate the delay, together with the software available to control of delay. Eventually, the paper provides an in-depth understanding of construction delay caused by the employer with proposed conceptual solutions in addressing the problem using available tools.

Keywords

Construction Industry, Employer-caused Delay Factors, Delay Aspects, Conceptual Framework.

Introduction

Construction delay is a significant problem facing the construction industry. Their impact level varies from project to project ranging from a few days to years. It is generally understood that the construction delay is the most critical factors affecting to deliver the project on time, within budget and expected quality. It can be found rarely that a project was completed within the specified time (Shebob, Dawood and Xu, 2012). For instance, the Sydney light rail project to the eastern suburbs has faced delay problems; the project budget is original A$ 1.6 billion which was to be completed in 2018 before the deadline was pushed back. The project's employer is defined under a Public-Private Partnership of Transport of NSW, NSW treasurer, ALTRAC light rail partnership and OpCo group. At an early stage of the project, Arcadis and APP Corporation was appointed as Independent Certifier (IC) to review and verify the design, procurement, construction, and commissioning of the light railway. ALTRAC consortium which is made of Transdev Sydney, Alstom Transport Australia, Acciona Infrastructure Australia and Capella Capital was awarded to design, build, operate and maintain the light railway project. This case of delay is forming an interesting academic point of view and that the contractor in this project seems to be struggling to complete the project. It is essential during the tender stage that the employer or the employer's representative is to review the history of delay for the shortlisted contractors before awarding the contract.

Employer-caused delay factors have not taken sufficient intention by the previous researchers. For instance, Tafazzoli and Shrestha (2017) have studied thirty (30) factors and causes of construction delay in the USA in which six (6) Employer-caused factors are only considered which are: excessive change order, delayed payment by the employer, delay in approving design documents, unnecessary interference by the employer and delay to furnish and deliver the site to the contractor.

In terms of solutions proposed for the construction delay matter, many previous studies have proposed a limited set of text recommendation. Frameworks also have been used to address the delay problem, including the employer-related factors, for instance, Chan and Kumaraswamy (1997), Pai and Bharath (2013) and Addo (2016) have provided plain text recommendations to suggest a solution for the construction delay problem such as effective data communication, recruit competent consultant, payments on time.

Belassi and Tukel (1996) has introduced a framework to study the success/failure factors in the projects at which they studied the factors relating to project manager and project team, relating to the project, relating to the organization and relating to the external environment; then, they provided a proposed system response of the success factors. Belassi and Tukel (1996) have not sufficiently addressed the success/failure factors concerning the employer. This study has suggested to collectively gather the success factors in previous studies and then conduct a pilot workshop to uncover all possible success factors caused by the employer.

In summary, this study aims to build and present a conceptual framework to address the employer-failure causes with an application of a practical case study for one of the large residential projects in the UAE to validate the outcomes.

Literature review

Construction projects have remained a critical factor in the countries' economies. The construction in many countries around the world forms a fundamental segment in the development of the economy. It became commonly known in the construction industry that projects in their different types are suffering from delay; it could be said that project with no delay became very rare. The delay of the projects is related to many different delay aspects such as social, technic and it is caused by many projects' parties with a various percentage of share. Shebob, Dawood and Xu (2012) are considering the delay is one of the biggest problems in the construction industry and it has a significant financial and social impact to all parties involved in the projects. The projects' delays have a destroyable impact on the local economy and the rate of projects' growth and developments. For instance, the new Perth Children's Hospital which was opened following nearly three years of delays has left a sizeable additional cost impact on WA State. This delay had cost the state more than $ 115 million including the compensation payments for the operator of the empty hospital car parking.

From the term of the construction delay's definition, previous studies have provided many different definitions to the construction delay but with similar general meaning. For instance, Assaf and Al-Hejji (2006) have defined it as the time overrun either beyond the contract date or beyond the date that the parties agreed upon for delivery while Rahimipour and Shahhosseini (2014) have described it as a sanction or event which prolongs the schedule of the project.

The employer-caused delay factors are not an exception of being addressed or studied partially in the previous studies. Bekr (2015) has studied the construction delay in public projects in Iraq at which 65 delay factors have been reviewed and analyzed; eight of them are mainly related to the employer which are : Delay in progress payments by the employer, breach or modification of contract by the employer, contract duration is too short, slow decision making process by the employer, changes in the scope of the project, delays in resolving contractual issues, conflict between contractor, employer and consultants and difficulties in obtaining work permits from authorities concerned. Despite Bekr (2015) have addressed the employer-related delay factors but it is still considered that factors addressed are incomplete. Similarly, Durdyev, Omarov & Ismail (2017) have addressed the employer-caused delay factors partially.

Generally, there are many previous studies for the construction delay have proposed a set of recommended measures to address the delay. For instance, Muhwezi, Acai & Otim (2014) have proposed a broad set of text recommendation such as 'changes should be assessed to evaluate the impact', 'proper planning and costing during the pre-contract phase' and 'payments on time.' Similarly, Assbeihat (2016) has also suggested a group of recommendations such as 'avoid too many changes', 'quick decision making' and 'payment timely.' It is essential to highlight that text recommendation to address the delay factors are considered insufficient from the practical point of view. A clear, detailed and accessible framework to address the delay is required to enable the site construction team to apply successfully.

In terms of constructing a practical framework to address the construction delay, Cooper (2006) has suggested a five-stage, five-gate framework for significant new product projects. This framework principle can be summarized through the following main phases: Scoping identification, concept development, framework development, framework evaluation, and final framework development. For each phase, the activity, the analysis, and the outcome should be identified to enable the process of building a successful framework is done. In this study, Cooper (2006) method and the concept is adopted to conclude a conceptual framework to address the employer-caused delays.

In summary, it can be concluded that a complete framework to address the delay caused by the employer is not existing; thus, it becomes essential to build a conceptual framework to address the employer-caused delays which can be used in the future studies to build a comprehensive and novel framework to address the employer delays.

Research methodology

This research is carried after a thorough literature review on both previous technical papers and theses in the field of the construction delay. The research methodology has followed a four-step approach which is well-defined as follows.

In the first step, a qualitative systematic literature review is conducted to explore the previous papers and theses for collection of employer-caused delay factors. The data databases selected for the search are Google Scholar, Scopus, Web of Science (WOS) and ProQuest; duplicate data are excluded. Chadegani, Salehi & Yunis (2013) conducted a scientific comparison of the WOS in which they stated that it has reliable coverage of many previous studies dating as far back as 1990; by contrast, Scopus covers a vast number of papers, but it is limited to recent articles. Thus, Web of Science (WOS) and Scopus are selected to ensure that a wide range of previous papers is gathered. Besides, it is selected to conduct a similar search in ProQuest to make sure that previous theses are also included. Accordingly, the researcher considered that data gathered from the selected databases are enough to represent a comprehensive range of previous researches. The search engine keywords are carefully selected to ensure maximum coverage of construction delay articles and theses; the keywords used are mainly "Construction", "Delay", "Factors" and "Causes." A descriptive summary of the search methodology is shown in Figure 1.

Secondly, the collected previous papers and theses have been in-depth reviewed and scanned for segregation of the employer-related factors; the factors are gathered collectively taking into consideration removing any duplication. In total, 39 employer-caused delay factors have been gathered. The collected employer-caused delay factors have been categorized under ten well-defined delay aspects or groups as the following:

- Managerial aspects: Leadership and staff management, planning capacity, communication skills, coordination skills, decision-making skills and management of changes.
- Social aspects: Construction culture, import of foreign labor and labors' ability to speak the local language.
- Technical aspects: Construction experience, qualifications, skills in using planning software, construction equipment technology, Building Information Management (BIM) technology, design defects, and construction defects.

- Financial aspects: Procurement, client's fund, client's payments, Letter of Purchase Order (LPO) and its financial procedure, subcontractor payments, cost of materials, cost of skilled laborers, indirect cost, prolongation cost, and cash flow.
- Contractual aspects: Contractual capacity/knowledge, knowledge of contractual obligations, breach of the contract and claims.
- Environmental aspects: Environmental impacts of the project, project land environment, climate, and weather.
- Scope aspect: Early definition of all parties' scope, awareness of employer's staff for all parties' scope, scope coordination, project timing about scope.
- Material Aspects: free issue material by the employer, material selection, mock-ups and benchmarks required by the employer.
- Resources Aspects: sufficiency of employer staff, availability of tools and software to monitor,
- Other Aspects: Any other than the above such as inappropriate analysis of contractors' history of delays.

The third step is involved in developing a conceptual framework to present solutions and to address each aspect or group of delays caused by the employer as part of the proposed conceptual framework. The researchers have adopted (when applicable) selected measures from the mitigation proposed list by Olawale and Sun (2010) for only measures which serve the employer factors and aspects. Cooper (2006) conceptual methodology is used to define the components of the framework which also included the available software and tools to help preventing controlling the delay of the employer.

In the fourth step, the proposed framework is validated by presenting some of the success or failure measures which are adopted by the employer in one of the massive construction projects as a case study. The case study has shown some tangible examples for what/what not the employer should adopt during the construction to control or reduce the delay impact due to his risk delays factors such as design changes, using capable software and implementation for risk regime.

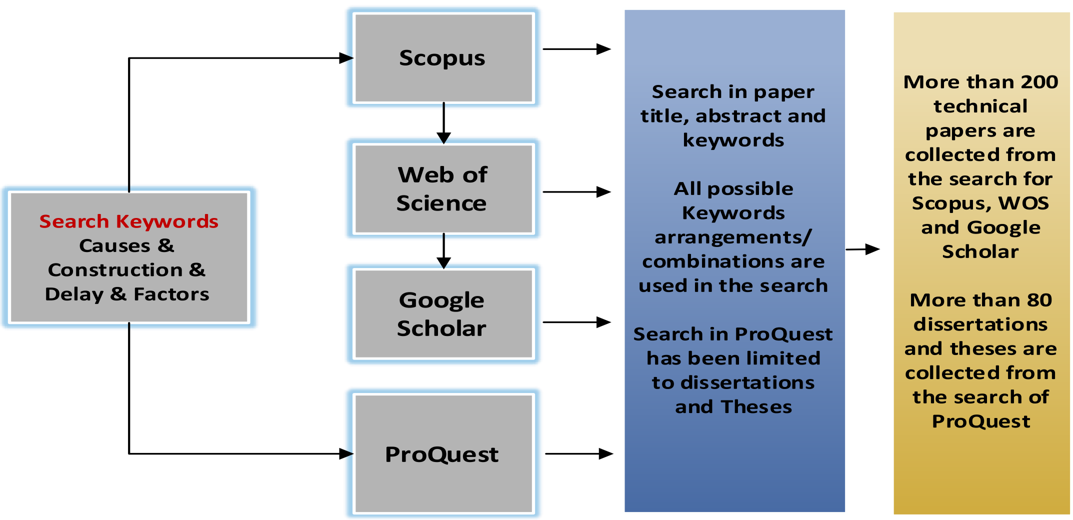


Figure 1: Search methodology in the selected databases

Conceptual Framework Outlines and Discussion

In Table 1, a comprehensive collection for the employer-caused delay factors is gathered and categorized; more than 200 technical paper and 80 dissertations and theses are reviewed and scanned thoroughly to gather employer-related factors taking into consideration removing the repetition with the same terminology. The total number of refined factors are 39 factors; subsequently, factors are categorized under the well-defined delay aspects as per the proposed definition and scope for each aspect in the methodology section. The aspects' categories have been defined and selected to ensure that almost all delay aspects are covered and included. For instance, 'delay in approving changes in the scope of work and in specifications' is classified under the aspect of 'managerial aspect' due to the fact that any delay and/or reluctant action from side of the employer is sourced from a problem in the managerial capacities of the employer and the employer's representative. Similarly, the factors 'lack of communication between parties including the employer', 'slowness in the decision-making process by the employer.'

For social aspects, the researchers, in this study, have categorized only two factors under this category which are 'delays in acquiring land from citizen' and 'bureaucracy in the employer's organization.' On the other hand, the researchers have not found any employer-caused delay factors which can be classified under the environmental and the resources aspects which may urge a requirement to conduct, as a part of the proposed future research, a pilot survey of a combination for a semi-structured interview and online questionnaire for the purpose of gathering all-known employer-related delay factors including these two aspects.

Table 1 has also presented that some employer-related factors are not to be categorized under any of the proposed aspects or groups. For instance, delay factors of 'original contract duration is too short', 'tendering system requirement of selecting the lowest bidder', 'site design changes', 'improper feasibility study', 'postponement of project', 'delay in the consent of the employer of the land to expand the road through the project' are considered falling under another aspect. Besides, Table 1 shows the employer-related success measures extracted selectively from Olawale and Sun (2010) for each delay aspects.

In Figure 2, a framework with detailed conceptual and development stages is presented in a step-by-step procedure of data collection for the employer-related factors and their relevant success factors is detailed. Initially, the framework scope is defined, followed by a three-step procedure to gather the previous employer-caused delay factors. In this step, 39 employer-related factors have been collected with a recommendation for further pilot questionnaire and direct interview to ensure collective employer factors matrix. In the next step, the full matrix of employer-caused delay factors is categorized under the well-defined delay aspects or groups. Full matrix of delay factors is to be selectively gathered from the study of Olawale and Sun (2010), previous studies and pioneer workshop. In specific, this study has limitedly collected the success factors from Olawale and Sun (2010) only and segregated them for each delay aspect. Ranking the top success factors for each employer-related factor is an essential part of this framework to ensure that a list of recommended success factors is in line with the practical construction solution. This ranking can be carried out using one of the statistical methods of analysis, such as Relative Importance Index (RII) by utilizing an online questionnaire to gather the feedback from the professionals in the construction field. Afterward, the researchers have suggested compiling a well-organized procedural execution matrix for each delay factor taking into consideration the top-ranked success factors.

Available software is a useful tool which can help the employer control and monitor the risk of his delays. In the proposed conceptual framework, the researchers have suggested some of the available software which are considered helping the employer effectively in monitoring and controlling the project relevant activities including his risks and delays. For instance, it is expected from the employer's representative to be able using the Primavera software which can help to monitor the as planned activities, the design changes and the updates for the actual progress at the site. Moreover, Conject and Aconex are one of the leading software which can help the employer controlling his documents to avoid any delay in responses and monitor quality of responses.

Framework validation and case study

This section presented a case study for one of the large projects in the construction field of which the project is delayed. Even though the delay was caused by a combination of factors in this project and the factors were initiated by different project's parties but it was noticeable that the employer was one of the leading parties for the project's delay. This study is presenting some of the delay causes and aspects by the employer along with the relevant success and failure measures adopted by the employer which dramatically influenced the project's progress.

One of the leading clients in Dubai has invested in developing the Badr Project. The project covers the construction of a mixed-use development spreading over a land area of 66,522 square meters covering a built-up area of 204,386 square meters including 11 residential low-rise buildings, 700 apartments, retails areas and recreational facilities. The project is used in this study to validate the proposed framework (conceptual stage only) by reviewing the employer-delay factors occurred in the project, the mitigation measures adopted and the missing mitigation measure.

.

Table 1: Employer-caused delay factors, delay factors categories, and success factors

Category	*Employer-caused delay factors*	*Measures extracted from Olawale and Sun (2010) related to employer only*
Managerial aspect	*Delay in approving changes in the scope of work and in specifications; Lack of communication between all parties including the employer; slowness in decision making process by the employer; suspension of work by employer; failure treatment the delays when implementing the project; unreasonable constraints by the employer; poor organizational structure of the employer's organization; delay to furnish and deliver the site to the contractor by the employer; lack of early planning for the project.*	***Preventive:*** *Ensuring the time and cost implication of a design change is always determined and agreed before going ahead with the change whenever possible; freezing design at the appropriate stage of a project or implementing intermediate design freezes at various project stages depending on the type of contract; having a risk register in place for the project as early as possible (e.g. from tender stage); having a strategy already developed for solving each of the identified risks in case they come to fruition; Ensuring design changes are reasonably timed when possible, e.g., late design changes may significantly impact the ability to control the project cost and schedule; Having a strategy already developed for solving each of the identified risks in case they come to fruition; allocating to the project experienced personnel that have handled similar type of complexity in the past; constantly monitoring the progress.* ***Corrective, Predictive and Corrective-Predictive:*** *Ensuring the cause of a design change is always determined; capturing all design change on a register with corresponding cost and schedule implications for discussion during project team meetings; efficient analysis of the direct and indirect consequence (domino effect) of a design change on other activities or areas of the project as one change can precipitate other changes; looking out for opportunities to improve cost and time performance during risk analysis; identification of potential design changes as a risk and devising a strategy for managing the risk especially in design and build projects; conducting a risk workshop involving all relevant project parties at the outset of the project in order to identify potential risks; running a risk analysis on the schedule using a schedule-quantities-risk-analysis (SQRA) on the project at an early stage when possible; Utilizing performance measurements, e.g. S-curve, KPI to monitor the output/performance.* ***Organizational:*** *Agreeing and putting in place change management procedure before the commencement of projects; open discussion by the relevant project party before the project starts about how design changes will be managed and incorporating this into the contract if possible; ensuring risk management is a sincere and open exercise.*

Social aspect	*Delays in acquiring land from citizens; bureaucracy in employer's organizations.*	**Preventive:** *Having a strategy already developed for solving each of the identified risks in case they come to fruition; allocating to the project experienced personnel that has handled the similar type of complexity in the past; constantly monitoring the progress.* **Predictive:** *Conducting a risk workshop involving all relevant project parties at the outset of the project in order to identify potential risks; running a risk analysis on the schedule using a schedule-quantities-risk-analysis (SQRA) on the project at an early stage when possible; utilizing performance measurements, e.g. S-curve, KPI to monitor the output/performance.* **Organizational:** *Encouraging, emphasizing and striving for a risk-sharing regime when possible (it may aid in buttressing partnership and openness among the project parties); ensuring risk management is a sincere and open exercise.* **Corrective:** *Looking out for opportunities to improve cost and time performance during risk analysis.*
Technical aspect	*Late in reviewing and approving design documents by the employer; application of quality control based on foreign specifications; lack of experience of the employer in construction projects; lack of capability of employer's representative; irregular attending of weekly meeting; wrong selection of the site by the employer.*	
Financial aspect	*Delay in progress payments by the employer; difficulty in budget availability from the side of the employer; underestimation of the cost of projects; investment criteria by the employer.*	
Contractual aspect	*Contract modification by the employer; type of project bidding and award; unavailability of incentives for contractor for finishing ahead of schedule; ineffective delay penalties; damaging penalties imposed on contractor; late contract award; claims problems; delay in approval of completed work by the employer (i.e., stag passing); claim due to late compensation of land acquisition.*	

Scope aspect	*Difficulties in defining project requirements.*	*Refer to the above*
Material aspect	*Delay in material supplied by the employer.*	
Resources aspect	*NA*	*NA*
Environmental aspect	*NA.*	*NA*
Other aspects	*Original contract duration is too short; tendering system requirement of selecting the lowest bidder; site design changes; improper feasibility study; postponement of the project; delay in the consent of the employer of the land to expand the road through the project.*	***Preventive:*** *Educating and advising the client on an alternative if an unachievable/unrealistic project timescale is stipulated; Conducting a process mapping exercise to validate the time allocated to a project.*

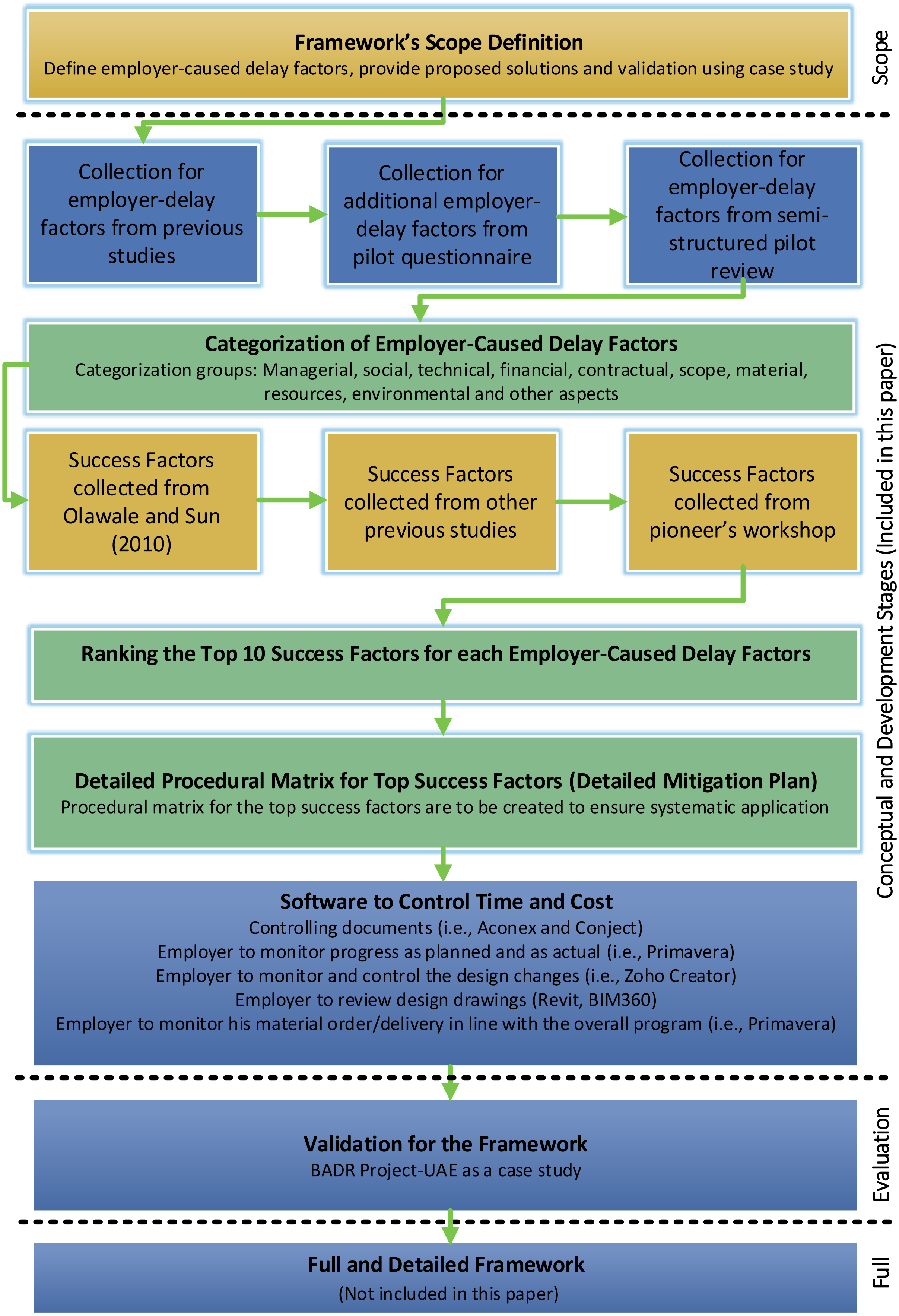


Figure 2: Framework chart with detailed conceptual and development stages to address the employer-caused delay factors

Employer, in Badr Project, has made many changes in the design during the construction phase such as changes in the GRC profiles and colors, changes in the architectural layout of the residential flats and changes in the material finishing of the buildings' elevation. These changes have dramatically impacted the work program. The time impact of these changes was not well-determined for the employer which caused, at a later stage of the project, a dispute between the employer and the contractor regarding the validity of the claim and its prolongation cost. From the perspective of the researchers, the initial determination of the time and cost impact for the design changes will increase the employer's capabilities to understand delay impact and its consequences

Besides, the cause of design changes should always be defined to guarantee the feasibility of changes. Some design changes can be frozen if the impact is well-defined by the employer at an early stage of the project. Having the change management procedure is established before the project commencement can help the employer to control and monitor the change impact; in Badr Project, at a later stage of the project's official commencement date, the change management procedure was established which affected the capabilities of the employer to control the delay caused by the design changes. Accordingly, it became well-noted that improper and late engagement for the change management regime in any project will decrease the employer's vision to control the design changes.

From the perspective of using appropriate software by the employer's team and how positively they are influencing the employer to control on his delay factors, Conject was used in this project as a platform for digital project's document control and delivery. It connected the employers, contractors and their project teams in the construction and it provided project-wide visibility and control for correspondences, request for information (RFI) and inspection requests. In specific, this software has provided a well-organized platform for the employer to monitor the documents and information flow.

Also, Primavera has been adopted by the employer's staff as the primary tool to monitor the as planned activities and the actual site progress through a weekly update for the progress. This software has provided a reliable tool for the employer to understand and monitor the time impact for the design changes during the construction. Primavera has provided the employer or the employer's representative with a clear vision for the design changes progress, design changes time impact, the influence of design changes on other construction activities. Moreover, this software has been used to efficiently analyze the direct and indirect consequences (domino effect) of a design change on other activities. It was apparent that using Primavera was one of the leading success factors for the employer to monitor, control and reduce the delay risks. Accordingly, it is highly recommended that the employer is hiring a representative who is well- trained with such type of software.

Providing the risk matrix at an early stage of the project with a clear procedure to monitor and to address is vital for any project's employer to increase his ability to involve correctly in the project. In Badr Project, the risk matrix was not well-defined in the project, this did not help the employer to evaluate the real impact for his decisions such as design changes, late of reviewing the design drawings, late of material selection, inadequate interference with the shop drawings review. For instance, the employer has interfered in the review of the shop drawings to improve the architectural facade elevations. This interference has affected negatively the normal flow of the project engineering work and has impacted the site progress. At a later stage, the contractor has placed a claim for additional engineering work which eventually borne by the employer as an additional cost. It is obvious that the risk regime, in this project, was not effectively placed to help the employer carefully understand unnecessary changes and their impact on the project time and cost.

From the perspective of the project's original duration, Badr Project was scheduled to finish by 27 months (22 months with a granted Extension of Time 'EOT' of five months). This duration was not realistic. Educating and advising the employer for the alternatives for an unrealistic time scale was not available during the tender phase for Badr Project. It is the responsibility of the employer's representative to inform the employer for the expected delay risk of unreasonable project's time frame and to advise for the available alternatives to achieve the goals such as inducing interim milestones, encouraging for contractor's incentives for achievements and acceleration cost. It is highly recommended to conduct a well-established study for the realistic time frame of the project during the tender stage as a critical success factor of the project.

Conclusion and further research

This study successfully conducted a review of a global literature for construction delay factors and developed a conceptual framework to address the employer-caused delay factors. The conceptual framework is created after a thorough review and scan for more than 200 technical papers and 80 theses or dissertations. The in-depth literature review revealed a matrix of 39 employer-related delay factors which have been categorized under well-defined aspects. Success factors for Olawale and Sun (2010) have been utilized to address the employer-caused delay factors. The software which are available in the construction market have also been presented and discussed as a part of the success factors to address the relevant employer delay factors. Badr Project in Dubai was used as a case study to validate the conceptual framework and to provide practical details about the employer-caused delay factors and their relevant success factors. Limitations of this study also need to be considered and clarified. The conceptual and development stages are only shown in this study. This conceptual framework is only related to the success factors presented in Olawale and Sun (2010).

Besides, the success factors in previous studies are recommended to be reviewed and scanned to address the delay in a holistic perspective in the futuristic studies. Future studies can be carried out on the employer- caused delay factors matrix for different types of construction projects to ensure that solutions are sophisticated and practical.

References

Addo, J.N.T., 2016. Delay and its effect on the delivery of construction projects in Ghana. *African Journal of Applied Research (AJAR)*, 1(1).

Assaf, S.A. & Al-Hejji, S., 2006. Causes of delay in large construction projects. *International journal of project management*, 24(4), pp.349-357.

Bekr, G.A., 2015. Causes of delay in public construction projects in Iraq. *Jordan Journal of Civil Engineering*, 159(3091), pp.1-14.

Belassi, W. & Tukel, O.I., 1996. A new framework for determining critical success/failure factors in projects. *International journal of project management*, 14(3), pp.141-151.

Chadegani, A., Salehi, H., Yunus, M., Farhadi, H., Fooladi, M., Farhadi, M. & Ale Ebrahim, N., 2013. A comparison between two main academic literature collections: Web of Science and Scopus databases. *Asian Social Science*, 9(5), pp.18-26.

Chan, D.W. & Kumaraswamy, M.M., 1997. A comparative study of causes of time overruns in Hong Kong construction projects. *International Journal of project management*, 15(1), pp. 55-63.

Cooper, R.G., 2006. The seven principles of the latest Stage-Gate method add up to a streamlined, new-product idea-to-launch process. *Stage-Gate International*.

Durdyev, S., Omarov, M. & Ismail, S., 2017. Causes of delay in residential construction projects in Cambodia. *Cogent Engineering*, 4(1), p.1291117.

Muhwezi, L., Acai, J. & Otim, G., 2014. An assessment of the factors causing delays in building construction projects in Uganda. *International Journal of construction engineering and management*, *3*(1), pp.13-23.

Olawale, Y.A. & Sun, M., 2010. Cost and time control of construction projects: inhibiting factors and mitigating measures in practice. Construction management and economics, 28(5), pp.509-526.

Pai, S.K. & Bharath, J.R., 2013. Analysis of critical causes of delays in Indian infrastructure projects. *International Journal of Innovative Research and Development (ISSN 2278–0211)*, 2(3), pp. 251-263.

Rahimipour, S. & Shahhosseini, V., 2014. A comparison of effective factors in creating delays from the contractors' and the employers' point of view in construction of schools in Tehran. *European Online Journal of Natural and Social Sciences: Proceedings*, 2(3 (s)), pp.pp-3350.

Shebob, A., Dawood, N., Shah, R.K. & Xu, Q., 2012. Comparative study of delay factors in Libyan and the UK construction industry. Engineering, *Construction and Architectural Management*, 19(6), pp. 688-712.

Tafazzoli, M. & Shrestha, P.P., 2017. Investigating causes of delay in U.S. construction projects. *53^{rd} University of Washington*, pp. 612-621.

TOWARDS ACHIEVING SUSTAINABLE HOUSING IN NIGERIA: THE OPTION OF PRE-FABRICATION

Igbayemi Daniel Akeremale, Patrick Tang, Willy Sher

School of Architecture and Built Environment, University of Newcastle, Callaghan, Australia

Abstract

Construction of buildings with prefabricated elements has been considered a very efficient approach for improving construction processes and productivity. It facilitates quality and reduces time and cost overruns. However, it is an effective method that the construction industry has found difficult to implement. This paper provides an overview of the use of prefabricated components for building construction in Lagos state, Nigeria. The paper also reports the global trends of prefabrication in building construction. These are derived from a systematic literature review in a quest to answer the research question of the study. Four databases were used, and a total of 884 records were located. This number was later reduced to 30 most relevant peer-reviewed journal articles that formed the background information for the research. This study reveals that despite the advantages of prefabricated methods of housing construction and practical examples of its successful application, many challenges still occur in practice. Key among these challenges are initial high costs of establishing prefabrication firms, lack of awareness of the potential of the prefabrication technology among the built environment professionals, non-availability of adequate local prefabrication firms, technical know-how and other technical challenges in installations among others. The study concludes that although there are a number of factors discouraging the use of prefabrication in building construction, the benefits over-shadow the challenges. Therefore, effort should be re-doubled to encourage the use of prefabrication technology in building construction to address the housing demand-supply gap in Lagos, Nigeria. Recommendations are provided for further study on the use of prefabricated methods of construction in Nigeria.

Keywords

Construction, Developing Country, Housing, Lagos State, Nigeria, Prefabricated Houses

Introduction

One of the present and continuing challenges confronting developing countries is adequate and affordable housing. This is more prominent and worrisome in Africa and Nigeria is no exception (Habitat, 2010, Hardoy and Satterthwaite, 1993, Ashkin, 2013). This challenge is largely due to the inability of the Government and other stakeholders to provide affordable housing to the populace who typically earn low incomes (Ibem and Aduwo, 2013, Aduwo et al., 2016). As a result, many are forced to live in slums or informal settlements (Daniel et al., 2015, Jiboye, 2011). Ownership of houses, besides being used for shelter, is a measure of social standing in the society (Ayedun and Oluwatobi, 2011). In spite of the value placed on housing (Ayedun and Oluwatobi, 2011, Xiaolin et al., 2014).

Ayedun and Oluwatobi (2011) and Ogunde et al. (2016) affirmed that only 10% of the population who wish to own houses can actually afford one. This is very low when compared with developed countries such as USA, UK and Singapore with 72%, 78% and 92% affordability respectively Phang (2010). Factors such as population increase, urbanisation, and industrialisation among others have been responsible for this state of affairs ((Aribigbola and Ayeniyo, 2012). There has been a continual increase in the demand for houses in Nigeria without a commensurate increase in supply. More worrisome is the housing conditions of low-income earners, who are most affected. Jimoh et al. (2016) and Ademiluyi (2010) also note that governments at the federal, state and local levels have been making efforts to reduce the housing deficit but with little or no success, resulting into continuous expansion of the problems. The aim of this paper therefore is to investigate the challenges of prefabricated housing in Nigeria. This is an alternative that provides housing in a quick timeframe and with economic advantage. The aim will also highlight the factors responsible for these challenges, with the aim of presenting a set of possible suggestions to address the problems.

According to Ademiluyi (2010), major reason for the poor performance in housing provision on the part of government includes**:** miss-match in policy implementation, lack of adequate data on the housing need of the people, inconsistencies in government policies between one administration and the other, irregular housing policy, in-effective co-ordination among the housing agencies, politicisation of housing issues and a reliance on traditional methods of construction. According to Nwanna (2015) and Jimoh et al. (2016), only 200,000 housing units were constructed in Nigeria from 1972 to 2012 through the National Housing Policy initiative of the Federal Government. The urgent task as stated by UN-Habitat is to make the urban housing sector function more effectively to increase access to affordable housing, especially for low-income earners (Gilbert, 2014, Ugochukwu and Chioma, 2015). As part of the effort to achieve this, researchers and practitioners in the built environment have argued for the use of prefabrication as a reliable alternative to conventional methods of construction (Chiang et al., 2006, Tam et al., 2007).

Prefabrication can be described as the composite construction or building parts produced in the factories for installation on site (Blismas et al., 2006). Another term associated with prefabricated construction is offsite construction (Pan et al., 2012). The use of prefabricated elements in building construction has been argued to be an effective and efficient approach to improving construction processes and productivity, ensuring construction quality and reducing time and cost (Ogunde et al., 2016). Over the past few decades, prefabrication has mainly taken the form of precast concrete components like facades, staircases, partition walls, and slabs, and in the fitting-out stage of projects, in the form of factory-made joinery and metalwork items (Gibb, 1999).

This paper is part of an ongoing study that is investigating the development of a supply chain management concept of prefabricated housing construction in Lagos State, Nigeria. The information presented in this paper is based on a review of literature relevant to the study. The literature shows that prefabrication technology in the construction of buildings has many benefits associated with it, but its uptake in developing countries has been slow as a result of a number of barriers. Therefore, this paper common barriers impending the uptake of prefabricated buildings are identified and present a way forward, based on the experience of other countries that has faced similar challenges.

Research Methodology

The methodology used for this study is systematic literature review. This has been able to systematically guide through answering the research question of the study, as described below. A systematic literature review was explored to answer the research question **-** Can prefabrication methods of building address the problems of housing shortage in Nigeria? The review has helped to summarise past research around this study and set out the background against which the study takes place. Besides, it helped to demonstrate better understanding of the phenomena and support the new findings. This was conducted between 2018 and 2019. The following keywords define the subject matter: Construction, Developing Country, Housing, Lagos State, Nigeria, and Prefabricated Houses. They were carefully selected to reflect the research topic and its focus study area. Articles containing these terms in the title/abstract/keywords were considered. Academic peered-reviewed journals with relevant publications on the topic were targeted from four databases of construction management. The databases used included: Web of Science, Scopus, Pro Quest, and ASCE (Table 1). Google Scholar was also used to locate additional records. Identified relevant records were moved to Endnote to manage citations. This helped to identify duplicate articles which were reduced to 422 from 884. A more detailed screening was later conducted to exclude articles that did not have the same focus as the study. At this stage, full text articles were considered. To search for relevant peer-reviewed journals, a combination of words were careful selected to reflect the topic in question. The PRISMA flowchart (Figure 1) shows how the 884 records initially identified from the databases were filtered gradually until only the most relevant papers were identified for detailed review. The selection of journals was based on being ranked by SCImago Journal & Country Rank as a first-tier journal by peer reviewers who specialised in relevant disciplines.

Table 1: Results from the database search

Searched terms	***Number of Articles from Databases***			
	Web of Science	***ProQuest***	***Scopus***	***ASCE***
Prefabricated Housing Construction	*104*	*62*	*36*	*60*
Sustainable Housing	*28*	*74*	*51*	*46*
Housing Prefabrication	*44*	*59*	*29*	*39*
Housing problems in Nigeria	*109*	*40*	*60*	*43*
TOTAL	*285*	*235*	*176*	*188*

(Source: Prepared by the Authors)

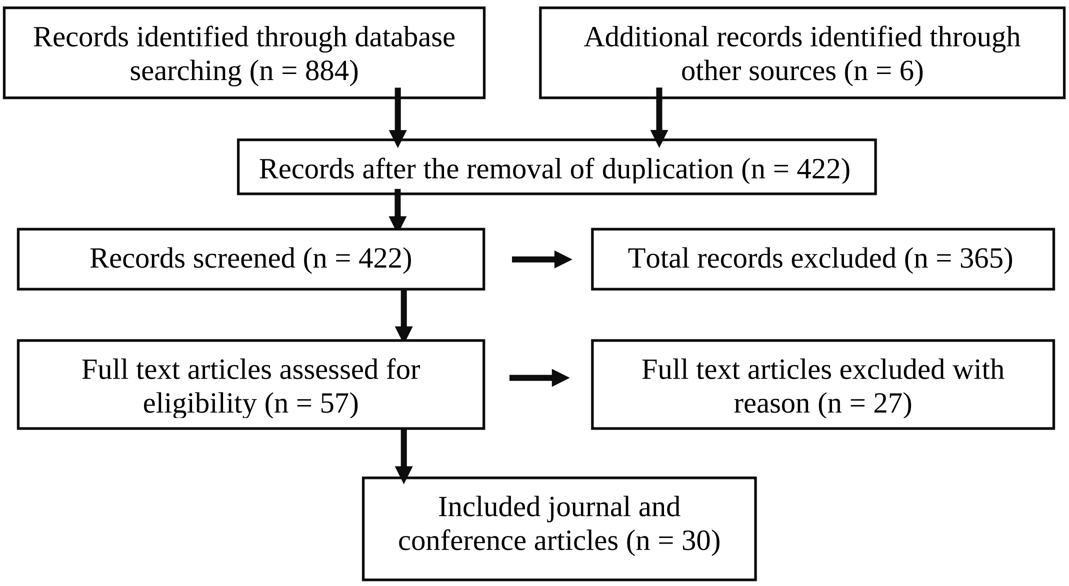


Figure 1: PRISMA flowchart of selected articles

(Source: Prepared by the Authors)

Global trends of prefabrication practice in building construction

The use of prefabrication in building construction is a technique that has been in existence since the 1850s (Jaillon and Poon, 2008, Steinhardt et al., 2013). However, its use became more prominent after World War I and II (Taylor, 2009). Prefabricated building technology has since then been adopted in different countries, most notably: USA, UK, Singapore, China, Australia, Finland, Malaysia, New Zealand, Sweden, Japan, India, Iraq and Ethiopia (Zhang et al., 2014, Zhang and Skitmore, 2012, Rahimian et al., 2017, Hwang et al., 2018).

In the UK, the uptake of building prefabrication was low initially (Taylor, 2009). Notwithstanding this, the greater demand for productivity lead to the influential UK reports by Latham and Egan in 1994 and 1998 respectively. These advocated for the UK construction industry to embrace prefabricated construction (Wolstenholme et al., 2009). Construction projects built using prefabricated construction methods achieve better quality, take less time, cost less, and reduce risk, since prefabrication involves moving parts of the building process to a controlled (factory) environment (Gibb and Isack, 2003, Ogunde et al., 2016).

The government of UK also set up an organisation (Build offsite) with the task of encouraging the use of prefabrication within the construction industry (Goodier et al., 2006). The Modular Building Institute in the United States was initiated to encourage the use of prefabrication in building construction in particular and the construction industry as a whole (Chen et al., 2010, Lu, 2009).

In Singapore, different drivers have encouraged the use of prefabrication in building construction. The shortage of human resources has had an adverse impact on the construction industry (Ting and Jin, 2000, Gao and Low, 2014). Prefabrication, the crucial part of integrated construction automation processes, has been the ideal and most practical way of sustaining the long-standing strategy of reducing the direct reliance on labour resources. More prefabrication work in Singapore means more work conducted in a comfortable in-house environment (Park et al., 2011), which is often preferred by workers. Production in a factory environment is better controlled, and as a result well prepared and reliable building components are produced for construction. According to the Housing Development Board in Singapore, 35% of new buildings from 2019 will be made of prefabricated components. Given the situation in Singapore, the benefits of prefabrication appear to be more obvious and the Building and Construction Authority (BCA) of Singapore have made prefabricated methods a requirement for every developer. (Hwang et al., 2018, Authority, 2017).

In Malaysia, the Construction Industry Development Board (CIDB) established an Industrialised Building System (IBS) centre that is responsible for championing the cause of improving the use of prefabrication technology in building construction. The government also enacted a number of policies to help boost the application of such technology (Badir et al., 2002, Din et al., 2012).

In the case of Nigeria, prefabrication technology has continuously been argued to be an alternate effective and efficient technology to address the housing shortage in the country (Ashkin, 2013, Opoko and Oluwatayo, 2014). Given this position, professionals within the Nigerian built environment have advocated a change from the conventional way of construction to a more advanced way for the housing needs to be met (Ashkin, 2013, Ogunde et al., 2016). Countries like UK, US, China, and Singapore, among others have been able to resolve their housing shortages through prefabrication building technology, hence the position of experts that their housing deficit could be managed through the use of prefabrication technology. Currently, the majority of houses in Nigeria are built using traditional construction techniques (Ashkin, 2013, OGUNSANYA et al., 2016). Therefore, the government and other stakeholders have major roles to play in promoting the adoption of prefabrication in building construction in Nigeria.

Before prefabricated building construction is promoted in Nigeria, it is necessary to have a holistic view and understanding of the components and other auxiliary services required to guarantee effectiveness in the technology. Therefore this study is to provide an overview of the use of prefabricated components for building construction in Lagos state, Nigeria. The paper also report the global trends of prefabrication in building construction.

Findings and discussions

This section summarises the arguments, assertions, opinions, declarations and acknowledgments of other researchers to support the position of the study. The literature shows that there are many barriers hindering the uptake of prefabrication technology in building construction. These include: high initial costs, dearth of manufacturing firms, and absence of government regulations (Blismas et al., 2010, Rahimian et al., 2017, Kolo et al., 2014).

Lagos is a cosmopolitan city with the largest population (over 10% of the total population in Nigeria. Lagos is the economic hub with large industrial presence. Over fifty thousand (50,000) aspiring young people move into the city every year in search of greener pastures (Olugbenga and Adekemi, 2013). Besides, Lagos hosts over 60% of construction clients in Nigeria, with more concentration of building professionals (Ajanlekoko, 2008, Ayedun et al., 2018). Lagos State was thus selected as a suitable location for this study. However, with the constant influx of people to Lagos State, decent and comfortable housing has been a continuous and major challenge. This has been responsible for the growth of urban blight and squalor, resulting in many inhabitants of the city living under subhuman conditions in slums and squatter settlements.

Conventional construction methods consist of the widespread use of in-situ concrete operations. The current situation in Lagos calls for alternative construction methods as well as for cost effectiveness and speedy housing delivery. This should improve affordability and alleviate problems. Many scholars have identified several benefits associated with the use of prefabrication in addressing the housing shortage (Arif and Egbu, 2010, Goulding et al., 2015), but the industry is yet to fully embrace this approach. Prefabrication, with its clear benefits, is hindered by a number of obstacles. Amongst these are: high initial costs, negative image, and lack of government regulations (Azman et al., 2012). However, the benefits over-shadow the negative effects (Ashkin, 2013). It has also been found that waste generation during prefabrication construction can be reduced by up to 100%, resulting into a huge savings for the developer (Tam et al., 2007).

Nigeria is still at the infancy stage of prefabrication in building construction, so much can be learnt from countries that have long practiced the system. For instance, policy support from the government (Singapore, China and Iraq), among others towards improving the technology is seen as a common feature in many of the countries where prefabricated housing technology is well established (Steinhardt et al., 2013, Luo et al., 2018, Persson and Engevall, 2008, Mostafa et al., 2018).

This study provides an overview of the Nigerian building industry where there are few factories producing prefabricated components (Ogunde et al., 2016). The few available ones also do not operate to their full potential as a result of poor demand for the technology, despite the increasing housing need. Negative perception is another barrier recorded in the literature (Steinhardt et al., 2013, Mao et al., 2013, Kolo et al., 2014). Currently, the use of prefabricated methods for building construction in Nigeria is quite small (Ogunde et al., 2016). As such, the construction sector needs to train construction professionals in the area of building prefabrication technology to bridge the housing deficit gap in Nigeria. This will also create more awareness among professionals and potential clients in Nigeria.

The literature shows that prefabrication technology in the construction of buildings has many benefits associated with it, but its uptake in developing countries has been slow as a result of a number of barriers. This paper identifies common barriers impending the uptake of prefabricated housing and presents a way forward based on the experience of other countries that have faced similar challenges. These includes: limited knowledge of prefabricated technology, lack of competent components prefabrication firms, technical-know-how, Initial cost. Identified manufacturing capacity is another barrier to prefabrication housing delivery. Countries with well-established housing prefabrication infrastructure such as US, UK, China, and Singapore all have appreciable numbers of factories that manufacture prefabricated components, but this is not the case in Nigeria.

Conclusion and directions for further research

Prefabricated housing construction has been identified as a good alternative to housing delivery in Nigeria. A move towards the realisation and promotion of prefabricated construction method is therefore considered necessary in resolving the huge and increasing housing deficit in Nigeria. Prefabricated Housing Construction has the advantage of shorter construction time, reduction of wastes, and reduction in total project cost, faster project delivery period, neater and more convenient working environment, among others.

The uncertainty between builders and developers, financial industry regulations, issues of public understanding, risks in adapting to new processes and systems, and inadequate investment by industry in research and development have been described as some of the biggest constraints for prefabricated housing delivery.

Therefore, a strong support through policy formation will be required from the Government. This will urge the establishment of a framework, strategies, enablement and the required codes that will promote the use of prefabrication technology in housing construction. Continuous development in the form of training and re-training of relevant professionals to update relevant skills in prefabrication building construction should also be ensured. Research efforts towards a more effective materials to achieve an improved acceptance of the technology will be needed. This will improve awareness and market penetration of prefabrication technology in the Nigerian construction industry.

This work adds to the debate on obstacles to the increased use and implementation of prefabrication in building construction. It acts as a steppingstone for the next phase of the research which aims at developing a framework that will improve the supply chain management in prefabrication housing delivery.

Acknowledgements

This study is supported by the “Australian Government Research Training Program Scholarship”, through The University of Newcastle, Australia. The Authors thank the anonymous reviewers for their comments, which has positively improved the article for presentation.

References

ADEMILUYI, A. 2010. Public housing delivery strategies in Nigeria: A historical perspective of policies and programmes. *Journal of sustainable development in Africa,* 12**,** 153-161.

ADUWO, B., EDEWOR, P. & IBEM, E. O. 2016. Urbanization and Housing for low-income earners in Nigeria: a review of features, challenges and prospects. *Mediterranean Journal of Social Sciences,* 7**,** 347-357.

AJANLEKOKO, K. 2008. Sustainable Housing Development in Nigeria-The Financial and Infrastructural Implication. Paper Presented At The International Conference On Spatial Information For Sustainable Development In Nairobi, Kenya, 2-5 October 2001. AvailableOnline Ht tp.

ARIBIGBOLA, A. & AYENIYO, O. I. 2012. Sites–and–Services as a Strategy for Achieving Adequate Housing in Nigeria inthe 21 st Century.

ARIF, M. & EGBU, C. 2010. Making a case for offsite construction in China. *Engineering, Construction and Architectural Management,* 17**,** 536-548.

ASHKIN, R. 2013. Innovative building technologies–the social housing angle. *Housing Africa*, 2013.

AUTHORITY, B. A. C. 2017. Building and Construction Authority. *Handbook for Solar Photovoltaic (PV) Systems*.

AYEDUN, ABIODUN, C., OLOYEDE, ADESIYAN, S., DURODOLA, DANIEL, AKINJARE & ADEDOYIN, O. 2018. An evaluation of strategies being adopted by Lagos state residents towards solving their residential housing problems. *International Journal of Civil Engineering and Technology,* 9**,** 1468-1477.

AYEDUN, C. & OLUWATOBI, A. 2011. Issues and challenges militating against the sustainability of affordable housing provision in Nigeria. *Business Management Dynamics,* 1**,** 1-8.

AZMAN, M., AHAMAD, M. & HUSSIN, W. 2012. Comparative study on prefabrication construction process. *International surveying research journal,* 2**,** 45-58.
BADIR, Y. F., KADIR, M. A. & HASHIM, A. H. 2002. Industrialized building systems construction in Malaysia. *Journal of architectural engineering,* 8**,** 19-23.
BLISMAS, N., PASQUIRE, C. & GIBB, A. 2006. Benefit evaluation for off-site production in construction. *Construction Management and Economics,* 24**,** 121-130.
BLISMAS, N., WAKEFIELD, R. & HAUSER, B. 2010. Concrete prefabricated housing via advances in systems technologies - Development of a technology roadmap. *Engineering, Construction and Architectural Management,* 17**,** 99-110.
CHEN, Y., OKUDAN, G. E. & RILEY, D. R. 2010. Decision support for construction method selection in concrete buildings: Prefabrication adoption and optimization. *Automation in Construction,* 19**,** 665-675.
CHIANG, Y.-H., CHAN, E. H.-W. & LOK, L. K.-L. 2006. Prefabrication and barriers to entry—a case study of public housing and institutional buildings in Hong Kong. *Habitat International,* 30**,** 482-499.
DANIEL, M. M., WAPWERA, S. D., AKANDE, E. M., MUSA, C. C. & ALIYU, A. A. 2015. Slum housing conditions and eradication practices in some selected Nigerian cities.
DIN, M. I., BAHRI, N., DZULKIFLY, M. A., NORMAN, M. R., KAMAR, K. A. M. & HAMID, Z. A. The adoption of Industrialised Building System (IBS) construction in Malaysia: The history, policies, experiences and lesson learned. Proceedings of the 2012 29th International Symposium of Automation and Robotics in Construction (ISARC), Eindhoven, The Netherlands, 2012. Citeseer, 26-29.
GAO, S. & LOW, S. P. 2014. Lean Construction Management. Springer.
GIBB, A. & ISACK, F. 2003. Re-engineering through pre-assembly: client expectations and drivers. *Building Research & Information,* 31**,** 146-160.
GIBB, A. G. 1999. *Off-site fabrication: prefabrication, pre-assembly and modularisation,* John Wiley & Sons.
GILBERT, A. 2014. Housing the urban poor. *The companion to development studies,* 21**,** 257-262.
GOODIER, C., GIBB, A., ASHLEY, D. & TAYLOR, M. 2006. Buildoffsite: Glossary of Term. DTI and Buildoffsite, London.
GOULDING, J. S., POUR RAHIMIAN, F., ARIF, M. & SHARP, M. 2015. New offsite production and business models in construction: priorities for the future research agenda. *Architectural Engineering and Design Management,* 11**,** 163-184.
HABITAT, U. 2010. State of the world's cities 2010/2011: bridging the urban divide. *Earthscan, London*.
HARDOY, J. & SATTERTHWAITE, D. 1993. Housing policies: a review of changing government attitudes and responses to city housing problems in the Third World. *Urban management: policies and innovations in developing countries***,** 111-160.
HWANG, B.-G., SHAN, M. & LOOI, K.-Y. 2018. Key constraints and mitigation strategies for prefabricated prefinished volumetric construction. *Journal of Cleaner Production,* 183**,** 183-193.
IBEM, E. O. & ADUWO, E. B. 2013. Assessment of residential satisfaction in public housing in Ogun State, Nigeria. *Habitat International,* 40**,** 163-175.
JAILLON, L. & POON, C.-S. 2008. Sustainable construction aspects of using prefabrication in dense urban environment: a Hong Kong case study. *Construction management and Economics,* 26**,** 953-966.
JIBOYE, A. D. 2011. Urbanization challenges and housing delivery in Nigeria: The need for an effective Policy framework for Sustainable Development. *International Review of Social Sciences and Humanities,* 2**,** 176-185.
JIMOH, R., ODENIYI, V. & JIBRIN, I. 2016. Housing Sustainability in Nigeria: A Mirage or Reality. *Covenant Journal of Research in the Built Environment,* 1.
KOLO, S., POUR RAHIMIAN, F. & GOULDING, J. S. 2014. Offsite Manufacturing: The Way Forward For Nigeria's Housing Industry. *ALAM CIPTA, International Journal of Sustainable Tropical Design Research and Practice,* 7.

LU, N. The current use of offsite construction techniques in the United States construction industry. Construction Research Congress 2009: Building a Sustainable Future, 2009. 946-955.

LUO, L., QIPING SHEN, G., XU, G., LIU, Y. & WANG, Y. 2018. Stakeholder-Associated Supply Chain Risks and Their Interactions in a Prefabricated Building Project in Hong Kong. *Journal of Management in Engineering,* 35**,** 05018015.

MAO, C., SHEN, Q., PAN, W. & YE, K. 2013. Major barriers to off-site construction: the developer's perspective in China. *Journal of management in engineering,* 31**,** 04014043.

MOSTAFA, S., KIM, K. P., TAM, V. W. Y. & RAHNAMAYIEZEKAVAT, P. 2018. Exploring the status, benefits, barriers and opportunities of using BIM for advancing prefabrication practice. *International Journal of Construction Management*.

NWANNA, C. 2015. Gentrification in Nigeria: the case of two housing estates in Lagos. *Global Gentrification: Uneven Development and Displacement, Policy Press, Bristol***,** 311-326.

OGUNDE, A., JOSHUA, O. & OMUH, I. 2016. Prefabrication Method of Building Construction in Lagos State, Nigeria: Prospects and Challenges. *International Journal of Engineering Technology and Computer Research (IJETCR)*.

OGUNSANYA, O. O., FANU, M. O. & OLADIPO, D.-A. 2016. Assessing the Adequacy of Public Housing Infrastructures in Lagos, Nigeria.

OLUGBENGA, E. & ADEKEMI, O. 2013. Challenges of housing delivery in metropolitan Lagos. *Research on Humanities and Social Science,* 3**,** 1-8.

OPOKO, P. A. & OLUWATAYO, A. 2014. Trends in urbanisation: implication for planning and low-income housing delivery in Lagos, Nigeria. *Architecture Research,* 4**,** 15-26.

PAN, W., GIBB, A. G. & DAINTY, A. R. 2012. Strategies for integrating the use of off-site production technologies in house building. *Journal of Construction Engineering and Management,* 138**,** 1331-1340.

PARK, M., INGAWALE-VERMA, Y., KIM, W. & HAM, Y. 2011. Construction policymaking: With an example of Singaporean government's policy to diffuse prefabrication to private sector. *KSCE Journal of Civil Engineering,* 15**,** 771-779.

PERSSON, F. & ENGEVALL, S. The shift from construction site to prefabrication in the construction industry: A case study. 2008. APMS.

PHANG, S.-Y. 2010. Affordable homeownership policy: implications for housing markets. *International Journal of Housing Markets and Analysis,* 3**,** 38-52.

RAHIMIAN, F. P., GOULDING, J., AKINTOYE, A. & KOLO, S. 2017. Review of motivations, success factors, and barriers to the adoption of offsite manufacturing in Nigeria. *Procedia Engineering,* 196**,** 512-519.

STEINHARDT, D. A., MANLEY, K. & MILLER, W. 2013. Reshaping housing: the role of prefabricated systems.

TAM, V. W., TAM, C. M., ZENG, S. & NG, W. C. 2007. Towards adoption of prefabrication in construction. *Building and environment,* 42**,** 3642-3654.

TAYLOR 2009. Offsite Production in the UK Construction Industry, A Brief Overview. 2009. *Construction Engineering Specialist Team: HSE: London***,** 30.

TING, S. & JIN, H. Prefabrication in the Singapore Construction Industry. 17 th International Symposium on Automation and Robotics in Construction, 2000.

UGOCHUKWU, I. B. & CHIOMA, M. I. B. 2015. Local building materials: affordable strategy for housing the urban poor in Nigeria. *Procedia engineering,* 118**,** 42-49.

WOLSTENHOLME, A., AUSTIN, S. A., BAIRSTOW, M., BLUMENTHAL, A., LORIMER, J., MCGUCKIN, S., RHYS JONES, S., WARD, D., WHYSALL, D. & LE GRAND, Z. 2009. Never waste a good crisis: a review of progress since Rethinking Construction and thoughts for our future.

XIAOLIN, Z., RICHARD, R. & ANTHONY, M. 2014. Addressing sustainable challenges in China: The contribution of off-site industrialisation. *Smart and Sustainable Built Environment,* 3**,** 261-274.

ZHANG, X. & SKITMORE, M. 2012. Industrialized housing in China: a coin with two sides. *International Journal of Strategic Property Management,* 16**,** 143-157.

ZHANG, X. L., SKITMORE, M. & PENG, Y. 2014. Exploring the challenges to industrialized residential building in China. *Habitat International,* 41**,** 176-184.

UNDERSTANDING THE EMOTIONAL INTELLIGENCE OF PROJECT MANAGERS WORKING WITHIN THE AUSTRALIAN MINING INDUSTRY

Mark Brennan[1], Samer Skaik[1], Ziyad Abunada[1]

[1]School of Engineering and Technology, Central Queensland University, Australia

Abstract

The number of complex projects within the Australian mining industry is continually increasing. A great concern within this industry is the disconnection between the diverse groups of project management practitioners (PMPs). Maintenance projects within this industry are of great concern and require PMPs to meet these developing challenges. Emotional Intelligence (EI) is believed to create a healthier and more productive work environment. EI is the ability for oneself to be aware of, understand, utilise and manage emotions in oneself and others. This research endeavours to engage PMPs within the various maintenance functions onsite wherein a hard copy survey was disseminated to them to measure the understanding of EI as well as help identify PMPs with EI. 43 respondents from various functions undertook a survey using a Likert scale to represent PMPs attitude towards the topic. The data collected from the survey was analysed by descriptive statistics. The study revealed that around 50% of project managers surveyed comprehended positive sentiments of EI. The results show 84% of respondents have a good to strong level of EI, and 16% of respondents have a below average level of EI. The results suggest that conducting EI training and educating project managers will help improve their self-awareness, self-regulation, motivation, empathy and social skills. Understanding these elements will help improve project manager and project worker relationships and provide better project outcomes.

Keywords

Emotional intelligence, interpersonal skills, mining industry, project managers.

Introduction

Project Management Practitioners (PMPs) traditionally rely on their extensive knowledge base and background experience to manage a project (Ramazani & Jergeas 2015). Having an extensive knowledge base and experience for a particular project topic can provide confidence within a project manager and project owner, however a report conducted by Chaos (2009) pointed out that 68% of all projects end up failing regardless of knowledge or experience. A balance between a PMP's technical ability and leadership capabilities is needed to increase personal development of their professional career (Ramazani et al. 2015). The importance of understanding the fundamentals of a project can prepare PMPs for managing and developing projects and project teams. The results of a study undertaken by Ramazani and Jergeas (2015) revealed a gap in project management education. Researchers believe that to overcome these challenges in managing projects, fresh innovative ideas are needed (Ramazani et al. 2015). An innovative idea is to deliver effective education as this is a fundamental tool that is needed to deal with projects in today's complex work environment. The aim of this research is to measure a project manager's level of comprehension about EI and understand the extent at which project managers believe that EI will help them perform better in the workplace.

Rationale of the study

Providing a balance of effective education combined with background experience and knowledge will enable project managers to better adapt to unforeseen circumstances within a project (Ramazani et al. 2015). Education and the ongoing development of project managers is becoming more important, as organisations started to invest heavily in project management (Ramazani & Jergeas, 2015 p.42). Love, Edwards & Wood (2011) state that organisations who provide training for their employees will see the benefits in future projects. EI has been identified as a critical component of a project manager's role (Clarke 2010). EI involves effectively managing multiple relationships, including behavioural dimensions such as communication and motivation, and identifying conflicts as they all play their part in project management success (Shamsuddin & Rahman 2014, p.77).

Ramazani and Jergeas (2015) suggest that project management competence is made up of elements such as, technical, behavioural, and contextual. These elements align with modern project management elements such as complexity, uncertainty and continual technological and organisational change (Ramazani et al. 2015). EI is the ability to control and express one's emotions and to handle interpersonal relationships judiciously and empathetically (Shamsuddin & Rahman 2014, p.77). Muller and Turner (2010) explain that the generalisation of EI is that all project managers can apply the necessary tools and techniques to be successful, regardless of the project manager's personality with the project type. Not all project managers have the competencies and understanding to run projects, as matching their expertise to a project or a specific function can be somewhat difficult (Clarke 2010).

To help prove this theory, Cote et al. (2010) engaged a group of undergraduate students to reflect on their own EI. The study investigated the level of each undergraduate understanding of EI. The first survey asked each student to review a picture of a person and answer three questions ranging from strongly disagree to strongly agree; the undergraduates were asked to look at a picture of a person and establish if the person in the picture could perceive, use and manage their emotions (Cote et al. 2010).

The second part of the study asked the students to reflect on their EI and consider how they manage their emotions. The results were inconsistent. A high percentage of students believed that the person in the picture had low EI why they had high EI. The inconsistency within the results suggest that the undergraduates do not have a good understanding of EI (Cote et al. 2010). The research suggests that conducting a training intervention can help persons such as project managers better understand their team's EI (Clarke, 2010). Understanding EI allows the project manager to develop their leadership ability, which in turn improves the outcome of the project.

Education and training are often an effective way to start closing the gap and ensure that project manages have the necessary knowledge (Clarke, 2010). With the correct training, project managers can develop their understanding of EI and gain the required learnings that are important for successful projects (Clarke 2010). It is crucial for the management team to employ a project manager that has good interpersonal workplace relationships between the internal stakeholders and external stakeholders (Mazura et al., 2013). To support this argument, Mazura et al. (2013) suggest that EI is the competence required to bring all project teams together. Mazura et al. (2013) further list four separate components of EI: (a) accurately perceiving emotion, (b) using emotions to facilitate thought, (c) understanding emotion, and (d) managing emotion and the ability to change emotions in oneself and others. An emotionally intelligent project manager has an ability to perceive their own emotions and understand the distinctions among them (Cote, et al. 2010). These project managers are emotionality intelligent and can gain considerable knowledge from other group members. Understanding another person's EI, the project manager could influence the individual or group by identifying, understanding and addressing their needs.

Significance of the study

Organisations, that engage PMPs, continue to encourage the development of effective workgroups. The development of these workgroups allows the organisation to better contribute to effective organisational goals (Ghuman, 2011). A quality that is significant to the development of a workgroup or individual is EI (Ghuman, 2011). Ghuman (2011) discusses that emotions are an important quality as they provide the ability for an individual to perceive and manage emotions that help the individual adapt to different life situations. The four abilities of EI an individual should possess are: perception (of emotions in oneself and others), encoding (of behaviour in emotional situations), memory (recall of successful and unsuccessful emotional responses), and reasoning (successful emotional response based on received emotional input and prior encoding) (Ghuman, 2011). Combining these four abilities of EI with the four separate components discussed by Mazura et al. (2013), will increase the probability of enduring a harmonious and positive interpersonal relationship in the workforce (Rey et al., 2014). To help PMPs acquire this knowledge, education in EI is needed (Clark, 2010). Lindebaum and Jordan (2012) emphasise that PMPs who engage in different formats of education handle activities within the project differently to those who do not undertake education. Education in EI will benefit the project manager's development by learning new skills and abilities that can be used professionally and personally (Lindebaum & Jordan 2012). Developing EI provides PMPs with new skills that may allow the workplace to grow and mature. Gulak (2016) states that "When managers and employees develop EI within their workforce, everyone benefits". Singhal, Garg, and Saxena (2014) discuss that EI is believed to be a fundamental factor of an organisation's performance and growth. EI plays an important role in helping employees cope with change and achieving set business objectives (Singhal et al. 2014).

Literature review

Leadership in project management

There are many leadership competencies that are the makeup of a good project manager, and one of these competencies is '*EI*'. Love, Edwards & Wood (2011) point out that transformational leadership displays a similarity to the key components of EI. This high level of EI equips individuals such as PMPs with the ability to influence the moods, motivations and performance of their team members. Love, Edwards & Wood (2011) describe EI as an area that has been overlooked and one that has potential to improve overall performance. Transformational leadership is one of the most prevalent approaches to understanding the effectiveness of an individual, a group and an organisational (Love, Edwards & Wood, 2011) as well as direction and motivation (Tse & Chiu 2012). Transformational leadership is a type of leadership that promotes individual self-worth and self-esteem (Tse & Chiu 2012). Transformational leaders have the ability match specific individuals to different work situations which enhances the group's identification by promoting value internalisation and self-engagement.

Singhal, Garg, and Saxena (2014) discuss that a transformational leader inspires team members to have a different outlook on the work and creates awareness of the goals, performance and outcomes of the organisation. The leadership style that the project manager applies, refers to the approach and manner through which leaders provide direction, implement plans and motivates employees (Frimpong et al. 2017). A project manager's leadership is a fundamental skill within the mining industry. The overall the aim of the manager is to align the most suitable project manager to the requirements of the project (Muller & Turner 2010). Once the project has been identified, the manager will require the services of a PMP. The PMP holds the most important leadership role within the project. They provide the knowledge, understanding and abilities and knowhow required to bring an entire project together. The PMPs position is to provide leadership within the project applying characteristics such as behavioural, temperamental, emotional and mental attributes (Muller & Turner 2010). Combining these characterises allows PMPs to refine their approach to the required leadership style (Frimpong et al. 2017). Love, Edwards & Wood (2011) assert that individuals who possess a high degree of EI are better adapted to solve disputes and general problems during pre and post construction and have the ability to make satisfactory solutions. EI is made up of competencies such as self-awareness, emotional resilience, motivation, sensitivity, intuitiveness, and conscientiousness. Having this ability allows a PMP to regulate their emotions within the project and promote times of change, adversity, self-motivation and perseverance. It is important for the project managers to align their own personal characteristics with the characteristics of the project team. Cavazotte, Moreno & Hickmann (2012) maintain that an individual with good EI can show their emotions and understand how certain things impact and affect others.

According to O'Boyle et al. (2010), having the ability to recognise emotions in others can benefit leaders such as PMPs as they can alter their own emotions to deal with a particular situation. The authors highlight that PMPs with a high level of EI are a better predictor of job performance that required emotional labour. They further assert that it is to be expected that PMPs that have high EI would be better in helping their employees maintain a level of confidence and that they have the ability to positively interact with project stakeholders while performing emotional labour. In addition, the authors state that EI is important in jobs where employees interact with customers, as leaders with high EI help employees alter their emotion expressions to meet the display rules of the organisation.

Muller & Turner (2010) discuss that project managers can be categorised into groups such as: project star, promising new comer, focused creative expert, uncreative decision maker or thick-skinned pragmatist. Each of these categories combines a PMP to a certain project. The researchers further classify projectsas large projects, small projects, high priority, small priority, extent of information access and provision, need for technology skills, and the level of participation in goal formation (Muller & Turner 2010). Project requirements can be based on an application in areas such as technology, engineering, construction, production and infrastructure projects. The complexity of the project can be high, medium or low; the strategic importance of the project can be mandatory, repositioning and renewal; and the contract type of the project can be either a fixed price, re-measurement or alliance.

Follesdal and Hagtvet (2013) discuss a four-branch model that provides a breakdown of what EI is and how it relates to effective leadership. The four-branch model discussed by Follesdal and Hagtvet (2013) aligns with the Mayer-Salovey Caruso EI test (MSCEIT). The MSCEIT test is a test that measures "how well people perform tasks and solve emotional problems, rather than having them provide their own subjective assessment of their emotional skills" (Langley Group, p.1 2016). Research conducted by Fiori and Antonakis (2011) also refers to the four-branch model of perceiving, facilitating thought, understanding and managing emotions as demonstrated in the table (1) below:

Table 1: Four-branch model relating to emotions

Branch One	**Perceiving emotions**	The ability to identify the physical or psychological stages in other people and accurately understand their needs based on their emotions. Perceiving emotions is important within a leadership role as some individuals find it difficult to inspire, motivate and simulate their emotions in oneself (Follesdal, et al. 2013 and Fiori and Antonakis, 2011).
Branch Two	**Exercising emotions**	A tool to facilitate judgment and memory. The ability to use emotions to solve problems and create self-assurance within people. By displaying these emotions, leaders have the ability to generate creativity and with creativity comes solutions to unforeseen problems (Follesdal, et al. 2013).
Branch Three	**Understanding emotions**	Leaders need to understand the relationship among various emotions and the ability to perceive the causes and consequences of these emotions. These emotions are important in maintaining enthusiasm, which is an essential element of motivation. Understanding these elements allows the project leader to better anticipate how individuals within the group react a change of circumstances (Follesdal, et al. 2013).

Branch Four	**The ability to manage your own emotions and the emotions of others**	The ability to make others aware of their problems, but also make them confident about resolving their problems. By managing their emotions, the PMP acts as a role model for the project workers on how to promote morale, cooperation, teamwork and motivation (Follesdal, et al. 2013). A manager needs to consider multiple variables when seeking a PMP for a project. This section of the report has discussed that a manager must seek a PMP with the relevant experience in the required field and ensure and their leadership style has the appropriate qualities such as emotion intelligence. (Follesdal, et al. 2013).

Training in EI

Acquiring a PMP with required qualities is not a straightforward process. Organisations invest time and money recruiting and selecting the right PMP for the position (Cardy et al. 2011). Seidle, Fernandez, and Perry (2016) discuss that training can be delivered in various methods. Classroom education is still a commonly used method in all types of training. This training is easy to implement and offers significant economies of scale. Coaching or mentoring is also a popular method of training. This type of training has increasingly become popular as it focuses more towards job training (Seidle, Fernandez and Perry 2016). Providing training in EI gives the PMP the required understanding of EI and how it can be applied to a project. Training providers such as universities and external training organisations can train project managers increasing their understanding of EI. Increasing a PMPs understanding of EI will provide a foundation for project managers and project workers. An organisation will generally allocate funding to train and develop a PMP in categories such as communication, motivation and relationships. These categories directly relate to EI and are essential for effective project management (Ramazani and Jergeas 2015).

Benefits from undertaking training

Training can be captured as;

- *Emotional perception*: The ability to perceive emotions of yourself and the member of the group or team;
- *Facilitating cognition:* To recognise the emotions of group members in a way that all group members are aware of each other’s emotions;
- *Emotional understanding:* To be able to understand the prevailing emotions of the group; and
- *Emotional management*: The ability for the group to manage the emotions of the entire group in a manner to allow them to successfully complete the challenges that the group faces (Ghuman 2011).

The Australian Institute of Management conduct education in EI. Undertaking this training will provide the participant with a better understanding of personal emotions, enhancing friendships, facilitating difficult conversations with confidence and creating a positive work environment for others (AIM, 2018). Walker (2017) states that an individual’s level of EI is often related to a person’s job satisfaction level. Walker (2017) suggests that if a person has satisfaction within their job, their level of EI will increase with age and education. Walker (2017) discusses that EI is positively correlated with job satisfaction and suggests that EI training in a practical application has ability to potentially increase job satisfaction. Similar research undertaken by Love, Edwards & Wood (2011) suggest that organisations usually select PMPs who are considered to have high job satisfaction, emotionally intelligent. Those organisations provide the necessary training to help the PMPs become more aware of EI since organisations will see significant development and increased productivity within their current and future projects.

Research methodology

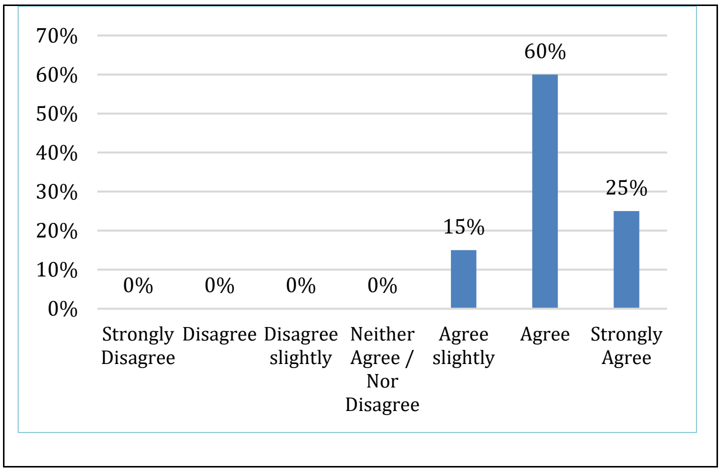
This study used the survey approach to achieve the research aim. The study was conducted at a central Queensland mining operation that operates on a 24 hour per day, 7 days per week schedule. The survey was disseminated over a three-week period that involved numerous project managers from a variety of different departments. This mining operation has a diverse range of employees that work various rosters, therefore quantitative research can be built to specific purposes (Zyphur and Pierides, 2017). Structured questions survey was designed and the participants were randomly selected from a variety of different project groups on site. A hard copy survey consisting of 15 Likert scale questions that put emphasis on EI was given to each participant during the daily morning pre-start meeting where the survey took place. The Likert scale used for the survey was sourced from the Institute for Health and Human Potential (2018). The survey provided to the respondents describes situations that everyone will experience sometimes throughout our lives (Institute for Health and Human Potential 2018). A pilot test was implemented prior to the start of the data collections. Two senior management team members were chosen to undertake this pilot test. The pilot test aimed to determine the ease of use, narrative flow and time required to complete the survey (Bryson et al. 2012). Minor amendment were then made to the survey for mass distribution. Participation was voluntary and the completion of the hard copy was considered as a consent to participate. The final number of surveys completed was 43 from a target of 50.

The time taken to review and complete the survey ranged between 3 and 5 minutes. The completed surveys were then deposited into a sealed box. The participants within this research consisted of project managers who engaged within maintenance projects on site. To ensure the entire process progressed accurately and ethically, it was paramount that a sound preparation procedure was developed and implemented to ensure that the obtained data from individuals within survey was accurate. The rationale for this study was to focus on project managers that have a high interaction rate with the project workers, aligns with the project management structure and have an invested interest in their own development and the development of the organisation. To minimise the effect of any identified weaknesses throughout the research project, the work included fortnight meetings with the project supervisor to examine the progress of the project. The data was aggregated and analysed by descriptive statistics and presented in a Microsoft Excel format. Marshall and Jonker (2010) maintained that descriptive statistics are a sound method of interpreting and summarising data to provide a description of the sample. Descriptive Statistics are methods that are used to summarise the characteristics of a sample and be displayed in graphs and charts (Bower, 2013).

Survey results, analysis and discussion

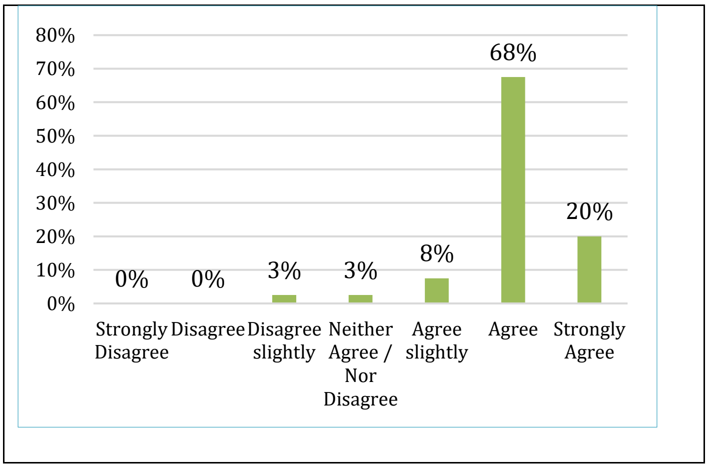
The survey was undertaken to identify the level of EI of project manages that work on maintenance projects within the Australian mining sector. The hard copy surveys were disseminated amongst various functions within the maintenance project group. 40 surveys were successfully completed, and two respondents chose not to participate and one respondent failed to provide answers to all the questions within the survey. The results show the project manages have the ability to adapt to change and continually provide a high standard of workmanship, solutions and performance which is crucial to the continual survival, success and sustainability of the organisation. The results also show that 84% of the workforce are in agreement with survey questions indicating that they are well in touch and understand how to deal with and manage their emotions. An observation during the survey suggests that the majority of respondents that undertook the survey generally have a strong relationship with their fellow workers. The work environment that the project managers and project workers belong to, shows signs of appreciation and respect.

The survey intended to measure the understanding of the EI. The response to the statement' *I have good understanding of my own emotion''* shows that 60% (24 out of 40) agree that they understand their emotions and revealing that working away from the family in remote locations can affect their personal relationships (Figure 1a). Employees ensured that they can observe the body languages of their fellows as an indication to their emotional conditions. A study undertaken by Jessen and Kotz (2011) discusses that body language such as facial expressions is a reliable source of emotional information. Meanwhile, the study investigated the impact of positive feedback on employees through the statement '' *I am a positive person''*.



Figure(1a): Understanding ones emotional feelings

The results indicate that 68% of participants believe that the positive feedback they got can inspire them and hence their colleagues within the work (Figure 1b). This result resonates with the work by (Zheng et al. 2015) which showed that employees feel satisfied by their managers positive feedback which contributes to employees' learning and work development (Zheng et al. 2015).



Figure(1b): positive feedback encourages my development

It is agreed that non-verbal communication can be identified as anger, fear, gratitude or happiness (Thompson et al. 2011). If a project is falling behind schedule, the project manager may feel disappointment towards the responsible person or group. Failure to clearly communicate your emotions can hinder the success of a project. This study highlights the level of communicating ones emotions through the question of '*I believe that I communicate my emotions well''*. Figure 2a shows that 43% (17 out of 40) agree they can communicate their emotions well. However, previous results found that people were more likely to confuse particular emotions with one another such as anger or disgust (Thompson and Hampton 2011). Yet, current results show that 30% (12 out of 40) (Figure 2a) agree that they miscommunicate their emotions and this may lead to confusion influencing the work performance.

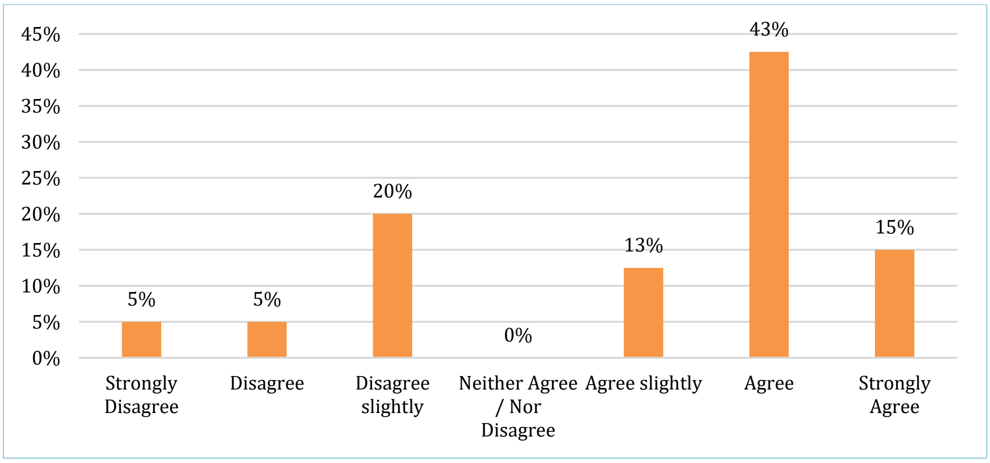
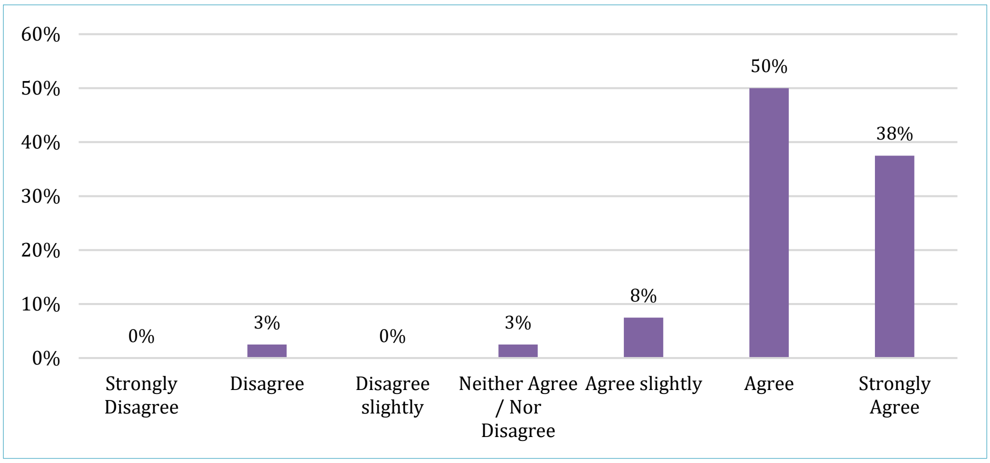


Figure (2a): I believe that I communicate my emotions well

Emotional well-being helps build positive relationships that create positive workforce, which in turns produce successful projects (Davis et al. 2006). Humour based individuals (supervisors) are expected to be well-received by the subordinates. The survey (Figure2b) revealed that 50% (20 out of 40) agreed that they have a good sense of humour which is believed to promote a higher commitment to practicing and incorporation their daily activities as well as induces amusement and important facet of positive emotions (Wellenzohn et al. 2018).



Figure(2b): I have a good sense of humour

The study also investigates the tendency of employees to make decision while they have not got enough information. The response to the statement '*I listen carefully without jumping to judgement*' shows that around 55% of the project managers in the study believe they are careful about their response to situations and they do not jump to conclusions before they got enough information. Jumping to judgement describes a person's tendency to make decisions or suggestions with minimal information (Lee et al. 2011). This current result can be viewed with the results from the statement '*I try to see things from another's perspective*' which reveal that 55% of the project managers (same percentage as those who indicated they do not jump over conclusions) also try to view things from others' perspectives and adopt their decisions accordingly (Figure 3b). However, this may not be the case when they need to react quickly particularly in issues that may be prone to negative consequences (Lincoln et al. 2010).

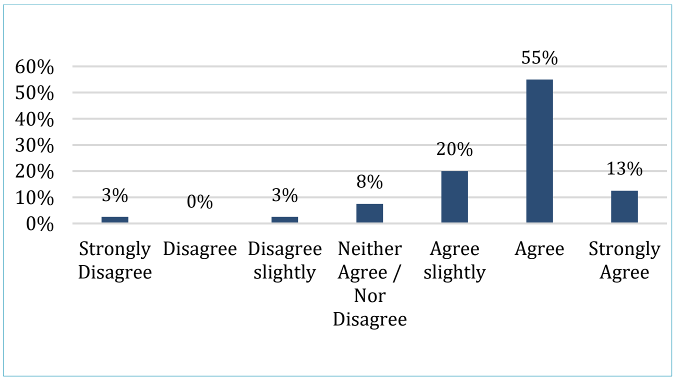
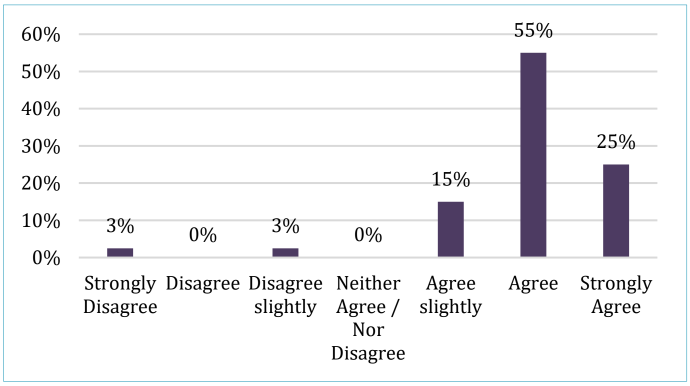


Figure (3a): I listen without jumping to judgment



Figure(3b): I am trying to see things from others' perspective

The study also examines the ability to control ones emotion and its impact on providing positive working environment. Houghton et al. (2012) discuss that emotional regulation can be defined as a heterogeneous set of processes that allow individuals. Results show that 56% (23 out of 40) agree that they can control their emotion in many situations by applying different techniques and trying the avoid the situation on time (Figure 4a). Pastor (2014) maintains that the ability to understand and use emotional states allows and individuals within the organisation to improve and redress situations.

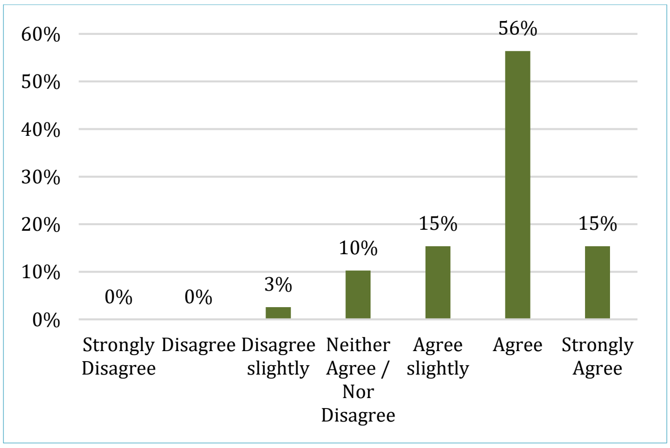
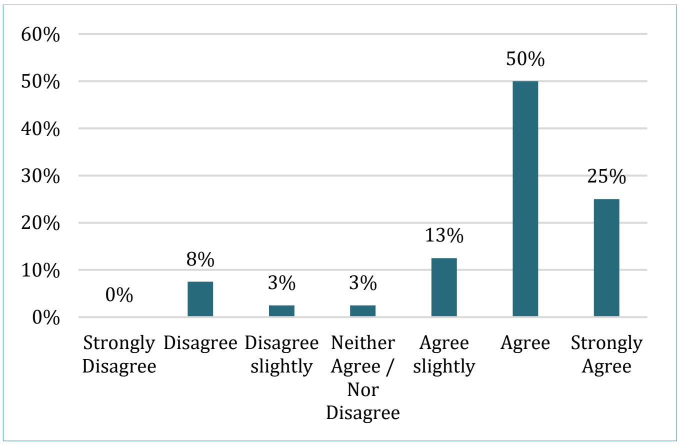


Figure (4a): I have the ability to control my emotions with others

Interestingly, the results reveal that around similar percentage (55%) who agree that they have the ability to control their emotions have also indicated that they believe their behaviour could affect others. In responding to the statement that 'I recognise my behaviours affects others', 55% of the project managers agree they are aware that their behaviour affects the outcome of the project (figure 4b). Behaviour control can be defined as the right or to direct and control how the worker does their work (Behavioural Control, 2018).



Figure(4b): I recognise how my behavior affects others

Conclusion

This study sought to understand the level of EI of project managers within the Australian mining industry. The research was completed by respondents undertaking a short Likert scale survey that was used to assess a project manager's self-awareness to EI. The study indicated that 84% of project managers believe they exercise a good level of EI and recognised that good EI is important to the success of projects and personal /professional development. However, it is the obligation of the organisation to establish the relevant training that will enable the project groups to successfully develop the skills required to produce successful projects. EI can support managing multiple relationships including, behavioural dimensions such as communication and motivation, and identifying/resolving conflicts. Observations during the survey showed that a significant number of project managers are in support for additional learning and development. The project managers felt that learning about themselves could potentially help in promoting better leadership qualities for professional development. The survey suggested that the majority of respondents believe the training in EI would help their understanding of EI and that EI positively impacts the performance of an individual and team. It is suggested that suitable training will enhance a project managers awareness in order to apply and utilise their emotions effectively. One could therefore conclude that, project managers working within an Australian mining industry would benefit from the implementation of a suitable EI training. It is evident that the respondents of the survey have shown great interest in increasing their EI as this contributes to overall job satisfaction. Yet, more research is required to understand the critical factors of individual's personality traits to identify the most appropriate training for the organisation.

Limitations within the study are influences that the researcher cannot control. Influences that cannot be controlled are factors such as individuals not wanting to complete the survey and or encouraging other group members to participate in the survey. Greener (2018) discusses limitations, that may also be applicable in this study, such as the layout of the survey and the type of questions within the survey that may contribute to poor research data being collected.

References

The Australian Institute of Management, Australia 2018, *leading with EI,* viewed 6th of August 2018, https://www.aim.com.au/courses/leading-emotional-intelligence

Bagshaw, M., 2000. EI - training people to be affective so they can be effective. *Industrial and Commercial Training*, vol. 32, no.2, pp.61–65.

Bryson, G., Turgeon, A. & Choi, P., 2012. The science of opinion: survey methods in research. *Canadian Journal of Anesthesia*, vol. 59, no. 8, pp.736–42.

Cardy, R, & Lengnick-Hall, L, 2011. Will They Stay, or Will They Go? Exploring a Customer-Oriented Approach to Employee Retention. *Journal of Business and Psychology*, vol. 26, no. 2, pp.213–217.

Cavazotte, Moreno & Hickmann, 2012. Effects of leader intelligence, personality and EI on transformational leadership and managerial performance. *The Leadership Quarterly*, vol. 23, no. 3, pp.443–455.

Clarke, N, 2010. The impact of a training programme designed to target the EI abilities of project managers. *International Journal of Project Management*, vol. 28, no. 5, pp.461–468.

Corona, C. & Randhawa, R.S., 2018. The Value of Confession: Admitting Mistakes to Build Reputation. *Accounting Review*, vol. 93, no.3, pp.133–161.

Cote, S., Lopes, P. N., Salovey, P., & Miners, C. T. H. 2010, EI and leadership emergence in small groups. *The Leadership Quarterly, Vol. 21, no.*3, pp. 496-508.

Davis, J. S. & Cable, J. H. 2006. Positive workplace: enhancing individual & team productivity. Paper presented at PMI® Global Congress 2006—North America, Seattle, WA. Newtown Square, PA: Project Management Institute.

Draugalis, J.L, & Plaza, C, 2009. Best Practices for Survey Research Reports Revisited: Implications of Target Population, Probability Sampling, and Response Rate. *American Journal of Pharmaceutical Education*, vol. 73, no. 8, pp.142

Dubravka Komić Stjepan Ljudevit Marušić & Ana Marušić 2015. Research Integrity and Research Ethics in Professional Codes of Ethics: Survey of Terminology Used by Professional Organizations across Research Disciplines. *PLoS ONE*, vol. 10, no. 7, p.e0133662.

Fast, N. J. 2009. *Power, incompetence, and hubris* (Order No. 3364498). Available from ProQuest Dissertations & Theses Global. (305007587). Retrieved from https://search-proquest-com.ezproxy.cqu.edu.au/docview/305007587?accountid=10016

Follesdal, Hallvard & Hagtvet, Knut, 2013. Does EI as ability predict transformational leadership? A multilevel approach. *The Leadership Quarterly*, vol. 24, no.5, pp.747.

Fiori & Antonakis, 2011. The ability model of EI: Searching for valid measures. *Personality and Individual Differences*, vol. 50, no.3, pp.329–334.

Frimpong, F, Gottwald, W. D., Ferreira, G. & Hargiss, K, 2017. Leadership Style and Project Success in Complex Humanitarian Emergencies: A Correlational Study. *Leadership Style and Project Success in Complex Humanitarian Emergencies: A Correlational Study*, pp. ProQuest Dissertations and Theses.

Garrett, Nathan, 2015. Textbooks for Responsible Data Analysis in Excel. *Journal of Education for Business*, vol. 90, no4, pp.169–174.

Ghuman, U., 2011. Building a model of group EI. *Team Performance Management: An International Journal*, vol. 17 no. 7/8, pp.418–439.

Greener, S., 2018. Research limitations: The need for honesty and common sense. *Interactive Learning Environments*, vol. 26 no 5, pp.567–568.

Gulak, K, Tramonte, Barbara & Benke, Meg, 2016. The Application of EI Theory in the Workplace: Implementing Adult Education Methods. *The Application of Emotional*

Jayawickreme, E.E., Zachry, C.E. & Fleeson, W., 2018. Whole Trait Theory: An integrative approach to examining personality structure and process. *Personality and Individual Differences*, no 136, pp 3

Jessen & Kotz, 2011. The temporal dynamics of processing emotions from vocal, facial, and bodily expressions. *NeuroImage*, vol. 58, no. 2, pp.665–674.

Jimenez, P., Winkler, B. & Dunkl, A., 2017. Creating a healthy working environment with leadership: the concept of health-promoting leadership. *The International Journal of Human Resource Management*, vol.28, no.17, pp.2430–2448.

Laerd Statistics 2018, *Descriptive Statistics*, viewed 20th of August 2018, https://statistics.laerd.com/statistical-guides/descriptive-inferential-statistics.php

Lincoln, T. M., Ziegler, M., Mehl, S. & Rief, W. 2010. The Jumping to Conclusions Bias in Delusions: Specificity and Changeability. *Journal of Abnormal Psychology*, vol. 119, no.1, pp.40–49.

Haddi & Benchaïba, 2015. A survey of incentive mechanisms in static and mobile P2P systems. *Journal of Network and Computer Applications*, vol. 58, pp.108–118.

Houghton, J. D., W. U, J., Godwin, J. L., Neck, C. P. & Manz, C. C. 2012. Effective Stress Management: A Model of EI, Self-Leadership, and Student Stress Coping. *Journal of Management Education*, vol. 36, no.2, pp.220–238.

Internal Revenue Service, Behavioural Control, viewed 17th of September 2018 https://www.irs.gov/businesses/small-businesses-self-employed/behavioral-control

Institute for Health and Human Potential (2018) *Test your EI free EQ Quiz*, 2018, viewed 23 August 2018, https://www.ihhp.com/free-eq-quiz/

Koopmann-Holm, B., Tsai, J.L. & King, Laura A., 2014. Focusing on the Negative: Cultural Differences in Expressions of Sympathy. *Journal of Personality and Social Psychology*, vol.107, no.6, pp.1092–1115.

Lindebaum, D. & Jordan, P.J 2012. Relevant but exaggerated: the effects of EI on project manager performance in construction. *Construction Management and Economics*, vol. 30, no. 7, pp.575–583.

Lee, Barrowclough & Lobban, 2011. The influence of positive affect on jumping to conclusions in delusional thinking. *Personality and Individual Differences*, vol.50, no.5, pp.717–722.

Love, P, Edwards, D. & Wood, E., 2011. Loosening the Gordian knot: the role of EI in construction. *Engineering, Construction and Architectural Management*, vol. 18, no. 1, pp.50–65.

Leicester University 2009, *Working with Percentages*, Student Learning Development viewed 15th September 2018 https://www2.le.ac.uk/offices/ld/resources/study-guides-pdfs/numeracy-skills-pdfs/Working%20with%20percentages.pdf

Mayer, J, Salovey, P, Caruso, D, *The Mayer-Salovey-Caruso Intelligence Test*, viewed 7th of May 2018, https://mikegosling.com/pdf/MSCEITDescription.pdf

Marshall & Jonker, 2010. An introduction to descriptive statistics: *A review and practical guide*. *Radiography*, vol. 16, no. 4, pp.1–7.

Mazura, A., Pisarskia, A., Chang, A. & Ashkanasy, N. M. 2013. Rating defence major project success: The role of personal attributes and stakeholder relationships. *International Journal of Project Management*, pp. International Journal of Project Management.

Malti, T., Eisenberg, N., Kim, H. & Buchmann, M. 2013, Developmental Trajectories of Sympathy, Moral Emotion Attributions, and Moral Reasoning: The Role of Parental Support. *Social Development*, vol.22, no.4, pp.773–793.

Mining People International, *Depression and mining: What to do if you're depressed,* viewed 16th of September 2018. https://www.miningpeople.com.au/news/depression-and-mining-what-to-do-if-youre-depressed

Miyagawa, Taniguchi & Niiya, 2018. Can self-compassion help people regulate unattained goals and emotional reactions toward setbacks? *Personality and Individual Differences*, vol.134, pp.239–244.

Muller & Turner, 2010. Leadership competency profiles of successful project managers. *International Journal of Project Management*, vol. 28, no. 5, pp.437–448.

O'boyle, E. H., Humphrey, R. H., Pollack, J. M., Hawver, T. H. & Story, P. A. 2011. The relation between EI and job performance a meta-analysis. *Journal of organizational behavior: OB; the internat. Journal of industrial, occupational and organizational psychology and behavior*, vol.32, no 5, pp.788–818.

Pastor, I., 2014. Leadership and EI: The Effect on Performance and Attitude. *Procedia Economics and Finance*, vol.15, pp.985–992.

Pellerin, R., Perrier, N., Guillot, X. & Léger, P.-M. 2013. Project Management Software Utilization and Project Performance. *Procedia Technology*, vol. 9, no. C, pp.857–866.

Pittarello, A., Conte, B., Caserotti, M., Scrimin, S., & Rubaltelli, E., *EI buffers the effect of physiological arousal on dishonesty*. Psychonomic Bulletin & Review, vol. 25, no. 1, pp.440–446.

Ramazani & Jergeas, 2015. Project managers and the journey from good to great: The benefits of investment in project management training and education. *International Journal of Project Management*, vol. 33, no. 1, pp.41–52.

Ramos, Mota & Corrêa, 2016. Exploring the management style of Brazilians project managers. *International Journal of Project Management*, vol. 34, no.6, pp.902–913.

Rey & Extremera, 2014. Positive psychological characteristics and interpersonal forgiveness: Identifying the unique contribution of EI abilities, Big Five traits, gratitude and optimism. *Personality and Individual Differences*, vol. 68. No. C, pp.199–204.

Rowe, S. F. & Sikes, S. 2006. Lessons learned: taking it to the next level. Paper presented at PMI® Global Congress 2006 — north America, Seattle, and WA. Newtown Square, PA: Project Management Institute

Santos, G.G., 2016. Career barriers influencing career success. *Career Development International*, vol. 21, no. 1, pp.60–84.

Saunders, Mark N.K.;Lewis, Philip;Thornhill, Adrian, 2012. *Research Methods for Business Students*, Pearson Education Limited.

Savelsbergh, Havermans & Storm, 2016. Development paths of project managers: What and how do project managers learn from their experiences? *International Journal of Project Management*, vol.34, no.4, pp.559–569.

Sekaran, U., & Bougie, R. (2016). *Research methods for business: A skill-building approach* (Seventh edition.).

Seidle, B., Fernandez, S. & Perry, J.L., 2016. Do Leadership Training and Development Make a Difference in the Public Sector? A Panel Study. *Public Administration Review*, vol. 76, no. 4, pp.603–613.

Shannon, J. Patterson, B., Lohmann, J. & Robinson, L., 2017. Influence of Employee Engagement Survey Results on Business Leaders' Decisions. *Influence of Employee Engagement Survey Results on Business Leaders' Decisions*, pp. ProQuest Dissertations and Theses.

Singhal, T., Garg, B. & Saxena, D., 2014. *Organizational Productivity through EI. Pranjana*, vol. 17, no.1, pp.47–55.

Social Research Methods 2006, *Descriptive Statistics*, viewed 20th of August 2018, https://www.socialresearchmethods.net/kb/statdesc.htm

Shamsuddin & Rahman, 2014. The Relationship between EI and Job Performance of Call Centre Agents. *Procedia - Social and Behavioral Sciences*, vol. 129, pp.75–81.

The Programs Managers Blog, 5 Behaviours that can ruin your project team, viewed 17th September 2018 http://www.the-program-manager.com/soft-skill/5-behaviors-that-can-ruin-your-project-team/

Thompson, E.H. & Hampton, J.A., 2011. The effect of relationship status on communicating emotions through touch. *Cognition & Emotion*, vol.25, no2, pp.295–306.

Tse, H.H.M. & Chiu, W.C.K., 2012. Transformational leadership and job performance: A social identity perspective. *Journal of Business Research*, pp.Journal of Business Research, 2012.

University of Southern California 2018, *Organising Your Social Sciences Research Paper: Limitations of the Study,* viewed 23rd September 2018, https://libguides.usc.edu/writingguide/limitations

Wiki, 2018, Business Ethics, wiki, viewed 22nd July 2018, https://en.wikipedia.org/wiki/Business_ethics

Wallace, M. & Sheldon, Neroli, 2015. Business research ethics participant observer perspectives. *Journal of business ethics: JOBE*, vol. 128, no. 2, pp.267–277.

Walker, S., Walker, T., Parnam, P. & Randall, 2017. The Explanatory Relationship Between EI and Job Satisfaction for Construction Industry Professionals. *The Explanatory Relationship Between EI and Job Satisfaction for Construction Industry Professionals*, pp. ProQuest Dissertations and Theses

Wellenzohn, S.T., Proyer, R.T. & Ruch, W., 2018. Who benefits from humor-based positive psychology interventions? The moderating effects of personality traits and sense of humor. *Frontiers in Psychology*, vol.9, pp.3

Zheng, X., Diaz, I., Jing, Y. & Chiaburu, D. S. 2015. Positive and negative supervisor developmental feedback and task-performance. *Leadership & Organization Development Journal*, vol. 36, no.2, pp.212–232.

Zyphur, M.J.J. & Pierides, D.C.C., 2017. Is Quantitative Research Ethical? Tools for Ethically Practicing, Evaluating, and Using Quantitative Research. *Journal of Business Ethics*, vol. 143, no.1, pp.

A PERFORMANCE-BASED BUILDING CODE ON STATUTORY MAINTENANCE: EXPLORING THE POLICY FOR CONSUMER SAFETY IN AUSTRALIA

Stephen Scimonello[1], Anona Armstrong[2], Himanshu Shee[3]

[1]Australian Institute of Building Surveyors, Sydney, Australia

[2] Business School, Institute for Sustainable Industries & Liveable Cities, Victoria University, Melbourne, Australia

[3]Business School, Victoria University, Melbourne, Australia

Abstract

Each state and Territory in Australia have adopted their own form of building regulation that incorporates the National Construction Code (NCC), Building Code of Australia Vol. 1 & 2. The use of performance solutions to meet the performance provisions within the NCC have inadvertently increased the dependency on active and passive fire safety systems. These safety systems are known as Essential Safety Measures (ESMs) and are required to be maintained over the life of the building. Several different forms of building policy including the maintenance of ESMs, creates a confusing situation for the community, building owners and companies operating throughout Australia. A critical review of the literature demonstrates that there is minimal research in this complex area. This paper builds on and expands the existing body of knowledge to the building regulatory framework and policy for ESMs through a performance-based building code. It concludes that there is an urgent need for further research into the policy and the consequences for consumer safety. This paper therefore examines the deregulated building regulation environment in Australia for statutory maintenance within a performance-based building code and the implications for consumer safety arising out of the policy. The study used literature review to explore building policy and regulations across all states of Australia. We found that very limited research is done in this space and lack a consistent approach in maintenance of ESM. Therefore, the area of future research in support of performance-based building codes are identified.

Key Words

Essential safety measures, National Construction Code, building control, regulatory enforcement, building regulation, Australia.

Introduction

Australia has a deregulated building management policy that is inconsistent in each state and territory with cost implications versus risk not being fully understood, or recognised (Heijden and de Jong 2009). The National Construction Code (NCC) comprises of the Building Code of Australia, Volume One and Two. Volume One is for class 2 to 9 buildings and refers to the design and construction of multi residential, commercial, industrial and public buildings. Volume Two is for class 1 and 10 buildings and refers to the design and construction of domestic type buildings i.e. houses, sheds, garages, carports, swimming pools, fences and the like.

Volume one and volume two of the Building Code of Australia (BCA) are the main referenced documents that are used for the technical design of all buildings to ensure that they meet the minimum level of safety, amenity, accessibility and sustainability in Australia (National Construction Code 2019).

In 1997, the Australian Building Codes Board adopted a nationalised performance-based building code (Productivity Commission 2004). When applying the performance provisions used in the NCC, compliance can be achieved by two ways, the first is via the 'deemed to satisfy' approach, that is applying the prescriptive path of the code to meet the performance requirements, and the second is via a performance solution, or a combination of the two. A performance solution is where an assessment is made against the relevant performance criterion that demonstrates that the proposed solution, meets the equivalence of the performance requirement (Australian Building Codes Board 2019).

The use of performance solutions to meet the performance requirements have inadvertently increased the dependency on active and passive fire safety systems. This dependency is placing a heavy reliance on the maintenance of these systems to enable them to work as intended (Bukowski and Babrauskas, 1994). In addition to the installation of these safety systems, they are also required to be maintained over the life of the building, and that places higher running costs for individuals and companies alike (Wong and Xie 2014). These safety systems are known as Essential Safety Measures (ESMs), and include features such as; sprinkler systems, smoke alarms, emergency lighting, exit doors, fire rated walls and management processes. All these measures are required to be regularly maintained at pre-determined levels and frequencies over the life of the building (Productivity Commission 2004) and this places higher running costs for building owners and companies alike (Horner, El-Haram and Munns, 1997; Bukowski and Babrauskas 1994).

Each state and Territory in Australia has adopted their own form of building policy that incorporates the National Construction Code, Building Code of Australia Vol. 1 & 2 (Heijden 2008). There appears to be a need for research to provide a consistent approach across Australia. Several different forms of building policy (Heijden 2008), including the maintenance of ESMs, creates a confusing situation for property owners and companies alike operating throughout Australia. This paper will add to the existing body of knowledge regarding the policy for ESM's and consumer safety and will shed light on the cause and consequences of noncompliance with the policy being the regulation for builders, industry and more importantly, the consumer.

Building regulations are generally not discussed in the Australian constitution and therefore administration is the responsibility of each state and territory. This has provided for different enforcement and administrative provisions adopted in the building regulations in each state and territory. Some would argue that it would be optimal to provide one clear national building law across Australia (Australian Institute of Building Surveyors 2019), however this was not considered as a viable alternative for each state and territory (Building Ministers Forum 2019). The paper therefore aims to explore the policies across states and territories and attempts to rationalise a coherent and unified policy, being the regulation regarding ESMs.

The following research questions are addressed:
RQ1: What is the current building regulatory framework and policy for ESMs across Australia?
RQ2: Will the outcomes of a performance-based building code protect consumer safety over the life of the building?

The paper is organised in six sections. Section 2 outlines the methodology used. Section 3 outlines the literature review of the policy regarding building maintenance. Section 4 provides a summary of each state and territory policy regarding ESMs and the implications for owners for non-compliance of the policy. Section 5 provides a discussion regarding the policy and provides the issues of non-compliance with the policy for consumer safety and how this can be impacted by noncompliance including describing the gaps in the literature. Section 6 outlines the findings that relate to the research questions and conclusions reached for further research to determine the policy for ESM's.

Methodology

This research used literature review approach to explore relevant articles from databases such as EbscoHost and Scopus using key words like essential building safety measures, National Construction

Code, building control, regulatory enforcement, building regulation in Australia context limited until 2019. The review focused mainly on all the building regulations and Acts that were applicable to all states. Further, we reviewed all applicable Acts and regulations including the policy from each states applicable ESM policy. The policies across all states were identified and compared to see if they have similarity or differences. The following section presents a detailed of the literature review.

Literature review on policy and regulation

Buildings are designed and regulated to ensure that they are fit for purpose, facilitate cost effective construction methods and provide mechanisms for ease of maintenance (Building Act 1993 Victoria).

Building regulation is a neglected subject in academic studies of policy and regulation (Heijden and de Jong 2009). Major catastrophic events such as the Childers Backpacker fire that killed 15 backpackers and Kew Cottages fire that killed 9 intellectually disabled residents, highlights the inability of existing code structures and policy to deal with previous building requirements (O'Brien 2016). Other major fires that have impacted with building policy in Australia are the Lacrosse fire in Docklands and the Neo 200 fire in Spenser Street Melbourne both in Victoria. It could be argued that there was a lack of effective maintenance for these buildings (Carter 2019). Current building policy does not rate protection of buildings as a high priority, instead it has an emphasis on life safety (Productivity Commission 2004, p. 106). Although a building has been assessed as compliant with the NCC, it does not necessarily offer protection of property, such an assessment methodology may not meet owners and community expectations, as well as insurance company requirements (Productivity Commission 2004).

Previous studies concluded (Productivity Commission 2004; Heijden 2008) that the role of maintenance is not readily understood by building owners and the general public. Interestingly O'Brien (2016) discusses the codification of existing building practice and how this can be transitioned into three principled mechanism for change and appears to be the first to review building regulation and practice to codification. These mechanisms are logical incrementalism being the process of codification of existing practice, emergent strategy being 'code by catastrophe' to meet community expectations as a reactionary approach to events, and co-participative change management models being the adoption of community involvement in all decision-making processes (O'Brien 2016). In this regard, ESMs could be viewed as an emergent strategy as this policy was adopted in Victoria in 1994 under the Kennett area of reforms to building policy in response to community expectations (Parliament of Victoria 2013).

The Framework Imposed

Performance based building codes commenced in Australia with the adoption of the nationalised performance-based Building Code of Australia (Heijden, 2008). The Building Code of Australia is now a fully integrated performance-based document. The Building Code of Australia is unique in that the majority of residential and commercial buildings are subject to a number of performance decisions that places heavy reliance on the maintenance of safety systems, such as active and passive safety systems, management processes and testing regimes. A privatised and de-regulated industry for building code assessment, has allowed greater flexibility and liaison with building professionals that has produced cost effective and innovative building and construction solutions (Heijden, 2008). This also provides greater flexibility in the use of performance-based building policy in the initial design process (Centre for International Economics 2013). However, ESM maintenance has not been integrated into this policy.

Heijden's research (2008) into the Australian building regulation regimes reviewed building policy throughout Australian states and territories. The research provided a number of responses from key industry groups including government departments, large construction firms and private industry stakeholders through a questionnaire approach; however, community expectations including building ownership obligations were not considered in detail. This research concluded that in the Australian deregulated construction industry, by using a performance-based code for building assessment, building policy has been rated as good to very good and has been more effective and provided cost savings in the construction process (Heijden, 2008).

With the use of performance-based building products increasing, greater emphasis and awareness for consumers and reliance on independent testing is required (O'Brien 2016). This situation is also true for the maintenance of safety systems that are required to ensure consumer and occupant safety is maintained over the life of the building (Australian Building Codes Board 2014). Commercial building tenants typically do not have any perceived expectations for the performance of buildings; but essentially only require that they are fit for purpose (Arditi & Nawakorawit 1999). Research completed by Arditi and Nawakorawit (1999) provides a valuable insight into the relationship between property managers, tenants and building ownership obligations that is still applicable today and is referenced in a number of peer reviewed articles. Community expectations and ownership obligations were also reviewed by Heijden (2008) and the Productivity Commission (2004) with their research indicating that community expectations and ownership obligations are not fully understood in terms of building policy. This could also be true with respect to the management processes of ESMs.

According to the Australian Building Codes Board, only 50% of buildings utilise a performance-based solution approach as opposed to the 'deemed to satisfy' provisions in the approval and construction process (Centre for International Economics 2013). The most recent study by the Productivity Commission (2004), found that 50% of building practitioners agreed with the findings that the greater use of performance-based regulation, increases the maintenance provisions and costs for buildings over their lifetime. The estimated benefit however from the use of performance-based building codes provide a net benefit annually of $780 million to the Australian economy (Centre for International Economics 2013). Therefore, quantification of the performance provisions of the building Code by the Australian Building Codes Board (2019) will further increase the use of performance assessments to achieve compliance, thereby increasing the maintenance requirements of active and passive systems by the owner and consumer over a buildings lifetime.

The differing policies around Australia

Australian Building Codes Board

The Australian Building Codes Board was established in 1994 under an intergovernmental agreement signed by all tiers of government to produce, administer and develop the content for the National Construction Code (Australian Building Codes Board 2019).

Essentially the NCC is called up in each state's legislative powers through their respective Acts of parliament and subordinate legislation. The NCC is the technical component of the policy and the administrative functions for the policy is administered by each state and territory. The administration of on-going ESM compliance emanating from the use of performance provisions falls to each state and territory to administer.

Victoria

In Victoria, the administration function for the maintenance of ESMs is contained within part 15 of the Building Regulations 2018 (Victoria). Part 15 specifies that all buildings having a BCA classification of 1b through to 9 are required to be maintained.

All buildings specified under the policy regardless of age are required to be maintained at pre-determined intervals throughout the life of the building. For all buildings that have been constructed, altered or extended after 1 July 1994, require either an occupancy permit or certificate of final inspection to be issued with a maintenance determination that specifies the element, frequency and standard to apply for maintaining the ESM. For buildings that were constructed prior to 1 July 1994, the ESM's are required to be maintained to fulfil their purpose (Building Regulations 2018 Victoria).

It is the responsibility of each local government authority through the municipal building surveyor and/or the chief officer of the relevant fire authority to enforce the maintenance provisions of all relevant buildings.

Buildings that are subjected to ESMs are divided up into three categories depending when they were constructed, altered or extended, these are;

- Buildings built after 1 May 2005
- Buildings built between 1 July 1994 and 1 May 2004
- Buildings built prior to 1 July 1994

(Building Regulations 2018 Victoria)

These regulations require the building owner to maintain their essential services for the building throughout the year and are required to self-regulate the ESM policy under part 15 of the building regulations 2018 (Victoria). Therefore, building owners are required to complete the appropriate testing mechanisms including maintenance logbooks and complete a yearly self-certification stating that all ESM's have been maintained throughout the preceding year. These maintenance checks, logbooks and self-certification must be available for display or viewing by the relevant local government authority through the municipal building surveyor and/or the Chief Officer of the relevant fire authority (Building Regulations 2018 Victoria).

The fines applied for non- compliance under Part 15 of the Building Regulations 2018 (Victoria) are summarised in the following table;

Table No 1: Implications for consumer noncompliance

Reference	Description of offence	Penalty Units
Reg. 216	Owner must comply with maintenance determination.	20
Reg. 218	Relevant building surveyor must prepare or update maintenance schedule for an existing building or place of public entertainment.	10
Reg. 223(1)	Owner must prepare annual essential safety measures report within 28 days before each anniversary of the relevant anniversary date.	20
Reg. 223(2)	Owner must prepare annual essential safety measures report within 28 days before 13 June 2018 and each anniversary of that date for buildings constructed before 1 July 1994.	20
Reg. 225	Records relating to essential safety measures must be made available.	20
Reg. 226	Maintenance responsibility of owner of building or place of public entertainment to ensure ESMs are maintained to fill their purpose.	20
Reg. 227	Essential safety measures not to be removed from approved locations	20
Reg. 228	Maintenance of exits and paths of travel by occupiers of buildings or places of public entertainment.	20

Source: Building Regulations 2018 (Victoria)

There are no mandatory reporting provisions requiring a building owner to submit to any authority that the buildings fire safety systems have been maintained for the preceding year.

New South Wales

In New South Wales (NSW), ESMs are referred to essential fire safety systems and are required to be maintained and be fit for purpose. The governing provisions are contained within the Environment Planning and Assessment Act 1979 (NSW) and the Environment Planning and Assessment Regulation 2000 (NSW). Specifically, the essential fire safety systems are referenced within Part 9 of the building regulations 2000 (NSW).

An annual fire safety statement is required to be completed and submitted by the owner of a building that has a BCA classification of 2 through to 9. It is only buildings that are classified as being a BCA class 2 to 9 that have been the subject of a building approval or fire safety notice by the local council after 1 July 1988, that are required to comply with the policy (Environment Planning and Assessment Regulation 2000 NSW). The annual fire safety statement must be provided to the local authority and the NSW Fire & Rescue Service in addition to having it displayed in a prominent position in the building (Department of Planning, Industry and Environment 2018). There appears to be a gap in the provisions for buildings constructed prior to 1 July 1988 that have not been subjected to a building approval or a fire safety notice, as there are no annual reporting and compliance requirements.

Recently the NSW government have created a competent fire safety practitioner for two areas, the first is for the design of fire safety systems and the second is for carrying out of maintenance work on fire safety systems (Department of Planning, Industry and Environment 2018 NSW). Only qualified competent fire safety practitioners are permitted to carry out certain maintenance requirements for the essential fire safety systems. This new requirement also requires that all fire safety statements must be issued by competent fire safety practitioners thereby requiring building owners when they submit their annual fire safety statements, to require it be completed by a competent fire safety practitioner.

The fines applied for non- compliance of essential fire safety systems are contained within Schedule 5 of the Environmental Planning and Assessment Regulation 2000, and are summarised in the following table;

Table No 2: Implications for consumer noncompliance

Schedule 5 Penalty notice offences	Individual $	Corporation $
clause 177 (1) Annual fire safety statement to be given to consent authority and Fire Commissioner and prominently displayed in building		
(a) for the offence of failing to give an annual fire safety statement that occurs during the first week after the time for giving the statement expires	1000	1000
(b) for the offence of failing to give an annual fire safety statement that occurs during the second week after the time for giving the statement expires	2,000	2,000
(c) for the offence of failing to give an annual fire safety statement that occurs during the third week after the time for giving the statement expires	3,000	3,000
(d) for the offence of failing to give an annual fire safety statement that occurs during the fourth or any subsequent week after the time for giving the statement expires	4,000	4,000
clause 177 (3) (b)	580	580
clause 180 (1):		
(a) for the offence of failing to give a supplementary fire safety statement that occurs during the first week after the time for giving the statement expires	1,000	1,000
(b) for the offence of failing to give a supplementary fire safety statement that occurs during the second week after the time for giving the statement expires	2,000	2,000
(c) for the offence of failing to give a supplementary fire safety statement that occurs during the third week after the time for giving the statement expires	3,000	3,000
(d) for the offence of failing to give a supplementary fire safety statement that occurs during the fourth or any subsequent week after the time for giving the statement expires	4,000	4,000
clause 180 (3) (b)	580	580
clause 182 (1)	3,000	6,000

Source: Environmental Planning and Assessment Regulation 2000 (New South Wales)

Queensland

In Queensland, ESMs are referred to as fire safety installations and apply to all buildings regardless of age but does not include a detached dwelling and non-habitable buildings (Building Fire Safety Regulations 2008 Queensland). The relevant legislation applicable for the maintenance of fire safety installations are;

- Building Act 1975
- Building Code of Australia (BCA)
- Building Fire Safety Regulation 2008
- Building Regulation 2006
- Fire and Rescue Service Act 1990
- Queensland Building Services Authority Act 1991
- Queensland Development Code (QDC)

The policy for maintaining buildings are detailed in the Queensland Development Code MP6.1 Maintenance of Fire Safety Installations (Department of Housing and Public Works 2008). The requirements to conduct maintenance on the fire safety installations is the responsibility of the building owner, if the building owner is the occupier. If the building has a tenant, then it is the tenant's responsibility to maintain. All buildings are required to have their respective fire safety systems maintained and tested with the building by the occupant or owner and they must lodge a yearly statement to the Queensland Fire Safety and Emergency Services certifying that the building has been maintained to the relevant standards (Building Fire Safety Regulations 2008 Queensland).

Queensland has further developed an increased safety requirement for higher risk buildings, this is the provision of a Fire Safety Adviser. The Fire Safety Adviser is required to be appointed and trained by the occupiers of buildings deemed to be a high occupancy building as defined in the Building Fire Safety Regulation 2008. The buildings that are deemed to be high occupancy are, a BCA class 2, 3, 5, 6, 7b, 8, 9a or 9b buildings that have 30 or more people employed, or a BCA class 2 or 3 building that has an effective height of more than 25 metres (Building Fire Safety Regulation 2008 Queensland). The Fire Safety Advisor does not necessarily need to be building specific however, it is the role of the Fire Safety Advisor to provide first response evacuation instructions and provide or arrange evacuation coordination instructions.

Budget accommodation have additional fire safety provisions that must be maintained. Budget accommodation buildings are buildings that accommodate six or more unrelated persons that have shared access to bathroom facilities including toilets (Building Fire Safety Regulations 2008 Queensland). These types of buildings are generally backpacker hostels, bed and breakfast establishments and the like.

The penalties for noncompliance of the policy are contained in the Building Fire Safety Regulations 2008 (Queensland). The applicable penalties for non-compliance with the prescribed fire safety installations are summarised in the following table;

Table No 3: Implications for consumer noncompliance

Reference	Description of offence	Penalty Units
Reg. 50	A person must carry out maintenance of a prescribed fire safety installation in compliance with QDC part MP6.1	30
Reg. 53	Person must give occupier must give the occupier of the building a notice about the defect in the approved form (a *critical defect notice*) within 24 hours after the person carries out the maintenance of the installation.	30
Reg. 54(1)	The occupier of a building must ensure that maintenance of each prescribed fire safety installation for the building is carried out by an appropriately qualified person	30
Reg. 54(2)	The occupier of a building must ensure each prescribed fire safety installation for the building is inspected and tested at intervals in compliance with QDC, part MP6.1.	30
Reg. 54(4)	The occupier of the building must ensure the repair is carried out or the corrective action is taken no later than 1 month after the maintenance of the installation was carried out, unless the occupier has a reasonable excuse	30
Reg. 55(1)	The occupier of a building must keep a record of maintenance, in compliance with subsections (2) and (3), for the maintenance of each prescribed fire safety installation for the building.	20
Reg55(A)	The occupier of a building must, at intervals in compliance with QDC, part MP6.1, prepare a statement (an *occupier statement*) that complies with the part about the maintenance of each prescribed fire safety installation for the building.	20
Reg. 55(2)	The occupier must keep a copy of each occupier statement with the record of maintenance for 2 years after the statement is prepared.	20
Reg. 55(3)	The occupier must, within 10 business days after the occupier is required to prepare an occupier statement, give the commissioner a copy of the statement.	20
Reg. 55B	Applies to occupiers of certain residential style buildings, eg budget accommodation where a fire safety management plan is required and a building used for conducting a residential service for which a fire safety management plan is required. The occupier must keep with eh fire safety management plan of the building, including records of maintenance and occupier statements prepared under sec. 55A of the Act.	20

Source: Building Fire Safety Regulations 2008 (Queensland)

Australian Capital Territory

In the Australian Capital Territory (ACT), ESMs are referred to as fire protection systems and equipment and these systems are also known as fire appliances within the Emergency Act 2004 (ACT). All buildings having a BCA classification of 2 through to 9 regardless of age are required to be maintained and be fit for purpose over the life of a building (Building (General) Regulation 2008 ACT). The Building (General) Regulation 2008 (ACT) applicable policy requirements for consumers that relate to the on-going maintenance of buildings, are;

- Emergencies Act 2004.
- Emergency Regulations.
- Building Act 2004 and regulations.
- Planning and Development Regulation 2008.

These provisions are generally administered by the Australian Capital Territory Fire & Rescue through the Emergencies Act 2004 (ACT). There are no obligations to submit proof of on-maintenance of a buildings fire protection systems and equipment, however the relevant chief officer of Fire & Rescue has the ability to undertake inspections, require upgrades to buildings and place limits of occupation of buildings (Emergencies Act 2004 ACT). This is generally administered under Part 5.4 of the Emergencies Act 2004 (ACT). The occupier of the building is required to ensure that all fire protection systems and equipment are maintained in accordance with a proper maintenance standard. This is required to be completed in accordance with AS1851 or AS/NZS2293.2 or a standard approved as part of the building approval or a standard of maintenance prescribed by regulation.

The penalties for noncompliance of the policy are contained in the Emergencies Act 2004 (ACT) and are summarised in the following table;

Table 4: Implications for consumer noncompliance

Description	Penalty
The occupier does not maintain the fire appliance in accordance with a proper maintenance standard	50 penalty units
A person commits an offence if the person removes, destroys, damages or interferes with; • a fire appliance; or a container used for housing or storing fire appliances.	50 penalty units.
The occupier of premises commits an offence if; • a fire appliance at the premises has been removed, destroyed or damaged or is defective; and the occupier knows or is reckless about whether the fire appliance has been removed, destroyed or damaged or is defective; and the occupier fails to repair or replace the fire appliance.	50 penalty units

Source: Emergencies Act 2004 (Australian Capital Territory)

South Australia

In South Australia (SA) ESM's are referred to essential safety provisions and will be administered through regulation 100 of the draft Planning, Development and Infrastructure (General) Development Assessment Variation Regulations 2019 (SA) once adopted. Ministerial Building Standard SA002 provides the performance and deemed to satisfy requirements for the installation, maintenance and testing of essential safety provisions installed (Department of Planning, Transport and Infrastructure 2019 SA). The Ministerial Building Standard SA002 is referenced through the Planning, Development and Infrastructure Act 2016 (SA).

All buildings having a BCA classification of 2 through to 9 are required to be maintained in accordance with the Ministerial Building Standard SA002 (Planning, Development and Infrastructure Act 2016 SA). There are certain exemptions to this policy for buildings that have a BCA classification of 1b or 2 that do not have a rise in storeys exceeding three with a maximum floor area of 2000sqm, or the building is a BCA class 3, 4, 5, 6, 7, 8 or 9b that does not have a rise in storeys of 2 and a maximum floor area exceeding 500 sqm.

The owner of a building must submit annually to the relevant local government authority, verification that all applicable essential safety provisions have been tested and maintained through completion of a Form 3, essential safety provision maintenance verification. This must be completed within 60 days after the end of each calendar year.

The penalty for noncompliance for the owner is a fine of up to $10,000 if the essential safety provisions are not adequately maintained and the annual statement is not submitted to the relevant government authority (Planning, Development and Infrastructure (General) Regulations 2017 South Australia).

Western Australia

In Western Australia, ESM's are referred to as safety measures and are administered through Part 8, Divisions 2A reg. 48A of the Building Regulations 2012 (Western Australia).

Under regulation 48A(2) of the Building Regulations 2012 (Western Australia) specifies that the owner of an existing building must ensure that the safety measures in each part of the building safety systems are capable of performing as intended. Therefore, the maintenance provisions rely on the building owner to maintain their essential safety systems to be fit for purpose. There are no formal reporting requirements, however a maximum fine of $5,000 applies if noncompliance is determined by the relevant authority (Building Regulations 2012 Western Australia).

Occupancy permits are required to specify the maintenance and inspection regimes for safety measures and all buildings having a BCA classification of 2 through to 9 are subject to this provision. Under section 44(1) of the Building Act 2011 (Western Australia), occupiers also have a role to ensure that maintenance of essential safety measures are maintained. This means that Occupancy Permits issued for buildings must be complied with, and this includes the testing and maintenance of essential safety provisions for the building.

The penalty for noncompliance by the owner is;

- for a first offence, a fine of $50 000;
- for a second offence, a fine of $75 000;
- for a third or subsequent offence, a fine of $100 000 and imprisonment for 12 months.

(Building Act 2011, Western Australia)

There are no mandatory reporting provisions requiring a building owner to submit to any authority that the buildings fire safety systems have been maintained for the preceding year.

Northern Territory

In the Northern Territory ESMs are referred to as fire safety measures and are required to be maintained in certain buildings as specified in schedule 2 of the Fire and Emergency Regulations 1996 (Northern Territory). Specific Building Code classification have not been used however the use of the building has been used to determine if maintenance of the fire safety measures are required. The buildings use ranges from residential accommodation to public and commercial buildings as classified in Vol. 1 of the BCA.

The legislative provisions that detail and enable the maintenance of buildings are;

- Building Act.
- Building Regulations.
- Fire and Emergency Act.
- Fire and Emergency Regulations.

Section 50 of the Building Act 1993 (Northern Territory), specifies that the building regulations provides for the maintenance and safety of existing or proposed buildings. Interestingly, the Fire and Emergency Act (Northern Territory) and accompanying regulations makes provisions for prescribed buildings to be inspected by the Northern Territory and Rescue Service (Fire and Rescue Service, 2019). This is to ensure that prescribed buildings are being maintained to ensure that their buildings fire safety measures are being maintained and fit for purpose.

Under the fire and emergency regulations, the owner of a prescribed building is responsible for maintaining the fire safety measures. The owner must prepare and make available for inspection all applicable logbooks, maintenance records and annual condition reports in accordance with Australian Standard AS1851.

There are a range of offences for owners that do not comply with the building fire maintenance provisions under the fire and emergency regulations, and are summarised in the following table;

Table 5: Implications for consumer noncompliance

Reference	Description of offence	Penalty Units
Reg. 11(1AA)(1)	Owner must ensure that all persons who work in the building are given instruction on measures for the protection of persons in the building from fire and related emergencies annually	100
Reg. 11(1AA)(3) & (4)	Owner must keep register of persons whom instructions were given 20 penalty units and owner must provide register for inspection on demand	100
Reg. 11(1AA)(d)	Owner must ensure that a buildings fire safety measures including designated fire exits ae not blocked are maintained	100

Source: Fire and Emergency Regulations 1996 (Northern Territory)

The Penalty Unit Acts 2009 detail a single unit to be $155 for the 2018/19 year.

Tasmania

In Tasmania, ESMs are referred to as essential building services and are required to be maintained under Part 14 of the Building Act 2016 (Tasmania). The Building Act (Tasmania) requires all maintenance of the essential building services to be maintained by the responsible owner. A responsible owner within the Act includes a building owner, an occupier of a building that is contractually obliged to maintain essential building services, or a body corporate formed under the Strata Titles Act 1998 (Building Act 2016 Tasmania). Essential building services apply to all buildings that have a BCA classification of 1b through to a 9 or 10 c building.

The responsible owner is required to maintain the building in accordance with the schedule of maintenance approved by a building surveyor when it does not relate to plumbing work. Under regulation 77 of the Building Regulations 2017 (Tasmania), the permit authority may also request an owner of a premises to provide copies of the maintenance schedule and evidence that the maintenance has been completed. A fine not exceeding 50 penalty units applies and if the offence is continued, a further fine or 15 penalty units per day during which the offence continues.

The implications for owners not complying with the maintenance implications under part 14 of the Building Act (Tasmania) are summarised in the following table;

Table 6: Implications for consumer noncompliance

Reference	Description of offence	Penalty Units
Sec. 205(1) of the Act.	The owner must maintain the Essential Building Services	100 penalty units or 500 penalty units for a body corporate
Sec. 205(3) of the Act.	A person performing maintenance work must complete in accordance with the Act.	100 penalty units or 500 penalty units for a body corporate.
Sec. 206(1) of the Act.	The responsible owner must ensure a schedule of maintenance is prepared and approved by the relevant permit authority in the case of plumbing work or a building surveyor in any other case.	100 penalty units or 500 penalty units for a body corporate
Sec. 206(2) of the Act.	A permit authority or building surveyor must not approve a schedule of maintenance for a building unless they are satisfied that the schedule of maintenance contains sufficient details for compliance.	100 penalty units or 500 penalty units for a body corporate
Sec. 206(3) of the Act.	A responsible owner must ensure that the schedule of maintenance for the building is reviewed yearly and any changes made are approved by a permit authority or building surveyor.	10 penalty units or 50 penalty units for a body corporate
Sec. 206(4) of the Act.	A responsible owner or occupier must comply with eh most recent schedule for the building that has been approved.	100 penalty units or 500 penalty units for a body corporate
Sec. 206(5) of the Act.	A responsible owner or occupier must keep records and provide those records to an authorised officer or chief officer within the meaning of the Fire Services Act 1979.	10 penalty units or 50 penalty units for a body corporate

Source: Building Act 2016 (Tasmania)

There is no mandatory requirement to lodge with the appropriate authority any yearly maintenance documents demonstrating compliance with the policy.

Discussion

There does not appear to be any substantive research or evidence in Australia regarding the compliance with the policy regarding ESMs. According to Carter (2019), the NEO 200 fire that occurred on the corner of Spencer and Little Bourke Street Melbourne on the 4 February 2019, confirmed the majority of the buildings ESMs were either not working or not maintained and over 40% of fire alarms and smoke detection systems in the apartments were not operable. This led to increased evacuation times for the building occupants due to the Metropolitan Fire Brigade officers advising and escorting residents out of the building. As a result of this fire, the Metropolitan Fire Brigade concluded that the complex design and fire safety assessments using the performance provisions contained in the BCA, relied heavily on the ESMs to safeguard occupant safety and provide for occupant evacuation, however these systems failed as they were not adequately maintained. Further it was concluded that the maintenance schedules were too complex and unrealistic and may not have been achievable to maintain with the buildings body corporate management not fully understanding the complex nature of ESM maintenance requirements (Carter, 2019) and thereby not complying with the policy.

When we look to other countries who have undertaken major upgrades on older existing complex buildings, it is interesting to note Hong Kong’s Mandated Building Inspection Scheme (MBIS) for building over 3 storeys. Research completed by Sing et al. (2015) identified approximately 24,000 buildings that will be subjected to the MBIS and that will require each building to be inspected and possibly updated every 10 years. This process however is different to Australia’s policy, as the Hong Kong MBIS may require building upgrades to meet current community standards and expectations. The

MBIS was originally conceived due to the deaths of over 101 people (Sing et al. 2015) as a result of the maintenance and repair of older buildings.

In a report the Productively Commission (2004), concluded that a number of fires occurring in commercial buildings in Australia were caused by a lack of maintenance processes and procedures. Interestingly Lind & Myingo (2012) concluded that property managers developed 3 to 5 year maintenance plans, however, they were only adhered to for the first 3 months.

There are several gaps in the current literature that is summarised below;

1. There is a lack of consistency in building regulatory framework regarding the policy for ESMs.
2. There is minimal information or evidence that demonstrates if the policy is working and effective for consumer safety.
3. There is minimal evidence regarding awareness of the policy that requires consumers to comply.
4. There is minimal evidence regarding the intentions of consumers to comply with the policy.
5. There is a lack of academic studies regarding ESM policy, consumer awareness and ability to comply with an increasing complex performance-based building code.
6. There is minimal academic research regarding the nationalised performance-based building code, and its translation into practice regarding the policy for ESM maintenance obligations to consumers.

Conclusion

This paper has shown that there is little existing research in regard to the policy for consumer safety in Australia as a result of a performance-based building code on statutory maintenance. With the cladding crisis currently engulfing Australia and requiring in some instances building upgrades using active fire safety systems to meet specific performance solutions (Victorian Building Authority 2019), the implications for consumers and property owners of these buildings in terms of maintaining ESMs are increasing exponentially. This has placed a spotlight on current industry paradigms and may show that the policy for statutory maintenance is either not fully understood and/or not a major consideration for consumers.

As demonstrated in this report, the end result for consumer safety, could either be a punitive jail sentence for non-compliance to major fines of neglect if the buildings major essential safety systems are not maintained in accordance with existing policy. Further research is required into this area to ensure that on-going safety of building occupants and consumers are protected in these highly complex residential and commercial buildings.

We conclude this paper by pointing out several possible future research agendas.

- To provide a consistent building regulatory framework regarding the policy for ESMs across Australia.
- To determine if the policy is working and effective for consumer safety through evidence-based research.
- To determine the intentions and beliefs of consumers regarding the ongoing ESM policy.
- To determine the links and interdependencies of consumers and their level of understanding of the complex nature of a performance-based building code and the policy for ESMs.
- To determine factors associated with sustained compliance for ESM’s for consumers.

References

Arditi, D. & Nawakorawit, M. 1999, ‘Issues in Building Maintenance: Property Managers' Perspective’, *Journal of Architectural Engineering*, vol. 5 no. 4 pp.117 – 132.

Australian Institute of Building Surveyors. 2019, *Building Regulatory Reform in Australia*, viewed 22 June 2019, < https://aibs.com.au/Public/Policy/Key_Policies/>.

Australian Building Code Board. 2014, *Maintenance of Safety Measures, Equipment and Energy Efficiency Installations*, Non-Mandatory Handbook, Australian Building Codes Board, Canberra.
Australian Building Code Board. 2019, *National Construction Code Building Code of Australia, Vol. 1 Class 2 to 9 Buildings*, Australian Building Codes Board, Canberra.
Australian Building Code Board. 2019, *National Construction Code Building Code of Australia, Vol. 2 Class 1 and 10 Buildings*, Australian Building Codes Board, Canberra.
Australian Building Code Board. 2019, Performance, viewed 17 August 2019, <https://www.abcb.gov.au/Initiatives/All/Performance>.
Bukowski, R.W. & Babrauskas, V. 1994, 'Developing rational, performance-based fire safety requirements in model building codes', *Fire & Materials*, vol. 18, no. 3, p173.
Building Regulations 2018 (Victoria) No 38, 2018.
Building Act 1993 (Victoria) No 117.
Building Fire Safety Regulation 2008 (Queensland).
Building (General) Regulation 2008 (Australian Capital Territory).
Building Regulations 2012 (Western Australia) Version 03-p0-00.
Building Act 2011 (Western Australia) Version 01-f0-00.
Building Act 2016 (Tasmania).
Building Act 1993 (Northern Territory).
Brien, D. L. 2016, 'Re-evaluation of the existing change management models to improve the response of the Building Code of Australia to environmental docility', PhD thesis, Central Queensland University, Rockhampton.
Carter, M. 2019, 'Presentation on Melbourne's NEO 200 Building Fire – Lessons Learnt', *Conference for the Australian Institute of Building Surveyors*, Sydney, Australia, 22-23 July 2019.
Centre for International Economics. 2013, *Benefits of building regulation reform (From fragmentation to harmonisation*), Viewed 4 May 2016, <http://www.thecie.com.au>.
Department of Justice. 2017, *Director's Maintenance of Prescribed Essential Building Services Determination version 1.1*, Government of Tasmania, viewed 22 July 2019, <https://www.cbos.tas.gov.au/topics/technical-regulation/building-standards/building-practitioners/building-maintenance>.
Department of Planning, Transport and Infrastructure. 2019, *Ministerial Building Standard SA 002 – Maintaining the performance of essential safety provisions*, Government of South Australia, viewed 22 July 2019, <https://www.saplanningportal.sa.gov.au/updates/news_item?a=537401>.
Department of Housing and Public Works. 2008, *Queensland Development Code MP6.1 Maintenance of Fire Safety Installations, Government of Queensland*, viewed 22 July 2019 <https://www.hpw.qld.gov.au/construction/BuildingPlumbing/Building/BuildingLawsCodes/QueenslandDevelopmentCode/Pages/QueenslandDevelopmentCodeCurrentParts.aspx>.
Department of Planning, Industry and Environment. 2018, *Building Regulation and Certification Reform*, Government of New South Wales, viewed 17 August 2019, <https://www.planning.nsw.gov.au/Policy-and-Legislation/Buildings/Building-Regulation-and-Certification-Reform>.
Department of Industry, Innovation and Science. 2019, *Communique*, Building Ministers Forum, Australian Government, viewed 22 June 2019, <https://www.industry.gov.au/sites/default/files/bmf-communique-8-february-2019.pdf>.
Department of Mines, Industry Regulation and Safety. 2019, Legislative framework, Building regulation, Government of Western Australia, viewed 23 June 2019, <https://www.commerce.wa.gov.au/building-and-energy/legislative-framework-building-services-and-plumbing>.
Department of Planning Transport and Infrastructure. 2019, *Ministerial Building Standard SA 002 – Maintaining the performance of essential safety provisions*, Government of South Australia, viewed 17 August 2019, <https://www.saplanningportal.sa.gov.au/updates/news_item?a=537401>.
Environmental Planning and Assessment Regulation 2000 (New South Wales).
Environmental Planning and Assessment Act 1979 (New South Wales).
Emergencies Act 2004 (Australian Capital Territory) No 29.
Fire and Emergency Regulation 1996 (Northern Territory).
Fire and Emergency Act 1996 (Northern Territory).
Fire and Rescue Service. 2019, *Maintenance of Building Fire Safety Measures*, Government of Northern Territory, viewed 22 July 2019, < http://www.pfes.nt.gov.au/fire-and-rescue-service>.
Fire and Emergency Services Act 1990 (Queensland).
Heijden, J v. d. 2008, '*Competitive Enforcement : Comparative Analysis of Australian Building Regulatory Enforcement Regimes',* Amsterdam.
Heijden, J v. d. & de Jong, J. 2009, 'Towards a Better Understanding of Building Regulation' *Environment and Planning B* vol. 35, no. 6, pp. 1038-1052.

Horner, RMW, Haram, E.L. & Munns, A.K. 1997, 'Building maintenance strategy: a new management approach' *Journal of Quality in Maintenance Engineering*, vol. 3 no. 4, pp. 273-280.

Lind, H & Munyingo, H, 2012, ‘Building maintenance strategies: planning under uncertainty’. *Property Management*, Vol. 30**,** pp 14-28.

Planning, Development and Infrastructure Act 2016 (South Australia).

Planning, Development and Infrastructure (General) (Development Assessment) Variation Regulations 2019 (South Australia).

Productivity Commission. 2004, *Reform of Building Regulation: Productivity Commission Research Report*, Commonwealth Government, viewed 4 August 2016, <http://www.pc.gov.au/inquiries/completed/building>.

Penalty Units Act 2009 (Northern Territory).

Sing, C. P., Chan, H.C., Love, P. E. D. & Leung, A. Y. T. 2015, ‘Building Maintenance and Repair: Determining the Workforce Demand and Supply for a Mandatory Building-Inspection Scheme’, *Journal of Performance of Constructed Facilities*, 30(2), p. 04015014. doi: 10.1061/(asce)cf.1943-5509.0000755.

Planning, Development and Infrastructure (General) Regulations 2017 (South Australia).

Standards Australia. 2012, *Emergency evacuation lighting for buildings Part 2: Inspection and maintenance*, AS/NZS 2293, viewed 17 August 2019, retrieved from Australian Standards Online.

Standards Australia. 1995, *Routine service of fire protection systems and equipment*, AS1851-2012, viewed 17 August 2019, retrieved from Australian Standards Online.

Victorian Parliament. 2013, *Building and Planning Amendment Bill*, viewed 15 September 2019 <http://www.parliament.vic.gov.au/publications/research-papers/8573-building-and-planning-legislation-amendment-governance-and-other-matters-bill-2013>.

Wong, KHl & Xie, Dy 2014, 'Fire Safety Management Strategy of Complex Developments' *Procedia Engineering*, vol. 71, pp 410-420.

SUSTAINABLE PROCUREMENT OF CONSTRUCTION PROFESSIONALS AND PROJECT OUTCOME DRIVERS

Terence Lam

Faculty of Built Environment, University of New South Wales, Sydney, Australia

Abstract

There is a lack of research on sustainable procurement practices for driving sustainable design and construction. This study identifies sustainable project outcomes and examines what performance drivers should be applied to drive such project outcomes from construction consultants. Four sustainable project outcomes were identified by qualitative multiple-case interviews with university estates: economic, functional, social and environmental sustainability which are the client's strategic objectives for design and construction of the estate. These aspects of sustainability can be measured by a reliable measure scale of contract sustainability key performance indicators (KPIs). Through hierarchical regression analysis of the results from a questionnaire survey of university estates, these sustainability KPIs were found to be significantly influenced by job performance factors: task performance factors (project staff and execution approach) and contextual performance factor (collaborative teamwork). To drive the sustainable project outcomes, project managers should apply contract sustainability KPIs related to cost (economic aspect) and quality (functional, social and environmental aspects) for performance monitoring. Such project outcomes can be optimised by focusing on the significant task and contextual job performance factors for selection of consultants. The holistic approach for procurement of professionals based on job performance factors and the application of contract sustainability KPIs for performance monitoring are the drivers for sustainable project outcomes. Further research should be conducted on other works organisations so that the results can become more robust and applicable to the wider public and private sectors in relation to sustainable procurement of professionals and contractors.

Keywords

Sustainable procurement, Project outcomes, Contract sustainability KPIs, Job performance factors

Introduction

A survey of 20 countries conducted by Brammer and Walker (2011) shows that although sustainable project outcome approach is adopted to select public-sector construction consultants and contractors, the extent and nature of this practice vary significantly from country to country. In Australia, previous research has shown that public authorities are at different stages of implementation of 'green' initiatives in construction planning and development, with considerable gaps in the tools and types of contract adopted for tendering and contracting processes (Sanchez *et al.,* 2013).

In fact, there has been a lack of research on sustainable procurement practices for achieving sustainable design and construction in the public sector. Existing research has been biased towards the development of green procurement policy for facilitating implementation of sustainable measures, and of tools to encourage sustainability in the supply chain when the public sector procures from suppliers in specific industries including construction, IT, food, and timber (Walker and Brammer, 2007). Even though there is a relatively well-developed body of research on sustainable procurement in private-sector organisations, studies have virtually been geared towards the environmental issues in procurement, with little research on social and other aspects of sustainable procurement to date. In a review of six sustainability measure tools for existing buildings adopted by major countries including NABERS in Australia, Environmental status in Sweden, Ecoprofile in Norway, Green Globes in Canada, HEQ in France and CASBEE in Japan, Pettersen (2003) found that the measure criteria of these tools are biased towards environmental issues. Furthermore, social, economic and functional factors can only be found in limited studies, for example, Benoit *et al.* (2010) on life cycle cost and McShane (2006) on social value of community infrastructure. There is a need to develop a holistic approach for sustainable procurement of professionals and contractors.

There is a trend to outsource professional architectural and engineering services for public-sector construction projects. To optimise sustainable design and construction from construction consultants, this study identifies sustainable project outcomes and examines what performance drivers should be applied to drive such project outcomes.

Contract KPIs for sustainable design and construction

Sustainability is defined as 'meeting the needs of the present without comprising the ability of future generations to meet theirs' (Brundtland, 1987). Elkington (2004) conceptualises sustainable development principles as 'triple bottom lines' where the environmental, economic and social values of the project should be balanced and harmonised. Sarja (2002) advocates that the sustainable design of structures should cover continuous operation and functionality because buildings need be functional in order to achieve the three triple bottom lines. Furthermore, Ling (2002) spells out the indispensable need for consideration of functional sustainability. Consultants must have proper design capability to produce a functional and satisfactory building that meets the client's needs. Kalutara, *et. al.* (2017) calls for an integrated approach to comprehensively assess sustainability from all environmental, economic, social and functional aspects in the management and maintenance of existing community buildings. Based on a consultation with sustainability experts in six local councils and a country-wide questionnaire survey in Australia, Kalutara, *et. al.* (2017) consolidated the measures of sustainability for public-sector projects into 18 principal factors which can be categorised into the four sustainable project outcomes for design and construction as follows:

- Environment sustainability: assessed by water management, material sustainability, energy efficient, waste management, air and noise pollution, and user comfort;

- Economic sustainability: life cycle cost, land value, local economy and additional capital investment;

- Social sustainability: local community engagement benefits and equity, neighbourhood character and employee well-being; and

- Functional sustainability: impact of failure and responses, level of service, and compliance to building standards and regulations.

Based on a questionnaire survey and a focus group investigation with occupants conducted in eight office buildings in Melbourne, Jailani *et al.* (2015) identified 20 sustainable building characteristics for measuring the sustainable project outcomes of commercial buildings, briefly outlined under the four categories of sustainability as follows.

- Environment sustainability: adequate natural lighting, feel well ventilated, artificial lighting in their office, good acoustic quality with acceptable noise level, and heating/cooling system responsive to temperature changes;

- Economic sustainability: minimising capital and operating costs through control over the natural lighting in the office, control over the ventilation in the office, control over the temperature in the office, and control over the opening of external windows in the office;

- Social sustainability: visually appealing, facilitates collaboration/interaction with other colleagues, design layout that facilitates movement within the building, tidy in appearance, conversation privacy in the office, and visual privacy in the office; and

- Functional sustainability: contains up-to-date IT and telecommunication services, good common amenity, functions at a comfortable level of humidity, functions at a comfortable temperature, and flexible enough to accommodate changes in different employee teams.

In relation to project management of public-sector construction, Lam and Gale (2014) identified critical success factors which can be transformed into contract KPIs for measuring the project outcomes for sustainable design and construction, as specified in the construction contract for performance monitoring. These KPIs are generally in line with the sustainability measures identified by Kalutara, *et. al.* (2017) and Jailani *et al.* (2015). They can be categorised into project outcomes of cost and quality, which are in turn related to the four aspects of sustainability as shown in Table 1. These KPIs can be termed the 'contract sustainability KPIs' which measure the 'sustainable project outcomes' for performance monitoring of design and construction.

Table 1: Sustainable project outcomes and contract KPI measures

Project outcome	Sustainable Project Outcome	Contract Sustainability KPI for design and construction
Cost (POC)	Economic	- life cycle cost minimised - minimal variation in cost against budget - at or below the approved cost limit
Quality (POQ)	Functional	- a functional building/refurbishment/maintenance that meets the client's needs; with minimal rework (making good defects and material waste)
	Social	- health and safety design and inspections to minimise accidents (employee well-being)
	Environmental	- sustainable design (reduction of energy, carbon emission, water consumption and waste, improvement of air quality and other aspects)

Job performance factors

According to the theory of job performance, performance comprises two elements: task performance relating to proficiency and skills in job-specific tasks (Van Scotter and Motowidlo, 1996); contextual performance relating to general communication and coordination skills as well as initiative and teamwork within an organisational setting (Borman and Motowidlo, 1993).

In relation to task performance, Morledge and Smith (2013) recommend that there should be three generic ability factors for final selection of consultants: capability of firm, competence of firm, and staff proposed for the project. CIRIA (1994) also considers execution approach for design and management of stakeholders is essential for project success. Capability refers to the size of firm as measured by the overall experience of firms in projects of similar function and the availability of sufficient staff, finance, facilities and quality management system to meet the demand of project programmes. Competence is related to past performance of a firm in the past projects. Past performance is considered to be a good predictor of future behaviour performance according to the theory of selection psychology (Ling, 2000). Project staffing is assessed based on the relevant expertise and experience of the personnel directly employed for the project, especially the project team leader.

When assessing contextual performance, Borman and Motowidlo (1993) states that conscientiousness, initiative, social skills, control and commitment should be considered. In an empirical study, Ling (2002) validated that conscientiousness is a significant factor influencing the performance of architectural and engineering consultants, as measured by the level of enthusiasm in tackling a difficult commission and the speed in producing design drawings. However, initiative (offering suggestions to improve design), social skills (interpersonal and communication skills), controllability (respect for team work and collaboration, compliance with instructions and speed of response) and commitment (loyalty to employer, preparedness to revise design and interest in the commission) were found to be insignificant to the consultant's performance. Based on the results of a research into the project outcomes of framework procurement for infrastructure maintenance projects, Lam and Gale (2014) confirmed that consultant frameworks, as compared to the traditional discrete appointment approach, can provide longer and stronger relationships, thus enhancing trust and collaboration and teamwork between the client and the service provider, and producing better performance outcomes to address the client's needs. The framework agreement provides an 'umbrella' contract with projects which may be procured at the call-off stage throughout the period of agreement which is normally a maximum of 4 years, thus establishing long-term collaborative arrangements.

These task and contextual job performance factors refer to the consultant selection criteria and were found to be consistent and reliable by Ling (2000) in developing an assessment framework for choosing construction consultants. The measures are summarised in Table 2 and predominantly related to the four aspects of sustainability.

Table 2: Consultant job performance factors

Job performance factors	Measure
Task performance	
Project staff (relevant expertise & experience)	- qualifications, experience (including the four aspects of sustainability: economic, functional, social and environmental) and time commitment of the project team leader - qualifications and experience of proposed staff (including the four aspects of sustainability) - management arrangements for sub-contracted services
Execution approach (design and management methods for the commission)	- quality of design to meet the client's strategic needs (potential value to student recruitment and learning, staff recruitment, carbon reduction) - quality of design to meet the client's practical needs (problem-solving ability to resolve functional requirements, operational efficiency, aesthetics, cost / time constraint) - managerial procedures (communication with clients; managing the programme and sub-consultants; working around existing occupiers; collaboration with other project team members)
Competence of firm (past performance)	- performance on past projects or job references from previous clients, including producing sustainable project outcomes
Size of firm / capability (overall experience & facilities)	- experience of the firm in similar university projects (including the four aspects of sustainability) - suitable qualifications of senior partners / managers - availability of technical facilities - financially stability - quality management system

Contextual performance	
Conscientiousness	- speed in producing design drawings or completing tasks - level of enthusiasm in tackling a difficult assignment (to produce sustainable project outcomes)
Trust and collaboration	- collaborative consultant frameworks - traditional discrete appointment of consultants

Hypotheses and research methods

This research aims to identify sustainable project outcomes of design and construction and examines what performance drivers should be applied to drive such project outcomes from construction consultants. The following were hypothesized to investigate the relationships.

H1: Economic, functional, social and environmental sustainability were project outcomes expected by the public-sector university client and could be measured reliably by the contract sustainability KPIs.

H2: Project outcome of economic sustainability, as measured by the sustainability KPIs related to cost (see Table 1), was positively correlated to the level of task and contextual job performance factors (see Table 2).

H3: Project outcomes of functional, social and environmental sustainability, as measured by the sustainability KPIs related to quality (see Table 1), were positively correlated to the level of task and contextual job performance factors (see Table 2).

Combined qualitative-quantitative methods were adopted for this research.

Fellows and Liu (2008) and Yin (2009) advocate that a case study approach can serve to investigate phenomena in a real context and from which rich conclusions can be drawn. To verify H1, qualitative multiple-case interviews were conducted with three heads of estates, three consultant management managers and one quantity surveyor of three university estate offices (all located in England) in order to identify the expected sustainable project outcomes and their contract KPI measures as reviewed by the literature search, using 'content analysis' of their practical views and experience. The reliability of the measure scale of sustainable project outcomes (as shown in Table 1) was further verified by Cronbach's alpha coefficients, using 60 sets of data collected from the questionnaire survey of university estates.

Regression analysis provides a powerful tool to analyse the relationship between the results and influences (Schleirfer and Bell, 1995). Quantitative hierarchical regression analysis was then conducted to validate the H2 and H3, using data from 60 consultancies collected from a country-wide questionnaire survey of the university estate offices. This quantitative study covered professional construction services commonly engaged in building construction: architectural, building services engineering, quantity surveying, project management and combined project management/quantity surveying professional service consultancies for new build, refurbishment and maintenance projects. The informant was asked, based on a construction consultancy he/she has recently completed, to indicate: firstly, the level of performance factors used to select consultants at the tender stage (predictor variables); and secondly, the average project outcomes actually achieved by the consultant in relation to sustainable design and construction (dependent variables) at the construction phase. For each project outcome, a hierarchical regression analysis was conducted to validate the relationship between the sustainable project outcome and the job performance factors, i.e. to identify the relative contribution of the two predictor blocks (task performance and contextual performance factors) to the project outcome, and to identify the significant performance factors within each block. Details of the regressions are given in Table 3.

Table 3: Regressions between project outcomes and job performance factors

VARIABLE	OPERATIONALISATION MEASURE
Dependent Variable (project outcome)	
POC Project outcome of economic sustainability, as measured by the contract sustainability KPIs related to cost	Score (between 1 and 5) for the average level of individual KPI measures during at the construction phase (see Table 1) POC score = sum of all sub-scale scores
POQ Performance outcome of functional, social and environmental sustainability, as measured by the contract sustainability KPIs related to quality	Score (between 1 and 5) for the average level of individual KPI measures at the construction phase (see Table 1) POQ score = sum of all sub-scale scores
Predictor Variable (job performance factor)	
Task performance factor (Block 1)	
PST Project Staff /relevant expertise and experience	Score (between 1 and 5) for the level of individual measures assessed at the tendering phase (see Table 2) PST score = sum of all sub-scale scores
APP Execution approach / design and management methods	Score (between 1 and 5) for the level of individual measures assessed at the tendering phase (see Table 2) APP score = sum of all sub-scale scores
COP Competence of firm / past performance	Score (between 1 and 5) for the level of individual measures assessed at the tendering phase (see Table 2) COP score = sum of all sub-scale scores
SFM Size of firm / overall experience and facilities	Score (between 1 and 5) for the level of individual measures assessed at the tendering phase (see Table 2) SFM score = sum of all sub-scale scores
Contextual performance factor (Block 2)	
CON Conscientiousness	Score (between 1 and 5) for the level of individual measures assessed at the tendering phase (see Table 2) CON score = sum of all sub-scale scores
CFW Trust and collaboration	Collaborative consultant framework = 1 Traditional discrete appointment of consultant = 0

Regression Equations:

$POC = \alpha_c + (\beta_{1c}PST + \beta_{2c}APP + \beta_{3c}COP + \beta_{4c}SFM) + (\beta_{5c}CON + \beta_{6c}CFW)$

$POQ = \alpha_q + (\beta_{1q}PST + \beta_{2q}APP + \beta_{3q}COP + \beta_{4q}SFM) + (\beta_{5q}CON + \beta_{6q}CFW)$

α = constant, or the Y-intercept of the regression line

β_n = regression coefficients for the predictor variables

PST, APP etc = values of the predictor variables

$_{c,\, q,}$ = indices for cost and quality

Results and discussion

Qualitative study

Each multiple-case interview was conducted by a semi-structured questionnaire which was developed based on Tables 1, taking approximately 45 minutes. As confirmed unanimously by the experienced heads of estate, consultant management managers and quantity surveyor, economic, environmental, social and functional sustainability are the strategic and practical needs of the university estate. One of the estate heads spelled out that all these aspects should be considered when assessing the performance output of consultants in the selection and the subsequent performance monitoring processes. They also agreed that the contract sustainability KPIs related to cost and quality are effective to measure and monitor the four aspects of sustainability for design and construction, as analysed in Table 1.

Cronbach's alpha coefficient is commonly used to indicate the internal consistency for measure scale (Pallant, 2016). Cronbach's alpha coefficient of a scale should be above 0.7. For short scales with fewer than 10 items, it is common to find relatively low Cronbach values, e.g. 0.5. The Cronbach's alpha coefficient for economic sustainability related to cost is 0.749, suggesting very good internal consistency and reliability for his sub-scale. The Cronbach's alpha coefficient for environmental, social and functional sustainability related to quality is 0.654, suggesting good internal consistency and reliability for this sub-scale. All of these quantitative results mean that the 'contract sustainability KPIs' is a reliable measure scale for all economic, environmental, social and functional sustainability. Based on the qualitative interview results and the Cronbach's alpha coefficients, Hypothesis H1, as suggested by Kalutara, *et. al.* (2017), Jailani *et al.* (2015) and Lam and Gale (2014), was validated.

Quantitatively study

Each sustainable project outcome was regressed against the two job performance factor blocks: task performance factor and contextual performance factor. The strength of impact of individual predictor blocks on the project outcome was examined by their 'R^2 Change values', and the correlation between the project outcome and individual performance factors was assessed by the adjusted R^2 value. Details of the hierarchical regression results are given in Table 4 and Table 5.

Table 4: Regression analysis for project outcome of economic sustainability related to cost

Block / Predictor variable	B	Beta	sr^2	p-value	Tolerance	R^2	Adjusted R^2	R^2 Change (Sig. F Change)	ANOVA Sig.
Blocks 1 & 2						0.730	0.719		0.0005
Block 1 PST	0.788	0.935	0.729	0.0005	0.835			0.599 (0.0005)	
Block 2 CFW	1.796	0.369	0.131	0.0005	0.830			0.131 (0.0005)	
Intercept Constant	-8.761								

Significant blocks: Block 1 and Block 2
Significant performance measure: PST in Block 1; CFW in Block 2
Final POC Regression Model:
$POC = \alpha_c + (\beta_{1c}PST) + (\beta_{6c}CFW)$
$POC = -8.761 + 0.788PST + 1.796CFW$

Table 5: Regression analysis for project outcome of functional, social and environmental sustainability related to quality

Block / Predictor variable	B	Beta	sr^2	p-value	Tolerance	R^2	Adjusted R^2	R^2 Change (Sig. F Change)	ANOVA Sig.
Blocks 1 & 2						0.483	0.462		0.0005
Block 1 APP	0.475	0.574	0.320	0.0005	0.972			0.240 (0.0005)	
Block 2 CFW	1.575	0.500	0.243	0.0005	0.970			0.243 (0.0005)	
Intercept Constant	5.725								

Significant blocks: Block 1 and Block 2
Significant performance drivers: APP in Block 1; CFW in Block 2
Final POQ Regression Model:
POQ $= \alpha_q + (\beta_{2q}APP) + (\beta_{6q}CFW)$
POQ $= 5.725 + 0.475APP + 1.575CFW$

Both 'task performance factor' and 'contextual performance factor' blocks have significant positive effect on the project outcomes of economic, functional, social and environmental sustainability, as measured by the contract sustainability KPIs related to cost and quality. Whilst the task performance driver contributes more to the project outcome of economic sustainability (a higher R^2 Change value of 0.599, with Sig. F Change value <0.0005), the contextual performance driver has stronger impact on the project outcome of functional, social and environmental sustainability (a higher R^2 Change value of 0.243, with Sig. F Change value <0.0005).

The results also identify the significant performance drivers within each block, each with a p-value of <0.05. Project staff (PST) is found to be a more significant driver for project outcome of economic sustainability, with p-value <0.0005 and sr^2 value being 0.729. This is consistent with the arguments of Yeung *et al.* (2008) and Morledge and Smith (2013). Design and cost management skills are particularly relevant to special teaching and laboratory facilities which have unique requirements on architectural, vibration and acoustic design and construction. These skills are essential for the control of approved budget, variations and life cycle cost, thus contributing to economic sustainability.

Execution approach (APP) is a more significant driver for performance in quality, with p-value <0.0005 and sr^2 value being 0.320. 'Execution approach' is a measure of consultant's design and management methods to meet the client's strategic and practical needs, thus achieving functional and environmental sustainability. Bennett *et al.* (1996) and Hoxley (1998) contend that problem-solving ability and understanding the client's brief and project scope are important requirements when selecting consultants.

Consultant framework (CFW) is a significant driver for all sustainable project outcomes related to cost and quality, having p-values of <0.0005. Consultant framework procurement approach encourages 'trust and collaboration' between the client and the consultant. Construction, refurbishment and maintenance programmes have high risks when executed in occupied university estates. Using the framework procurement can nurture longer and stronger relationships and collaboration, thus driving project outcomes and success, as supported by Constructing Excellence (2005). Within the context of occupied working environment, the results confirm that the impact of consultant framework is particularly significant to two aspects of sustainability: firstly, optimal health and safety design and inspections to minimise accidents and ensure well-being of employees (social sustainability); secondly, optimal design and cost control to maintain approved budget and to minimise cost variations (economic sustainability).

All of these results infer that economic sustainability was positively correlated with task performance factor of project staff (PSF) and contextual performance factor of consultant framework (CFW), both having a p-value of <0.0005, thus Hypothesis H2 was validated. Furthermore, functional, social and environmental sustainability was positively correlated with task performance driver of execution approach (APP) and contextual performance driver of consultant framework (CFW), both having a p-value of <0.05. Hypothesis H3 was therefore validated. Both validations are supported by Morledge and Smith (2013), CIRIA (1994) and Lam and Gale (2014).

Conclusions

Four aspects of sustainability and two significant job performance factors are identified by this study for optimising sustainable project outcomes from construction consultants. As confirmed by the qualitative study, functional, environmental, economic and social sustainability are the public-sector client's strategic objectives and practical needs. Cronbach's alpha coefficients also verifies that the 'contract sustainability KPIs' is a reliable measure scale for all the four aspects of sustainability. These KPIs should be adopted for performance monitoring of the professional consultant's sustainable design and construction.

The regression analysis generalises that sustainable project outcomes are significantly driven by task and contextual performance factors, as supported by the job performance theory. Within these driver blocks, 'project staff' and 'consultant framework procurement' are found to be significant performance drivers for economic sustainability, whilst 'execution approach' and 'consultant framework procurement' are significant drivers for project outcomes of functional, social and environmental sustainability. The results infer that project managers should focus on these significant performance factors for selection of construction professionals at the tender phase in order to achieve the sustainable project outcomes.

The holistic approach for procurement of professionals based on job performance factors and the application of contract sustainability KPIs for performance monitoring are the drivers for sustainable project outcomes.

These results enhance procurement and project management theories. Previous research on public-sector sustainable procurement focuses on the environment aspect of sustainability whilst social, economic and functional aspects can only be found in limited studies. Sustainable procurement should be holistically achieved by embracing all the four aspects of sustainability. More importantly, it is necessary to apply the contract sustainability KPIs to manage and enhance the project team's performance in design and construction (see Table 1).

Apart from university estates, further research should be conducted on other works organisations so that the results can become more robust and applicable to the wider public and private sectors in relation to sustainable procurement of professionals and contractors.

References

Benoit, C., Norris, G.A., Valdivia, S., Giroth, A., Moberg, A. Bos, U. Prakash, S., Ugaya, C. and Beck, T. (2010), 'The guidelines for social life cycle assessment of products: just in time!', *The International Journal of Life Cycle Assessment*, Vol. 15 (2), pp.156-163.

Bennett, J., Pothecary, E. and Robinson, G. (1996), *Designing and Building a World-Class Industry*, Centre for Strategic Studies in Construction, Reading.

Borman, W. C. and Motowidlo, S. J. (1993), 'Expanding the Criterion Domain to include elements of Contextual Performance', in Schmitt, N. and Borman, W.C. (eds) *Personal Selection in Organizations*, Jossey-Bass, San Francisco.

Brammer, S. and Walker, H. (2011), 'Sustainable procurement in the public sector: an international comparative study', *International Journal of Operations & Production Management*, Vol. 31 (4), pp. 452-476.

Brundtland, G.H. (1987), *Our Common Future: The World Commission on Environment and Development*, Oxford University Press, Oxford.
CIRIA (1994), *Value by Competition: A Guide to the Competitive Procurement of Consultancy Services for Construction*, Construction Industry Research and Information Association (CIRCA), London.
Constructing Excellence (2005), Why use a framework agreement? available at http://goo.gl/MdQAxQ (accessed 23April 2013).
Elkington, J. (1997), *Cannibals with Forks: The Triple Bottom Line of 21st Century Business*, Capstone Publishing Ltd, Oxford.
Fellows, R. and Liu, A. (2008), *Research Methods for Construction*, Wiley-Blackwell, Oxford.
Gorgolewski, C.B.M (2014), 'Assessing occupant satisfaction and energy behaviours in Toronto's LEED Gold high rise residential buildings', International Journal of Energy Sector Management, Vol. 4 (4), pp. 492-505.
Hoxley, M. (1998), *Value for Money: The Impact of Competitive Tendering on Construction Professional Service Quality*, RICS, London.
Jailani, J., Reed, R. and James, K. (2015), 'Examining the perception of tenants in sustainable office buildings', *Property Management*, Vol. 44 (4), pp. 386-404.
Kalutara, P., Zhang, G., Setunge, S. and Wakefield, R. (2017), 'Factors that influence Australian community buildings' sustainable management', *Engineering, Construction and Architectural Management*, Vol. 24 (1), pp. 94-117.
Lam, T. and Gale, K. (2014), 'Highway maintenance: impact of framework agreements on contractor performance', *Engineering. Construction and Architectural Management*, Vol. 21 (3), 336-347.
Ling, Y. Y. (2000), 'A theoretical framework for selection of consultants by design-build contractors', *Journal of Construction Procurement*, Vol. 6 (2), 147-63.
Ling, Y. Y. (2002), 'Model for predicting performance of architects and engineers', *Journal of Construction Engineering and Management*, Vol. 128 (5), 446-455.
McShane, I. (2006), 'Social value and the management of community infrastructure', *Australian Journal of Public Administration*, Vol. 65 (4), pp. 82-96.
Morledge, R. and Smith, A. (2013), *Building Procurement*, Wiley-Black, Oxford.
Pallant, J. (2016), *SPSS Survival Manual*, Open University Press**,** Maidenhead.
Petersen E. H. (2002), 'BEAT 2002 - an LCA based assessment tool for the building industry', in *Proceedings of the Sustainable Building Conference 2002*, Oslo, Norway.
Sanchez, A.X., Lehtiranta, L., Hampson, K.D. and Kenley, R. (2013), "Sustainable Infrastructure Procurement in Australia: Standard vs. Project Practices", in Kajewski, S. and Manley, K. and Hampson, K. (ed), *Proceedings of the 19th International CIB World Building Congress: Construction and Society, May 5-9 2013*. Brisbane, Qld: Queensland University of Technology.
Sarja, A. (2002), *Integrated Life Cycle Design of Structure*, Spon Press, New York.
Schleirfer, A. and Bell, D. (1995), *Data Analysis, Regression and Forecasting*, Course Technology Inc., MA.
Van Scotter, J. R. and Motowidlo, S. J. (1996), 'Interpersonal facilitation and job dedication as separate facets of contextual performance', *Journal of Applied Psychology*, Vol. 81 (5), 525-531.
Walker, H.L. and Brammer, S. (2007), Sustainable procurement in the United Kingdom public sector, University of Bath, available at https://purehost.bath.ac.uk/ws/files/415713/2007-15.pdf (accessed 1 September 2019).
Yeung, J. F.Y., Chan, A. P. C. and Chan, D. W. M. (2008), 'Establishing quantitative indicators for measuring the partnering performance of construction projects in Hong Kong', *Construction Management and Economics*, Vol. 26 (3), 277-301.
Yin, R.K. (2009), *Case Study Research: Design and Methods*, Sage, London.

DESIGN THINKING FOR THE BUILT ENVIRONMENT: A CASE STUDY OF A FIRST-YEAR UNDERGRADUATE SUBJECT

Sara Omrani[1], Holly Russell[2], Robin Drogemuller[1], Vaughan Coffey[1]

[1]Civil Engineering and Built Environment, Queensland University of Technology, Brisbane, Australia

[2]Learning and Teaching Unit, Queensland University of Technology, Brisbane, Australia

Abstract

Design Thinking is a relatively new approach and has been mostly only employed in design courses in the higher education sector. In the first semester of 2019, Queensland university of Technology has introduced a design thinking unit for the Bachelor of Urban Development course. The cohort of students enrolled in this unit were from Construction Management, Urban and Regional Planning, and Quantity Surveying disciplines. This study investigates the effectiveness of Design Thinking as a problem-solving approach for the first-year students studying built environment related majors. The students enrolled in the unit were surveyed at the beginning and end of the semester followed by a focus group. The effect of Design Thinking on students' skills such as collaboration and problem-solving was proved to be positive.

Keywords

Design Thinking, Built Environment, Higher Education, Problem Solving Framework, Collaboration

Introduction and Background

Each degree program at Queensland University of Technology (QUT) has a course advisory committee that has representatives from the industry sector that is the destination of the graduates. This committee provides advice and feedback to the academics who have responsibility for the respective courses. The Bachelor of Urban Development (Honours) degree has three majors - Construction Management, Quantity Surveying and Cost Engineering, and Urban and Regional Planning. Each of these is a four year degree. There are some common units within these degrees, but the level of specialisation increases as the students progress in their courses.

One issue that often arose at these meetings was the need for deep problem solving skills for graduates of these courses. These courses were scheduled for internal reaccreditation in 2018. When analysing the internal program data and discussing the degree with students and alumni through focus groups, the course team identified the need to enhance the teaching of problem-solving skills and collaboration. This, coupled with feedback from industry partners that prioritised innovative thinking and collaboration, led the course team to research innovative approaches to teaching problem-solving skills and collaboration, and ultimately to selecting design thinking as a methodology for building these skills. Design thinking has been researched widely in higher education and shown to support the development of critical thinking, problem solving and collaboration skills (Koh, Chai, Hong & Wong, 2015).

This led to discussions in 2018 on introducing design thinking into these courses. The result was that the courses were changed to incorporate a new "Design Thinking in the Built Environment" unit as a common unit into all three courses. It was also decided that the unit should be in the first year of the courses so that students would be able to apply their learnt skills in later years of the courses. This would reinforce the learnings from this unit and provide more experience in these problem solving skills to graduates through their application in subsequent assignments. There were 228 students enrolled in the unit since it was part of all three courses. The tutorial groups were each of around 50 students.

Design thinking (IDEO, 1991) was chosen as a method for creative problem solving that is an approach to avoid linear thinking, where students successively follow the simplest path as they make decisions to solve problems. Design thinking provides students with opportunities to develop solution focused thinking as they collaborate to frame ill-defined problems. Plattner, Meinel, and Leifer describe the process as: *defining the problem, needfinding and benchmarking, ideating, building and testing*. It was believed that this clearly structured process, aimed at developing student's abductive reasoning skills, coupled with the focus on human centred design (Kelley, D & Kelley, T, 2015), lends itself well to bringing Urban Development students together from different disciplines to tackle contemporary problems within the build environment. It was considered important that group work be a part of the unit because (i) team work pervades our industry and (ii) this would allow the students opportunities to discuss issues and learn to propose and defend their respective points of view.

There were two aspects that needed to be covered in the course. Firstly, the students needed to develop an understanding of design thinking and they also needed relevant problems to tackle. Given that this unit was offered in the first semester of first year across all three courses, the starting point for planning the lecturer program and tutorials was that the students knew nothing about formal problem solving in general and design thinking in particular. It was as also assumed that students had little formal knowledge of the built environment and building procurement processes. A parallel unit covers residential construction. The use of group work was also considered important so that the students would start to develop the teamwork skills necessary to work in our industry.

As with any first year unit, there is tension between ensuring that all of the students have sufficient common background, introducing them to more independent learning processes, presenting enough material so that the first assessment items require some independent thinking and showing that all of this was relevant to their future careers. The lecture program with the tutorial and assessment program are set out in Table 1.

After introducing the unit in week 1, week 2 addressed the first two stages in Design Thinking. The problem area – sustainability - was introduced in week 3. Sustainability was chosen as the problem area for a few reasons, the majority of the cohort were first-year students and the assumption was they do not have ample knowledge about their major to work on problems specific to their area and it was felt that there would be enough common knowledge of sustainability across the student group for them to make reasonable progress in a short time. Weeks 4 and 5 covered additional stages in Design Thinking. Industry experts were brought in for weeks 6 – 8 to provide a sound context for the students in each of the disciplines that were enrolled in the unit. This was well received by the students. Weeks 9 and 10 completed the stages of Design Thinking. Week 11 covered issues around collaboration, with discussion with the students on their experiences collaborating in this unit. In week 12 we covered problems that may arise with Design Thinking as an approach, with working in groups and in problem solving in general.

The groups each had 4-5 members. Students were given two weeks to form groups and the remaining were allocated randomly as, being first year students, there would be few existing relationships between students.

Table 1: Unit Program

Week	Lecture	Tutorial	Assessment	Comment
1	Introduction to design thinking	Introduction		Introducing the subject, teaching methods, assessment
2	Empathy and Define Finding research material	Empathy & Define exercise		Covering the first two stages of design thinking
3	Sustainability	Define		Continuing with design thinking process
4	Pitching and feedback	Pitching activity		Teaching the students how to pitch an idea
5	Ideate and Prototype	Preparing presentations	Presentation by individuals to their group	Covering the next two stages in design thinking
6	Urban planning	Empathy & Ideation		First of the industry presentations on problem solving
7	Construction Management	Ideation		Second industry presentation
8	Quantity Surveying	Prototyping		Third industry presentation
9	Test	Prototyping		Covering the next stage in design thinking
10	Reflection	Test		Covering the next stage in design thinking
11	Collaboration	Assessment 2 pitch	Pitch prepared by group	Discussions on collaboration and how it works
12	When things go wrong	Reflection		Dealing with Murphy's law
13	Summary & review	Reflection & feedback	Individual reflection on unit and assessments	Discussion and wrap up

Methods

In order to understand students' existing experience with problem solving and collaboration and their perception of the effectiveness of design thinking as a problem-solving methodology, we conducted online surveys at the beginning and end of the semester and focus groups at the end of the semester.

Online Surveys

The surveys were introduced to the students at the first and last lectures. The survey questions consists of four major categories: demographic questions, collaboration skills, problem-solving skills, and confidence and likelihood of collaborating with other people and solving problems. The survey focuses on the participants' perception of their capabilities in the questioned areas using 4-point Likert scale ranging from strongly agree to strongly disagree. It was started with demographic questions including age, gender, and highest level of education. The survey, then asked two questions to determine students' experience with design thinking; eight questions that asked students to rate their collaboration skills;

five questions that asked students to rate their problem solving skills; three questions that measured students' confidence to work collaboratively and solve problems, and four questions that measured their likelihood to work together and share their ideas with others for problem solving. At the final section participants were given the chance to provide any additional comments. The survey questions were developed in collaboration with QUT's Student Success Group. The major categories and corresponding subcategories of the surveys are presented in Table 2.

Table 2. Categories and sub-categories of the surveys

Main category	**Sub-categories**
Collaboration	Contribution
	Team Communication
	Seeking help and clarification
	Listening
	Explaining point of view
	Managing conflict
	Collaboration with diverse groups
	Flexibility
Problem solving	Problem refinement
	Coping with Change
	Creative thinking
	Evidence-based decision making
	Synthesis of ideas
Confidence	Collaboration
	Problem solving
Likelihood	Collaboration

At the beginning of the survey, the participants were asked to create their own unique code comprising of the first letter of their name, first and last letter of their mother's name, and the day of the month that they were born in. This unique code enabled us to link the responses from both surveys while keeping the identity of participants anonymous.

Focus groups

Two focus groups involving 16 students were conducted at the last week of the semester. The aim of the focus groups was to capture subjective experiences of students on design thinking and its impact on their collaboration and problem solving skills. Focus groups are suitable for understanding of participants' perspectives and experiences (Stalmeijer, McNaughton and Van Mook 2014).

One of the authors (H.R.) who was not associated with teaching and grading the unit conducted the focus groups to eliminate any possible perception of coercion. A question set was followed in both groups to assure the consistency.

Results and Discussions

Online Surveys

From 228 students enrolled in Design Thinking for the Built Environment (UXB100) unit, 41 students responded to the first survey and 12 responded to the second survey. More than half of participants have identified themselves as males (58% in the first survey, and 71% in the second survey) where more than 70% (in both surveys) were domestic students. The majority of the students (82.5%) have recently finished high school and it was their first semester at university. Most of the students were born between 1999 and 2001 indicating the age bracket of 18-20 years old at the time of the study.

The collaboration section of the survey comprises of eight four-point Likert-type questions that focus on different components of collaboration skills. Figure 1 represents the results of collaboration category for both surveys.

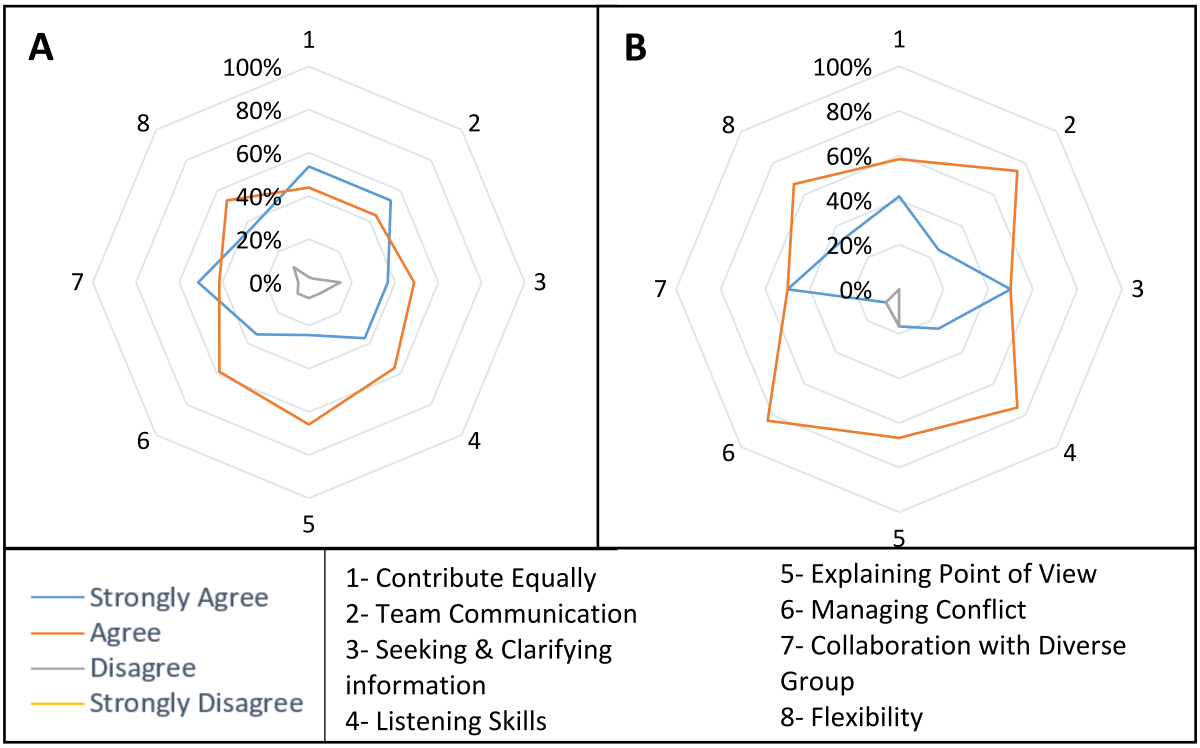


Figure 1. Results of collaboration section of the first survey (A) and the second survey (B)

In general, students expressed high level of confidence in collaboration skills indicated by very low percentage of “Disagree” responses and zero “Strongly Disagree”. Comparison of the results of the two surveys shows an increase in the percentage of “Agree” responses and a decrease in “Disagree” percentage. This trend remains the same when we look at the cumulative percentages of all the questions under collaboration category which is presented in Figure 2. Another difference that stands out in Figure 2 is the reduction in “Strongly Agree” responses. Having said that a shift of negative response towards positive responses (Agree and Strongly Agree) is evident, indicating an increase in overall students’ confidence in collaboration.

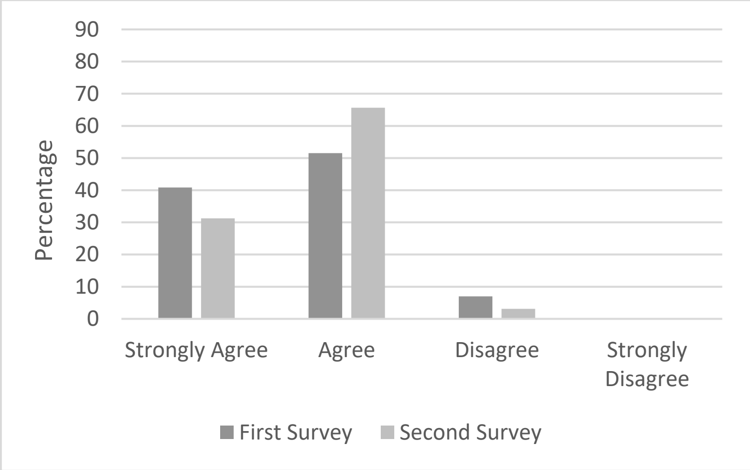


Figure 2. Cumulative results of collaboration section for the first and second surveys.

The problem-solving section of the survey comprises of five four-point Likert-type questions that focus on different components of problem-solving skills. The survey results for problem solving section of both surveys are presented in Figure 3. Similar to the collaboration category, students show confidence in their problem-solving skills as indicated by a very low "Disagree" response rate. Comparison of the two surveys shows a noticeable increase in "Agree" and a decrease in "Strongly Agree" and "Disagree" responses. The same trend is evident in cumulative responses to the problem-solving category as presented in Figure 4. In general, these graphs indicate a slight increase in students' confidence in their problem solving skills.

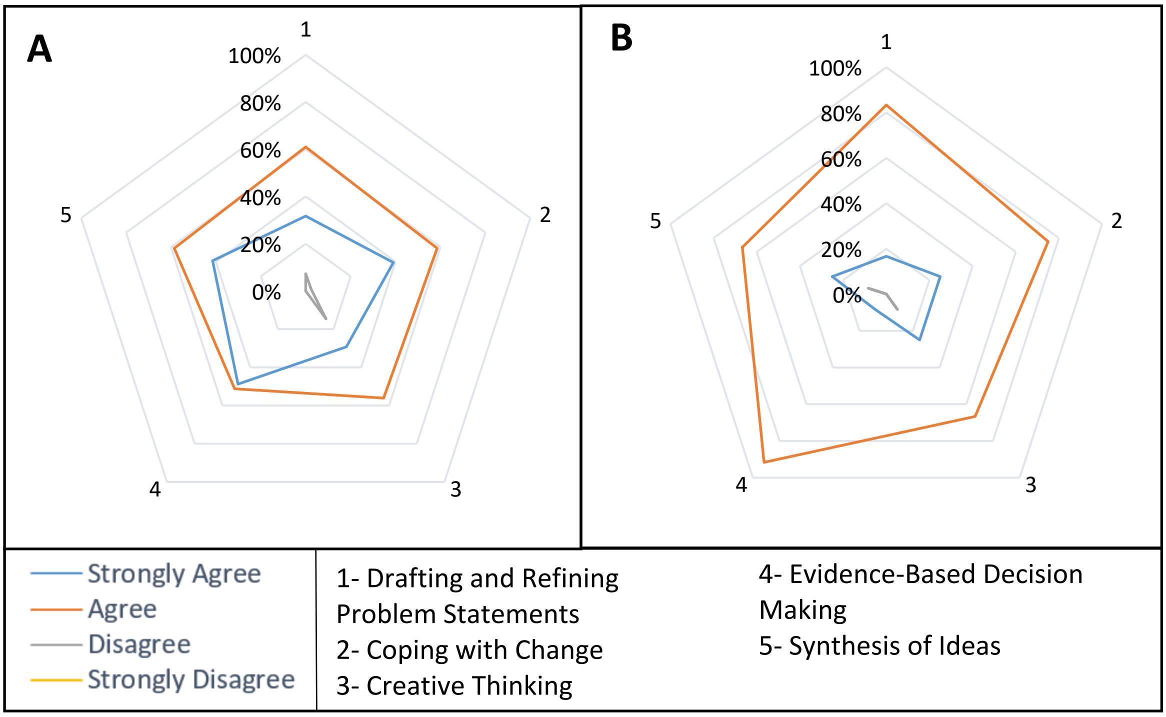


Figure 3. Results of problem-solving section of the first survey (A), and the second survey (B)

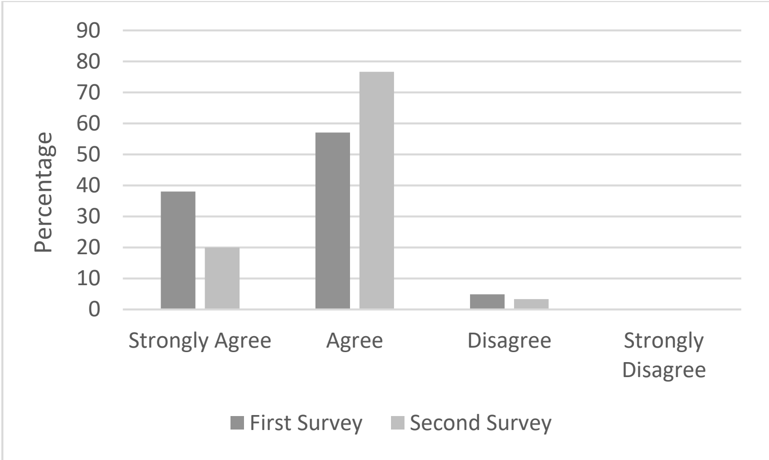


Figure 4. Cumulative results of the problem-solving section of the first and second surveys

Confidence and likelihood

The participants were also asked about their confidence, likelihood, and opinion about the importance of participating in collaborative activities and problem solving. The results are summarised in the table below (Table 3).

Table 3. Participants' responses to the confidence, likelihood, and opinion section of the surveys.

		Participants' response to the surveys 1 and 2 (%)							
		Strongly Agree		Agree		Disagree		Strongly Disagree	
		1	2	1	2	1	2	1	2
Questions	1. I am confident to work together with others from diverse professional backgrounds.	46.3%	50%	51.2%	50%	2.4%	0%	0%	0%
	2. I am confident to present my perspective to a diverse group.	39%	25%	41.5%	75%	17%	0%	2.4%	0%
	3. I am confident to solve problems.	26.8%	25%	58.5%	75%	12.2%	0%	0%	0%
	4. I am likely to share my ideas with others from diverse professional backgrounds.	36.6%	50%	56.1%	50%	7.3%	0%	0%	0%
	5. I am likely to work with others to solve problems.	36.6%	33.3%	51.2%	41.7%	12.2%	25%	0%	0%
	6. I think it is important to work with others from different professional backgrounds to solve problems.	56.1%	33.3%	34.1%	66.7	9.8%	0%	0%	0%

Comparison of the results of survey 1 and 2 represents a shift towards positive responses in all questions except for number 5, the likelihood of working with others to solve problems, which shows about 13% increase in "Disagree" response percentage (Figure 5). This can be attributes to the negative experience of some students in group work. Their dissatisfaction was expressed during the semester via emails and was also pointed out in the "additional comment" section of the second survey.

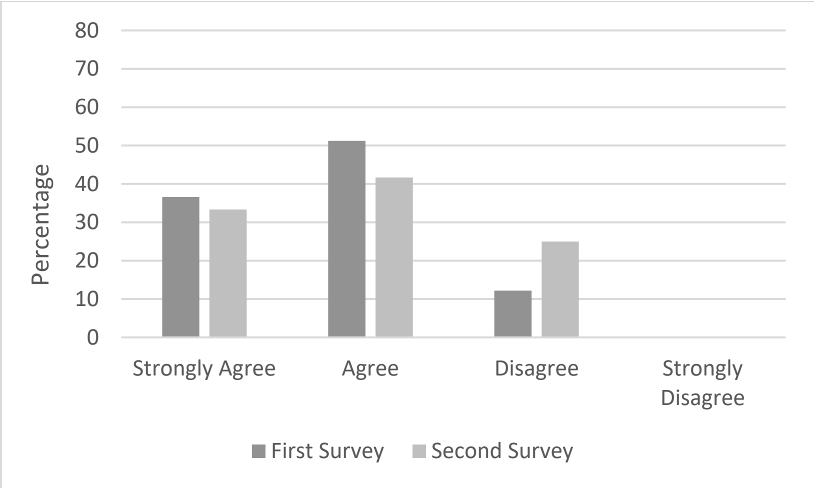


Figure 5. Results of the likelihood of working with others to solve problems.

The highest positive shift is observed in item number 2, the confidence in presenting perspective to a diverse group. This item has the highest negative response rate in the first survey (about 19.5% in total) which all is transferred to the positive band in the second survey (Figure 6). Presenting and expressing opinion can be an intimidating experience which can be improved through practice (Leary 2019). People are also more comfortable to speak out in a familiar environment and for familiar audiences. The positive jump in students' confidence in presenting their perspective to a diverse group can be the result of combination of all the factors stated above.

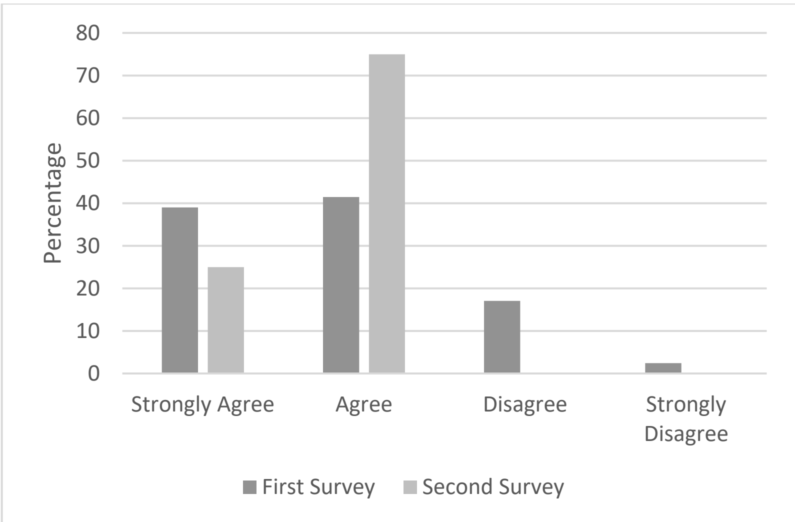


Figure 6. Results of the confidence in presenting perspective to a diverse group.

Focus group

The statements of participants derived from the focus groups was analysed resulting in three main categories and three themes. The three main categories are: 1) Students' experience with design thinking during the semester, 2) Students' experience in collaboration during the semester, and 3) Students' intention to use design thinking in the future. The common themes across all categories are discussed below.

A. Empathy

One of the themes that was bold in categories 1 and 3 was Empathy. Getting to know the stakeholders' perspective was mentioned as something new in the category 1, participants' experience with the design thinking. Empathy was also mentioned in category 3, intention to use design thinking in the future. Taking into account the users and stakeholders' perspectives and feelings was new to most of the participants. Using empathy was also mentioned as one of the positive aspects of Design Thinking in the second online survey. The idea of getting to know the users as a fundamental step was appealing to the students and they mentioned that they are going to use this approach in the future as part of the problem-solving process.

B. Structured process

Structured process of design thinking was repeated across all the categories. In Category 1, it was mentioned as one of the differences with the other problem-solving methods that students had experienced with. Design thinking was also perceived as a fundamental method that is necessary for those who do not have experience. For category 2, experience of collaboration, the participants ascertained that the structured process of design thinking has helped them in working collaboratively and to structure the group work. The structure of design thinking has provided students with a process to follow and this is something that they want to pursue in future problem solving tasks (category3).

C. Problem type

Different perspectives about the type of the problems that can benefit from design thinking was found in Category 1. Participants found Design Thinking useful for wicked problems and not so much for small and easy problems. In some cases students did not see the relevance of Design Thinking to urban planning problems. Some thoughts this approach is more useful for social problems.

Discussion

In overall, the positive responses significantly outweigh the negative ones across all the categories and questions. This represents students' high confidence in their problem solving and collaboration skills. Interestingly, the results across different categories have shifted towards "Agree" in the second survey. This is true for both negative responses (Disagree and Strongly Disagree) and for "Strongly Agree" response representing a more positively moderate perception of students from their collaboration and problem-solving skills after being exposed to the design thinking.

In terms of collaboration, some students have expressed their dissatisfaction with group works in some instances via emails during the semester and through comment section of the surveys. There were complains about unequal contribution from different group members. This was reflected in the responses related to their likelihood of working with others to solve problems. We also learned that there were some students from different stages of their degrees. Having had different experiences, mindsets, and commitments, some had difficulties to work in groups and even preferred to deliver the group assessment all by themselves.

The design of this unit was relying on attendance of students to the tutorials and group work under supervision of their tutors. However, as the semester progressed the attendance decreased significantly. This was another group work issue that was expressed by students.

As mentioned in the introduction, given the stage of their studies, students were asked to work on sustainability as the problem area. Interestingly, some students complained about having to cover sustainability yet again. They wanted something more focused on their major. This prevented some students to see the relevance of Design thinking as a problem-solving method for the built environment related issues and could not comprehend its application to their future carrier.

Conclusion and future work

Design thinking for the built environment was delivered for the first time in semester 1, 2019. There was a strong focus on problem solving and collaboration in this unit. In the initial survey students expressed a relatively high confidence in both of their collaboration and problem-solving skills, this was further improved in the second survey showing that the skills taught in this unit had a positive impact on the targeted skill set.

Having said that, there were some negative experiences among the students involving group work and collaboration. One major issue was unequal contribution from different members in some instances. In the next iteration of the unit, more focus will be placed towards the group formation, roles, and responsibilities of each member.

One of the challenges of this unit was to define a problem area that suits the students' knowledge and is relevant to the built environment. Accordingly, sustainability in the built environment was chosen. However, this was not perceived well by the students as they did not see its relevance to their major. Other options with more relevance to the built environment will be explored for the next year.

Currently, similar approaches and unit offerings is being undertaken in other faculties and disciplines within QUT. The research team is in liaison with the relevant unit-coordinators to compare their experiences and the results of their unit with the intention to improve the students' experiences across these units.

References

Kelley, D. and Kelley, T. (2015) *Creative Confidence: Unleashing the creative potential within us all*. Harper Collins, USA.

Koh, J. H. L., Chai, C. S., Wong, B. & Hong, H. (2015). *Design thinking for education: Conceptions and applications in teaching and learning*. Singapore: Springer.

Plattner, Hasso; Meinel, Christoph; Leifer, Larry J., eds. (2011). *Design thinking: understand, improve, apply*. Understanding innovation. Berlin; Heidelberg: Springer-Verlag. pp. xiv–xv

Leary, Mark R. 2019. *Self-presentation: Impression management and interpersonal behavior*: Routledge.

Stalmeijer, Renée E, Nancy McNaughton and Walther NKA %J Medical teacher Van Mook. 2014. "Using focus groups in medical education research: AMEE Guide No. 91 36 (11): 923-939.

AN INVESTIGATION INTO THE TERMS OF INCLUSION FOR SURROUNDING NEIGHBORS OF RESIDENTIAL GATED COMMUNITIES – A CASE OF PALM LAKES ESTATE, TINLEY MANOR, KWA-ZULU NATAL.

Letsoko Vuyiswa[1], Pillay Nischolan[2]

[1]Town and Regional Planning/ Engineering and the Built Environment,University of Johannesburg, Johannesburg, South Africa

[2] Town and Regional Planning/ Engineering and the Built Environment,University of Johannesburg, Johannesburg, South Africa

Abstract

Gated communities have become a global phenomenon and a key feature of neoliberal suburbia. Gated communities are typically privatized physical locations whose access is restricted by walls, fences, gates or booms that detach their communities from their surrounds. These private developments have been seen as the only housing option for majority of middle to high income earners in society in response to crime and have been critiqued for deepening social exclusion, residential segregation of the poor and wealthy, deepening social divides and fragmenting the urban form. This has an added dimension in South African cities for such urban trends imitate apartheid's geography of exclusion rather than the transformative agenda of urban integration and inclusion. A growing trend in South African cities in the presence of informal settlements that are located at the periphery of these privatized developments. Literature on gated communities has focused mainly on their negative impacts to the surrounding communities however limited research considers the potential positive impacts these gated communities may have for their surrounding poorer neighbours. The study employed a mixed method approach of quantitative inquiry using questionnaires and qualitative interviews to understand the linkages gated community residents have with communities located outside the gates. This study revealed, contrary to popular belief, gated communities rely heavily on surrounding communities for the labour workforce and the poorer communities in turn need the gated communities for a place of work. This study therefore intends to contribute to this gap in knowledge.

Keywords

Residential Gated Communities, Inclusion, Socio-spatial relationships, Labourers, Planning, Architecture,

Introduction

Gated communities are a global phenomenon and have become a distinct feature of contemporary urbanism. The worldwide popularity of these developments has sparked growth in the literature focusing on experiences and narratives across the globe that mainly emphasize their negative impacts on society whilst their positives are less pronounced (Lemanski, 2006). Gated communities are criticized for intensifying the exclusion and inequality of urban space by increasing residential segregation of the rich and poor, expediting socio-spatial divides, fragmenting the urban form and restricting the freedom of movement (Caldeira 2000; Low 2003). Justification of these bounded spaces are typically the fear of crime, the need providing an improved the quality of life as well as the need for privacy, exclusivity and convenience (Nasution and Zahrah,2015; Ramoroka and Tsheola, 2014; Landman, 2002; Breetzke et al,2014; Tibbalds, 2001; Lemanski, 2004; Blakely and Snyder, 1997).

Furthermore, Lemanski (2004) highlights that these developments are also born out of not-in-my-backyard (NIMBYism) mentalities that employ walls as a defence mechanism and provide a form of escapism to relive fear of the outside "world", similar to the walls and motes during the medieval times to restrict trespassers from access (Micthell,1995; Landman,2010). This implies that these developments are architecturally policed and are viewed as purified spaces detached from the dirt and dangers which lurk outside the gates. Therefore, these privatized spaces "reinforce the fear of the unknown beyond the gates and exclude on the notion of socio-economic difference" (Lemanksi, 2007,p.397). As a result, gating serves as a panacea to maintain the shared safety, values, belonging and identity of the neighbourhood (Hook and Vrdoljak, 2002). These exclusionary practises are facilitated by the walls and gates which cluster homogenous groups of society with limited or no opportunity for diversity and produce urban spaces where spatial exclusion and social exclusion become intertwined (Lemanski, 2007; Rodgers, 2004). This study aims to question the attitudes and perceptions of gated community residents to the 'difference', evident at the periphery of the gates, in the informal settlement communities neighbouring these gated utopias.

The Royal Palm Estate

The Royal Palm Estate, or better known as Palm Lakes Estate to its residents and developers is a gated residential estate located approximately 50km from central Durban and forms part of the greater Tinley Manor Beach Town. The estate was developed in early 2005 and has grown significantly over the past 15 years. The estate was formerly a sugar cane farm which was then sold over to a Belgian developer who developed the land as an estate. The rapid growth is due to the calm nature of the area, away from city living and the close proximity of the estate to important destinations, one important one being the King Shaka International Airport which is approximately 30km away. Access to Durban is relatively easy as the N2 National highway is 4km away from the estate. Palm Lakes estate also enjoys close proximity to the Tinley Manor Beach, which is 6km away and draws more and more visitors every year. The main draw of the estate is the affordability which entices middle class buyers, thus its popularity over the past few years.

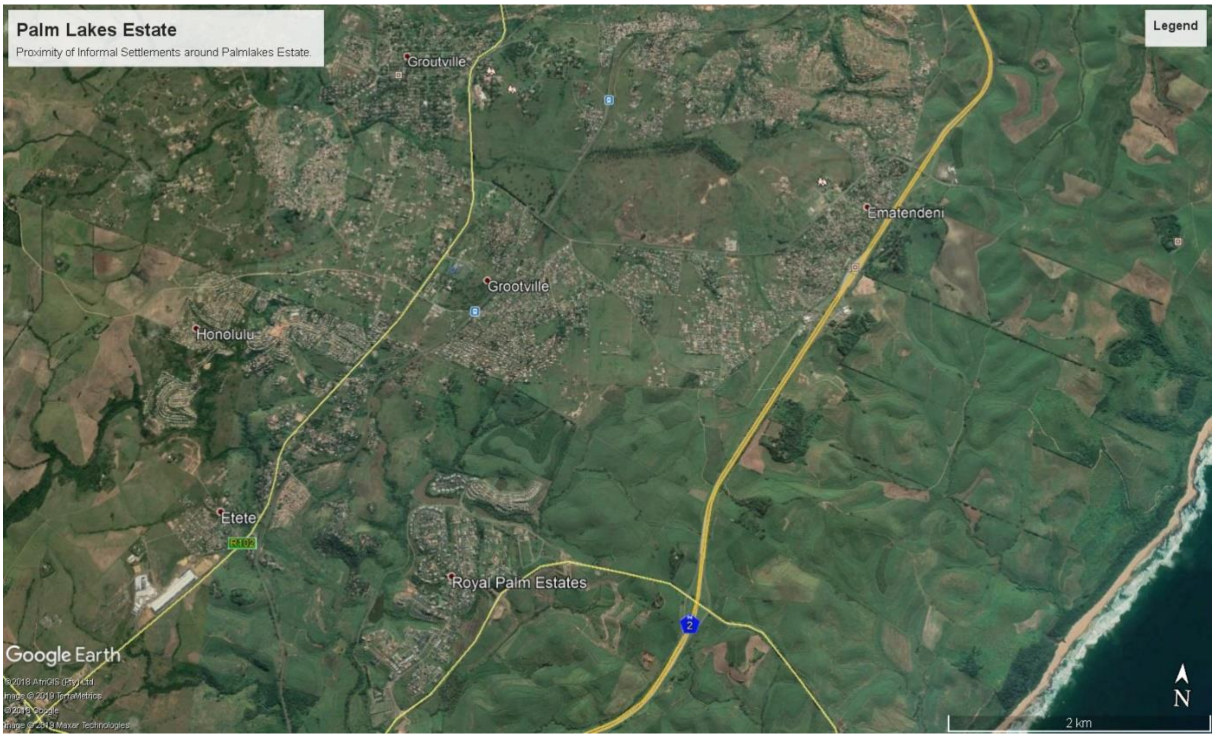


Figure 1: Map showing proximity of Palm Lakes Estate in relation to Groutville and surrounding informal settlements.

Literature Review

Unpacking the concept and history of gated communities

The notion of gating is not unique to the contemporary city. In fact, archaeological evidence reveals that walled personal enclaves trace back to 300BC in Rome where wealthy Roman communities built walled communities at the edge of the city to protect themselves from potential threats such as theft and kidnapping by lower class communities (Blakely, 2008). The same is also evident in various ancient African cities such as the Great Zimbabwe civilizations. Their re-emergence in the contemporary city was initially as a result of a real-estate boom in United States during the1970s (Blakely and Snyder, 1997), gated communities have since spread all over the world in cities as different as Beijing, Brazil, and Buenos Aires amongst others. The processes of globalisation, neoliberal policies and the resultant urban shifts of such processes have led to a growth in the privatization of public space and providing a platform for the intensification of gated developments in cities.

It was not until the late 1990s that these developments also gained popularity in South African cities, since then these developments have taken centre stage in most new developments and have become a key feature of the post-apartheid city (Landman, 2010). Gated developments have been defined as being “residential areas with restricted access such that normally public spaces have been privatized” (Blakely and Snyder, 1997,p.1). Similarly, Landman (2010) perceives gated communities as being physical locations that have walls or fences which are detached them from their surrounds and also have gates/booms which restrict access into these locations and as a result the public spaces within these developments are privatized. In literature that there two main typologies of gated communities, broadly categorized as enclosed neighbourhoods (roads remain public property or roads remain private property) and security villages (large residential security estates, residential security complexes, secure high-rise apartment blocks and secure office parks)(Blakely and Snyder, 1998; Landman; 2012; Blakely, 2008; Grant and Mittlesteadt, 2004). Spocter (2011,p.173) outlines that within these sub-types, “one would most probably find further differences, but then this is done at the risk of the typology being too large and unwieldy”. The focus for this study is the large residential security estates, which is a sub type of the security villages.

The post-apartheid city and the rise of gated developments

Literature addressing the post-apartheid urban form in South Africa mainly focuses the continuation of spatial inequalities and differences rather than on the urban integration and transformation (Beall et al., 2002; Tomlinson et al., 2003; Turok, 2001; Watson, 2003). Although there have been efforts towards implementing integrated development planning as well as mixing socio-economic groups, in these dual South African cities the extremes seldom overlap (Rogerson and Rogerson, 2015). The privatization of space through the notion of gating has been seen as a key motive hindering the transformative agenda and enabling the persistence of apartheid-like geographies in cities (Lemanski, 2007).

The growing levels and fear of crime in South Africa have fundamentally been used as justifications for such developments. As a result, these types of developments have been seen as the only housing option for some social groups in the South African society as residents have responded to this fear by creating territorial enclosures and employing security staff in a desperate attempt to recreate idyllic suburbia (Landman, 2003; Lemanski,2007). A major critique of these gated developments in post-apartheid cities is that they are viewed as a contradiction, as they evoke past disparities on grounds of social class, status and exclusivity in a country which is sought to be democratic and encourage the integration and interaction of various groups of people at multi-levels of society (Landman and Ntombela, 2006). The vision of a non-racial and integrated spatial form is continuously at conflict with residents’ independent response of creating boundaries that oppose such inclusivity and instead produce a “neo-apartheid” which divides not only based on race but on social class and exclusivity (Lemanksi, 2004).

Hook and Vrdoljak, (2002) outline that the choice for elite groups of society to choose to live in a gated community relates to their desire to detach themselves from the broader civic society and socio-economic difference that exists outside the gates. This ‘difference’ is ironically in some cases less than five hundred metres from the periphery of the gated community. Although gated communities tend to be located in and surrounded by wealthy areas there is a growing trend in the post-apartheid South African cities where poverty and wealth coexist as informal settlements locate in close proximity to these gated communities (Lemanski and Oldfield, 2008). These informal settlements provide largely low-income and predominately black African households the opportunity to reside in better-located parts of the city.

Socio-spatial relationships of gated communities and their poorer neighbour

The majority of academic literature on gated communities across the globe tends to link the gating phenomenon with negative impacts on social and residential segregation to their surrounding neighbours. Le Goix (2005) focuses on three general types of arguments on the relationship between gated communities and their relationship to surrounding communities. In the first argument, he outlines that gated communities represent the post-industrial societal changes such as individualism, segregation, and fragmentation by the commoditising of urban public spaces. Secondly, gated communities are symptoms of urban pathologies, among them social exclusion and segregation are the most prominent. As a result, the gating of neighbourhoods and decline of public spaces in neighbourhoods has a negative impact on the poor. The third argument is that the growing gated communities are an act of secession by the upper class, certain race, and ethnic groups from society. Consequently, these developments are a direct rejection of social mix in urban areas and redistribution of the welfare system thus perpetuating inequalities in cities.

There are however a smaller group of scholars (Salcedo, Torres, 2004; Manzi and Smith-Bowers, 2005; Sabatini and Cáceres, 2004; Sabatini and Salcedo, 2007; Roitman 2010) and empirical research that suggests that there are potential positive impacts of gated communities on their surrounding neighbours and ability for them to contribute to social integration. Among such cases is Le Goix (2005) study in the United States which indicated that there exists strong functional integration (employment) between gated and non-gated settlements as these gated locations provide employment opportunities for surrounding non-gated settlements. As a result, this presented an opportunity for an increase in the social mix within these spaces. Similarly, in Salcedo and Torres (2004) study in Chile it is evident that the residents’ poorer neighbourhoods which are situated in close proximity to the gated communities are grateful for their presence as they attract modernity and improvements to the area which they also benefit from. This functional integration is evident in South African cities, where Diepsloot informal settlement residents are dependent on Steyn City gated community for informal domestic employment (Ballard, 2019). Thus, these informal settlements are labour pockets not only for the whole city but for these gated developments.

Additionally, this study also indicated that the gated community residents had a positive image of their poorer neighbours and were happy to employ them to work in the gated communities (Salcedo and Torres, 2004,p. 39–40). This indicates that this spatial proximity of these two diverse communities leads to and enhanced tolerance of the ‘other’ and a greater understanding or the socio-economic difference. Sabatini and Salcedo (2007) refer to this as symbolic integration when residents of gated and non-gated communities see each other not just as ‘the others’, but as people who belong to the same neighbourhood and share a common identity.

Problem Statement

Gated communities have become a distinct feature of the urban landscape in the South Africa resulting in the spatial distortions of the urban form and the micro-society of space. As previously mentioned, opportunities for interaction across the divide are restricted by increasing privatisation in the form of gated residential territories due to the fear of crime, under-management of space and the desire for social exclusivity. A growing trend in South African cities in the presence of informal settlements that are located at the periphery of these gated developments. Recent literature on gated developments and their implications for built environment professionals and society has been growing universally additionally there has been an increased focus mainly on their negative impacts to the surrounding communities. There has however been very little theoretical knowledge pertaining to their positive impacts and in-depth understanding on the relationships and linkages of these gated communities with their surrounding neighbours. This study aims to contribute to this gap in knowledge.

Research Methodology

This research aims to investigate the terms of inclusion for surrounding neighbors of residential gated communities. The study area was the Palm Lakes Estate, Tinley Manor, Kwa-Zulu Natal, South Africa. The research consisted of a mixed method approach and employed primary and secondary sources to investigate the research question. The following method was employed;

Task 1: Review of Literature

In this task, the authors conduct an extensive and critical review of literature of; Concepts and History behind gated communities, The Post-Apartheid city and rise of gated developments and socio spatial relationships of gated communities and their poorer neighbors. The literature forms the theoretical and conceptual framework for this research and the lens in which the authors interpret the empirical data.

Task 2: Primary Data

For this study, the authors utilised a questionnaire and semi-structured interviews for the primary methods and data collection, furthermore a case study approach was utilised to further investigate and explore the topic. The authors intended to question and interview 20 respondents, however only 18 interviewees responded to the call to participate forming a 90% feedback, nonetheless the data received proved powerful.

Task 3: Analysis of Data

The analysis of data for this research is by far the most important aspect of this paper. The data was collected from 18 respondents from various education levels, ages, races and genders. This quantitative data was analysed using graphs to visual understand the data. Furthermore, the qualitative interviews were analysed using an interpretivist paradigm to construct a meaningful reality of the data.

Discussion and Findings

In this section, we discuss the findings of this research. We start with the quantitative data for this research and thereafter move onto the qualitative findings and then the case study will be used for comparative analysis. It must be noted that we required 20 participants for the study and only 18 participants came forward in the study. To form the group of participants, permission was asked from the estate and the survey was distributed via the estate staff to residents. The data below is representative, in part of the demographics of the estate.

Quantitative Data Analysis and Discussion

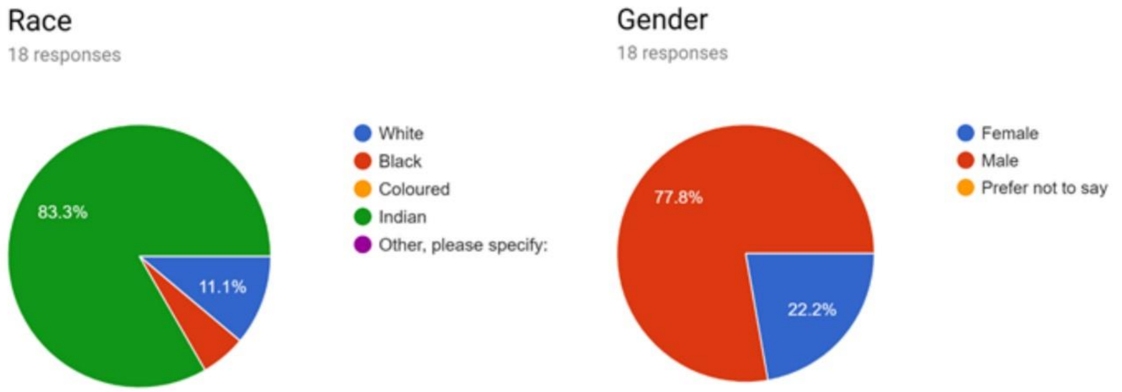


Figure 1: Graph representing the race demographic and gender of participants in the study.

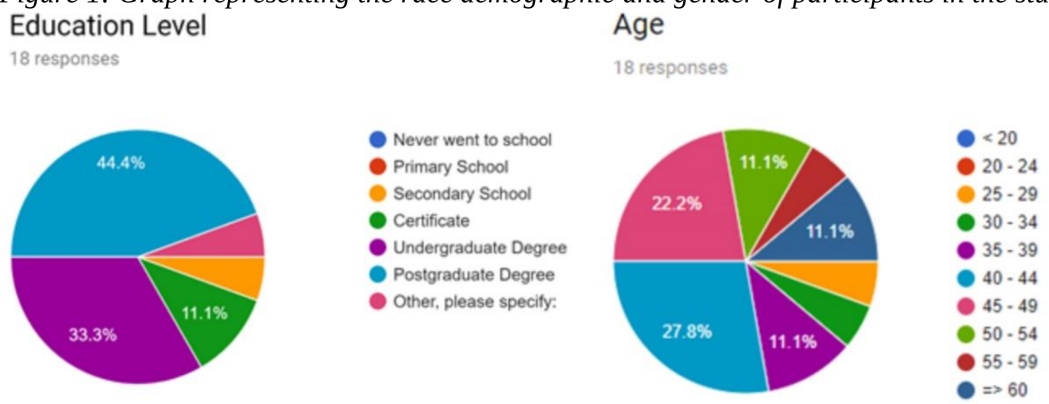


Figure 2: Graph representing the education level and age of participants in the study.

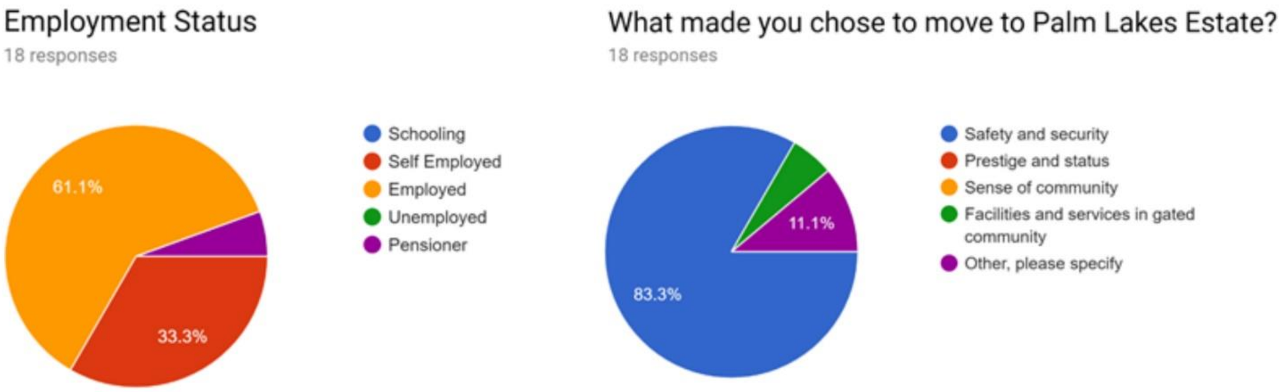


Figure 3: Graph representing the employment status and reason for choosing Palm Lakes as a place of residence of participants in the study.

Figure 4: Graph representing the reason for choosing to live on the estate age of participants in the study.

Demographic Profile of Participants

In this section, the researchers studied the demographic profile of the participants of the study, all respondents live on the Palm Lakes estate. The first question posed to respondents was the racial status, from this it was observed that 1 (5.6%) participant was Black African, 2 (11.1%) participants were White and 15 (83.3%) participants were Indian. This profile is representative of the 850 Households on the estate, were it was found that the largest race population was Indian, followed by White and then Black African. In the second question, we probed the area of gender group. It must be noted that this data is not representative of gender, as Palm Lakes Estate is a Family Estate and is formed largely of married couples with families. However, 14 (83.3%) were Male and 4 (22.2%) were Female. The next area of investigation was to determine the level of education of the participants. This area was vitally important as it explained the type of people and also the income band, which was not probed but can be determined from the level of education. From the study, it was determined that 1 (5.6%) participant had mentioned "Other" as their qualification level, which turned out to be a short course. 1 (5.6%) participant had an education at secondary school level, 2 (11.1%) participants had a certificate level of education. 6 (33.33%) participants possessed an undergraduate university degree and 8 (44.4%) hold a postgraduate university degree. From this, it is understood that the majority of participants hold university degrees and are professionals. It can be further interpreted that the participants and large majority of residents on the estate are professionals. The fourth area that we investigated was the age group of participants. This was also a very important area that needed investigation as it would give detail of the type of people occupying the estate. It was noticed that the majority of residents (50%) are between 40 and 50 years old, the rest of the participants formed the other half. It was further noticed that a quarter of respondents were between 25 to 39 and the other quarter were over 50 years old. From this data, it is clear that a large number of residents are under the age of 50. This narrates that the estate is actually one that has a young population group. The fifth area of investigation was the employment status of the participants. 11(61.1%) of the participants answered that they were full time employed and 6 (33.3%) answered that they were self employed and 1 (5.6%) respondent was a pensioner. In this profile it can be determined that the majority of participants are financially stable. If we turn our attention to the average cost of a house on the estate, which is R3 000 000.00, it can be determined that the majority of residents earn an above average salary, which we place in the middle-class category. The sixth question posed to respondents was the reason they chose the estate. 83.3% of respondents overwhelmingly chose the estate for safety reasons. Examining the high crime rate South Africa faces, this comes as no shock and ultimately narrates the story of why there is an increasing number of security estates in the country. The final topic covered in the quantitative data was the number of years the respondents lived on the estate. From this, it was discovered that 14 (77.8%) of respondents are fairly new residents, living on the estate for no more than two years. 3 (16.7%) of participants responded that they have been living on the estate between 3-5 years and 1 (5.6%) respondent for more than 10 years. Although the estate is reaching its 15^{th} year in existence, most of its residents are fairly new.

Relationship Investigation of surrounding neighbors of Palm Lakes Estate

Table 1: Questionnaire responses in linear scale of relationships between informal settlements and gated communities.

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Do you consider Groutville informal settlement as a neighbour to Palm Lakes Estate?	1	0	7	8	2
Do you agree that there is a relationship between Palm Lakes Estate and Groutville informal settlement?	1	3	3	8	3
Do you believe that Palm Lakes Estate provides the residents of Groutville informal settlement with employment opportunities?	1	0	4	6	7
Do you believe Groutville informal settlement poses a security threat (i.e. crime) to Palm Lakes Estate?	2	3	7	3	3
Do you believe Groutville informal settlement poses a threat to property values in Palm Lakes Estate?	2	4	2	5	3

In this section of the research, the authors investigated the relationships between the Palm Lakes Estate and the neighbouring informal settlements. This study required participants to determine their answer through a linear scale research instrument. The authors probed both physical spatial relationships as well as social and economic relationships. In the first question, the authors probed a spatial enquiry into their thoughts of neighbouring communities. 10 of the respondents agreed that the Groutville informal settlement was a neighbour to Palm Lakes, 7 respondents were neutral about the matter and 1 respondent strongly disagreed. Form this spatial enquiry, the residents seem to have accepted the fact that the informal settlement is indeed a neighbour. The second question posed to residents was one of social relationships, the authors asked respondents if they believed a relationship existed between the communities. 11 respondents agreed that a relationship existed between the communities. 3 respondents were neutral on the matter and 4 respondents disagreed. It is clear that residents of the estate do believe that there is a relationship that exists between Palm Lakes and Groutville and this is an important determining factor of this research, this does prove that there is some sort of inclusion that is occurring. The third question we posed to participants was if they believed that Palm Lakes Estate provided employment to Groutville residents; 13 participants were in agreement of this, 4 remained neutral and 1 participant disagreed. It is evident from the responses that resident believe that Palm Lakes Estate does provide employment to the surrounding informal settlements. The fourth question that was posed to respondents was if they think that Groutville informal settlement possesses a security threat to Palm Lakes Estate; 6 residents agreed, 7 residents remained neutral and 5 residents disagreed. From this we can interpret that residents have different feelings about security threats from the informal settlement;

However, from the authors experiences on the estate, this threat is minimal as the estate has tight security measures that have been put into place. The final question posed to participants was if they believed that Groutville informal settlement posed a threat to the property value in the Palm Lakes estate; 8 respondents agreed, 2 remained neutral and 6 disagreed. This result seemed to balance the views of residents in the estate. However, recent property prices and sales have suggested that the value of property in the estate has only been increasing in recent years. From the areas questioned in this section, we are able to form a true picture of residence beliefs of various aspects examined. We take this enquiry further in the next section of qualitative interviews in order to better understand the resident's feelings towards the surrounding informal settlements.

Qualitative Data Analysis and Discussion

In this section we performed structured interviews to probe the research question further. To further inform the research, a qualitative method had to be implemented to gain understanding from the participants of the study. The authors formulated six questions for this task.

Question 1: What are your perceptions of Groutville informal settlement and its residents?

"I would like to believe that they are just people trying to make an honest living and to provide for themselves and their families in the circumstances they find themselves."

"The residents seem harmless and just want to be as close to their place of work as possible. However, having an informal settlement next door to any property really decreases the value and poses a risk crime generally speaking."

"In a democratic South Africa, we will have to accept these informal settlements as they are also human and have to have shelter and are less fortunate than others so they don't have any alternative to live close to these estates so they can find work and it is easily accessible to the estate for work."

These sentiments are just three respondents and are representative of the 18 participants as similar responses are noted from the other candidates. From the above responses, we can form an understanding of the perceptions made in the minds of residents of Groutville informal settlement. In these sentiments, residents seem to have empathy towards the Groutville community. We can see that the residents are comfortable with having the settlement nearby. Respondents further reinforce the mutual beneficial relationships such as workers living close to work etc. It also seems that the residents believe that these settlements have occurred because of the job opportunities available in the estate. It is also good to note that the respondents accept a democratic South Africa were people can live in harmony side by side, given the nature of our unpleasant past.

Question 2: What is the nature of your contact with of Groutville informal settlement and its residents?

"None"

"We employ a domestic worker and gardener from the area"

"Some of my staff live at Groutville informal settlement and work on the Estate."

The responses from all 18 responses can be captured in the above sentiments. The nature of contact seems to differ amongst residents; however, the majority of participants have responded that they employ domestic workers and gardeners from the area. The second largest responses are from residents that believe that skilled, semi-skilled and highly skilled workers are employed in the construction industry in Palm Lakes. This in fact is a true statement as many workers involved in construction come from the Groutville informal settlement. A few respondents note that they have no contact with the Groutville informal settlement and its residents. It is important to understand the dynamic of employer and employee in this area. Palm Lakes consist of a majority of above average earners who are predominantly professionals which seek to employ the services of various types of occupations. Therefore, the demand is met by the supply of workforce from the Groutville informal settlement.

Question 3: What benefits do you think could result in a relationship between the residents of Groutville informal settlement and Palm Lakes Estate?

“Benefits are creating employment, Sustaining homes. The situation is two-fold, the continuation of employment; creation of wealth/income will be impossible without each other. Residents are unable to go to work if employee does not come to work. It's a form of job creation & continuation of income generation for both parties. (Industrialisation) bringing the industry to the residents of Groutville whereby the residents of Palm Lakes will have to travel out to work.”

“The estate should assist create a vegetable garden on the outskirts of the fence line and supply water from its dams and the vegetables can be sold to the residents of Palm Lakes. In this way employment will be created and crime will be reduced.”

“A close-knit community could be developed resulting in lesser threats.”

“Upliftment of the community by employing them and teaching building skills.”

In this question of the qualitative study, the authors probed the relationships that could result between the Groutville and Palm Lakes communities. On initial examination of the answers, the authors note that majority of Palm Lakes residents are in favour of creating mutual relationships between the community and themselves. These relationships are more than work related relationships that are previously mentioned in this research but also upliftment of the community. From this we see a flourishing and enriching approach by residents which goes beyond their personal needs. All residents agree that relationships can be created and crime reduced by giving employment to the residents of Groutville. The authors also interpret that the residents of Palm Lakes seek help from the estate management to uplift the community, this can be achieved as a collective and would greatly benefit both communities.

Question 4: What positive impacts do you believe Groutville informal settlement contributes to Palm Lakes Estate or other surrounding neighbourhoods?

“Employment in various sectors e.g. security; maid services; landscaping. Various Skills in the building industry.”

“General labour, skilled and semi-skilled labour.”

From this question, all participants believed that the estate positively benefits from the labour force. Probing this further we see a mutual beneficial relationship that exists. The need for labour is great in the area as the estate is expanding rapidly. It seems that this growth will not slow down soon as more and more families are moving to the area, which is very beneficial to all residents of the informal settlements as this occurrence provides jobs for them.

Question 5: What negative impacts you believe Groutville informal settlement contributes to Palm Lakes Estate or other surrounding neighbourhoods?

“Perception of property devaluation”

“There are some incidents of crime in the area, however if everyone from the area has a job the crime will reduce significantly”

“The noise levels, pollution”

From this question, the authors have drawn attention to three main themes as listed above. The first area of concern is the devaluing of property, even though this is a concern for some residents, most residents don't see this as a threat. This has various factors linked to it; The estate is gated and is highly securitised, the informal settlement is a neighbouring township but not an immediate neighbour, the vast area of the Palm Lakes estate far surpasses the area of the Groutville settlement (Spatially). These factors currently form the basis of valuation in the area, furthermore the informal settlements existed prior to Palm Lakes, however have grown significantly as the estate grew, for understandable reasons. The second theme noted by residents is the crime factor. Although there has been no reported case of crime from outside the estate fence, residents are concerned about their safety outside the estate. Most residents are all for the creation of jobs to reduce the crime related behaviours in the area. The last theme is a minor one, the noise and pollution levels is a common occurrence in informal settlements due to lack of services. A suggestion made by residents is for again a mutually beneficial agreement between Palm Lakes Estate and Groutville informal settlement to engage in helping with service delivery to the people. However, this suggestion is wholly dependent on government and private sector funding.

Question 6: Do you believe Palm Lakes Estate has a role to play in uplifting its surrounding communities?

"Yes, help to restore the area, with landscaping medium size houses, reconstruct design facilities, to attract investors."

"Absolutely. Job creation in the past 14yrs has increased with various developments. (building industry) Employments of maids in various house-holds."

"Yes, Palm Lakes does employ work force from the informal settlement and its surrounding areas but there can be more done for e.g. create vegetable gardens, small scale chicken farming, skills development facilities."

One of the main themes realised in this research is one of employment of members from the informal settlement, it has been a strong sentiment from all participants. However, the residents also believe that more can be done to uplift the community such as creation of formalised housing for the community and restoration of the landscape. These factors can be mutually beneficial to both communities. An area of interest however, that has become an underlying theme from participants is the creation of entrepreneurial spirit, empowering the community with the virtue of business. This by far has been a very important suggestion by participants. Although the estate is growing year on year, it is also extremely vital to understand that at some stage the building industry will suffer a slump, like in most parts of the world. Therefore, a business model must be developed for the dwellers of informal settlements on order to sustain their livelihoods.

Conclusion and Recommendations

This research intended to investigate the terms of inclusion at gated estates. The Palm Lakes Estate, Tinley Manor, Kwa-Zulu Natal, South Africa was used as a case to investigate this phenomenon as it has an informal settlement in close proximity to it. Although gating of estates creates separation of people between classes and mimics an apartheid style of exclusion, the safety climate in South Africa is an important factor to consider. In the process of research, four outstanding themes have been formulated; Safety, Job Creation, Upliftment of the Community and Property values. Taking the point of Safety into consideration, the Palm Lakes estate creates a high sense of security and 90% of participants responded to having chose the estate due to its high security, far outweighing any other benefit. The data extrapolated shows that residents value safety as the biggest concern. The second theme that comes into play is the issue of job creation, were participants believed strongly in the need for job creation within the area. The authors experience on the estate confirms this occurrence as we have personally seen a high employment rate from the Groutville informal settlement. A symbiotic relationship is in existence at the estate. It is important to take special note of employment as estates of this kind become beneficial to the area in which they exist, secondly by creating employment for the people of the area, it becomes a deterrent to crime. The authors believe that this by far is a crucial finding were a phenomenological occurrence has great benefit. The third theme discovered by this research is the need for community upliftment. Community upliftment remains a concern of most participants interviewed in the study. It can be revealed that the Palm Lakes community believes strongly in the upliftment of the community of Groutville. Suggestions put forward by residents reveals that they think certain services can be provided by the Groutville community such as; fruit and vegetable production, livestock supply amongst other services such as supply of labour in the building industry and domestic workers for the estate. The final theme discovered by this research is the value of properties in Palm Lakes estate due to the close proximity of an informal settlement nearby. However, this occurrence has not deterred buyers according to the history of sales in the area (refer to figure…), but still remains a concern to some home owners. Holistically looking at the properties, Groutville informal settlement seems as though it has become more of an asset to Palm Lakes estate rather than a liability. Through this research, the authors have discovered the terms of inclusion of surrounding informal settlements into gated communities. A major relationship of work force and supply of goods comes to the surface, creating a symbiotic occurrence between the two communities. The authors recommend, as a general rule across estates in South Africa to implement strategies at all times to hire local labour from the area that surrounds the estate and furthermore to form more meaningful relationships with the communities that surround their estate resulting in mutual beneficial relationships. Furthermore, Gated communities should set up programmes where they contribute to social upliftment of less fortunate communities that surround the estate, further reinforcing relationships.

References

Beall, J., Crankshaw, O. And Parnell, S. 2002,'*Uniting a Divided City: Governance and Social Exclusion in Johannesburg*',London: Earthscan Publications.

Blakely, E.& Snyder, M.1997,'*Fortress America*', Washington: Brookings Institution.

Caldeira,T.P.R. 2000, '*City of Walls: Crime, Segregation and Citizenship in Sao Paulo*', University of California Press, Berkeley, CA.

Grant, J.&Mittlelsteadt, L.2004,'*Types of Gated Communities*', Environment and Planning B: Planning and Design, vol.31,pp.913-930.

Hook, D.,&Vrdoljak, M. 2002,'G*ated communities, heterotopia and a 'rights' of privilege: A 'heterotopology' of the South African security-park'*, Geoforum, vol.33,no.2,p.p 195-219.

Low, S. 2003,'*Behind the gates: life security and the pursuit of happiness in fortress America*', London, Routledge.

Ramoroka,T. &Tsheola,J.2014,'G*ated-communities and the privatization of public spaces in urban South Africa: Democratic social integration or exclusion?'*, Journal of Geography and Regional Planning, vol.7,no.4,p.p 58 -68.

Nasution,A.D.,&Zahrah,W.2015,'T*he Space is Not Ours, the Life of Public Open Space in Gated Community in Medan*', Indonesia, Procedia - Social and Behavioral Sciences,vol.202,pp.144-151.

Landman,K.2002,'*Gated communities in South Africa: building bridges or barriers?*', International Conference on Private Urban Governance, Mainz, Germany, 6-9 June 2002.

Landman,K.2012,'*Gated communities in South Africa: Tensions between the planning ideal and practice'*, Town and Regional Planning, vol.61.

Landman,K.,& Ntombela,N.,2006, 'O*pening up spaces for the poor in the urban form: trends, challenges and their implications for access to urban land*', Urban Land Mark Position Paper 7 Paper prepared for the Urban Land Seminar, November 2006 Muldersdrift, South Africa.

Lemanski, C.2004,'A *new apartheid? The spatial implications of fear of crime in Cape Town, South Africa'*, Environment and Urbanization,vol.16,no. 2,p.p101-112.

Lemanski C, 2006,'*Spaces of exclusivity or connection: linkages between a gated community and its poorer neighbour in a Cape Town master-plan development*',Urban Studies,vol.43,pp.397-420.

Lemanski,C.,&Oldfield,S.2008,'*The parallel claims of gated communities and land invasions in a Southern city: polarised state responses*', Environment and Planning A: Planning and Design,p.p.1-15.

Le Goix, R. 2005, "*Gated Communities: Sprawl and Social Segregation in Southern California*", Housing Studies, vol 20, no.2, pp. 323-343.

Rodgers, D.2004,'*Disembedding the city: crime, insecurity, and spatial organisation in Managua, Nicaragua'*, Environment and Urbanization,vol 16, pp. 113–124.

Rogerson,C.M.,&Rogerson,J.M.,2015,'*Johannesburg 2030: The Economic Contours of a Linking Global City'*, American Behavioral Scientist, vol. 59,no 3,pp 347–368.

Sabatini F., Cáceres G.2004, '*Barrios Cerrados en Santiago de Chile: Entre la Exclusión y la Segregación Residencia*l', Santiago, Pontificia Universidad Católica de Chile.

Sabatini F., Salcedo R.2007, "*Gated communities and the poor in Santiago, Chile: Functional and symbolic integration in a context of aggressive capitalist colonization of lower ‐ class areas*", Housing Policy Debate, vol no.18, 3, pp. 577-606.

Salcedo, R. & Torres, A.2004,'G*ated communities in Santiago: wall or frontier?'*, International Journal of Urban and Regional Research, vol 28, pp. 27–44.

Spocter,M.2011,'*Spatio-temporal aspects of gated residential security estates in non-metropolitan Western Cape'*. Urban Forum, vol.22,no.2,pp.169-181.

Tibbalds, F. 2001,'*Making people-friendly towns: improving the public environment in towns and cities',* 2nd edition. Spon Press: London.

Tomlinson, R., Beauregard, R. A., Bremner. L. & Mangcu, X.2003,'*Emerging Johannesburg: Perspectives of the Postapartheid City*'. London: Routledge.

Turok, I.2001,*'Persistent polarisation postapartheid? Progress towards urban integration in Cape Town*', Urban Studies, vol.38, pp. 2349–2377.

Watson,V. 2003,*'Urban research, planning and action—their relationship in the context of metropolitan Cape Town, in: C. Haferburg and J. Ossenbru¨GGE (Eds) Ambiguous Restructurings of Post-apartheid Cape Town*', pp. 55–64. Hamburg: Lit Verlag Mu¨nster.

INDUSTRY 4.0 AND ITS IMPACT ON SKILLS DEVELOPMENT ON BUILT ENVIRONMENT PROFESSIONALS: A SOUTH AFRICAN PERSPECTIVE.

Letsoko Vuyiswa[1], Pillay Nischolan[2]

[1]Town and Regional Planning/ Engineering and the Built Environment,University of Johannesburg, Johannesburg, South Africa

[2] Town and Regional Planning/ Engineering and the Built Environment,University of Johannesburg, Johannesburg, South Africa

Abstract

Given the rapid advances of technology in various fields of human life, we are entering into the Fourth Industrial Revolution (4IR). This revolution has been touted as the answer to many of South Africa's problems with the integration of computerisation to digitise more areas of life, and has been described as a "post-work era" whereby human relevance is at risk of redundancy. In this paper, many questions arise about how these transformations affect jobs, skills, and professionals such as architects, urban planners, urban designers within the built environment. The paper employed a qualitative inquiry and focused on two aspects of the 4IR. The first considers the expansion of automation in the workplace and raises questions such as: how is the relationship between the skills of built environment professionals and technology are changing? How can we expect it to affect employment in the built environment sector? The second is related to how job transformation will influence requirements for knowledge and skills; the main question is: which competence profile, considering hard and soft skills, is required and expected in the work of the future? The study reveals that human irrelevance and redundancy of jobs in the built environment is unlikely given that professionals within these fields possess unique critical thinking, complex problem solving, creativity skills that are irreplaceable by computation. Additionally, the 4IR requires human touch which will be an important asset for built environment professionals. As a result, these professionals would acquire new professional roles thus knowledge in multidisciplinary fields will be a necessity.

Keywords

Fourth Industrial Revolution, Industry 4.0, Skills development, Built environment, Technology

Introduction

Given the rapid advances of technology in various fields of human life, we are entering into the Fourth Industrial Revolution (4IR) also known as Industry 4.0. 4IR has been touted as the answer to many of South Africa's problems with the integration of computerisation to digitise more areas of life, and has been described as a "post-work era" whereby human relevance is at risk of redundancy. This revolution is characterized by a blend of various technologies that is "blurring the lines between the physical, digital, and biological spheres" (Schwab, 2016:1). It is said to disrupt the routine and manual tasks of everyday life through its' innovations (Dhauo and Manda, 2019).

The advent of this revolution has attracted widespread debates about the challenges and opportunities it poses to the future of work and skills development. Additionally, whilst 4IR introduces digitalization, automation, robotics and artificial intelligence (AI) which can generate opportunities for the economy and society, there is great uncertainty regarding job security in this new era (Chetty, Aneja, Mishra, Gcora and Josie, 2017). Infact, the World Economic Forum predicts a net loss of five million jobs in fifteen developed and emerging markets by 2020 resulting from developments in 4IR (WEF, 2016a; 2016b). Furthermore, as many as two thirds of all jobs, mostly in developing countries such as South Africa, could be at risk (WEF, 2016a). Kamaruzaman, Hamid, Mutali and Rasul (2019) outline that this risk to job losses is directly linked to the mismatch of skills required by jobs that will be relevant in the era of 4IR. Similarly, built environment professionals would need to ensure they are equipped to meet the changing skill needs which is the key focus of this paper.

Literature Review

Evolution or Revolution: Unpacking the elements of the Fourth Industrial Revolution (4IR)

Research on Industry 4.0 is a relatively new topic. The term is well known not only in academia but also in industry. In literature, there has been much debate about whether the 4IR is a new 'revolution' or an 'evolution' of the three former revolutions. Broadly, the first industrial revolution saw the transition from manual and animal power to steam power and enabled a significant development in the level of mechanisation (Nowotarski and Paslawski, 2017). Cooper and Sebake (2018) highlight that the second industrial revolution was driven by electricity, steel, oil, railways, telecommunications, industrial chemistry and metallurgy; and introduced production lines, mass production, control theory, accounting, scientific management, all-weather roads, bicycles, automobiles, aircraft, plastics, radio and universal time; allowed much greater construction works and more powerful engines; and globalization. The third industrial revolution was seen as the technological revolution where technology was introduced into production as well as the automation of processes (Cooper and Sebake, 2018).

The fourth industrial revolution gained attention in 2011 when the German government established a critical strategy for industrial production. This implied an Industry 4.0 which is "is part of an interconnected world, changed by the ICT (information and communications technologies) revolution."(Bonilla Silva, da Silva, Gonçalves and Sacomano, 2018,p.3). Maskuriy, Selamat, Ali, Maresova and Krejcar (2018) highlight that the critical components of 4IR are; cyber-physical systems (CPS), Internet of things (IoT), Internet of services (IoS), artificial intelligence (AI), big data, and smart production. Therefore, this revolution is a culmination of all innovations of previous revolutions. Literature suggests that this revolution will convert and have impacts the built environment industry as profoundly and irrevocably as each of its three predecessors, and more rapidly than any of them. The question, is how and what will the implications of this be?

The Built Environment 4.0 and Technology

The built environment sector significantly affects the economy, the urban environment and society as a whole. The various disciplines within the built environment sector such as construction, architecture, urban planning etc. play a key role in defining the day-to-day lives of civilizations and are at the forefront of achieving smart cities which is central to the developmental agenda of the 21st century in relation to the 4IR. Alaloul, Liew, Zawawi and Mohammed (2018) outline that industries such as construction, which are part of the built environment, have been usually late in advancements in technology. Furthermore, Osunsanmi, Aigbavboa and Oke (2018) assert that the progress on fusing technology and industries within the built environment in South Africa is still at infancy stage as the adoption of ICT has been mainly concentrated on the use of software. Oesterreich and Teuteberg (2016) opined that a contributing factor to delays in innovation and technological progression is mainly due to the lack of investments in research and development within the built environment sector.

Nevertheless, some disciplines, such as architecture, urban planning and construction, within the built environment have adopted innovative technologies that resulted from influences during the third industrial revolution which was driven by information technology. For example, architects started using 3D computer-aided design software's as a representational tool to improve precision and expand the limits of their creations (Naboni and Paoletti, 2015). Additionally, the dissemination of BIM Platform

(Building Information Modeling), GIS (Geographic Information Systems) and Revit among others has encouraged innovation within the built environment (Leal, Salgado and Silvoso, 2018). However, Osunsanmi, *et al* (2018) asserts that this is not sufficient for the fourth industrial revolution as this revolution has created a new relationship between the built environment and technology, a relationship which involves digitization and the rise of the built environment 4.0.

This implies the use of "crude tools where the internet, wireless sensors, software and other advanced technology such as lasers and drones work together towards enhancing project performance and improve client satisfaction" within the built environment (ibid,p.208). Maskuriy et al (2018) acknowledge this and indicate that digitization in 4IR coupled with availability of digital data and online digital access has potential opportunities for revolutionizing the BIM platform by integrating it into an IT environment which can transition the "current 'react to event' practise to 'predict the event practice'"(p.25). Moreover, integrating BIM into cloud computing enables "project stakeholders to collaborate in real-time from different locations" which enhances productivity (Craveiro, Duarte, Bartolo and Bartolo (2019, p.24) cited in Maskuriy (2018).

The Fourth Industrial Revolution (4IR) and skills development in the Built Environment.

The literature on the impact of Industry 4.0 on jobs and skills has undergone a reversal from a pessimistic to a more optimistic outlook. The report, Future of Jobs, published at the World Economic Forum in 2016, predicted that the 4IR would result in five million job cuts with a widening of the skills gap that would mean that jobs with the risk of the greatest decrease are mainly are mundane office work and production jobs easily replaceable with automation (World Economic Forum 2016). This could possibly also result in the polarization of job quality, as some jobs could be regarded as redundant. Frey and Osborne (2013) reported that 47% of United States jobs and 42% of German jobs will disappear within 20 years due to automation, especially for skilled labor. In developing countries such as South Africa, fears of job losses are intensified by anxieties of a 29% unemployment rate and the inability for government to curb it (Manda and Dhaou, 2019).

Manda and Backhouse (2017, p.246) suggest that the Fourth Industrial Revolution demands for a "new breed of worker, one that is skilled, innovative and technologically savvy" therefore raising the need for new 'future' skills which possibly do not exist to ensure humans aren't replaced through automation. This implies a direct link to the mismatch of skills required by jobs that will be relevant in the era of 4IR and job losses. This speaks to education and training, and the need to ensure that future built environment professionals are equip with the appropriate skills to be able to contribute in the 4IR (Leal *et al*, 2018). Kamaruzaman *et al* (2019) conducted a study in Malaysia to ascertain which skills would be required in the 4IR by engineering graduates and related fields such as the built environment.

The study revealed that in 2022 which is when 4IR will be in full effect, seven key skills would be required namely; analytical thinking and innovation; active learning and learning strategies; creativity, originality and initiative; critical thinking and analysis; complex problem solving; emotional intelligence; and system analysis and evaluation will be the preferred skills, as well as technology design and programming; leadership and social influence; and problem solving. Their study revealed, as can be seen in the figure below, that although there are some cross cutting skills, there is a current mismatch of existing skills and the skills required in the 4IR.

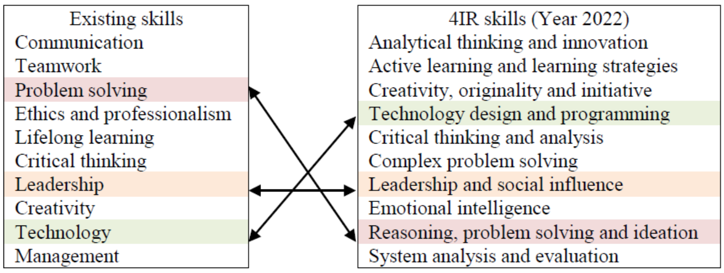


Figure 1: Existing Skills and Required 4IR Skills in the Built Environment,

In order to reduce this variance in skills there is an urgent need to reskill and upskill professionals to keep up with the technological advances the 4IR will bring. Dhaou and Manda (2019) acknowledge that the fourth industrial revolution brings new challenges and opportunities that require human intelligence and skills. This renews hope that humans will not be redundant in this new revolution. Infact, the World Economic Forum (2016:1) highlights that "only one type of organization will thrive a human one". This emphasises the need for human touch in the 4IR.

Problem Statement and Research Methodology

Recently, many researchers have put forth their own analysis and predictions about the Fourth Industrial Revolution, but each of them is different. This is possibly due to the fact that 4IR is moving at a rate so fast, it is impossible for us to predict the future however the impact of changes caused by this revolution is increasingly been felt and there is a pressing need to assess these impacts in the context of the built environment sector. Furthermore, the expansion of automation in the workplace has led to increased anxieties on how 4IR could affect employment in the built environment as well as how job transformation will influence requirements for knowledge and skills for built environment professionals. This raises questions on what competency profile would be required by built environment professionals in the work of the future. The study aimed to address problem by providing an in-depth perspective that could also contribute to research within this relatively new field.

The study employed a qualitative approach, making use of ten semi-structured interviews with various (architects, construction managers, urban planners and urban designers) professionals within the built environment during August and September 2019. Interviews were selected as the most appropriate to elicit a relevant an in-depth response that recorded the experiences of relevant individuals in order to discover a phenomenon, question or problem to provide a closer, more detailed understanding of the topic of inquiry" (Picken, 2018, p. 201). This approach is particularly relevant for this study as the objective of the study is not to generalize findings but rather provide an in-depth understanding and contribution of the Fourth Industrial Revolution and impacts on professionals within the built environment. The interviews were transcribed and analysed thematically to establish several key themes that arose consistently.

Discussion and Findings

In this section of the research, the authors discuss their qualitative interview responses. The questions posed to interviewee are mostly geared towards their perceptions of the fourth industrial revolution with close concentration on the built environment. We posed 5 questions to the respondents and noted a few typical or common responses.

Question 1: What is your understanding and perception of the fourth industrial revolution?

"It is an era that has come with disruptive changes in human kind. Conventional practices and thoughts are being eroded in almost every field in attempt to better the lives of people"

"An era of technological evolution, displacing the pre-existing systems and processes for existing i.e.; living, working, being"

"This is the advancement and refinement of automation an improvement from the third revolution"

"Artificial Intelligence and the internet of things"

In this question, respondents answered in the same lines. Most respondents believe that the fourth industrial revolution is primarily a digital revolution, for all intents and purposes, this is true. Most of the respondents believed that the fourth industrial revolution will disrupt life as we know it, challenging conventional practices. Some respondents thought that it is an improvement on the other revolutions culminating in an advancement through automation. Respondents also believed that the fourth industrial revolution is about artificial intelligence and the internet of things. Although no single respondent gave us a clear-cut definition of the fourth industrial revolution, it is clear that some understanding exists. The concept of the fourth industrial revolution is fairly new to the world; however, the authors believe that it is gaining pace rapidly amongst built environment professionals, judging on their basic understanding of the concept.

Question 2: What role do you believe built environment professionals have in the fourth industrial revolution?

"Honestly, built Environment professionals do not have any choice except to adapt with the changing times of technology. They have to digitize their services in order to keep up with the era, or else they might become irrelevant or left behind"

"To enable harmony between human existence and existing in a polar realm, suppose it's the same role/challenge-built environment professionals have had since the beginning of time. To Co-exist through revolutions/evolution and not dominate/ conquer them"

"Human perspective to influence policy and or design and innovation"

"The fourth industrial revolution is an opportunity for built environment professionals to tackle challenges such as climate change and the negative impacts of development on infrastructure that we currently face by embracing the new technologies brought by the 4IR to address these challenges"

In this question of the research we probed an area feared by many in relation to the fourth industrial revolution, the role that one would play in this revolution. Some respondents see it as an opportunity for great things to come, a revolution to aid and abet human life and the various things we do to survive and to make our lives better. Most respondents believed that the technology will assist professionals in performing tasks more intelligently than ever and saw it as a positive outlook going forward. Some respondents believed by not embracing the fourth industrial revolution, they may become irrelevant. However true this maybe, the majority of respondents believed that the fourth industrial revolution always required human intervention. Although the fourth industrial revolution will see automation and artificial intelligence as its core, human intervention in the processes and outputs will always be required to facilitate activities. In this question, the authors seek to understand what built environment professionals thought of the fourth industrial revolution and what their role was. Although respondents revealed a harmony between man and machine, feared for job loss or irrelevance and a human touch was required, none of the respondents packaged this together. However, a basic understanding was noted with all interviewees, which again proves that the notion of the fourth industrial revolution is spreading throughout the built environment fields and professionals.

Question 3: What impact/s (positive and negative) do you believe the fourth industrial revolution will have on the built environment?

"The positive impact is that, it might help speed up services through digitization. The negative part is that, jobs and relevance might be on the verge of being lost"

"Positive impacts include advances in information and communication technologies which allows for easier collation and analysis of data and ultimately solutions to Built environment challenges. Negative impacts will probably be a change in jobs but this can be combated by ensuring that built environment professionals as well as the curriculum in schools changes to adapt to this"

"Perceived Negativity: Poor Substance output, Development of mass junk space, earth wastefulness, poor quality of life, higher human internal conflict, loss in control of the external realm"

"It will lead to more crime, marginalization of those that do not have access to the internet of things or various apps. It will also improve the turnaround time for mega projects to be approved and lead to faster response from all stakeholders involved in the built environment"

In this question we probed the area of the positive and negative effects the fourth industrial revolution will have on professionals. The common response from the professionals was generally that it will make tasks easier to perform and speed up regular tasks. Again, in this question, professionals harped on job losses, albeit greatly in the construction sector due to automation. However, many professionals also believed that job profiles would change in future and that humans will adapt to the change and embrace the fourth industrial revolution. Although respondents did agree the change in job profiles, some professionals mentioned that that the fourth industrial revolution could affect humans socially, in regards of their new roles in society, poor substance output, poor quality of life and access to this technology. Some respondents mentioned that the poor would suffer the most within this revolution as the basic access to the fourth industrial revolution technologies will be limited. Upon further thoughts, some respondents mentioned that digital crimes would increase. On a positive note, professionals agreed that the process of development will greatly benefit the built environment industry in terms of processing of data and approvals faster and more efficiently. From the respondent's views, the authors note various positive and negative areas of concern and interest. By far, the issues relating to the poor and crime are worrying. The authors of this research wish to further probe this area of research in a separate publication as it is a large area of knowledge that needs to be investigated.

Question 4: Do you believe the fourth industrial revolution has any impact on the skills development of professionals within the built environment?

"Honestly, I don't think so. Things that professionals learnt from school years ago will need to be replaced. Basically, professionals will need to go and re-learn new information. However; there are things that technology cannot replace. That is where professionals can capitalize. Nonetheless; 4th IR remains a threat"

"Yes, I think developments or any type of learning system / process needs to be re thought period. This revolution might just be an excuse for impact/change. Natural existence is concerned with the only constant of change. Everything should evolve together, never one without the other"

"Yes, if tech is there to sort everything out for young upcoming professionals. They are less likely to understand how their profession actually works"

"The whole notion of the 4IR is premised on technology advancement this means that there will definitely be changes in the skills development of professionals in the built environment, professionals will have to equip themselves with more technological skills to remain relevant in the industry"

In this question, the authors probed the areas of skills development of built environment in the fourth industrial revolution. A common theme developing in this research is the need to be upskilled due to the constant change in technology in the industry. Many of the respondents note that there will be some relearning of approaches and methods in their profession however some professionals believe that some methods and approaches will have to be rethought entirely. From these responses, it reveals that professionals are well aware of the changes that are to come, however again note that the human touch will still remain important. Some of the respondents noted that future professionals may become lazy due to the advancements of technology or that their thinking ability may not be as sharp as it should have been, however true this may seem to be, the future will hold the truth to this. Looking back at the past and current trends, we see a dramatic difference in how humans produce everything from food to buildings, mostly in a positive light. Although the professionals remain constant in this research, they do bring up the changing professions and job profiles more and more often. Many of the professionals believe that the new professionals will have to be technologically prepare for this revolution to remain relevant in the industry.

Question 5: What skills do you believe built environment professionals need to be able to effectively operate in the fourth industrial revolution?

"We need to familiarize ourselves with digital knowledge like coding, IT Systems, Social media networks, attend seminars on the built environment, and keep up with the trends. In that way, we will be ahead instead of lagging behind"

"Constant learning and execution of all 'operational tools', open mindedness , common sense, humility, something to say and have that conversion into the 'built realm' , understanding what it is you're actually doing here daily, your impact on humanity and the big picture, your role and responsibility in sharing your absolute message to the world as everything else can be learnt"

"Use of modern machines and related software packages"

"Open mindedness is key as the 4ir requires innovative and responsible professionals"

In this question, we asked respondents to share their thoughts on what skills they though to be important to embrace the fourth industrial revolution. Various responses were noted, although the common thread related by professionals was the need to familiarise one's self with technology and software. Although the current generation is tech savvy and is able to use software efficiently, the new generation will have to further themselves by knowing how to programme the software to output what they want it to do. Professions will move from mere outputs to great inputs in various industries, according to the respondents this will be the biggest change that the fourth industrial revolution will bring. Although respondents believe that they should keep up with technology, many of the professionals still factor in the human touch and intelligence when regarding changes due to the fourth industrial revolution. The overall sense is the human impact on humanity and not just cold-hearted, machine-driven outputs. The authors find that throughout the research, the respondents note that the human factor by far will be the most important skill in the fourth industrial revolution.

Conclusion and Recommendations

The built environment sector is one of the core sectors of the South African economy and this is mainly due to the fact that there are various disciplines within this sector that are vital to the social and economic development of society. Despite its importance in the economy, this sector has been sluggish in its adoption of ICT and new technological innovations which has potential impacts on the professionals in this field in the new digital revolution, the 4IR.

This research intended to ascertain what the impacts of the 4IR on skills of built environment professionals in South Africa. It intended to provide a detailed understating on what future skills these professionals would require in the 4IR to ensure their contributions are not redundant. The study recommends key themes and the effort levels to achieve the desired outcomes of the fourth industrial revolution for professionals within the built environment sector, which can be seen in the table below.

Table 1: Summary of Key Themes and Outputs of the study

Theme	Output	Effort Level for Impact
Understanding and defining the Fourth Industrial Revolution.	Basic Knowledge of the 4IR is noted, however more efforts must be put into place to further educated professionals on the true implications of the 4IR	8/10
Job losses	Although concerning to the world at large, the redefinition of changing job profiles must be brought to the surface.	9/10
Human Factor	The human factor, by far will affect the 4IR. This area should be built into all changing courses of education and must be emphasized.	10/10
Automation of Tasks	The automation of laborious tasks will take precedent in this revolution, however through human interaction these processed can be carefully controlled to make sure that quality is always the centre of production.	8/10
Skills Development	Skills development will remain a central topic in the 4IR. Universities must embrace this and develop students to confront the digital world.	10/10
Mind Set	Overall, Professionals will have a mindset change to adapt to the challenges of the 4IR	8/10

This study concludes that just as the future of technology, industry, and business in the 4IR cannot be accurately predicted, the resulting changes in the world of work are even more difficult to predict and ambiguous. In the end, it is important to figure out how to create more jobs within the 4IR rather than debate over whether it will lead to an increase or decrease in the number of jobs. We need to consider which sectors will create more jobs, what can be done to speed the growth of these sectors, and what kind of education and training will people need to develop new competencies required in the future. More importantly, the ability for built environment professionals to adapt successfully to disruptions from technological advancements will require being able to unlearn old technologies and practices and re-learn new ones. At the same time, new technologies offer innovative modes of education and delivery of learning that have the potential to address the implication of rapidly changing skills demand. Moreover, the 4IR indicates that there is a need for continuous learning as existing education systems alone do not suffice as a result there will be a need for a learning society where professionals continually adapt and re-adapt their skills.

References

Alaloul.W.S.,Liew.M.S.,Zawawi.N.A.W.A., & Mohammed.B.2018,'*Industry Revolution IR 4.0:Future Opportunities and Challenges in Construction Industry*' MATEC Web of Conferences, February 2 – 10,2018.

Bonilla.S., Silva.H.R.O., da Silva.M.T., Gonçalves.R.F.,& Sacomano.J.B.2018, *'Industry 4.0 and Sustainability Implications: A Scenario-Based Analysis of the Impacts and Challenges'*, Sustainability, vol.10.

Chetty, K., Aneja, U., Mishra, V., Gcora, N., & Josie, J.2017, '*Bridging the digital divide in the G20: Skills for the new age. Economics'*, Discussion Papers, No. 2017-68. Berlin, Germany: Kiel Institute for the World Economy, The 40th Australasian Universities Building Education Association.

Craveiro, F., Duarte,J.P, Bartolo,H., Bartolo, P.J.,2019, 'Additive manufacturing as an enabling technology for digital construction: A perspective on Construction 4.0',Automation and Construction,vol.103,pp. 251–267.

Cooper,A.K.,& Sebake.N.2018, *'Neighbourhood 4.0: A response to urban futures'*, Out-Of-The Box 2018 Conference Proceedings, 24-25 October 2018, CSIR, Pretoria, South Africa.

Frey, C., & Osborne, M.2013,'The future of employment: How susceptible are jobs to computerisation?', Oxford, UK: Oxford Martin School, University of Oxford.

Kamaruzaman,F.M., Hamid,R., Mutalib,A.A., & Rasul,M.S.2019, '*Conceptual framework for the development of 4IR skills for engineering graduates'*, Global Journal of Engineering Education,vol.21,no.1.

Leal.B.M.F.,Salgado.M.S.,&Silvoso.M.M.2018,'*Impact of Fourth Industrial Revolution in Architecture Undergraduate Course'*, ZEMCH 2018 International Conference, Melbourne, Australia, 29th January – 1st February 2018.

Manda.M.I.,& Dhaou.B.S.2019, 'Responding to the challenges and opportunities in the 4th Industrial revolution in developing countries', ICEGOV2019, Melbourne, VIC, Australia, April 3–5, 2019.

Maskuriy, R, Selamat. A, Ali.K.N, Maresova.P.,& Krejcar, O.2019, *'Industry 4.0 for the Construction Industry—How Ready Is the Industry?*'Economies,vol.7,no.68.pp.1-14.

Naboni, R.; Paoletti, I. Advanced Customization in Architectural Design and Construction; Springer: Milano, Italy, 2015.

Nowotarski,P.,& Paslawski,J.2017, '*Industry 4.0 Concept Introduction into Construction SMEs'*, IOP Conference, Series: Materials Science and Engineering.

Oesterreich.T.D.,& Teuteberg.F.2016, "*Understanding the implications ofdigitisation and automation in the context of industry 4.0.A triangulation approach and elements of a research agenda for the construction industry*", Computer in industry,vol.83,no.10, pp. 121-139.

Osunsanmi.T.O., Aigbavboa.C.& Oke.A.2018, '*Construction 4.0: The Future of the Construction Industry in South Africa',*World Academy of Science, Engineering and Technology International Journal of Civil and Environmental Engineering,vol.12, no.3.

Picken, F. (2018). The Interview in Tourism Research. In Hillman, W. & Radel, K. (eds.). Qualitative Methods in Tourism Research: Theory and Practice. Channel View Publications.

Schwab, K.2016, 'The fourth industrial revolution',. Geneva: World Economic Forum.

World Economic Forum.2016,'The future of jobs: employment, skills and workforce strategy for the fourth industrial revolution', World Economic Forum, Geneva, Switzerland.

COWORKING: THE NEW DESIGN OF WORKPLACES

Dulani Halvitigala[1], Hera Antoniades[2], Chris Eves[3]

[1]School of Property, Construction and Project Management, RMIT University, Melbourne, Australia

[2]Faculty of Design Architecture and Building, University of Technology Sydney, Australia

[3]School of Property, Construction and Project Management, RMIT University, Melbourne, Australia

Abstract

Globalisation of business, innovative technologies and increase in knowledge-based industries have had significant impacts on organisations' business practices. This has subsequently affected the demand for space in built-facilities. As a result, the demand for flexible office space solutions such as coworking, or provision of communal, flexible office spaces on a short-term basis, have become a rapidly growing phenomenon.

By conducting a case study analyses of two large property trusts in Australia, this research paper examines how the office layouts and configurations are adapted in coworking spaces to facilitate such innovative spaces. Findings identify that the main design strategies for coworking spaces are to enhance space autonomy, create communities, facilitate collaboration, create spontaneous encounters, create multi-purpose and multi-generational spaces, create productive work environments and reduce individual workplace footprints. The research findings emphasise the importance of having more dynamic and creative office layouts and configurations that are better aligned with the interests of landlords, space operators and diverse groups of office space users in flexible office arrangements.

Keywords

Flexible spaces, Coworking, Office layouts, Office space designs

Introduction

The coworking culture in Australia and overseas is a rapidly emerging workplace phenomenon in today's knowledge-based economy. One of the main characteristics associated with coworking is to provide independent spaces within shared office spaces (Spinuzzi, 2012; Parrino, 2013). These spaces provide members with the opportunity to work alone or interact with like-minded people on a pay-as-you-go basis (Bouncken and Reuschl, 2016). The members can use the space anywhere from between a day to a month and longer.

Many landlords are challenged by this growing demand for flexible, scalable, collaborative spaces. Additionally, there are major implications on the performance and utilisation of commercial real estate and the increased burden of over utilisation of building facilities, such as lifts, escalators and associated facility usage due to space intensification. One of the slowest adaptors to this growing work practice has been office landlords who have been cautious in welcoming coworking operators into their buildings (Green, 2014). However, vibrant and engaging coworking spaces have the potential to create several tangible and intangible benefits to office landlords. These benefits are discussed in conjunction with the analysis from this research.

A recent survey by Deskmag (2019), titled 'The Global Working Survey' indicates an upward trend with coworking spaces and coworking members. Below in Table 1 are the results of the survey.

Table 1: Global Working Survey

At 31st December	Number of Coworking spaces	Number of Coworking members
2015	8,900	545,500
2016	12,100	890,000
2017	15,500	1,270,000
2018	18,700	1,650,000
2019 (estimated)	22,400	2,170,000
2020 (estimated)	26,300	2,680,000

Source: Deskmag (2019)

The table above indicates that from 2015 to 2018 the number of coworking spaces more than doubled due to the demand for these flexible work environments. Currently the average flexible leasing term is over 24 months, as opposed to under 12 months in 2013 (Colliers International 2018). Activity based working strategies complement flexible office environments, however whilst it is important to deliver functionality there is also the need to provide a balance with comfort and wellness (Colliers International 2019). To this end a well-designed office space environment and industry centric spaces have during these last few years, emerged as a desirable model.

Therefore, the aim of this research is to examine how office landlords have adapted their office layouts and configurations to facilitate innovative spaces. The objective of the paper is to conduct a case study analysis of two large property trusts in Australia. This will provide a platform for further exploration on the viability of the long-term stability and strategic approaches for coworking hubs. The first part of the paper discusses the literature for coworking spaces and the varying factors which influence the transformation of traditional office spaces into engaging coworking vibrant hubs. The research continues with an analysis and discussion of the two case studies undertaken. The conclusion summarises the main space design strategies adopted to facilitate such innovative spaces.

Literature Review

Coworking spaces are beneficial for those who desire an environment which facilitates creativity, critical thinking, knowledge sharing and collaboration. However, these requirements can present a challenge to landlords who provide the traditional office space environment. Additionally, research highlights the benefits of collaboration for start-ups to encourage creativity and innovation, and acknowledge that working in solidarity will not necessarily produce the required results (Gandini 2015; Gerdenitsch et al. 2016). Similarly, co working spaces enhancing innovation and entrepreneurship are identified as a “new form of urban infrastructure” (Merkel 2015).

Design and aesthetic surroundings

Freelancers and self-employed individuals will require suitable fit out spaces. Therefore, the design and aesthetic surroundings of co working space, and how the space is used is equally important. For instance, if the users are undertaking complex work which requires concentrated spaces with privacy, and an environment of no disturbance, this will encourage the development of soundproof cubicles, and so the intent of coworking spaces is defeated (Liegl 2014). However, whilst these coworking spaces are designed to encourage networking and collaboration, the outcomes are also dependent on user mix and location (Gandini 2015). Recent research focusing on specific space environments, rather than a CBD metropolis, has explored the question of whether coworking promotes entrepreneurship.

Therefore, the landlord faces the scenario of redesigning and modifying existing office spaces from the traditional blueprints to a vibrant engaging hub. In this regard, the research identified the need for a "supportive and a productive business climate" coupled with a "physical environment where creativity and innovation can flourish" (Fuzi 2015). Similarly, there is an expectation that coworking spaces will provide flexibility, and opportunities to access social support (Gerdenitsch et al. 2016).

Changing nature of the workforce

Serviced offices were introduced many decades ago and offered a different package of benefits. This included reception and secretarial services, phone lines, faxes and postal services, dedicated office space to the same users i.e. the right to occupy the same space during the term of the tenancy and short-term leases. However, with the changing nature of the workforce and the technological improvements many of these benefits have been superseded due to the advancement of mobile phones, internet and cloud-based access (Waters-Lynch and Potts 2017). Therefore, a key consideration for landlords is how to better design office spaces, simultaneously meet the changing nature of the workforce.

There appears to be an increasingly popular demand to position coworking centres in key regional areas (Cameron 2012; Forbes 2014). There are numerous benefits of coworking spaces for users such as the cost elimination of setting up a home-based office and clearly separating home life styles and professional work commitments. A clear detachment is the elimination of merging the home and office environment (Land et al. 2012); and further research suggests co-workers have started to leave their computers at coworking centres, rather than taking their work home (Kjaerulff 2010; Cameron 2012; Forbes 2014). Therefore, these changing work patterns provide a guide for commercial landlords to rethink the design of spaces and how the spaces are used within industry. Where once upon a time, the traditional long-term lease rental was the expectation for corporate businesses and freelance individuals chose to work from home; however, the last decade has witnessed a shift in the traditional office environment (Dixon and Ross 2011; Bryant 2003; Brunelle 2013; Ross and Blumenstein 2013).

Industry Perspective

In 2017, WeWork raised the profile of coworking hubs, and influenced the awareness of a new working style. This included a focus on optimum spatial design and a community environment. Similar outcomes occurred with Workspace365, WOTSO Workspace and Gravity to name a few (Office Hub 2018). Internationally, major flexible office space provides such as Regus, Servcorp, The Executive Centre, Compass Offices and Asia Pacific Serviced Offices shifted from the traditional serviced office space model to the coworking hubs model which offered greater flexibility and innovative modern office designs (Office Hub 2018). A number of Asian providers provide for instance, an in-house barista, sleeping pods and wellness rooms.

The younger workforce of today is a key driver of the coworking space and according to research undertaken by Office Hub (2018:5), "more than 76,000 people looking for flexible office space in 2017-18, coworking is most popular among 25-34-year-olds and steadily decreases in popularity among the older the age group". In a study undertaken by Steelcase360 (Knight Frank 2017) four main principle designs were identified to leverage millennial behaviours. These included a need to design for identity which includes the notion of social awareness and the awareness of environmental issues; the second was to design for growth, which includes team hub spaces, non-hierarchical and informal collaborative spaces. Thirdly the design should incorporate work-for-life, which covers support and physical wellbeing and a reflection of work-life integration; and fourthly to incorporate technology.

These design principles are also reiterated within the industry (Hub Australia 2019, Colliers 2018), where the space provides an experience encompassing community and culture. Again, comparisons are drawn against the traditional open plan office environment where the design is limited to identical workstations and standardised meeting rooms. Similarly, Oktra (2019) which is based in the UK states that the look and feel of the spaces is equally important as is space utilisation. Therefore, with the traditional 9 to 5 work environment shifting, remote working is becoming more popular and desirable.

Collaboration, innovation, increased teamwork, and lateral thinking have become the buzz words of the coworking culture. Similarly, office space designs which provide an environment for cutting edge creativity, providing optimal use of space coupled with good lighting and enhanced workflow are transforming the traditional office space environment into more vibrant and engaging spaces.

The next section of the paper explains the methodology utilised for the case study analyses as the primary data source, and the secondary data source being a desktop analysis complementing the data from the case study.

Methodology

Due to the explorative nature of this research, a qualitative approach was adopted as the most effective research methodology (Silverman, 2013). Qualitative data is contextual; its analysis involves developing insights based on a deep understanding of a particular context (Cassell et al., 2018), which is the objective of this research. Case study analyses of two large Australian Real Estate Investment Trusts (REITs) were undertaken to examine how the office layouts and configurations in their coworking spaces were adapted in order to facilitate flexibilities in such workplaces. These two REITs are two of the largest Real Estate Investment Trusts in Australia and collectively own and manage of over $18 billion worth diversified portfolios of high-quality Australian office, retail and logistics property assets (Annual reports of REITS). Both REITs have moved into the flexible office market and have included coworking spaces in their office portfolios. One of the REITs have entered the market directly by developing and operating their own coworking spaces while the other REIT has leased several spaces to coworking operators who operate such workplaces. Therefore, the research question was examined from two different investment perspectives in relation to the coworking sector which is directly owning and operating coworking spaces and indirectly involving in the sector by leasing spaces to coworking operators.

Data were collected in two phases. Firstly, secondary data were collected by conducting an extensive, in-depth desktop analysis of the information provided on the two selected REITs' webpages in relation to their coworking spaces. Their websites were thoroughly analysed to collect secondary data in relation to the nature and operation of their coworking practices. Secondly, one-to-one, semi-structured, in-depth interviews were conducted with the National Directors of flexible space solutions in the two selected REITs to obtain further clarification on their coworking strategies and practices. Semi-structured forms of interviews were used since they offer a versatile way of collecting data, allowing the interviewer to use probes with a view to clearing up vague responses, or to ask for elaboration of incomplete answers (Welman and Kruger, 2001). Both interviewees held the highest level of responsibility for key property related investment and management decisions for their coworking spaces. Interview questions were designed to elicit in-depth understanding of their perceptions and experience of developing flexible and adaptable office layouts to facilitate the demand from coworking spaces and their users. The topics covered in the interview questions included, most commonly requested office configurations by coworking space users, their impact on office design and space planning and how coworking space users' demand for alternative workplaces are addressed in landlords' new and existing buildings. The findings were analysed using thematic analysis, which aimed to identify patterns or themes within qualitative data collected (Creswell, 2009).

Research findings and discussion

Before the analysis commenced, the researchers read the in-depth interview transcripts and the secondary information collected from desktop analysis and developed an appropriate coding system. This was based on the research question, interview guideline and the findings from existing literature. Accordingly, major themes were identified, supported with quotes from the interviewees. The key themes identified the following main design features and configurations that were adapted in coworking spaces to facilitate flexibility and novelty in such spaces.

Efficient and functional office spaces

Both organisations had used efficient floor plates for their coworking spaces. They consisted of large uninterrupted, regular shaped floor plates, simplified building specifications and good natural light. Those floor spaces had long building spans which have allowed the spaces to be arranged for different types of work settings. Furthermore, the floor to ceiling height in their coworking spaces was consistent throughout the space allowing efficient use of the floor space and good natural lighting and ventilation.

Space intensification in flexible office spaces would place additional structural stress on building services if not designed for the future demands associated with such high density uses (Brittain et al. 2004). Therefore, both interviewees emphasised that the buildings where their coworking spaces are located have flexible building services which are capable to sustain the demand from space intensification and high occupant density in such flexible spaces. Those buildings have flexible building services such as HVAC systems, electrical systems, lighting, information and communication technologies and vertical transportation that are able to cope with the additional operational requirements caused by high occupant density in coworking spaces.

These coworking spaces were also supported by well-distributed cutting-edge Information and Communications Technologies which allow technological access in all parts in their coworking spaces to support flexible work settings. As suggested by one organisation, their coworking spaces "*feature smart technology throughout, embracing elements like lighting that adjusts based on usage, a custom app for members and advanced WiFi systems*" (Organisation 1). Plug-and-play services and wireless systems for electricity, data, voice and conferencing provide facilities for members to choose their preferred work stations and work anywhere they like within the coworking space.

Multi-purpose and multi-generational spaces

The existing literature has identified that individuals using coworking spaces vary across demographic and economic segments and have noticeably different perceptions on work-life balance and corporate hierarchy in workplaces (Green, 2014). Confirming this, both interviewees shared a common view that their coworking membership consists of individuals from four generations who have different work patterns and expectations related to physical work environments. Therefore, the designs of their coworking spaces have responded to this generational gap by creating workplaces that meet the requirements of the members from different generations.

Their coworking office layouts comprised of four main types of spaces. The aim being to facilitate different work settings which accommodate the various work practices of members from different generations and business backgrounds. These include:

- Concentrative work settings – Enclosed work settings which can be used for concentrated individual work requiring creative and innovative thinking and problem solving.
- Collaborative work settings – Large open spaces where members can meet to collaborate and work together. These spaces contain clusters of workstations in open spaces with a variety of furniture arrangements.
- Interactive work settings – Spaces such as meeting rooms, conference rooms and project rooms where members can interact on various topics.
- Community spaces – Spaces where members can have casual meetings and socialise. Such spaces consist of onsite cafes, large lounges and communal kitchens. These spaces are also used by members to meet their clients and have meetings with them.

Overall, the internal office designs in their coworking spaces were not based on one-size-fits-all traditional applications and were comprised of multipurpose office spaces that can be easily tailored to suit different activities. This enhances the space autonomy and efficiency in their coworking spaces and reduces the individual workplace footprints. Both interviewees emphasised that their office layouts consist of multiple variations of work point styles, from traditional work stations to open collaborative areas, spaces shared between members and their external clients and breakout areas. Such work settings provide different work environments for individuals and organisations with different business orientations. As one organisation explained, some of their coworking spaces provide "*specially configured and secured flexible workspaces specifically designed to cater large financial institutions working on fintech projects*" (Organisation 1). Furthermore, their work settings have spaces that are suitable for organisations and individuals that are going through different stages in their business cycles such as starting up, transitioning and going through periods of growth or downturn. Such variation in work settings provides members with a choice of how, when, and where they work. Furthermore, easily removable partitioning has been used throughout their office layouts, which has provided the possibility of alternation and reconfiguration as needed in the future.

Creating communities

Social and professional connection with other knowledge workers is one of the primary reasons for members' preference to use coworking spaces. Social participation is typically enabled through a variety of platforms such as casual networking, seminars and workshops, expert sessions and social events. The coworking spaces of both case study organisations distinguished themselves from serviced offices by offering various social spaces, knowledge sharing environments, networking events, leisure activities and hosted events to promote interaction among members. One organisation also organises one-to-one industry-focused mentoring sessions with industry leaders with the intention of increasing the sense of belonging and community. Office layouts of the coworking spaces of both organisations consisted of large community spaces that created opportunities for serendipity and networking encounters. As explained by one organisation "*our members have the option to use four themed conference rooms, a fully equipped podcast audio and video production studio, a large multipurpose room that accommodates over 50 people*" (Organisation 1).

Furthermore, the availability of shared spaces such as large open kitchens including unlimited coffee, open courtyards, onsite cafes and spacious lounges in both organisations' office layouts facilitates personal introductions and fosters planned and spontaneous meetings among members. These shared spaces are located near the entrance of the coworking spaces and provide members a sense of shared culture and purpose when entering the space. Their coworking spaces also have used various material design features such as easily visible white boards, inspirational quotes at the entrance of the space and digital discussion platforms projected onto walls to further increase social interactions and communication within the membership community.

Facilitating collaboration

The findings identify that coworking spaces were designed to create an environment that fosters collaboration, creation and productivity among space users. As one organisation explained, their "*choice of premium interior has been delicately chosen with a broader mission in mind – to craft the optimal setting for creation, collaboration and comfort*" (Organisation 1). In fact, both interviewees suggested that their coworking spaces distinguished themselves from traditional office layouts by offering explicit emphasis on collaborative activities among space users throughout the design of their coworking spaces.

Large open spaces that facilitate professional collaboration with like-minded or complementary professionals within the membership community was a main theme in their space design. The design of their coworking spaces '*provides spaces that favour collaboration over competition, in open rather than closed spaces for members which facilitate modern knowledge sharing economy*' (Organisation 2). It was reiterated by the other organisation which emphasised that their coworking spaces are designed to "*help you connect with other businesses and collaborate with your team. If you wish to stretch your business contact list, you will be rubbing shoulders with property, tech and marketing experts within Melbourne's esteemed business precinct*" (Organisation 1). Such collaborative, informal, knowledge-sharing working spaces promoting interaction provide further options to grow for individuals or start-up companies within their coworking communities. Both interviewees emphasised that a greater portion of their coworking spaces has been allocated for collaborative spaces. As a result, their members have the opportunity to knowledge share and collaborate with other individuals who they would not normally have exposure to, often connecting them with more business opportunities in the future in their relevant industries.

Both interviewees discussed the importance of having a greater proportion of collaborative spaces within their coworking spaces. They identified several benefits of having collaborative success including accessibility to information and ideas, exchange of knowledge and skills and enhanced problem-solving ability for individuals and companies from different backgrounds. It was suggested that the relaxed work environments in their coworking spaces express the values of collaboration, openness, community and accessibility. However, the interviewees emphasised that even though these values were encouraged in practice in their coworking spaces, the individuals have the freedom to choose what space arrangement they prefer to work in. As suggested by one organisation '*our space is designed to encourage collaboration, while also providing privacy and tranquillity for our members*' (Organisation 2).

Adapted aesthetics

Another main way of differentiating coworking spaces from traditional office spaces is through bespoke design aesthetics that blend work and play environments. Both case study organisations emphasised that their coworking spaces consist of open and transparent work settings, distinctly recognisable material used and unique furniture which have created non-traditional, creative and innovative work environments. Such design choices clearly reflect the images of non-bureaucratic, non-hierarchical, adaptive and innovation-friendly work settings. Extensive use of collaborative, interactive and community spaces in their coworking spaces suggest that such design features facilitate creativity and novelty over traditionality and predictability in work environments. Furthermore, their office spaces have incorporated biophilic office designs which provide more access to greenery and natural light with the intention of putting the space users closer in touch with nature and facilitate their creative thought patterns. As emphasised by one organisation "*our space is all about the natural light, polished concrete and exposed industrial ceilings, softened with bespoke wooden surfaces and live greenery to optimise clarity, comfort and productivity of the users*' (Organisation 1). Both coworking spaces have used modern, reconfigurable furniture which ensures that the space can be adapted to different work settings. Internal design features such as exposed gas and water pipes and modern stucco surfaced walls in their coworking spaces provide texture and identity to those spaces.

Colour coding of the walls and appropriate colourful artwork were also considered to be important when designing coworking spaces. The interviewees shared a common view that their strategy was to create coworking spaces that standout, distinguishable and memorable with the use of contemporary colours and unique characteristics with the highest aesthetic quality. The walls in their coworking spaces have achieved varying degrees of contrast with the use of multiple colour combination. This supported different work functions in coworking spaces. At the same time, they emphasised that over-specification and over-complication of building designs and specifications were avoided in coworking spaces as the objective was to create home-like spaces for users with warmth and inviting atmospheres.

Amenities and facilities

High quality building amenities to complement high density occupation levels in coworking spaces was also a main consideration when designing such spaces. Their coworking spaces have access to various amenities and facilities such as 24/7 access, on-hand concierge, internal high-quality cafeterias, larger atria/lobbies and lounges, administrative support, as well as cybercafés where members can have coffee while working. Furthermore, members have access to childcare facilities, gymnasiums, games rooms, yoga studios, meditation classes, green spaces within the premises, on-site secured lockers, bicycle storages, changing rooms and shower facilities within the building. Some coworking spaces also included a range of value-added services such as wellness facilities and business supporting activities such as networking and collaboration events and training facilities for coworking space users from various industries. The findings suggest that coworking spaces in case study organisations aimed to differentiate their spaces from the rest of the coworking spaces by providing various amenities and services as part of the design of their spaces.

Both interviewees stated that high quality building amenities would create all-inclusive home environments for occupiers and enhance the physical and psychological wellbeing of coworking space users who usually work in high density office environments. It was also suggested that the availability of modern amenities and facilities in coworking spaces allows members to work in an environment that represents an enhanced brand of their organisation.

Conclusion

The findings presented in this paper indicate users enjoy coworking vibrant hubs. For instance, popularity to provide engaging breakout and networking areas is a major consideration in the office space design. Additionally, a modern and innovative office design is also an influential factor.

Other key points of consideration include the size of the floorplate and the associated space intensification. With the growing demand for office environments offering social connectivity and interaction, there is a blurring of boundaries between traditional office space designs and dynamic adaptable environments. Additionally, with the changing nature of our work patterns, a broad workspace is inviting, and the design language will incorporate diversity and individual experiences such as courtyards, cafes and social destinations.

This case study analysis addresses the approach and strategies of large scale, sophisticated landlords – REITs – in relation to the design of coworking spaces. Large scale landlords' investment behaviours and experiences could be different from small scale, less sophisticated landlords due to a number of reasons. For instance, their strong market position, size and stability of the cash flows, awareness of the current and future market trends and the professional advice received when developing their investment strategies would differentiate them from small, less-sophisticated investors. Furthermore, the case study organisations generally own prime quality buildings located in prime locations. Therefore, the findings of this research must be seen as only truly representative of the groups that participated in this research. A study addressing the design strategies in small scale, less sophisticated coworking spaces would add another dimension to the findings of this research.

References

Bouncken, R.B. and Reuschl, A.J. (2016), Coworking-spaces: how a phenomenon of the sharing economy builds a novel trend for the workplace and for entrepreneurship, *Review of Managerial Science*, Vol. 3, pp. 1-18.

Brittain, J., Jaunzens, D. and Davies, H. (2004). Designing for Flexible Building Services in Office-based Environments: Understanding Client Needs, The Chartered Institution of Building Services Engineers, London, available at: www.cibse.org/

Brunelle, E. (2013), Leadership and Mobile Working: The Impact of Distance on the Superior-Subordinate Relationship and the Moderating Effects of Leadership Style, *International Journal of Business and Social Science*, Vol. 4, No. 11, pp. 1-14.

Bryant, S.E. (2003), The role of transformational and transactional leadership in creating, sharing and exploiting organizational knowledge, *Journal of Leadership & Organizational Studies*, Vol. 9, No. 4, pp. 32- 44.

Cameron, C. (2012), Coworking Offices– The Emerging Trend and Implications for Queensland in an era of High-speed Broadband, Department of Employment, Economic Development and Innovation, Queensland Government.

Cassell, C., Cunliffe, A. L., and Grandy, G. (2018). The SAGE handbook of qualitative business and management research methods. Thousand Oaks, California; London: Sage Publications.

Colliers International. (2018), The Flexible Workspace Outlook Report 2018, APAC.

Colliers International. (2019), The Flexible Workspace Outlook Report 2019, APAC.
Creswell, J. (2009). Research design: Qualitative, quantitative, and mixed methods approaches (3rd ed.). Thousand Oaks, CA: Sage Publications.
Deskmag. (2019). 2019 Coworking Forecast, Deskmag Carsetn Foertsch.
Dixon, M. and Ross, P. (2011),
VWork: Measuring the benefits of agility at work, Regus/Unwired, [On-line] http://www.regus.com/images/Regus-VWork-7-nocrops_tcm304-39506.pdf (May 2011).
Forbes, T. (2014), Queensland Public Servants Trial Digital Hubs, Flexible Work Arrangements, ABC: News [Online] http://www.abc.net.au/news/2014-09-07/queensland-public-servants-trial-digital-hubs-flexible-work/5724826?section=qld (7 Sep 2014).
Fuzi, A. (2015), Co-Working spaces for promoting entrepreneurship in sparse regions: the case of South Wales. Regional Studies, *Regional Science*, Vol 2, No 1, pp.462-469
Gandini, A. (2015), The rise of coworking spaces: A literature review, Ephemera, *Theory and Politics in Organization*, Vol. 15, No 1, pp. 193-205.
Gerdenitsch C., Scheel T.E., Andorfer J., Korunka C. (2016), Coworking Spaces: A Source of Social Support for Independent Professionals, *Frontiers in Psychology*, Vol. 7, article 581.
Green, R. (2014). Collaborate or compete: How do landlords respond to the rise in coworking?, *Cornell Real Estate Review*, Vol. 12, pp. 52-59.
Hub Australia, https://www.hubaustralia.com/workspace-design-size/ (accessed 1st September 2019)
Kjaerulff, J. (2010), Internet and Change, Intervention Press, Arhus, Denmark
Knight Frank (2016), Sydney coworking insight, http://research.knightfrank.com.au/resinsight161024.pdf
Knight Frank (2017), Culture Clash: Flexible Workspace, Coworking, and The Future.
Land, C., Otto, B., Böhm, S. and Johansson, M. (2012). Creative Community or Co-mutiny? Practices, Positions and Political Potentials in Coworking Spaces, Proceedings of the 6th Art of Management and Organization Conference 2012: Creativity & Critique, University of York (4-7 September, 2012), pp. 47-48.
Liegl, M., (2014), Nomadicity and the Care of Place—on the Aesthetic and Affective Organization of Space in Freelance Creative Work, *Computer Supported Cooperative Work (CSCW)*, Vol. 23, pp163–183
Merkel, J., (2015), Coworking in the city, Ephemera, *Theory and Politics in Organization*, Vol. 15, No 1, pp. 121-139.
Office Hub., (2018), The Australian Coworking Market Report 2017-2018, marketing@office-hub.com (Accessed 28th March 2019)
Oktra Insights https://www.oktra.co.uk/insights/what-makes-a-successful-coworking-design/ (Accessed 2nd September 2019)
Parrino, L. (2013), “Coworking: assessing the role of proximity in knowledge exchange”, Knowledge Management Research & Practice, Vol. 13 No. 3, pp. 261-271.
Ross, P.K. and Blumenstein, M. (2013), Cloud computing: The Nexus of Strategy and Technology, *Journal of Business Strategy*, Vol. 34, No 4, pp. 39-47.
Silverman, D. 2013. Doing Qualitative Research. A Practical Handbook. Sage Publications. London.
Spinuzzi, C. (2012), “Working alone together: co-working as emergent collaborative activity”, Journal of Business and Technical Communication, Vol. 26 No. 4, pp. 399-441.
Waters-Lyncha, J., Potts, J., (2017), The social economy of coworking spaces: a focal point model of coordination, *Review of Social Economy*, Published online 16/1/2017.
Welman, J. C. and Kruger, S.J. (2001). Research Methodology (2nd ed.). South Africa: Oxford University Press.

THE POTENTIAL OF USING BIM TO IMPROVE THE SAFETY OF TEMPORARY STRUCTURES ON CONSTRUCTION SITES

Jacob Terris[1], Madhav Nepal[1]

[1]School of Civil Engineering and Built Environment, Science and Engineering Faculty, Queensland University of Technology, Brisbane, Australia

Abstract

The building industry continues to experience high rates of injury and devastating fatalities all around the world. One of the most significant safety risk areas is falls from heights, which typically result from the incorrect use or faulty structure of temporary structures. The use of Building Information Technology (BIM) has significantly increased over the past decade as the construction industry embraces new technologies to increase efficiencies. However, the potential applications of BIM technologies to improve safety on construction sites, particularly when it comes to temporary structures, is still not adequately researched. This research, though an in-depth review of the existing literature, aims to identify and investigate: the issues involved with the design of temporary structures, the current use of BIM technologies in the industry, and the potential for BIM to improve safety in temporary structures. The outcomes of this research will inform for developing a holistic BIM-based process and approach for designing and building temporary structures and automatically detecting safety hazards on construction sites.

Keywords

BIM, Temporary Structures, Safety Hazards, Scaffolding, Building Projects, Construction Technology

Introduction

The topic of safety in construction has been a longstanding issue, with the number of injuries and fatalities due to site-related incidents remaining high. According to the ILO (2017), more than 1.8 million workers die on construction sites globally. From a local perspective, statistics from Safe Work Australia (2015) reveal construction industry in Australia records the third-highest number of fatalities in the world. This high rate of incidents coupled with the demand for safer worksites and the need for the industry to keep up with technological advancements highlights the need for the building industry to implement effective safety planning to assist in the reduction of incidents and fatalities.

Temporary structures are a key component on most construction sites around the globe and are critical to consider during construction planning (Ratay, 1996). Temporary structures (particularly scaffolding) play a significant part in providing a safe working platform for construction workers (Ismail & Ghani, 2019). In particular, scaffolding systems can ensure easy and tactical positioning, accessibility and improved safety when working from heights. Failure and inattention to the planning process for temporary structures adversely affect the quality, productivity, and most importantly safety of construction projects (Chini & Genauer, 1997).

Despite the importance of planning for temporary structures, and the promise that scaffolding systems will improve safety on a site, the hazards of working on temporary structures are high. According to Halperin & McCann (2004, p.35), "scaffolding related falls are the second leading cause of falls with an average of 52 deaths per year." Furthermore, Safe Work Australia (2015), found that over 401 construction workers were killed within a ten-year period due to incidents involving falls from height from ramps, ladders, stairways or scaffolding. Workplace Health and Safety (WHS) authorities in Australia have found that 40% of all temporary structures do not comply with national safety and design standards (Safe Work Australia, as cited in Wang, 2014). The primary causative factor in temporary structures often not going through the necessary planning steps is due to the time-consuming and error prone nature of manual construction planning.

Failures and inefficiencies are prevalent in current safety methodologies utilised for processing and resolving safety related issued on construction projects (Melzner, Zhang, Teizer & Bargstadt, 2013). Information technology that supports construction professionals in the laborious task of identifying and resolving safety hazards whilst addressing the individual nature and complexity of job sites can result in safer building practices whilst using less effort. Building Information Modelling (BIM) is a computer generated, three-dimensional model-based process that gives construction professionals the insight and tools to efficiently plan, design, build and manage construction projects (Marzouk & Elmansy, 2018, p. 54). According to del Puerto & Clevenger (2010, p. 5), BIM provides a powerful new platform for developing and implementing “design for safety” tools and methods to facilitate both safety planning tools during the pre-construction phase and safety tools such as hazard checking systems that can be utilised throughout the lifecycle of the project. At the start of a construction project, further emphasis is required on the safety aspects of designing temporary structures. Kim & Teizer (2014, p. 75) also consider how the construction industry has become outdated, with the use of paper-based systems and manual safety checking processes still in place.

Numerous studies have highlighted the significant advances in BIM technology for construction planning, however, the literature has shown a gap in its application for improving the safety of temporary structures. This paper aims to evaluate the existing risk identification and planning process for temporary structures and (ii) examine the potential for BIM technologies to improve the same and to make recommendations for how BIM technologies can be utilised to further improve safety planning of temporary structures on construction sites. This study is significant as BIM still lacks the ability to adequately plan and analyse the use of temporary structures. The literature review covers the current strategies and systems for identifying risks to improve the safety of temporary structures.

Current risk analysis and hazard mitigation for temporary structures

The intricate and ever-changing nature of the construction industry and its project specific environment is commonly recognised. As a result, safety planning and execution for temporary structures in a largely uncontrolled environment becomes increasingly complicated. With the resultant consequences of poor planning and execution being accidents and fatalities, it is recognised that further actions are required to mitigate risks. It is widely expected within the industry that the mandate is to provide a safe working site, with hazards identified and mitigated before an incident occurs. It has been recognized that current safety checking practices are being undertaken through manual efforts i.e. on-site identification of hazards by site management after the temporary structure has been erected. Contemporary literature attributes a lack of integration between safety and construction in the industry to the time-consuming, manual and error-prone nature of current scaffolding planning practices. A recent article written by Melzner, et al. (2013), concluded that through the integration of safe design at the planning phase of a construction project, hazards can be identified, quantified and ultimately mitigated before the commencement of works. The construction industry is currently limited in planning the erection and maintenance of temporary structures however due to a lack of temporary structure plans in construction documentation. Furthermore, due to the absence of temporary structure plans in construction documentation, the current planning process is reactive, inefficient and most importantly error prone due to human oversight (Kim & Ahn, 2011). A key issue with the current process is that design for temporary structures is not included within construction documentation as architects, engineers and other relevant consultants do not possess the essential knowledge and training to carry out an infallible safety in design assessment (Zarges and Giles, 2008; Lingard and Blismas, 2018).

Though an analysis of previous literature on the topic, the limitations with the current risk analysis and hazard mitigation process can be summarised as:

1. The process heavily relies on manual observations which are laborious, inefficient and error-prone.
2. The process is based on experience and prior knowledge and experience, which can be deficient due to human oversight and biased judgement.
3. The construction documentation lacks formal plans for temporary structures, which make the planning of temporary structures ad-hoc and reactive.

It has been identified through current literature that manual planning of temporary structures is likely to introduce a high probability of errors and safety risks. The use of computer-assisted planning, design and assessment of temporary structures holds promise to improve the safety of temporary structures.

BIM technologies to improve the safety of temporary structures

In the Australian construction sector, the implementation of BIM for safety planning and management has been underwhelming, largely due to the time constraints and costs involved with the enactment; as opposed to benefits realised (Azhar, 2011). There is anecdotal evidence to suggest that the implementation of BIM within the Australian construction sector is increasing (McGraw Hill, 2014). Although BIM technologies are yet to be widely adopted in the Australian construction industry, BIM has proven to be a promising tool to support construction safety practices (Melzner, Zhang, Teizer, & Bargstadt, 2013). A survey conducted in 2008 found that 79% of BIM users indicated that BIM dramatically improved project outcomes (Azhar, 2011). Furthermore, a study conducted in Australia concluded that the implementation of BIM technologies resulted in a significant improvement in project performance (Marzouk & Elmansy, 2018).

With the number of workplace fatalities considerably higher than other industries, the need to implement BIM to improve the safety and compliance of temporary structures is paramount. Despite significant industry and technological advancements, BIM technologies still currently lack the ability to plan and analyse the erection and use of temporary structures on construction sites. With further advancement, BIM technologies have the potential to significantly improve the safety of temporary structures through automated temporary structure design, automated hazard detection systems and automated spatiotemporal analyses of those designs.

Automated temporary structure design

The complex and divergent nature of construction projects means that the development of project specific temporary structure plans is highly labour-intensive process that typically succumbs to human error in capturing all of the required safety standards. From a project standpoint, this process is causing productivity loss as the manual efforts to create a temporary structure plan is a lengthy process. Through a number of case studies, contemporary literature indicates that a number of algorithms have been created which decipher the structure and calculate the external temporary structure requirements in BIM (Kim, Cho and Kwak, 2016; Smart Scaffolder (2018). Although both of these algorithms were able to create temporary structure models autonomously, they both lack the capabilities to integrate with construction programs; an imperative tool to capture workflows in the construction environment. Furthermore, both algorithms were unable to automatically identify hazards in the model nor implement risk mitigation strategies.

Automated hazard checking of temporary structure models

Existing literature in the field has shown that the current methods for hazard checking, heavily rely on the physical checking of drawings or three-dimensional models for the creation of temporary structures (Azhar, 2011). As the primary cause of errors in this process is due to human oversight, the automation of hazard identification for temporary structure models in BIM would substantially increase efficiency and decrease the margin for human error (Wang, 2014). It has been established that it is possible to create an algorithm that checks for code compliance and risk of falls (Kmardeen, 2010 & Scia Scaffolding, 2018). However, a critical flaw in the generated algorithms is that they all still require manual checking for verification and there isn't currently an algorithm available that is guaranteed for future use.

Automated spatiotemporal analysis of temporary structure models

Temporary structures are heavily trafficked by numerous trades throughout the project lifecycle. These trades can often be carrying out their work in close confines with other trades, particularly if their work space is a point of egress. A common causative factor for hazards on temporary structures is a lack of planning towards how the space will be used. It is therefore imperative that cautious and precise planning is carried out to avoid space-time conflicts and ensure a safe working platform. An automated spatiotemporal analysis of the temporary structure can reduce space-time conflicts and lack of working space (Jongeling, Kim, Fischer, Mourgues, & Olofsson, 2008, p. 784). Melinker & Sloan (2011) define spatiotemporal analysis as "data collected across time as well as space and has at least one spatial and one temporal property…. describes a phenomenon that exists at a certain time t and location x". Contemporary literature indicates that the manual creation of critical path method (CPM) schedules, culminated with two-dimensional drawings is unable to provide the spatial insight required for the safe and effective planning and management of temporary structures (Melinker & Sloan, 2011).

Recent literature on the topic indicates that BIM can and has been utilised to simulate and manage trade movements on a basic structure (Kim, Cho & Zhang (2016). Through case studies on the topic, it was determined that the input algorithms were sufficient to identify spatial conflicts and mitigate safety risks due to lack of working space (Akinci, Fischer, Kunz & Levitt (2000).

Review methodology

Over the past two decades, there has been a substantial increase in the availability of literature, discussing the possibilities and practicalities of BIM for construction safety. The literature review was carried out to explore the previous research on the studied area and create a theoretical foundation upon which this analysis is based. The literature review aimed to recognize the current risk analysis and hazard identification process, adoption of BIM within the Australian construction industry and the use of BIM to improve the safety of temporary structures. This process was critical in identifying the current limitations and understanding the inputs required to allow BIM to safely plan and execute temporary structure plans. This review was carried out through the use of several online databases including the Queensland University of Technology (QUT) library database, Google Scholar and State Library of Queensland databases. Authority, currency, audience, objectivity, relevance, coverage and accuracy were considered when assessing the credibility of each article. The review focused on peer reviewed journal articles and case studies to contextualise the issue.

In selecting the thirty-two articles that form part of this literature review, a focus was placed on practical applications of BIM Modelling for safety planning; using case studies to contextualise the issues. Through this analysis, the limitations within the current BIM models was highlighted. This informed the extent of the current knowledge gaps within the industry. It was important to select articles that had clear conclusions on future BIM development.

Discussions and conclusions

This paper presented an overview of the current risk analysis and hazard mitigation practice for temporary structures. It examined BIM-related research efforts to advanced safety planning and analysis through automated temporary structure design, automatic detection systems, and automated spatiotemporal analyses of designs.

It is evident that there is already a great deal of literature available on the topic of safety in construction, and more specifically falls from heights. This is because it has been identified as a high-risk topic and area that promptly needs addressing. Through an examination of the existing literature it was revealed that the primary limitations that impeded the safety of temporary structures are due to the need for excessive manual inputs concerning:

a) Manual creation of scaffolding models;
b) Manual work path planning (spatial movement of crews); and
c) Manual hazard detection and identification.

It is evident from the literature that BIM-based software system has a long way to go in providing the comprehensive support for safety planning and automated safety assessment of temporary structures.

Through the review of existing literature, it has been identified that there are significant knowledge gaps when it comes to BIM implementation for safety planning within the industry. These being; how is the current safety knowledge of temporary structures implemented into a computer-based algorithm i.e. if reaching this height then it must be tied back to the structure; how does the algorithm update plans to suit the project lifecycle; how does the software make decisions on safety hazards and what knowledge does the algorithm require to rectify these. Understanding these knowledge gaps is essential as future research and case studies into the topic can focus on bridging the knowledge gaps.

The practical implications of this research aim to bridge the identified knowledge gaps and ultimately provide safer temporary structures for the building and construction industry. An integrated BIM software that automates both the creation and subsequent safety checking of temporary structure models will be extremely beneficial to streamline the links between the design and construction, and to simplify the current site safety procedures and sign-offs, which will benefit site personnel through improved site safety. (Collins, Zhang, Kim, & Teizer, 2014). Safer sites have far-reaching implications for the industry through reduced injury and lost time injuries (LTI's). A reduction in LTI's will see increased revenue for builders as compensation claims reduce, along with increased workforce and reduced delays from insufficient subcontractor labour. Furthermore, a BIM-based safety planning and assessment can be instrumental for compliance monitoring, environmental changes and checking to ensure relevant health and safety procedures, regulations and provision are followed. Environmental changes include adjustments to suit wind rating, special needs access, obstructions and existing site conditions. Through ongoing compliance monitoring, the construction sector will experience reduced workplace health and safety inspection visits.

Moreover, it is also evident that to further develop these models the integration of human safety checking knowledge is imperative. It has been identified through this research that whilst a completely automated system would be beneficial, ultimately some organisations aren't looking for full automation; requiring a level of human input. A critical flaw in BIM's current use is the lack of implementation, which hampers the development of confidence placed in automated planning.

This research found gaps in the current knowledge of BIM to improve the safety of temporary structures. Most construction companies select an individual to complete hazard identification and ensure that the temporary structure design is compliant; this is done on a case-by-case basis. To help the construction industry become more consistent, efficient, and effective in their design of temporary structures, future research in the field is recommended to develop a software-based system that takes away the element of human input. A key challenge in eliminating human inputs is trust in the process and system. Further research into the topic will ultimately guide the improved safe use of temporary structures. With current implementation of BIM for temporary structures still remaining low, further research is required for better understanding of the safety issues and challenges for temporary structures in relation to the existing construction planning practices. Detailed case studies will be extremely valuable to understand the nuances of temporary construction works in "real life" contexts and formalising BIM-based safety planning and assessments.

References

Akinci, B., Fischer, M., Kunz, J. & Levitt, R., 2000. Automated Generation of Work Spaces Required by Construction Activities, Stanford: Centre for Integrated Facility Engineering.

Azhar, S., 2011. Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. Leadership and Management in Engineering, pp. 241-252.

Collins, R., Zhang, S., Kim, K. & Teizer, J., 2014. Integration of Safety Risk Factors in BIM for Scaffolding Construction. Computing in Civil and Building Engineering, pp. 307-314.

Halperin, K. & McCann, M., 2004. An Evaluation of scaffold safety at construction sites. Journal of Safety Research, pp. 141-150.

ILO, 2017. World Statistic. [Online] Available at: http://www.ilo.org/moscow/areas-of-work/occupational-safety-and-health/WCMS_249278/lang--en/index.htm

Ismail, D. & Ghani, K. D. A., 2019. Potential Hazards at the Construction Workplace due to Temporary Structures. Procedia - Social and Behavioural Sciences 49, pp. 168-174.

Jongeling, R. et al., 2008. Quantitative analysis of workflow, temporary structure usage, and productivity using 4D models. Automation in Construction, pp. 780-791.

Kim, H. & Ahn, H., 2011. Temporary Facility Planning of a Construction Project Using BIM (Building Information Modeling). Miami, American Society of Civil Engineers.

Kim, J. & Fischer, M., 2007. formalization of the features of activities and classification of temporary structures to support an automated temporary structure planning. Pittsburgh, Computing in Civil Engineering, pp. 338-346.

Kim, J., Fisher, M., Kunx, J. & Levitt, R., 2015. Semiautomated Scaffolding Planning: Development of the Feature Lexicon for Computer Application. Journal of Construction Engineering.

Kim, K., Cho, Y. K. & Kwak, Y. H., 2016. BIM-Based Optimization of Scaffolding for Plans for Safety. Construction Research Congress 2016: pp. 2709-2718.

Kim, K., Cho, Y. & Zhang, S., 2016. Integrating work sequences and temporary structures into safety planning: Automated scaffolding-related safety hazard identification and prevention in BIM. Automation in Construction, pp. 128-142.

Kim, K. & Teizer, J., 2014. Automatic design and planning of scaffolding systems using building information modeling. Advanced Engineering Informatics, pp. 66-80.

Kim, K., Yong, C. & Kinam, K., 2018. BIM-Driven Automated Decision Support System for Safety Planning of Temporary Structures. American Society of Civil Engineers.

Koskela, L., Owen, R. & Dave, B., 2010. Lean construction, building information modelling and sustainability. In *ERACOBUILD Workshop on BIM and Lean*, 15-16 April 2010, Malmö, Sweden

Leondes, C., 2003. Computer aided and integrated manufacturing systems. London: World Scientific. Marzouk, M. & Elmansy, N., 2018. Roadmapping BIM Implementation Processes Using IDEF0 Diagrams. International Journal of 3-D Information Modeling, pp. 49-63.

McGraw Hill Construction, 2014. The Business Value of BIM for Construction in Global Markets, Bedford: McGraw Hill Construction.

Melzner, J., Zhang, S., Teizer, J. & Bargstadt, H., 2013. A case study on automated safety compliance checking to assist fall protection design and planning in building information models. Construction Management and Economics, pp. 661-674.

del Puerto, C. L. & Clevenger, C. M., 2010. Enhancing Safety throughout Construction using BIM/VDC. EcoBuild Proceedings of the BIM-Related Academic Workshop, pp. 1-7, Washington D.C.

Ratay, R., 1996. Handbook of temporary structures in construction. McGraw-Hill Education. Safe Work Australia, 2015. Work Health & Safety Perceptions: Construction Industry, Canberra: Creative Commons.

Safe Work Australia, 2015. Work-related injuries and fatalities in construction, Australia, 2003 to 2013 June 2015, Canberra: Creative Commons.

Safe Work Australia, 2017. Australian Workers' Compensation Statistics 2016-2017, Canberra: Creative Commons.

Safe Work Australia, 2015. Construction Industry Profile. [Online] Available at: https://www.safeworkaustralia.gov.au/system/files/documents/1702/construction- industry-profile.pdf

Scia Scaffolding, 2018. Providing an accurate design and time-saving workflow. [Online] Available at: https://www.scia.net/en/system/files/documents/Scia-Scaffolding.pdf.
Smart Scaffolder, 2018. Smart Estimator. [Online] Available at: https://smartscaffolder.com/our-products/smart-estimator/estimate/
Wang, X., 2014. Using Building Information Modelling (BIM) for Smarter and Safer Scaffolding Construction, Brisbane: Sustainable Built Environment National Research Centre.
Zarges, T. & Giles, B., 2008. Prevention through design (PtD). Journal of Safety Research, pp. 123-126.
Zhang, S. et al., 2014. BIM-based fall hazard identification and prevention in construction safety planning. Safety Science, pp. 31-45.
Zhang, S. et al., 2013. Building Information Modeling (BIM) and Safety: Automatic Safety Checking of Construction Models and Schedules. Automation in Construction, pp. 183-195.
Zou, P., Yu, W. & Sun, A., 2009. An investigation of the viability of assessment of safety risks at design on building facilities in Australia. Melbourne, University of New South Wales.

RULE-BASED AUTOMATED DESIGN CHECK FOR MODULAR BUILDING

Yanhui Sun[1,2], Jeremy Wu[2], Jingyuan Fan[2], Jun Wang[3], Xiangyu Wang[1,2]

[1] Australasian Joint Research Centre for Building Information Modelling, Perth, WA, Australia

[2] School of Design and Built Environment, Curtin University, Perth, WA, Australia

[3] School of Architecture and Built Environment, Deakin University, Melbourne, VIC, Australia

Abstract

Unlike conventional buildings, modular buildings require more time in design and planning but less time in execution. Lacking experience and knowledge of downstream processes, underlying design issues become a critical barrier hindering the application of modular buildings. This paper contributes in developing a rule-based automated design check system for modular buildings harnessing the concept of design for manufacture, transportation, and assembly (DfMTA).The rule-based design check system includes DfMTA, Building Information Modelling (BIM), and Rule-based Engine three main parts that can facilitate entire modular construction process, in terms of design, manufacturing, transportation and assembly.

Keywords

Modular Building; Design Check; Design for Manufacture, Transportation, and Assembly (DfMTA)

Introduction

In recent years, modular buildings have been embraced by construction industry in the United Kingdom, the United States, Japan, Sweden, Australia, Singapore, China and Hong Kong (Goodier & Gibb 2007; Steinhardt & Manley 2016; Tam et al. 2015; Zhang et al. 2016). As opposed to traditional on-site constructed buildings, modular buildings seek to raise prefabricated modules or units of building at off-site manufacture factory, eliminating the on-site construction activity. Prior to on-site assembly, prefabricated units of modular building have been installed finished floor, wall, ceiling, cabinets as well as Mechanical, Electrical and Plumbing (MEP) system (Murray-Parkes & Bai 2017).

The application of modular buildings largely represents in apartments, hotels, hospitals and school dormitories comprising large amount of repetitive units due to their modularisation and standardisation (Generalova, Generalov & Kuznetsova 2016). Meanwhile, hybrid system of modular building, in a combination with concrete, steel and timber, drives the implementation of high-rise buildings (Lacey et al. 2018; Lawson, Ogden & Bergin 2012). Comparing to traditional buildings, the advantages of modular buildings are composed with less construction process, improved quality, reduced costs, and enhanced sustainability (Blismas, Pasquire & Gibb 2006; Jaillon & Poon 2008).

In spite of above mentioned benefits facilitate harnessing modular buildings, there are still considerable barriers hindering its advancement. Goodier and Gibb (2007) conducted a questionnaire survey of 75 construction organisations, where 46% respondents confirmed the longer lead-in times is an inevitable constrain of modular construction. Even though rapid manufacturing and installation processes attracts the attention of stakeholders, a potential longer design process which is the early stage of modular construction, triggers significant concern over the implementing modular buildings. Moreover, Blismas

(2007) demonstrated that the longer design process can be derived from lack of experience and knowledge of modular design. Designers have to spend disproportionate time in modular design checking for delivering detailed drawings. Because modular design differs from conventional building design, there is urgent need for off-site modules manufacturing to receive inalterable detailed drawings as early as possible. On the other hand, the improper modular design results in major clash and penetration issues in the stage of manufacturing that increases both construction period and costs (Jang & Lee 2018). In accordance with the improper modular design, oversize and overweight modules exceeds limit of transportation regulation and lifting capacity, which is a crucial factor in modular construction delay (Chiang, Chan & Lok 2006; Othuman Mydin et al. 2014).

The primary objective of this paper is to investigate the significance of design checking in modular construction, whilst proposing the improved approach for modular design check. The next section presents existing status of modular design and the development of design check. The devised framework of improved design check method is demonstrated in the section that follows. A summary of the contributions and discussion about future research are in the last section that concludes this paper.

Background

The current status of modular design

The design for modular construction is deeply related to module classification, which includes concrete, steel and timber. Aligned to traditional on-site constructed buildings, the discrepancy of primary material results in diverse structures and systems, which is determined at the early modular design stage. The structures and systems of modular building can be summarised according to the different primary materials:

- ***Precast concrete*** is widely adopted in modular construction that benefits from its outstanding performance in fire resistance, thermal insulation, sound insulation and durability. The design of precast concrete in building is stemming from prefabricated components, in terms of columns, beams, walls, staircases and windows. The precast panelised walls and floors boost modular buildings to a higher level of prefabrication enhancing not only construction process but building performance as well. Ultimately, the entire volumetric modules, for instance prefabricated bathroom units (PBU), prefabricated volumetric units (PVC), and prefinished prefabricated volumetric construction (PPVC) are produced at off-site factory that eliminates on-site assembly process considerably (Glass 2000).
- ***Steel*** modules comprising modular steel building modules, light steel framed modules, and container modules, are embedded in modular construction in recent years. From the perspective of load bearing, steel modules can be designed as column supported or continuously supported. Moreover, designers employ hybrid system, a combination of steel and concrete, to build medium and high-rise modular buildings (Lacey et al. 2018).
- ***Timber*** modules has become popularity in modular along with advanced timber implementation, including cross-laminated timber (CLT), glue-laminated timber (GLT), and nail-laminated timber (NLT). As an environmental friendly material, timber associated with concrete and steel, are embraced by designers in modular buildings (Foster, Reynolds & Ramage 2016).

Figure 1: (L) PPVC module, (M) Light steel framed module, (R) CLT module

The mandate of the modular design is to deliver sophisticated design drawings before procurement activities commence. It is coincident with conventional building design, designers deliver detailed drawings in order to meet requirements of architecture, structure and MEP. Otherwise, designers also need to secure the suitability of downstream processes. It is the concept of Design for Manufacture and Assembly (DfMA), a state-of-the-art design process that considers manufacture and assembly processes improving modular building quality, whilst maximising off-site manufacturing and minimising on-site construction. As a result, a comprehensive and high standard modular design is deemed necessary for modular buildings integrated with DfMA approach.

Furthermore, Building Information Modelling (BIM), a digital representation of full detailed physical and functional information of building, has been widely used in modular design. Depending on parametric design of BIM, designers are able to create a library of standard parametric modular components. It is possible to efficiently generate BIM model, when designers create a substantial library that comforts to not only modular design requirements, but requirements of entire modular construction (Zhang et al. 2016).

Given all aforementioned considerations, it should be noted that as opposite to traditional building design, manufacture, transportation and assembly are essential requirements for modular design. Checking modular design involving the suitability of downstream processes plays a vital rule in modular construction. The following section presents the development of design check historically that

The development of design checking

Prior to delivering construction drawings, it is imperative to scrutinise design details according to rules and regulations stipulated by related authorities. These rules and regulations are described in agreement with specific logical structure. Many previous researches studied the logical structure of regulatory codes for design checking. It can be derived from the decision tables representing the design provisions of designers. The decision table and decision tree developed from the former, store relevant rules in the form of conditions and respective actions that was utilised to structural steel design, reinforcement concrete design and seismic design as well (Fenves 1966; Fenves, Gaylord & Geol 1969; Wright & Fenves 1979). Associated with the development of computer science, the method of decision table was devised as computer programs to inspect relevant rules and regulations. Implementing these applications, design standards and building codes can be checked in predicate logic structure (Fenves, Garrett & Reed 1995).

Although aforementioned applications can detect design issues integrated with decision table and computer science, these approaches of design check still consume large amount of manpower, time and costs in inputting design drawing data (Kerrigan & Law 2003). Therefore, several researchers developed rule-based automated design check systems that translates building rules and regulations in the form of

IF (conditions) THEN (actions) clauses (Macit İlal & Günaydın 2017). Eastman et al. (2009) summarised structure of rule checking into four stages, in terms of rule interpretation, building model preparation, rule execution, and report of checking results. Ding et al. (2006) provided automated inspect compliance of building codes utilising 3D object-based model coupled with Express language. Zhang et al. (2013) devised rule-based automated safety check associated with BIM model representation. Jiang and Leicht (2015) proposed automated rule-based constructability checking based on BIM contents.

Adopting automated rule-based design checking, it is possible to shorten the process of building design. However, from the perspective of modular design, there is few researches focusing on development of modular design checking. The motivation of this paper stems from this research gap, and the framework of automated rule-based design check system is to present in the next section.

Framework of rule-based design check system for modular building

Figure 2 illustrates the framework of the proposed BIM-based Automated Design Check system, which includes three main parts: (1) Design for Manufacture, Transportation and Assembly (DfMTA), (2) Building Information Modelling (BIM), and (3) Rule-based Engine. Each of them is explained in detail in the following subsections.

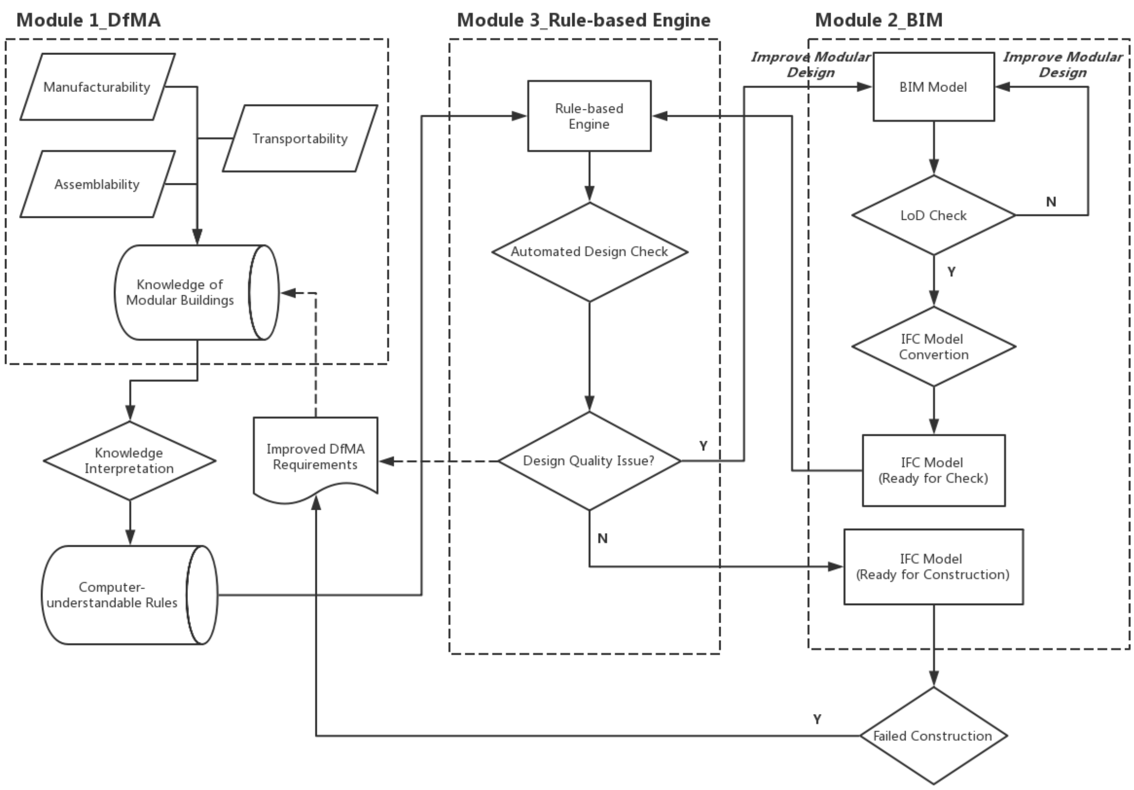


Figure 2: Framework of BIM-based Automated Design Check for Modular Buildings

Design for Manufacture, Transportation and Assembly (DfMTA)

In this framework, a knowledge database of Design for Manufacture, Transportation and Assembly (DfMTA) in modular buildings is established at the first step. Rules and regulations of modular buildings adopted in devised system focuses on downstream processes of modular construction comprising 1) Design for Manufacture, 2) Design for Transportation, and 3) Design for Assembly (Figure 3).

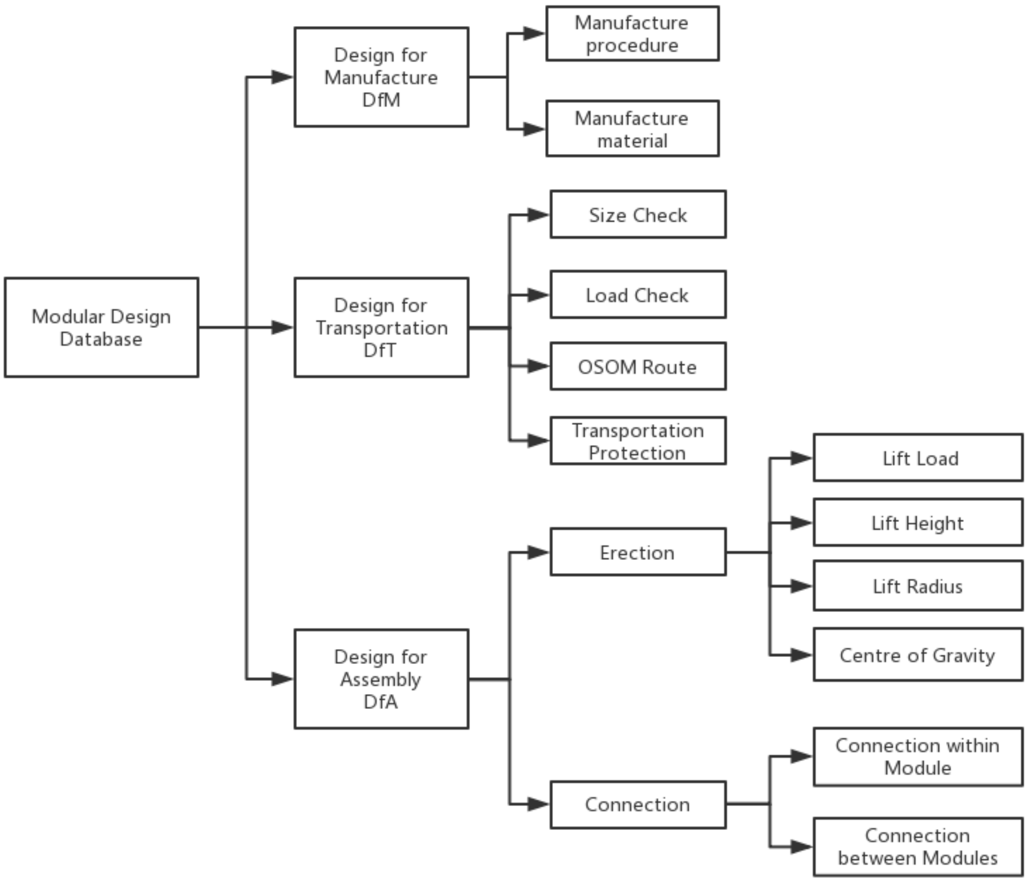


Figure 3: DfMTA Database for Modular Design

Design for Manufacture (DfM)

DfM includes two parts: 1) Manufacture Procedure, 2) Manufacture Material. The rule of manufacture procedure represents entire module production process with different materials and systems that detects all essential components of module provided. The rule of manufacture material is formed with domestic and oversea primary material information facilitates material selection for specific component.

Design for Transportation (DfT)

As shown in figure 3, DfT considers transportation regulations that limits size and weight of module. When produced module is oversize or overweight, it is inevitable to apply oversize and overmass (OSOM) permit, while checking the OSOM route for modular transportation according to various states and regions. During the transit, there are rules and requirements for module protection.

Design for Assembly (DfA)

From the perspective of DfA, the limitation of load, height, radius, along with centre of gravity compose lifting rules during modular assembly. Moreover, connections within module as well as connections between modules have considerable impacts on building performance, in terms of vertical and horizontal alignment, water-tightness, fire resistance, etc.

Aforementioned rules of DfM, DfT and DfA will be defined as a predicate for mapping knowledge in natural language to formal rules` form. In accordance with predicate evaluation result, rules are to formalise into computer-understandable format. At last, rule interpretation is to explicate rules by the name and properties (dimension, weight, material, etc.). The object name will be identified by the condition where the rules apply. Then the detailed properties will be inspected by the properties upon which the rules apply.

Building Information Modelling (BIM)

According to Leite et al. (2011), a high-accuracy BIM model is the cornerstone of design checking. BIM model preparation is the second part of development of design check system, following DfMTA database establishment and rule interpretation. In this study, BIM model of modular building is to generate associated with fully details information of components comprising length, width, height, weight, material, and relevant information about DfM, DfT and DfA.

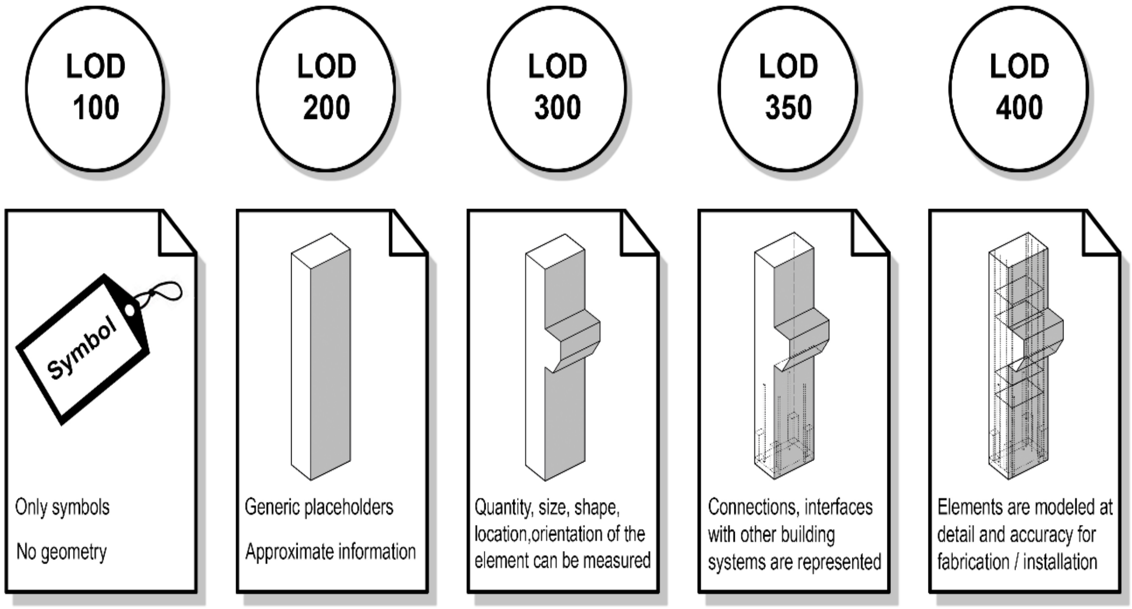


Figure 4: LoD of BIM Model

Furthermore, Level of Detail/Development (LoD), describing the precision of BIM model, will be utilised to verify the completion of BIM model. LoD demonstrates the degree to adoption of geometry and attributes (Figure 4). The proposed system embraces with LoD 400 composed with geometry, manufacture, transportation and assembly information. Improving BIM model unless LoD checking passes. The next step is BIM model conversion into Industry Foundation Classes (IFC) model which is an open and neutral file format widely adopted in BIM technology.

Rule-based Engine

The rule-based engine platform is developed based on open application-programming interface (API). It allows designers to utilise the design checking system in different BIM software. Embedded with rules interpreted from DfMTA database, the checking results can be presented in IFC model and result report that highlights potential design issues coupled with relevant recommendations. According to graphical presentation of checking results, designers can revise modular building model directly and then deliver final construction model to all stakeholders. In addition, DfMTA database can be improved referring to checking results as well.

Conclusion and Future Works

This paper presents a framework of BIM-based automated design check for modular building. It provides designers an efficient solution to self-check their design and continuously improve design quality by considering modular manufacturing, transportation, and assembly.

In the future, this developed system will be evaluated in three real projects that selected from West Australia, New South Wales and Victoria, respectively. The effectiveness of the automated check approach will be validated based on one completed project, to detect all modular design issues in terms of manufacturing, transportation, and assembly. The construction drawings and models will be collected at the first step, while the issues records and reports which were generated throughout manufacturing, transportation and assembly processes will be assembled as well. In accordance with LoD check standard in Module 2, the collected BIM models are to add detailed module properties first. Then, developed rule-based engine is able to automatically check modular design issues to compare with recorded issues during downstream processes. Meanwhile, due to the test, knowledge database of DfMTA can improve that benefits maturity of rule-based engine. Afterwards, automated check system will be adopted on newly developed project from the preliminary design stage to validate its efficiency. The design team will use it to detect design flaws and optimise modular design solutions. It is imperative to record the modular design period, especially checking time to compare with conventional projects. Moreover, the project cost from design to completion will be recorded as a benchmark to compare with completed projects of similar scale. At last, Interviews with project members will be conducted to evaluate the proposed approach and provide suggestions and recommendations for future`s work.

Reference

Blismas, N 2007, *Off-site manufacture in Australia: Current state and future directions*, Cooperative Research Centre for Construction Innovation, Brisbane.

Blismas, N, Pasquire, C & Gibb, A 2006, 'Benefit evaluation for off-site production in construction', *Construction Management and Economics*, vol. 24, no. 2, pp. 121-30.

Chiang, YH, Chan, EHW & Lok, LKL 2006, 'Prefabrication and barriers to entry - a case study of public housing and institutional buildings in Hong Kong', *Habitat International*, vol. 30, no. 3, pp. 482-99.

Ding, L, Drogemuller, R, Rosenman, M, Marchant, D & Gero, J 2006, 'Automating code checking for building designs - DesignCheck', *Clients Driving Innovation: Moving Ideas into Practice*, pp. 1-16.

Eastman, C, Lee, JM, Jeong, YS & Lee, JK 2009, 'Automatic rule-based checking of building designs', *Automation in Construction*, vol. 18, no. 8, pp. 1011-33.

Fenves, SJ 1966, 'Tabular decision logic for structural design', *Journal of Structural Engineering*, vol. 92, pp. 473-90.

Fenves, SJ, Garrett, JH & Reed, KA 1995, *Computer representations of design standards and building codes: U.S. perspective* The International Journal of Construction Information Technology, University of Salford, U.K.

Fenves, SJ, Gaylord, EH & Geol, SK 1969, *Decision table formulation of the 1969 AISC specification*, University of Illinois, Urbana, Illinois.

Foster, RM, Reynolds, TPS & Ramage, MH 2016, 'Proposal for Defining a Tall Timber Building', *Journal of Structural Engineering*, vol. 142, no. 12, p. 02516001.

Generalova, EM, Generalov, VP & Kuznetsova, AA 2016, 'Modular buildings in modern construction', *Xxv Polish - Russian - Slovak Seminar -Theoretical Foundation of Civil Engineering*, vol. 153, pp. 167-72.

Glass, J 2000, 'The future for precast concrete in low-rise housing'.

Goodier, C & Gibb, A 2007, '*Future opportunities for offsite in the UK*', *Construction Management and Economics*, vol. 25, no. 6, pp. 585-95.

Jaillon, L & Poon, CS 2008, 'Sustainable construction aspects of using prefabrication in dense urban environment: a Hong Kong case study', *Construction Management and Economics*, vol. 26, no. 9, pp. 953-66.

Jang, S & Lee, G 2018, 'Process, productivity, and economic analyses of BIM based multi-trade prefabrication-A case study', *Automation in Construction*, vol. 89, pp. 86-98.

Jiang, L & Leicht, RM 2015, 'Automated Rule-Based Constructability Checking: Case Study of Formwork', *Journal of Management in Engineering*, vol. 31, no. 1.

Kerrigan, S & Law, KH 2003, 'Logic-based regulation compliance-assistance', p. 126.

Lacey, AW, Chen, WS, Hao, H & Bi, KM 2018, 'Structural response of modular buildings - An overview', *Journal of Building Engineering*, vol. 16, pp. 45-56.

Lawson, RM, Ogden, RG & Bergin, R 2012, 'Application of Modular Construction in High-Rise Buildings', *Journal of Architectural Engineering*, vol. 18, no. 2, pp. 148-54.

Leite, F, Akcamete, A, Akinci, B, Atasoy, G & Kiziltas, S 2011, 'Analysis of modeling effort and impact of different levels of detail in building information models', *Automation in Construction*, vol. 20, no. 5, pp. 601-9.

Macit İlal, S & Günaydın, HM 2017, 'Computer representation of building codes for automated compliance checking', *Automation in Construction*, vol. 82, pp. 43-58.

Murray-Parkes, J & Bai, Y 2017, *Handbook for the design of modular structures*, Modular Construction Codes Board, Monash University, Australia.

Othuman Mydin, MA, Othuman Mydin, MA, Sani, NM & Phius, AF 2014, 'Investigation of Industrialised Building System Performance in Comparison to Conventional Construction Method', *MATEC Web of Conferences*, vol. 10.

Steinhardt, DA & Manley, K 2016, 'Adoption of prefabricated housing-the role of country context', *Sustainable Cities and Society*, vol. 22, pp. 126-35.

Tam, VWY, Fung, IWH, Sing, MCP & Ogunlana, SO 2015, 'Best practice of prefabrication implementation in the Hong Kong public and private sectors', *Journal of Cleaner Production*, vol. 109, no. 1, pp. 216-31.

Wright, R & Fenves, SJ 1979, *Analysis of tentative seismic design provisions for buildings*, U.S. Government printing office, Washington, U.S.

Zhang, J, Long, Y, Lv, S & Xiang, Y 2016, 'BIM-enabled Modular and Industrialized Construction in China', *Procedia Engineering*, vol. 145, pp. 1456-61.

Zhang, S, Teizer, J, Lee, J-K, Eastman, CM & Venugopal, M 2013, 'Building Information Modeling (BIM) and Safety: Automatic Safety Checking of Construction Models and Schedules', *Automation in Construction*, vol. 29, pp. 183-95.

INVESTIGATING THE INFLUENCE FACTORS OF CARBON EMISSIONS OF THE U.S. ROAD TRANSPORT SECTOR: A RESEARCH AGENDA

Peng Wu[1], Josua Pienaar[2]

[1]School of Design and the Built Environment, Curtin University, Perth, Australia

[2]School of Engineering and Technology, Central Queensland University, Australia

Abstract

Global climate change has attracted rising research attention. The transport industry contributes significantly to the global climate change in terms of greenhouse gas emissions. This paper aims to propose a research work that aims to investigate the carbon emissions of the U.S. transport sector, which is one of the largest transport sectors around the globe. Specifically, this research work aims to investigate the quantity of carbon emissions from two sources: passenger and freight transport, due to their distinct differences. In addition, it also aims to propose a mathematical calculation method to identify the influence factors that have contributed to the increase or reduction of carbon emissions in these two sources respectively. The data collection and analysis processes are also discussed in this paper. It is believed that this approach is appropriate for the road agencies to understand their impact on global climate change and establish relevant policies to mitigate their impact.

Keywords

Global climate change; Carbon emissions; Decomposition; Policy

Introduction

The US transport sector is one of the larges sources of energy consumption and greenhouse gas (GHG) emissions (Greene and Plotkin 2011). The US transport sector accounts for 27% of the national GHG emissions and almost 30% of global GHG emissions in 2015 (U.S. Environmental Protection Agency 2017a). In addition, the transport sector accounts for 70% of the petroleum consumption in 2013, thus putting significant impact on the environment in terms of emissions (U.S. Energy Information Administration, 2014). In the transport sector, road transport is considered as the largest contributor in terms of energy consumption and GHG emissions. According to the U.S. Energy Information Administration (2014), light-duty vehicles and freight trucks account for 76% of the energy consumption in the transport sector in 2012. In addition, the US Environmental Protection Agency (2017b) stated that light-duty vehicles and freight trucks (medium- and heavy-duty trucks) account for almost 83% of the GHG emissions from the transport sector in 2015. Given the significant impact of road transport on the sustainable performance of the overall transport sector, the U.S. Environmental Protection Agency and the U.S. Department of Transportation are taking actions to gradually reduce carbon pollution. These actions include setting up new emissions standards and encouraging the use of renewable fuels.

It should be noted that the establishment of relevant policies to achieve emissions reduction relies on an accurate estimation of emissions and the revealing of influencing factors leading to the changes of emissions in the past. As such, many studies have been conducted to address this issue. For example, Wang et al. (2011) analysed the CO2 emissions from the transport sector in China and found that the economic activities per capita and the transportation modal shifting are the two biggest factors causing a significant increase in CO2 emissions. Studies have also been conducted in the road transport sector to identify the influencing factors of carbon emissions in this specific sector. For example, Lu et al. (2007) decomposed the carbon emissions of Germany, Japan, South Korea and Taiwan into five factors, which are emission coefficient, fuel intensity, vehicle ownership, population intensity and economic growth. It is found that while economic growth and the increase of vehicle ownership contribute significantly to the increase of carbon emissions, population intensity (i.e. the population growth per unit GDP), helps reduce the carbon emissions in the same period. Similarly, Gambhir et al. (2015) developed a prediction model of the carbon emissions from China's road transport sector for 2050 and analysed the contributing factors that have influenced the carbon emissions level. It should be noted that there are several limitations of previous studies. The road transport sector includes passenger transport and freight transport activities, which are measured differently. Previous studies, e.g. Wang et al. (2011) adopted a conversion coefficient to integrate passenger transport and freight transport through experience, which may lead to inaccurate estimation. Correspondingly, the prediction of the future trend of emissions in the road transport sector should also be based on separate considerations on passenger transport and freight transport. In addition, as one of the largest contributors to global emissions, the U.S. transportation sector has rarely been targeted, leaving a significant research gap about examining the effectiveness of emissions reduction policies and strategies in the U.S.

Based on these research gaps, this study aims to: 1) propose a method to evaluate the carbon emissions of the U.S. transportation industry from 2007-2016; and 2) propose a method to identify the influencing factors which contribute to the change of carbon emissions and quantify the contributions from the perspectives of passenger and freight transport.

Literature review

Road transportation plays an important role for the transportation sector to achieve its emissions reduction target. As such, a number of studies have been conducted to evaluate the factors that influence the emissions level of the industry. Table 1 lists a few studies, origins, research targets and the influence factors.

Table 1. Studies that investigate the influence factors of road transport emissions

Year	Studies	Country	Targets	Influence factors
2005	Kwon (2005)	UK	Passenger	Emission coefficient; Fuel structure; Fuel intensity; Occupancy rate; Distance; Population
2007	Lu et al. (2007)	Taiwan, Germany, Japan and South Korea	Road Transport	Emission coefficient; Fuel intensity; Vehicle ownership; Population intensity; Economic growth
2009	Papagiannaki and Diakoulaki (2009)	Greece and Denmark	Passenger	Ownership effect; Distance; Fuel mix; Car capacity change; Car engine change; Population
2013	Li et al. (2013)	China	Freight	Emission coefficient; Fuel intensity; Market concentration level; Market share of freight transportation; Industrialization level; Economic growth.
2014	Sobrino and Monzon (2014)	Spain	Road Transport	Carbon intensity; Energy intensity; Use intensity; Motorization; Job intensity; Workers income intensity; GDP
2015	Gambhir et al. (2015)	China	Road Transport	Share of vehicle types; Energy intensity of vehicle types; Emission intensity of vehicle types
2017	Talbi (2017)	Tunisia	Road Transport	Energy intensity; Economic development level; Urbanization; Motorization, Energy consumption

These current studies on road transportation emissions can be categorised into three groups in terms of research targets, including road transportation, passenger transport and freight transport. The first group of studies focus on road transport as a whole sector. The most commonly used influence indicators include energy intensity, carbon intensity, motorization, population and economic growth. By focusing on road transport as a whole sector, these studies are able to identify influence factors that contribute to the overall emissions of the whole sector. However, it should be noted that passenger transport and freight transport have distinct differences. For example, the car capacity change, i.e. the number of passengers per vehicle, may play an important role in the carbon emissions of passenger transport, as can be seen from Papagiannaki and Diakoulaki (2009), such factor is not commonly used for freight transport. As such, it is necessary to develop separate models for passenger and freight transport in the road transport sector.

One of the commonly adopted method to analyse the influence factors of energy consumption and emissions is Divisia index technique (Ang, 2004). According to Ang (2004), Divisia index technique can deliver perfect decomposition whereby no unexplained residual term exist in the results. In addition, the Log mean Divisia Method (LMDI), as one of the Divisia index technique, can handle zero values in the data set. As such, LMDI can be selected as an appropriate method in this study.

Method

Mathematical representation of the carbon emissions

The carbon emissions of road transport are calculated using two sources of data. The sources of fuel and fuel consumption are obtained from the Transportation Energy Data Book. The latest edition is Transportation Energy Data Book Edition 37. It includes sources of fuel and fuel consumption of the transportation sector in 2016 (Davis and Boundy 2019). This study evaluates the carbon emissions of road transport from 2007 because of the change of method in evaluating fuel use by the Federal Highway Administration in 2007. In order to ensure data consistency, the period from 2007-2016 is investigated. The Transportation Energy Data Book publishes transportation energy by mode (including light vehicles, buses and medium/heavy trucks) and fuel type (including gasoline, diesel fuel, liquefied petroleum gas, natural gas and electricity which are related to road transportation).

In addition, the carbon dioxide emissions coefficients published by the U.S. Energy Information Administration is referred to (U.S. Energy Information Administration 2016). For the carbon dioxide emissions coefficients of electricity generation, the State Electricity Profiles (under the summary section) published by the U.S. Energy Information Administration is referred to (U.S. Energy Information Administration 2019). Table 2 presents the carbon dioxide emissions coefficients of fuels and Table 3 presents the carbon dioxide emissions coefficients of electricity generation adopted in this study.

Table 2. Carbon dioxide emissions coefficients by fuel (Sources: U.S. EIA, 2016)

Fuel types	Carbon dioxide factors (kg CO_2 per volume or mass)	Carbon dioxide factors (kg CO_2 per million Btu)
Gasoline	8.89 / gallon	71.30
Diesel fuel	22.40 / gallon	73.16
Liquefied petroleum gas	6.23 / gallon	64.01
Natural gas	53.12 / thousand cubic feet	53.07
Notes: As the Transportation Energy Data Book does not provide detailed consumption of the three LPG types, including Propane, Butane and Butane/Propane Mix, the weighted average of the carbon dioxide emissions coefficients of the three types is used. The carbon dioxide emissions coefficients of Propane, Butane and Butane/Propane Mix are 63.07, 64.95 and 64.01 kg CO_2 per million Btu respectively.		

Table 3. Carbon dioxide emissions coefficients of electricity (Sources: U.S. EIA, 2018)

Year	Electric power sector net generation (Thousand Megawatthours)	Electric power sector carbon dioxide emissions (thousand metric tons	Electric power sector carbon intensity (kg CO_2 per million Btu)
2007	4,088,364	2,547,032	182.58
2008	4,051,686	2,484,012	179.68
2009	3,883,020	2,269,508	171.29
2010	4,054,902	2,388,596	172.64
2011	4,027,498	2,287,071	166.42
2012	3,972,030	2,156,875	159.14
2013	3,982,483	2,173,806	159.97
2014	3,998,464	2,168,284	158.93
2015	3,975,050	2,031,452	149.77
2016	3,964,107	1,928,401	142.57

As five sources of energy, including gasoline, diesel fuel, liquefied petroleum gas, natural gas and electricity, are included, the carbon emissions from road transport are calculated by Eq. (1).

$$CO_{2,road} = \sum_i CO_{2,i} = \sum_i E_i \times CC_i \qquad \text{Eq. (1)}$$

Where:

E_i refers to the energy consumption from energy source i (reported in Btu) and CC_i refers to the carbon dioxide emissions coefficients of energy source i, which can be found in Table 2 and Table 3.

Mathematical representation of the decomposition model

Logarithmic Mean Divisia Index (LMDI) was adopted to analyse the contribution of various factors to the carbon emissions level of the road transportation sector. It should be noted that passenger transport and freight transport are reported differently because they are affected by different influencing factors. As such, two separate decomposition models were developed for passenger transport, including light vehicles (cars, light trucks, motorcycles) and buses (transit, intercity and school), and freight transport (medium/heavy trucks).

The decomposition model for passenger transport can be represented by Eq. (2):

$$CO_2 = \sum_{ij} CO_{2,ij} = \sum_{ij} \frac{CO_{2,ij}}{E_{ij}} \times \frac{E_{ij}}{E_i} \times \frac{E_i}{E} \times \frac{E}{V} \times V = \sum_{ij} EF_{ij} \times TS_{ij} \times ES_i \times EI \times V \qquad \text{Eq.(2)}$$

where:

E_{ij} is the energy consumption of source i in mode j; E_i is the energy consumption of source i; E is the energy consumption of the passenger transport sector; V is the total passenger transport service (measured by million passenger kilometres); EF represents emission factor; TS refers to transport structure, i.e. the share of transport mode j in the passenger transport sector; ES refers to energy structure, i.e. the share of energy source i in the passenger transport sector; EI represents the energy intensity of the passenger transport sector.

The change of carbon emissions in the passenger transport sector can therefore be decomposed into the five factors of EF, TS, ES, EI and V, using Eq. (3) to Eq. (8)

$$\Delta CO_2 = \Delta CO_{2,EF} + \Delta CO_{2,TS} + \Delta CO_{2,ES} + \Delta CO_{2,EI} + \Delta CO_{2,V} \quad \text{Eq.(3)}$$

$$\Delta CO_{2,EF} = \sum_{ij} L\left(CO_{2,ij}^T, CO_{2,ij}^0\right) ln \frac{EF_{ij}^T}{EF_{ij}^0} = \sum_{ij} \frac{CO_{2,ij}^T - CO_{2,ij}^0}{\ln CO_{2,ij}^T - \ln CO_{2,ij}^0} \, ln \frac{EF_{ij}^T}{EF_{ij}^0} \quad \text{Eq.(4)}$$

$$\Delta CO_{2,TS} = \sum_{ij} L\left(CO_{2,ij}^T, CO_{2,ij}^0\right) ln \frac{TS_{ij}^T}{TS_{ij}^0} = \sum_{ij} \frac{CO_{2,ij}^T - CO_{2,ij}^0}{\ln CO_{2,ij}^T - \ln CO_{2,ij}^0} \, ln \frac{TS_{ij}^T}{TS_{ij}^0} \quad \text{Eq.(5)}$$

$$\Delta CO_{2,ES} = \sum_{ij} L\left(CO_{2,ij}^T, CO_{2,ij}^0\right) ln \frac{ES_{ij}^T}{ES_{ij}^0} = \sum_{ij} \frac{CO_{2,ij}^T - CO_{2,ij}^0}{\ln CO_{2,ij}^T - \ln CO_{2,ij}^0} \, ln \frac{ES_{ij}^T}{ES_{ij}^0} \quad \text{Eq.(6)}$$

$$\Delta CO_{2,UC} = \sum_{i=1}^{9} L\left(CO_{2,i}^T, CO_{2,i}^0\right) ln \frac{UC^T}{UC^0} = \sum_{i=1}^{9} \frac{CO_{2,i}^T - CO_{2,i}^0}{\ln CO_{2,i}^T - \ln CO_{2,i}^0} \, ln \frac{UC^T}{UC^0} \quad \text{Eq.(7)}$$

$$\Delta CO_{2,A} = \sum_{i=1}^{9} L\left(CO_{2,i}^T, CO_{2,i}^0\right) ln \frac{EE^T}{EE^0} = \sum_{i=1}^{9} \frac{CO_{2,i}^T - CO_{2,i}^0}{\ln CO_{2,i}^T - \ln CO_{2,i}^0} \, ln \frac{A^T}{A^0} \quad \text{Eq.(8)}$$

As there is only one transport mode in the freight transport sector, a simplified decomposition model is also developed, as shown in Eq. (3)

$$CO_2 = \sum_i CO_{2,i} = \sum_i \frac{CO_{2,i}}{E_i} \times \frac{E_i}{E} \times \frac{E}{P} \times P = \sum\nolimits_i EF_i \times ES \times EI \times P$$

Where:

E_i is the energy consumption of source i in the freight transport sector; E is the energy consumption in the same sector; P refers to the total freight transport service (measured by million ton kilometres); EF represents emission factor; ES represent energy structure; and EI represents energy intensity.

Data related to transport activities, including passenger transport and freight transport, are collected from Organisation for Economic Co-operation and Development (OECD) database, which can be found from the below two links directly: < https://data.oecd.org/transport/passenger-transport.htm#indicator-chart> and < https://data.oecd.org/transport/freight-transport.htm#indicator-chart>.

Some preliminary results

Figure 1 shows the annual carbon emissions of the US's road transport sector from 2007 to 2016. As can be seen from Table 1, the annual carbon emissions value has reduced from 1.61 billion tons in 2007 to 1.57 billion tons in 2016. This number is consistent with a few reports targeting at GHG emissions from the U.S. transport sector, e.g. U.S. EPA (2018). It should be noted that the annual carbon emissions value has recorded a 2.5% decreasing rate over 9 years. The weighted average reduction rate is only 0.28% per year. In 2012 and 2013, the road transport sector recorded the lowest emissions value at 1.53 billion tons. At the UNFCCC workshop in 2011, the U.S. government has committed for a 17% reduction relative to 2005 emissions in 2020. Under the Paris Agreement, the U.S. government has committed a 17%-24% reduction target relative to 2005 emissions in 2025. It appears that road transport, representing 83% of the emissions from the transport sector (U.S. Environmental Protection Agency 2017b), has limited contribution towards the achievement of the reduction target.

Figure 1 also highlights the two most important sources of carbon emissions, which are light vehicles and medium/heavy trucks. The share of light vehicles (often used for passenger transport) and medium/heavy trucks (for freight transport) is relatively stable, at approximately 70% and 30% respectively over the analysis period. The annual carbon emissions value of light vehicles has decreased from 1.21 billion tons in 2007 to 1.11 billion tons in 2016; an 8.3% reduction. Comparatively, the annual carbon emissions value of medium/heavy trucks has increased from 0.38 billion ton in 2007 to 0.45

billion ton in 2016; a 16.4% increase. It should also be noted that in 2013, the passenger transport sector recorded the lowest emissions value at 1.08 billion tons CO_2.

Figure 1 also presents the detailed values of carbon emissions from various modes. As can be seen from Figure 1, the annual carbon emissions values are divided into passenger and freight transport. Passenger transport has been the mode with the largest emissions value from 2007 to 2015. A general decline trend can be identified. The carbon emissions value of passenger transport is reduced from 1.22 billion ton in 2007 to 1.10 billion ton in 2015, a 9.8% decrease. The most two significant sources of carbon emissions in the passenger transport sector are cars and light vehicles. On the other hand, the emissions values from freight transport are relatively small when compared with passenger transport.

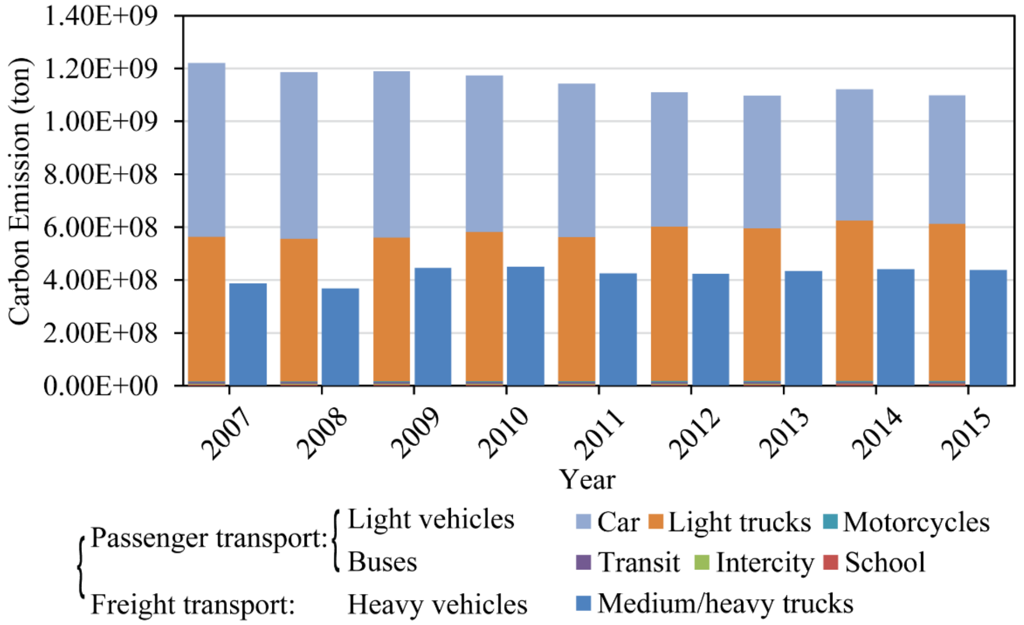


Figure 1. Emissions of various modes of the U.S. road transport sector from 2007-2015.

Future work

There are two major future research areas of this work. One is to investigate what factors are influencing the change of carbon emissions of the passenger and freight transport. As for the passenger transport, emission factor (i.e. the emission factor of various sources of energy), transport structure, (i.e. the share of transport modes, e.g. light vehicles and buses), energy structure (i.e. the share of energy source), energy intensity and the number of passengers are considered as factors that can influence the carbon emissions of this sector. Similarly, for freight transport, emission factor, energy structure, energy intensity and the volume of freight transport service are considered as factors that can influence the carbon emissions of freight transport. The next step is to evaluate whether these factors lead to an increase or decrease of the carbon emissions level. The other research area is to investigate the policies that have proven to be useful to mitigate emissions. For example, if energy intensity has proven to be useful in reducing carbon emissions, what are the policies that help reduce energy intensity and whether these policies have successfully reduced energy intensity are the other future research area.

Conclusions

Given the relatively high importance of road transport to the achievement of global greenhouse gas emissions reduction target, this study aims to propose methods that can be used to investigate the factors that influence the greenhouse gas emissions of this sector, so as to further evaluate the effectiveness of policies related to achieving the reduction target. A few indicators, including emission factor, transport structure, energy structure, energy intensity, the number of passengers and the volume of freight transport service will be evaluated in a future study.

References

Davis, S. C. and R. G. Boundy. (2019). "Transportation Energy Data Book: Edition 37." Retrieved 20 May, 2019, from https://tedb.ornl.gov/wp-content/uploads/2019/03/Edition37_Full_Doc.pdf.

Gambhir, A., K. Lawrence, D. Tong and R. Martinez-Botas (2015). "Reducing China's road transport sector CO 2 emissions to 2050: Technologies, costs and decomposition analysis." Applied Energy 157: 905-917.

Greene, D. L. and S. Plotkin (2011). "Reducing greenhouse gas emission from US transportation." Arlington: Pew Center on Global Climate Change.

Kwon, T.-H. (2005). "Decomposition of factors determining the trend of CO2 emissions from car travel in Great Britain (1970–2000)." Ecological Economics 53(2): 261-275.

Li, H., Y. Lu, J. Zhang and T. Wang (2013). "Trends in road freight transportation carbon dioxide emissions and policies in China." Energy Policy 57: 99-106.

Lu, I., S. J. Lin and C. Lewis (2007). "Decomposition and decoupling effects of carbon dioxide emission from highway transportation in Taiwan, Germany, Japan and South Korea." Energy policy 35(6): 3226-3235.

Oak Ridge National Laboratory. 2017. Transportation Energy Data Book Edition 36. Available from: https://cta.ornl.gov/data/download36.shtml (Cited 21 Mar 2018)

Papagiannaki, K. and D. Diakoulaki (2009). "Decomposition analysis of CO2 emissions from passenger cars: The cases of Greece and Denmark." Energy Policy 37(8): 3259-3267.

Sobrino, N. and A. Monzon (2014). "The impact of the economic crisis and policy actions on GHG emissions from road transport in Spain." Energy Policy 74: 486-498.

Talbi, B. (2017). "CO2 emissions reduction in road transport sector in Tunisia." Renewable and Sustainable Energy Reviews 69: 232-238.

U.S Environmental Protection Agency. (2018). "U.S. Transportation Sector Greenhouse Gas Emissions 1990-2016." Retrieved 23 May, 2018, from https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100USI5.pdf.

U.S. Energy Information Administration. (2014). "Annual Energy Outlook 2014: With Projections to 2040." Retrieved 21 March, 2018, from http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pd.

U.S. Energy Information Administration. (2016). "Carbon dioxide emissions coefficients." Retrieved 20 May, 2019, from https://www.eia.gov/environment/emissions/co2_vol_mass.php.

U.S. Energy Information Administration. (2019). "Electricity." Retrieved 20 May, 2019, from https://www.eia.gov/electricity/data.php#generation.

U.S. Environmental Protection Agency. (2017a). "Sources of Greenhouse Gas Emissions." Retrieved 21 March, 2018, from http://epa.gov/climatechange/ghgemissions/sources.html

U.S. Environmental Protection Agency. (2017b). "Fast facts on transportation greenhouse gas emissions." Retrieved 22 March, 2017, from https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions

Wang, W., M. Zhang and M. Zhou (2011). "Using LMDI method to analyze transport sector CO2 emissions in China." Energy 36(10): 5909-5915.

CONCEPTUAL MODEL ON ESTIMATING EMBODIED CARBON IN CONSTRUCTION SUPPLY CHAINS USING VALUE CHAIN AND BLOCKCHAIN

M.N.N. Rodrigo[1], Srinath Perera[1], Sepani Senaratne[1], Xiaohua Jin[1]

[1]Centre for Smart Modern Construction, School of Computing, Engineering and Mathematics, Western Sydney University, Sydney, Australia

Abstract

Building construction contributes up to 40-50% of the global carbon emissions while Australian building sector accounts for about 36% of the overall carbon emissions. Thus, building industry is the key control point to create a low carbon economy thus ensuring a sustainable environment. Lifecycle carbon consists of Operational Carbon (OC) and Embodied Carbon (EC). The latest trend of introducing zero carbon projects focus on reducing OC through usage of various materials such as insulation, triple glazing among others, which contribute to increase of the EC in the building. Hence, focus should be on reducing overall net carbon emission, not OC alone. Thus, the study focuses on reducing the EC of construction projects. EC estimating can be carried out using different databases and tools. However, due to the issues existent in these databases and tools, the accuracy of the EC estimates prepared using these databases and tools is questionable. Therefore, it is intricately important to introduce an accurate methodology of estimating EC. Hence, the study is aimed at identifying the issues existent in carbon estimating and proposing a conceptual model on estimating EC in construction supply chains accurately. The proposed methodology eliminates the existent issues in carbon estimating.

Keywords

Embodied carbon, Embodied carbon estimating, Carbon databases and tools, Conceptual model, Value chain, Blockchain

Introduction

Urbanisation is currently taking place at an unprecedented pace throughout the world (Huang et al. 2018), increasing the construction activities to accommodate the demand on housing, infrastructure and other facilities. The building construction industry is accountable for approximately 40% of materials, which enter into the global economy and contribute up to 40-50% of the global carbon emissions (Asif et al. 2007). Carbon emissions in buildings have been increasing at an annual rate of 2% between 1971 to 2004 (IPCC 2007). Australian building sector accounts for about 36% of the overall carbon emissions (Huang et al. 2017). Australian GHG emissions (excluding land use, land-use change and forestry) has increased approximately by 30% between the decade of 1990 and 2000 (Kember et al. 2013). Birrell and Healy (2009) forecasted GHG emissions to increase from 554 million tonnes in 2000, up to an approximate of 774 million tonnes by 2020. Australia being one of the highest GHG emitters on a per capita basis (Garnaut 2008), there is an immediate need for Australia to introduce transition into its cities to ensure low-carbon profiles in a much more efficient form and function with respect to carbon emissions (Philp & Taylor 2015). The Australian government is keen on reducing the country's GHG emissions at least by 5% below the 2000 levels by the year 2020 (Department of the Environment 2015). Therefore, it is intricately important to reduce carbon emissions in the Australian construction industry.

Emerging trends towards delivering energy efficient buildings, such as passive houses, zero emission buildings among others, have been introduced to address the extensive intention of reducing operational energy and OC emissions in buildings (Fu et al. 2014; Skaar et al. 2018). Zero carbon buildings contain additional layers of insulation, triple glazed windows, solar panels among others focusing on the reduction of OC, which leads to increase of EC within them. The focus should have been on reducing net carbon emissions. Thus, reducing EC emissions has become intricately important. Gardezi et al. (2015) studied reduction of EC footprint in housing projects in Malaysia by utilisation of recycled materials in conventional construction. Victoria et al. (2017) investigated the carbon and cost critical elements or hotspots in office buildings. Several studies have been carried out by various researchers on estimating carbon (Victoria et al 2017; Jiao et al 2012), however, there is a deficiency of studies which address the current issues existent in the databases and software that are used to estimate EC. Therefore, the study is aimed at identifying the issues existent in carbon estimating and proposing a conceptual model on estimating EC in Construction Supply Chains (CSCs) accurately.

Literature Review

Construction industry contributes to carbon emissions immensely. Allwood et al. (2010) opined that more than 1/3 of the global carbon emissions are related to buildings. Furthermore, life cycle carbon emissions occur throughout the life cycle of a building/product/service. The following section discusses important aspects on carbon emissions, carbon estimating, issues existent in the available carbon estimating databases and tools, value chain concept and blockchain technology.

Embodied carbon

Life cycle carbon comprises of Embodied Carbon (EC) and Operational Carbon (OC). OC refers to the carbon emissions caused by energy consumed during the use of buildings (Teng et al. 2018) while EC is the carbon emissions that occur during the production process of a product/service within the system boundaries (Hammond & Jones 2011a; Victoria et al. 2016). Though OC is emitted during the operational phase of the building, EC is accountable throughout various stages related to the entire life-cycle of the building (Ashworth & Perera 2015). These phases are identified as 'system boundaries' when estimating EC. Victoria and Perera (2018) identified the scope of EC calculations to be considered as the system boundary. There are several system boundaries as illustrated in Figure 1.

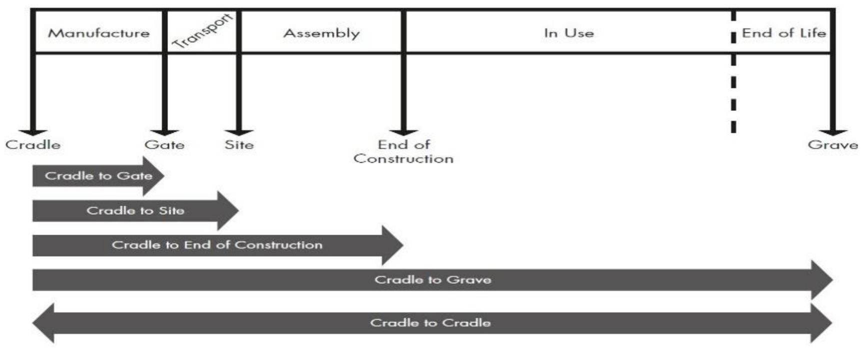


Figure 1: System boundaries for estimating EC

Source: Ashworth and Perera (2015)

Cradle-to-gate refers to carbon emissions from the raw material extraction (cradle) stage up to the factory gate of the final processing operation (Ashworth & Perera 2015; RICS 2012). It simply includes mining, raw materials extraction, processing and manufacturing. In cradle-to-site, the carbon emitted during the material distribution process between the manufacturer's gate and site, has to be added to the carbon emissions incurred in cradle-to-gate stage (Ashworth & Perera 2015; RICS 2012). Cradle-to-end of construction considers the carbon emitted up to the end of construction on site (Ashworth & Perera 2015). Cradle-to-grave refers to the carbon emitted from materials extraction stage through manufacturing, transportation, construction, use and demolition (Ashworth & Perera 2015). Cradle-to-cradle refers to carbon emissions related to recycle or re-use of demolished building materials for a new building construction activity (Ashworth & Perera 2015; RICS 2012).

Embodied carbon estimating

Carbon estimating plays an important role in the construction industry as construction related activities contribute to climate change and global warming immensely (Baldasano & Reguart 2014). Therefore, it is quite necessary to estimate carbon, ultimately to reduce construction industry related carbon emissions (Rodrigo et al. 2019). Several studies have been carried out on EC estimating. Monahan and Powell (2011) calculated the EC in a low energy, affordable house constructed using a novel offsite panellised modular timber frame system in Norfolk UK with the use of Life Cycle Assessment (LCA) framework from cradle-to-site and carbon emission factors. Hammond and Jones (2008) estimated the EC of 14 case studies, using the inventory of carbon and energy database developed by them (Refer Section 2.5.4 for more details), and found the average EC for habitable floor area is 403 kgCO2/m2. Nadoushani and Akbarnezhad (2014) developed a framework and a MATLAB program to estimate EC emissions of the construction phase during the design and project planning phase to compare alternative designs and decide on the optimum one. Moncaster and Symons (2013) designed a new whole life EC and energy of buildings tool complying with TC350 standards to estimate whole life cradle-to-grave EC and embodied energy of buildings. Apart from these studies several researchers have identified different EC estimating databases and tools as discussed in the next section.

Embodied carbon estimating databases and tools

There are many databases and tools that are used for carbon estimating developed by various researchers and organisations for the ease of practitioners and academics as illustrated in Table 1.

Table 1: Summary of the EC estimating databases, software and tools

Type	EC estimating tool	Type of Software	Details	Last Updated	System Boundary	Location	Publicly Available	Free
Databases	ICE	Excel Sheet	EC	June 2019	cradle-to-gate	UK	Yes	Yes
	Hutchins UK Blackbook	Book	EC	2010	cradle-to-gate	UK	Yes	No
	WRAP	Web Application	EC			UK	For registered users	Yes
	Ecoinvent	Web Application	LCA	Oct 2017	cradle-to-gate	Switzerland	Yes	No
	AusLCI	Excel Sheets/ XML Format	EPD	2016	cradle-to-gate	Australia	Yes	Yes
Tools	CapIT Online Carbon and Cost Estimator	Published as Hutchins UK Building Blackbook	EC	2011	cradle-to-gate	UK	Yes	No
	BRE Green Guide Calculator	Web Application	EC	Jan 2015		UK	For licensed BREEAM/ EcoHomes/ Code for Sustainable Homes Assessor	No
	CFCCP	Excel Sheet	EC		cradle-to-end of construction		Yes	Yes
	AFD Carbon Estimating Tool		EC and OC	2017	site-grave	France		
	BEES Software	Web Application	CO2 cost in $/ton	2010	cradle-to-grave	USA	Yes	Yes

Type	EC estimating tool	Type of Software	Details	Last Updated	System Boundary	Location	Publicly Available	Free
	GaBi Education Software	Software Application	LCA	2017	cradle-to-grave	Germany	Yes	Yes
	Athena Estimator	Software Application	LCA	Feb 2017	cradle-to-gate/grave	USA	Yes	Yes
Tools (Cont'd)	SimaPro	Software Application	LCA	2017	cradle-to-grave	Netherlands	Yes	No
	eToolLCD	Web Application	LCA	2010	cradle-to-grave	Australia	Yes	No
	ECE Tool	Web Application	EC	2019	cradle-to-gate	Australia	Yes	No

The databases and tools are available as books, excel sheets, web applications and software applications. The ones available in excel sheets are free and publicly available to any user. However, the WRAP database and BRE Green Guide Calculator is available for registered users only while all other identified databases and tools are publicly available for all users. It was further noticed that some databases or tools provided data related to EC only or both EC and OC while some provided data related to LCA or Environmental Product Declaration (EPD). Similarly, the system boundaries considered in each database or software is different from one another. Though, ICE, Hutchins UK Building Blackbook (Franklin & Andrews 2010), Ecoinvent, AusLCI, Athena Impact Estimator for Buildings and ECE tool considered cradle-to-gate system boundary, all others have considered different system boundaries. Only few databases such as ICE, Ecoinvent, AFD Carbon Estimating Tool, Athena Impact Estimator for Buildings and SimaPro have been recently updated while others have not been updated recently.

On the other hand, ICE is a primary data set on EC whereas Hutchins UK Building Blackbook and its software, CapIT Online Carbon and Cost Estimator have been developed based on ICE (Ashworth & Perera 2015; Victoria et al. 2015). Each of the databases or tools as demonstrated in Table 1 have been developed considering data relevant to their respective country, though some of them have been produced in the UK, all others have been created in various countries. Therefore, when using these databases and tools it is quite necessary to have a thorough understanding on the characteristics and limitations of each database or tool. Besides, there exists issues with the databases and tools that are currently used for estimating EC, which have been explained in the following section.

Issues in existing embodied carbon estimating databases and tools

EC estimating databases and tools at present are lacking in transparency, simplicity and accuracy, especially in the way that data are collected (De Wolf et al. 2016). Haynes (2010) noted that it is quite difficult to estimate carbon emissions accurately and moreover, the calculations are subject to more variability. Pomponi and Moncaster (2016) agreed that it is quite doubtful on the accuracy of the EC calculations due to lack of comprehensively detailed information and specific manufacturer's data for various components (Moncaster & Symons 2013). Due to lack of standardisation and unavailability of data, estimating tools consider different assumptions according to their benefit (De Wolf et al. 2016). Hence, accuracy of carbon estimates remains questionable and debatable. There are few other reasons for questioning the accuracy of current carbon estimating databases and tools, as discussed below.

One of the key issues existing with the usage of currently available EC estimating databases and tools, is the insufficiency of consensus on the system boundaries used by each estimating tool (De Wolf et al. 2016). Carbon estimating databases and tools have defined a system boundary applicable to each of them as demonstrated in Table 1. Hence, debate continues about the system boundaries that should be applied to estimate EC (Haynes 2010). On the other hand, Pomponi and Moncaster (2016) found that over 90% of the LCA studies are cradle-to-gate, which neglects the carbon emissions after the product leaves the manufacturing plant. Victoria et al. (2015) opined that it is difficult to standardise the system boundary as most of the data available are on cradle-to-gate, and suggested that if one needs to calculate cradle-to-grave, he/she can employ other ways of capturing data without standardising any restrictions. However, Rashid and Yusoff (2015) opined that most of the LCA of buildings have considered cradle-to-grave system boundary. In summary, it signifies the fact that even researchers are of different opinions due to the availability and consideration of different system boundaries in EC calculations.

Different carbon estimating databases and tools have been developed using data of different geographical locations as illustrated in Table 1. Therefore, when using a particular carbon estimating technique, this has to be considered. As a result, the difference in geographical locations can affect the accuracy of the EC estimates. Moreover, Fouche and Crawford (2015) highlighted that lacking of Australian data is an issue that is currently faced by carbon estimators in Australia. Even though there are several carbon estimating databases and tools developed in other countries, Australia is lacking of an EC estimating database or tool. At present, measurement and reduction of EC of buildings have not yet been included within the legislation of many countries (Birgisdottir et al. 2017). Innovation Growth Team (2010) recommended the industry to agree with the government on a standard method of estimating EC which could be used as a design tool. Gavotsis and Moncaster (2014) stated that there should be an agreement on standards, boundaries and the method used for calculating EC. Another key issue identified in current EC estimating databases and tools is incomplete data (Crawford 2008). The issues existent in carbon estimating can be avoided by estimating EC in CSCs using value chain concept and blockchain technology as discussed in research findings.

Construction Supply Chain

Mentzer et al. (2001, p. 4) defined a supply chain as “a set of three or more entities (organisations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer.” A CSC has been identified as a complex interconnected web of information systems, operational activities and management techniques which exist amongst entities that maintain relationships of varying strengths with one another (Wang 2007). Carbon emissions occur throughout the CSC and these can be appraised accordingly as discussed in detail in research findings.

Value Chain

Value Chain (VC) has been identified as the process, a product or service that moves along, from raw materials/conception stage to final consumption while adding value at each stage to create a compelling value proposition (Noke & Hughes 2009; Porter 1985). Martek and Chen (2016) elaborated VC as an entire process where raw materials are extracted from nature and manipulated, shaped, combined and assembled, by various stages and processes, until a final entity is formed for an intended use. The VC represents a tool, which will disaggregate the business into strategically relevant activities, that will create the most crucial value (Edwards et al. 2004). VC allows an exploration of linkages among the economic activities within a construction project (Machacek et al. 2017). Buckley (2012) opined that it is possible to assess carbon emissions throughout the entire VC, while identifying the significant contributions and managing them afterwards by reducing those emissions.

Blockchain

Blockchain comprises of a decentralised distributed ledger where encrypted transactions are created, validated and recorded in an incorruptible way (WU Global Tax Policy Center 2017). Blockchain technology uses a ledger of transactions that are maintained on a peer-to-peer network that comprise of ‘nodes’ (Santori et al. 2016). Nodes act as the entry points for new data, entity for validation and propagation of new data that was submitted to the blockchain (Lewis & Larson 2016). The blockchain technology consisting of a peer-to-peer network that enables decentralisation along with improved immutability, security, transparency and trust (Rodrigo et al. 2018).

Research Methodology

The research methodology followed in the study is as illustrated in Figure 2.

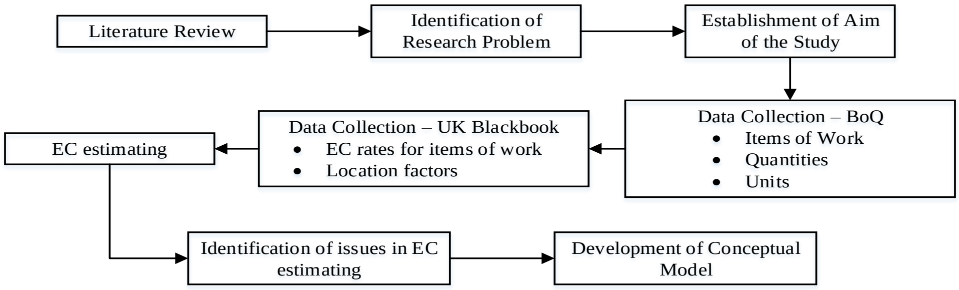


Figure 2: Research methodological framework

EC estimating can be carried out using the available carbon estimating databases and tools. However, the literature review revealed that there are many issues existent in the available carbon estimating databases and tools, establishing the research problem and thus the aim of the study. Due to these issues, the accuracy of the EC estimates prepared using the existing databases and tools is quite questionable. Rather than relying on the literature findings, it was required to carry out EC estimating for a project using a secondary source to investigate the issues existent in estimating EC using the existing databases and tools. Hutchins UK Building Blackbook was selected as the secondary source to estimate EC of a land development project in Sydney, Australia. UK Blackbook provides EC rates as per items in the bills of quantities (BoQs). Therefore, the BoQ of the project was obtained. The items of work, quantities and units were obtained from the BoQ while EC rates for each item of work and location factors were obtained from the UK Blackbook. Subsequently, EC calculations were carried out as discussed in detail in the following section. Consequently, the issues and challenges faced by the researcher while carrying out EC estimating was recorded and discussed under research findings. Thus, it was revealed that it is necessary to develop a new accurate methodology for estimating EC in CSCs. The proposed method of estimating EC uses first principles where EC emissions related data are collected from the EC contributors to improve accuracy of calculations. The proposed conceptual model on estimating EC in CSCs has been discussed in detail in the latter part of research findings.

Research Findings

The findings of the study have been elaborately discussed in this section. Initially, the EC estimating carried out using UK Blackbook was explained, followed by identifying the issues existent in estimating EC using UK Blackbook. Subsequently, how these issues can be eliminated by estimating EC using the proposed methodology of estimating EC is discussed. Later on, the proposed conceptual model on estimating EC in CSCs has been introduced.

EC estimating using secondary sources for 'installation of stormwater pipes' in a land development project

EC estimating can be carried out using different carbon databases and tools. Data collected from the BoQ and UK Blackbook was used to estimate EC. An item 'installation of stormwater pipes' in the BoQ is considered to explain the process that was followed to estimate EC. The entire CSC of installation of stormwater pipes comprise of manufacturing and delivery of pipes to site, excavation of trenches, laying of pipes, backfilling and compacting and disposal of excavated material. However, in the BOQ there were three work items related to installation of 375mm sized stormwater pipes as illustrated in Table 2.

Table 2: BOQ work items for installation of stormwater pipes

Description	Quantity	Unit	Rate (AUD)	Amount (AUD)
Excavate, bed and backfill subsoil lines	287	m	48.34	13,873.58
Pipes (supply and lay) 375mm Class 2 RRJ<1.5m deep	287	m	175.86	50,470.93
Transport excess materials to nominated stockpile	10	m^3	13.75	137.50

After identifying the work items related to installation of stormwater pipes, EC calculation for these items were carried out. EC emission rates for the work items could be obtained from the Hutchins UK Building Blackbook. However, as the UK Blackbook considers the system boundary cradle-to-gate, the calculations are based on the system boundary cradle-to-gate only as demonstrated in Table 3.

Table 3: EC calculation for installation of stormwater pipes (Drainage below ground)

Description	Quantity	Unit	EC Rate ($kgCO_2$)	EC Amount UK ($kgCO_2$)	EC Amount Australia ($kgCO_2$)
Manufacturing of concrete pipes, BS 5911 Part 1, Class L, 375mm	287	m	104.088	29,873.26	31,665.65
Excavation in trenches; by machine; for drainage pipes of the like, including disposal and filling. Trenches to suit 400mm dia pipes; average depth 1.50m	287	m	8.942	2,566.35	2,720.33

The quantities of work items related to EC calculation could be directly obtained from the BOQ of the project and EC rates of work items could be directly obtained from the UK Blackbook. However, the EC rates were related to the UK built environment. Therefore, a location factor needed to be considered to convert the EC amounts to the Australian context. The location factor considered for the calculation was 1.06, which was obtained from the indicative international location factors published along with the UK Blackbook. During the calculation process, many issues were aroused indicating and resembling the issues identified in literature related to estimating EC using the existing databases and tools, which is discussed in detail in the following section.

Issues in EC estimating using secondary sources for 'installation of stormwater pipes'

Several issues were identified when estimating EC using an existing database such as Hutchins UK Building Blackbook and those identified issues have been discussed elaborately in this section.

Different system boundaries - UK Blackbook has published carbon emission factors for the system boundary, cradle-to-gate. However, a BOQ of a project provides costs for the system boundary, cradle-to-end of construction. In order to compare carbon and cost values, both calculations need to be considered within one system boundary. Therefore, it is required to estimate both; costs and EC, within the system boundary, cradle-to-end of construction. UK Blackbook provided the EC rates considering cradle-to-gate system boundary and in order to cover the entire system boundary, it is required to estimate EC between gate-to-end of construction to enable comparison between carbon and cost values. In order to estimate EC between system boundaries, gate-to-end of construction, primary data need to be collected related to transportation and also from the site. As it is a time consuming, difficult process and as it is an area that is lacking of previous research, this study proposes a new method of estimating EC using primary data to avoid such issues identified related to the differences in system boundaries.

Different geographical locations - The geographical location considered in the carbon emission rates provided in the Blackbook, is the UK. Therefore, when calculating EC for a project in Australia, the UK carbon emission rates needed to be converted using a location factor. The accuracy of such calculations is quite questionable as procurement, technology, availability of materials, labour and plant may vary within any individual project and any individual country. Hence, in order to estimate EC for a project in a particular country, it is required to obtain data related to that particular country to avoid inaccuracies.

Lack of standardisation - During data collection, it was observed that the organisations do not estimate EC as there is no demand or necessity to carry out these EC calculations. Though the organisations are aware of the importance of reducing EC, less focus is made on it, due to the lack of standardisation in EC estimating. If more focus on estimating and reducing EC was given by these organisations, data collection would have been easier and more accurate as well. As there was lack of data, some assumptions had to be made while facing few limitations emphasising the tendency for inaccuracies in this calculation method.

Aged or lack of data on new products - UK Blackbook has been published in 2010. The project considered for calculation was in 2018. Therefore, when considering data published in 2010, to a project in the year 2018, inaccuracies tend to exist. As a result, the accuracy of estimated EC using UK Blackbook becomes questionable. On the other hand, for certain work items, the Blackbook does not have the required carbon emission rates; i.e. trench excavation for a 375mm pipe. In order to avoid this issue, a data that is closer to the work item need to be considered for calculation purposes, whereas in this scenario the data related to trench excavation for a 400mm pipe was considered and pro-rata based calculation was carried out to find the EC rate for the 375mm pipe. Aged or lack of data for certain work items is a major issue faced in carrying out the EC calculations.

Incomplete data - The UK Blackbook provides data within the system boundary, cradle-to-gate and not cradle-to-cradle or cradle-to-end of construction. Therefore, when using data from this secondary data source, it does not provide a complete estimate. Incomplete data can ultimately create inaccuracies in the EC estimates. This is a grave issue that needs to be avoided to improve accuracy in EC estimating.

Use of probabilistic data/assumptions - EC calculations carried out using secondary data sources will be based on many probabilistic data/assumptions. The calculations carried out in this study using UK Blackbook considered many assumptions. Hence, the accuracy of such calculations is quite questionable.

There is a need of identifying and establishing an accurate method of estimating EC of the work items in construction projects, which will be explained later in this paper. The next sub-section discusses how the previously identified issues could be resolved using the new methodology of estimating EC.

Possibilities of resolving the issues in estimating EC using the new methodology of estimating EC

With the existence of issues underlying in the current EC estimating databases and tools, the accuracy of EC estimates carried out using them, is quite questionable. Therefore, in this research, a new methodology of estimating EC is developed by combining the VC concept and blockchain technology to estimate EC emissions in CSCs. Therefore, it is important to identify whether the previously identified issues in the previous section, can be resolved using the proposed methodology of estimating EC and a summary of it has been illustrated in Table 4.

Table 4: Summary of issues and possibility of proposed methodology to resolve them

Issues	Reference	Can the proposed methodology resolve?	How will the issue be resolved?
Different system boundaries	De Wolf et al. (2016); Pomponi and Moncaster (2016)	Yes. Cradle-to-end of construction has been selected as the system boundary suitable for the study.	Rather than having different system boundaries, the study will consider cradle-to-end of construction as the system boundary.
Different geographical locations	Athena Sustainable Materials Institute (2018); AusLCI	Yes. Data will be collected from the contributors of EC,	Unlike the other databases, methods and tools, which were developed based on data from their respective countries,

Issues	Reference	Can the proposed methodology resolve?	How will the issue be resolved?
	(2011); Franklin and Andrews (2010);	thus, it will be based on Australian data.	the study will be using the data related to Australia.
Lack of standardisation	Gavotsis and Moncaster (2014); Innovation Growth Team (2010)	No, but the basic foundation step of developing an accurate methodology will be achieved.	The study will develop an accurate methodology for estimating EC, which can be later on standardised within the regulations and legislation.
Aged or lack of data on new products	Victoria et al. (2015)	Yes. Latest data will be obtained in this study to resolve this issue.	As the proposed methodology will collect data from the participants who contribute to EC emissions, it is possible to gather latest data and data on new products.
Incomplete data	Crawford (2008)	No, the proposed methodology will not provide 100% complete data but to a certain extent it will provide comparatively better data.	Comparatively the proposed method will be complete as data will be collected from the contributors of EC emissions, however, as the considered system boundary is cradle-to-end of construction, the entire life cycle will not be considered, making it incomplete in a certain way.
Use of probabilistic data or assumptions	Gantner et al. (2018); Yeo et al. (2016)	Yes. The proposed method would avoid usage of probabilistic data or assumptions.	As the proposed methodology will be collecting data from the contributors of EC, probabilistic data and assumptions can be avoided.
Lack of Transparency	De Wolf et al. (2016)	Yes. The new methodology provides transparency.	As data are obtained directly from contributors of EC and as blockchain provides greater transparency, this issue can be resolved.

Conceptual model on estimating EC in CSCs

The prevailing issues in the current EC estimating databases and tools as discussed in the literature review and previous section, emphasise the importance of introducing an accurate methodology of estimating EC. Therefore, this section explains the methodology in detail, which is proposed in this study to estimate EC. The current EC estimating databases and tools consist of EC data related to various types of materials, composite items, or for other similar dimensions/factors. However, the methodology proposed in this study focuses on EC emissions occurring in CSCs. EC emissions occur from cradle-to-cradle, however, as the study focuses on the system boundary, cradle-to-end of construction, EC emissions occur as illustrated in Figure 3. The three chain concepts of the study; supply chain, value chain and blockchain are clearly demonstrated through the conceptual model.

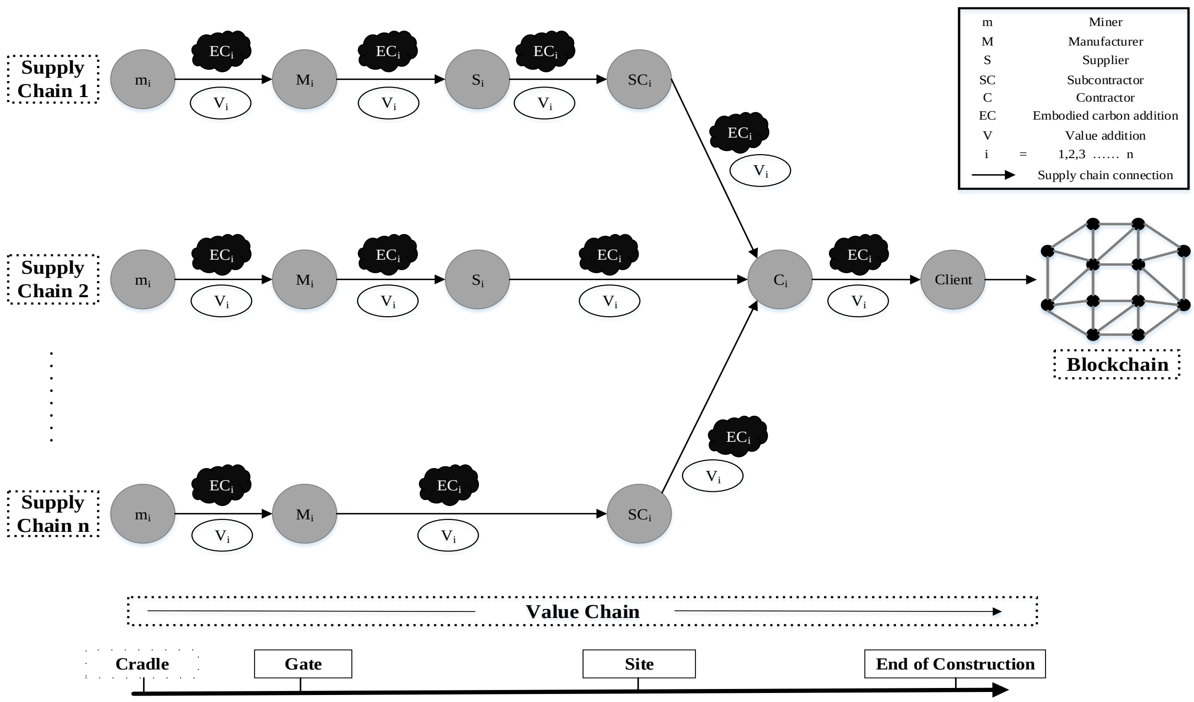


Figure 3: Conceptual model on estimating EC in CSCs

Figure 3 denotes (1) supply chain concept, where EC is emitted in CSCs; (2) value chain concept, where each member in the supply chain adds value at each supply chain node; and (3) blockchain technology, where all data related to CSCs are entered to a distributed ledger and shared through a peer-to-peer network contributing to decentralisation. Usually Summation of all values provides the total cost of the project, while summation of all EC amounts offers the total EC emissions of the project. Miners, manufacturers, suppliers, subcontractors and contractors are the key stakeholders contributing to EC emissions in a construction project. At different stages such as raw material extraction stage (cradle), manufacturing stage (gate) and construction stage (site-to-end of construction), values (V_1, $V_2 \dots V_n$) are added within the CSC by each stakeholder, whereas, similarly EC emissions (EC_1, $EC_2 \dots EC_n$) are added at the end of each stage. This philosophical understanding is used in the conceptual model to estimate EC in CSCs. All stakeholders input data into a blockchain peer-to-peer network to improve accuracy and transparency while sharing the distributed ledger. Thus, the three chains; supply chain, value chain, and blockchain, can be philosophically connected as demonstrated in the conceptual model on estimating EC in CSCs. This paper presents the findings of an ongoing research, thus, the blockchain system will be developed, tested and validated subsequently.

Conclusion

EC estimating can be carried out using various databases and tools. However, the literature review and the EC estimate prepared using the secondary source, Hutchins UK Building Blackbook revealed that there are many issues in these calculations. The issues identified through the study are due to different system boundaries, different geographical locations, lack of standardisation, aged or lack of data on new products, incomplete data, use of probabilistic data/assumptions and lack of transparency. Due to the issues existent in the databases and tools, the accuracy of EC estimates prepared using these databases and tools is questionable. Hence, the study proposed a new methodology of estimating EC in CSCs using the VC concept and blockchain technology. Further, the analysis on the proposed conceptual model revealed that the existing issues in using databases and tools for EC estimating can be eliminated through the new methodology. On the other hand, as the proposed method uses first principles to estimate EC in CSCs, an accurate estimate is ensured. As this paper is presenting the conceptual model of estimating EC in CSCs using VC and blockchain, which is only the initial part of a research project, in the near future the developed conceptual model will be tested using real data of a construction project and finally implemented on a blockchain, which is yet to be carried out.

References

Allwood, J.M., Cullen, J.M. & Milford, R.L. 2010, 'Options for Achieving a 50% Cut in Industrial Carbon Emissions by 2050', *Environmental Science and Technology*, vol. 44, no. 6.

Ashworth, A & Perera, S 2015, 'Economics of Sustainability and Carbon Estimating', in *Cost Studies of Buildings*, Routledge, New York, pp. 491-529.

Asif, M., Muneer, T. & Kelley, R. 2007, ‘Life cycle assessment: A case study of a dwelling home in Scotland’, *Building and Environment*, vol. 42, no. 3, pp. 1391-1394

Athena Sustainable Materials Institute 2018, *Athena Impact Estimator for Buildings*, Athena Sustainable Materials Institute, viewed 2 August 2018, Available from: http://www.athenasmi.org/our-software-data/impact-estimator/

AusLCI 2011, *AusLCI*, viewed 9 September 2018, Available from: http://www.auslci.com.au/index.php/Home

Baldasano, M & Reguart, M 2014, 'Calculation of Carbon Footprint in Building Project', paper presented to *World Sustainable Building Conference 2014*, Spain.

Birgisdottir, H., Moncaster, A., Wiberg, A.H., Chae, C., Yokoyama, K., Balouktsi, M., Seo, S., Oka, T., Lützkendorf, T. & Malmqvist, T. 2017, 'IEA EBC annex 57 ‘evaluation of embodied energy and CO2eq for building construction’', *Energy and Buildings*, vol. 154, pp. 72-80.

Birrell, B & Healy, E 2009, 'Population Growth and Australia's 2020 Greenhouse Gas Emission Commitments', *People and Place*, vol. 17, no. 4, pp. 18-28.

Buckley, B 2012, The 4-step plan for cutting value-chain emissions, GreenBiz, viewed 24 August 2018, Available from:https://www.greenbiz.com/blog/2012/04/05/managing-supply-chain-emissions

Crawford, RH 2008, 'Validation of a hybrid life-cycle inventory analysis method', *Journal of Environmental Management*, vol. 88, no. 3, pp. 496-506.

De Wolf, C, Yang, F, Cox, D, Charlson, A, Hattan, AS & Ochsendorf, J 2016, 'Material quantities and embodied carbon dioxide in structures', *Proceedings of the Institution of Civil Engineers: Engineering Sustainability*, vol. 169, no. 4, pp. 150-161.

Department of the Environment 2015, *Australia's emissions projections 2014-2015*, Department of the Environment, Australia.

Edwards, T, Battisti, G & Neely, A 2004, 'Value creation and the UK economy: a review of strategic options', *International Journal of Management Reviews*, vol. 5, no. 3, pp. 191-213.

Fouche, M. & Crawford, R. 2015, 'The Australian construction industry’s approach to embodied carbon assessment: a scoping study', paper presented to *49th International Conference of the Architectural Science Association: Living and Learning, Research for a Better Built Environment*, Melbourne, Australia, 2-4 December.

Franklin & Andrews 2010, *Hutchins UK Building Blackbook: The Capital Cost and Embodied CO2 Guide, Volume 2 - Major Works*, Franklin & Andrews, London.

Fu, F., Luo, H., Zhong, H. & Hill, A. 2014, 'Development of a Carbon Emission Calculations System for Optimizing Building Plan Based on the LCA Framework', *Mathematical Problems in Engineering*, vol. 2014, pp. 1-13.

Gantner, J, Fawcett, W & Ellingham, I 2018, 'Probabilistic Approaches to the Measurement of Embodied Carbon in Buildings', in *Embodied Carbon in Buildings*, pp. 23-50.

Gardezi, S.S.S., Shafiq, N., Abdullah, N.A.W., Khamidi, M.F. & Farhan, S.A. 2015, 'Minimization of Embodied Carbon Footprint from Housing Sector of Malaysia', *Chemical Engineering Transactions*, vol. 45, pp. 1927-1932.

Garnaut, R 2008, ‘Australia's Emissions in a Global Context’, in *The Garnaut Climate Change Review*, Cambridge University Press, Australia.

Gavotsis, E & Moncaster, A 2014, 'Practical limitations in Embodied Energy and Carbon measurement, and how to address them: a UK case study', in *Proceedings of World Sustainable Building Conference 2014*, Spain.

Hammond, GP & Jones, CI 2008, 'Embodied energy and carbon in construction materials', *Proceedings of the Institution of Civil Engineers - Energy*, vol. 161, no. 2, pp. 87-98.

Haynes, R 2010, *Embodied energy calculations within life cycle analysis of residential buildings*.
Huang, B., Xing, K. & Pullen, S. 2017, ‘Carbon assessment for urban precincts: Integrated model and case studies’, *Energy and Buildings*, vol. 153, pp. 111-125.
Huang, W., Huang, Y., Lin, S., Chen, Z., Gao, B. & Cui, S. 2018, ‘Changing urban cement metabolism under rapid urbanization - A flow and stock perspective’, *Journal of Cleaner Production*, vol. 173, pp. 197-206.
Innovation Growth Team 2010, *Low Carbon Construction Final Report*, UK.
IPCC 2007, *Climate Change 2007 - Mitigation of Climate Change*, Cambridge University Press, United Kingdom.
Jiao, Y., Lloyd, C. & Wakes, S. 2012, ‘The relationship between total embodied energy and cost of commercial buildings’, *Energy and Buildings*, vol. 52, pp. 20-7.
Kember, O., Jackson, E. & Chandra, M. 2013, *GHG mitigation in Australia: An oversview of the current policy landscape*, World Resources Institute.
Lewis, A & Larson, M 2016, *Understanding Blockchain Technology And What It Means for Your Business*, DBS
Machacek, E, Richter, JL & Lane, R 2017, 'Governance and Risk-Value Constructions in Closing Loops of Rare Earth Elements in Global Value Chains', *Resources*, vol. 6, no. 4.
Martek, I & Chen, C 2016, 'Value chain supply procurement strategies in international construction', *Management Decision*, vol. 54, no. 2, pp. 501-521.
Mentzer, JT, DeWitt, W, Keebler, JS, Min, S, Nix, NW, Smith, CD & Zacharia, ZG 2001, 'Defining Supply Chain Management', *Journal of Business Logistics*, vol. 22, no. 2, pp. 1-25.
Monahan, J. & Powell, J.C. 2011, 'An embodied carbon and energy analysis of modern methods of construction in housing: A case study using a lifecycle assessment framework', *Energy and Buildings*, vol. 43, no. 1, pp. 179-188.
Moncaster, A.M. & Symons, K.E. 2013, 'A method and tool for ‘cradle to grave’ embodied carbon and energy impacts of UK buildings in compliance with the new TC350 standards', *Energy and Buildings*, vol. 66, pp. 514-523.
Nadoushani, Z.S.M. & Akbarnezhad, A. 2014, 'A Computational Framework for Estimating the Carbon Footprint of Construction', paper presented to *31st International Symposium on Automation and Robotics in Construction and Mining (ISARC 2014)*, Sydney, Australia, 9-11 July 2014.
Noke, H. & Hughes, M. 2009, 'Climbing the value chain - Strategies to create a new product development capability in mature SMEs', *International Journal of Operations and Production Management*, vol. 30, no. 2, pp. 132-154.
Philp, M. & Taylor, M.A.P. 2015, 'Research agenda for low-carbon mobility: Issues for New World cities', *International Journal of Sustainable Transportation*, vol. 11, no. 1, pp. 49-58.
Pomponi, F & Moncaster, A 2016, 'Embodied carbon mitigation and reduction in the built environment - What does the evidence say?', *Journal of Environmental Management*, vol. 181, pp. 687-700.
Rashid, A.F.A. & Yusoff, S. 2015, 'A review of life cycle assessment method for building industry', *Renewable and Sustainable Energy Reviews*, vol. 45, pp. 244-248.
RICS 2012, *Methodology to calculate embodied carbon of materials*, RICS, UK.
Rodrigo M.N.N., Perera, S., Senaratne, S., & Jin, X. (2018). Blockchain for Construction Supply Chains: A Literature Synthesis. In *Proceedings of ICEC-PAQS Conference 2018*. Sydney, Australia: ICEC and PAQS
Rodrigo M.N.N., Perera, S., Senaratne, S., & Jin, X. (2019). Embodied Carbon Mitigation Strategies in Construction Industry. In *CIB World Building Congress 2019*. Hong Kong SAR, China: CIB.
Santori, MA, DeRidder, CA & Grosser, JM 2016, 'Blockchain Basics: A Primer', *Advisory*, 2 May 2016.
Skaar, C., Labonnote, N. & Gradeci, K. 2018, 'From Zero Emission Buildings to Zero Emission Neighbourhoods : A Mapping Review of Algorithm-Based LCA', *Sustainability*, vol. 10, no. 7.
Teng, Y., Li, K., Pan, W. & Ng, T. 2018, 'Reducing building life cycle carbon emissions through prefabrication: Evidence from and gaps in empirical studies', *Building and Environment*, vol. 132, pp. 125-136.
Victoria, M.F. & Perera, S. 2018, 'Parametric embodied carbon prediction model for early stage estimating', *Energy and Buildings*, vol. 168, pp. 106-119.

Victoria, M.F., Perera, S., Davies, A. & Fernando, N. 2017, 'Carbon and cost critical elements: a comparative analysis of two office buildings', *Built Environment Project and Asset Management*, vol. 7, no. 5, pp. 460-470.
Victoria, M.F., Perera, S., Zhou, L. & Davies, A. 2015, 'Estimating embodied carbon: a dual currency approach', *Proceedings of the 1st International Conference on Sustainable Buildings and Structures*, China, 29 October - 12 November 2015.
Wang, Y 2007, *'Using Information and Communication Technology to Facilitate Supply Chain Management in the New Zealand Construction Industry'*, Master of Business thesis, Auckland University of Technology.
WU Global Tax Policy Center 2017, Blockchain 101 for Governments WU Global Tax Policy Center, Geneva
Yeo, Z., Ng, R. & Song, B. 2016, 'Technique for quantification of embodied carbon footprint of construction projects using probabilistic emission factor estimators', *Journal of Cleaner Production*, vol. 119, pp. 135-151.

URBAN TRANSFORMATION TRAJECTORIES OF NEW ZEALAND'S EARLIEST CITIES UNDERGOING DECLINE: IDENTIFYING LINKS TO THE NEWLY ENFORCED BUILDING (EARTHQUAKE-PRONE BUILDINGS) AMENDMENT ACT 2016

Itohan Esther Aigwi[1], Robyn Phipps[2], Jason Ingham[3], Olga Filippova[4]

[1]School of Built Environment, Massey University, Auckland, New Zealand

[2]School of Built Environment, Massey University, Auckland, New Zealand

[3]Department of Civil and Environmental Engineering, The University of Auckland, Auckland, New Zealand

[4]Departmentof Property, The University of Auckland, Auckland, New Zealand

Abstract

Some of New Zealand's earliest cities not currently experiencing the much growth they had anticipated for due to insufficient population to adequately utilise their older building stock, are now featured with a significant proportion of derelict and underutilised historical buildings in their city centres which may be from the impacts of the newly enforced Building (Earthquake-prone Buildings) Amendment Act 2016 (BEPBAA) and other factors. The presence of so many abandoned historical buildings in these areas usually creates a difficult situation for their local authorities to manage immediately, hence leading to a condition of gradual decline or stagnation in population and economic growth bases. This paper sought to identify New Zealand's earliest cities currently experiencing inner-city shrinkage and examine the links, if any, between the identified shrinking cities and the impacts of the BEPBAA.

The findings from the document analysis revealed Whanganui and Invercargill as two typical provincial urban areas which though were among New Zealand's earliest cities, are currently experiencing a socio-economic decline. Also, findings from the key informant interviews revealed the following factors as impacts of the BEPBAA that may have promoted the decline of typical provincial areas in New Zealand: (i) pressure on building owners from BEPBAA compliance deadlines; (ii) attitudes of councils in different seismic hazard areas; (iii) risk of future amendment of the BEPBAA; (iv) safety concerns and high seismic retrofit costs; (v) unsophisticated investors in provincial areas; and (vi) lack of actual seismic retrofit cost data sharing. These findings reflect secure connections between socio-economic and policy-related influences and the population growth trends in New Zealand's areas. The implication of these findings could be useful for researchers and policy regulators to have a better understanding of the unintended, intended, and future consequences of how the BEPBAA may have promoted the prevalence of derelict and underutilised historical buildings in the inner cores of typical provincial areas in New Zealand.

Keywords

Earthquake-prone, Historical buildings, Provincial areas, Decline, BEPBAA, Urban regeneration

Introduction

Over the last few decades, many cities in developed countries have experienced diverse economic and demographic trajectories, with the global urban growth phenomenon being characterised by a sharp contradiction, portraying urban growth as uneven in many circumstances. With a growth rate of about 1.13 per cent per year, the world population of approximately 7.7 billion people have been estimated to reach 9.7 billion people by 2050 (UN-DESA, 2015; Wilkinson & Osmond, 2018). While the proportion of the urban population is currently estimated at 53.3 per cent, it is expected to progress at a faster pace to up to 70 per cent in the next few decades (United Nations-Habitat, 2013; Tripathi *et al.*, 2019).

Many cities in developed countries have experienced diverse economic and demographic trajectories over the past few decades, with the global urban growth phenomenon being characterised by a sharp contradiction, portraying urban growth as uneven in many circumstances (Adhya, 2017). While bigger cities may have been experiencing substantial economic and population growth, there is usually simultaneous decline, displacement, and devaluation of smaller cities in the same country (Friedrichs, 1993; Wiechmann & Bontje, 2015). Such situations often result in the emergence of shrinking cities with specific challenges and prospects (Adhya, 2017). Some socio-economic factors such as loss of employment prospects, reduced property value, decreasing tax base, and deterioration of infrastructure are closely connected in a downward spiral towards the outmigration of the population of shrinking cities (Adhya, 2017).

"Shrinking cities" could be referred to as urban areas or regions with a population of at least 10,000 people, and have experienced a continuous decline or stagnation in their population, economic and employment trajectories for over two years (Wiechmann & Pallagst, 2012) to 50 years (Reckien & Martinez-Fernandez, 2011). Whereas the focus of urban researchers, policymakers and the media were on inquiries regarding cycles of urban dynamics such as urbanisation, suburbanisation and re-urbanisation several decades ago (Haase *et al.*, 2014), it is only recently that inner-city decline and regeneration began to receive most attention (Reckien & Martinez-Fernandez, 2011; Yakubu *et al.*, 2017; Martinez-Fernandez *et al.*, 2016). Nevertheless, like most planning paradigms centre around urban growth, the primary concerns of government authorities are usually focused on buttressing the image of cities as "growth machines" (Logan & Molotch, 2007). As a result, cities that are experiencing rapid growth are often perceived as admired, desirable and successful, while a kind of stigma that identifies residents as those living in an area with a reduced sense of pride, is placed on shrinking cities (Leo & Anderson, 2006). Hence, shrinking cities in New Zealand have been disparagingly referred to as "zombie cities" by famous economist and media commentator, Shamubeel Eaqub (National Business Review, 2014; Aigwi *et al.*, 2019).

In New Zealand, a majority of the population have been living in towns and cities since the early 19th century, and as at 2014, 86 per cent of New Zealanders were living in urban areas (Schrader, 2016). The growing city life across New Zealand's earliest urban areas stimulated commercial interactions and formation of purposeful socio-cultural clusters for people of like minds in city centres, hence, city centres became the highpoint of Western civilisation (Thorns & Schrader, 2010). Most of New Zealand's earliest cities prospered at some point over the years, and their anticipation for future growth led to a massive investment in the built environment during their early existence. Besides, the inner cores of these ancient cities were characterised with buildings of different architectural styles that reflected socio-cultural inclination for distinctiveness at that time (Schrader, 2016). As a result, these buildings are now categorised as historical buildings, of which some of them have significant heritage values. These heritage values include the conservation of the history and narration of a city's existence, sustenance of the architectural history, collective cultural identity and significance of a place, and increased sense of belonging and attachment to a place (Aigwi *et al.*, 2018).

For some of New Zealand's earliest cities, the growth that they had anticipated for occurred, while for others, that expected growth did not happen. Accordingly, some of these earliest cities not currently experiencing the much growth they had anticipated for due to insufficient population to adequately utilise their building stock, are now featured with a significant proportion of derelict and underutilised historical buildings in their city centres (Yakubu et al., 2017). Most of these historical buildings are being threatened by obsolescence factors (Langston, 2011), building regulations, poor building conditions, and socio-economic factors. Hence, these factors have been found to influence the high presence of underutilised historical buildings in the inner-cities of New Zealand's provincial areas (Yakubu et al., 2017). As a consequence, these cities begin to experience shrinkage (Martinez-Fernandez *et al.*, 2012; Pallagst, 2008). The characteristics of cities experiencing shrinkage could, therefore, be viewed as a significant global politico-economic and planning problem.

Besides, lessons from the 2010/2011 Canterbury seismic events and the risk of further earthquake occurrences in New Zealand highlighted the vulnerability of historical buildings and the significance of their resilience to earthquakes (Russell & Ingham, 2010). Consequently, historical buildings are classified as potentially earthquake-prone buildings (EPBs) because they are mostly unreinforced masonry buildings (URM) which typically have a low resistance to the impacts of earthquakes (Ingham & Griffith, 2010). Local authorities in New Zealand have been mandated to adopt legislative approaches for the identification and assessment of earthquake-prone buildings within specified timeframes (MBIE, 2016a). Hence, the local authorities are mandated to use the BEPBAA to compel building owners into seismically upgrading their historical buildings to promote safety for users. Otherwise, the building owners will lose their buildings to demolition when the given timeframes specific to their seismic hazard area elapses.

While most owners of potentially earthquake-prone historical buildings may be uncertain about the cost-benefit implications of investing in the seismic upgrade of their building, they may tend to wait for the specified legislative timeframes to elapse, and in worst cases may eventually abandon their buildings (Beauregard, 2013). The presence of so many abandoned historical buildings in the inner cities of New Zealand's provincial areas then creates a difficult situation for their local authorities to manage immediately, hence leading to a situation of gradual decline or stagnation in population and economic growth bases. Some of these affected provincial areas are among New Zealand's earliest cities which are now characterised with significant collections of underutilised historical buildings.

It is within these above circumstances that this paper addresses the objectives of (i) identifying provincial cities among New Zealand's earliest cities currently experiencing inner-city shrinkage; and (ii) examining if there are links between the identified shrinking cities and impacts of the newly enforced Building (Earthquake-prone Buildings) Amendment Act 2016. The research design involves the primary citations of the research background, review of extant literature to justify the underlying research problems, materials and data collection method, results and analysis of findings, discussion and implication of findings, and conclusion.

Defining urban areas in the New Zealand context

From the perspective of urban morphology, urban areas emerge from the urbanisation of a place and are generally categorised into suburbs, towns, cities or metropolis (McGranahan & Satterthwaite, 2014). A metropolis is a region that consists of a densely populated urban core consisting of housing, infrastructure and industry, that is shared with other satellite territories with a lesser population (Squires, 2002). The urban cores of metropolitan areas are typically connected to these satellite territories through socio-economic ties such as employment, edification, and entertainment, measured through indicators such as commuting patterns.

Although the term 'urban area' could be used as a substitute name for 'town' or 'city' in some instances, it could also be distinguished from a town or city based on either population size or economic character. New Zealand's urban areas are defined without the basis of administrative subdivisions or legal existence. According to the SSGA18 (New Zealand's official statistical standard for geographic areas 2018), which replaced the existing NZSAC92 (New Zealand's standard areas classification 1992), New Zealand's urban areas are ranked into four categories (i.e., 7 major, 13 large, 22 medium and 91 small urban areas) by population size (Statistics New Zealand, 2018b).

Additionally, Statistics New Zealand defines a town as an area with a population ranging between 1,000 – 20,000 people, administered as built-up areas of districts (Statistics New Zealand, 2018b). New Zealand towns differ significantly in size and significance. There are five types of towns in New Zealand, which are categorised based on the kind of industry predominant to an area (Thorns & Schrader, 2010):

1. Market towns – were laid out to service their farming hinterlands (e.g., Timaru, Masterton, Oamaru, etc.);

2. Milling and mining towns - emerged due to their proximity to natural resources such as timber and gum (e.g., Dargaville), coal (e.g., Brunner), and gold (e.g., Dunedin);
3. Port towns – were developed as shipping and fishing centres (e.g., Whanganui, Oamaru and Riverton);
4. Military towns – were created as military bases for soldiers during the New Zealand Wars (e.g., Pātea, Hamilton, etc.); and
5. Construction towns – were developed as construction bases for significant infrastructure projects going on in New Zealand during the early 19th century (e.g., Ōhakune, Mangakino, Twizel, etc.).

Setting the scene: historical background of New Zealand's earliest cities

The prominent factors that influenced the advancement of New Zealand's towns into the earliest cities encompass their aptitude to attract industry, commerce, and government, by building strong transportation links and dominating their hinterlands (Thorns & Schrader, 2010). Towns that effectively applied these highlighted factors to their benefit developed to become cities. In the early 1870s, the first five cities to emerge in New Zealand were Christchurch, Nelson, Auckland, Wellington and Dunedin. Whereas Christchurch and Nelson were formed by patent letters (i.e., a practice under the British law where towns could be designated as cities if they became the seat of a bishop), Auckland, Wellington and Dunedin were conferred as cities by their provincial authorities (Thorns & Schrader, 2010). By 1886, the Municipal Corporations Act introduced a population threshold of 20,000 people for towns to become cities in New Zealand (Statistics New Zealand, 2018b). Moreover, while these ancient cities (except Nelson) had enough development influence to dominate their immediate hinterlands (e.g., Christchurch over Timaru; Auckland over Hamilton), none of them had sufficient power to dominate each other (Thorns & Schrader, 2010).

About 50 years after the proclamation of the first five New Zealand cities, Whanganui, Hamilton and Invercargill became the next early cities after passing the 20,000-population threshold from the 1926 census data as shown in Table 2 (Grimes & Tarrant, 2013). By the 1956 census, other early towns such as Palmerston North, Hastings, New Plymouth, Napier, Timaru, Gisborne and Nelson also became cities following the 20,000-population benchmark (Grimes & Tarrant, 2013). As the population threshold for city status was increased to 50,000 in 1989, some places such as Whanganui and Gisborne that had populations greater than 30,000 people were left as 'large urban centres' just for official purposes (Thorns & Schrader, 2010). These newer designated cities were called regional (or provincial) cities and their growth portrayed a typical urbanised society and rising preference for city life in New Zealand.

The key factors that facilitated the growth of New Zealanders living in cities in some areas include (Thorns & Schrader, 2010): (i) the rapid growth of dairy and sheep farming in New Zealand's South Island developed Invercargill from a market town into a city; (ii) the growth of Wattie's canning operations and two other freezing operations significantly developed the commerce and industry sector of Hastings; and (iii) the strong national and regional transportation links of Palmerston North made new industries to be attracted to the place.

Signposting significant historical events faced by New Zealand's earliest cities

New Zealand was discovered by Māori ancestors from East Polynesia in the late 13th century as the world's last habitable landmass (Wilson, 2005). Although the Europeans originally became aware of the existence of New Zealand in 1642, the initial European settlers began to arrive from Sydney in large-scale sometime around the 1840s (Wilson, 2005). The whalers and sealers started visiting during the late 19th century, of which some decided to settle for cultivation in the early 20th century (Wilson, 2005). New Zealand became part of the greater Pacific trade system during these periods, with goods sold to other nations like China.

At Waitangi on February 6th 1840, New Zealand's first governor, William Hobson, invited over 500 Māori chiefs around the country to sign a treaty with the British Crown (Wilson, 2005). The treaty ceded the sovereignty and rights of the Māori people to the British Crown in exchange for a guaranteed control over the rights, lands and treasures of British subjects. Besides, before the signing of the treaty, Edward Wakefield, who was a colonial promoter of the New Zealand Company, had already started dispatching British settlers to Wellington (Wilson, 2005).

The gold rush in New Zealand was triggered by the discovery of gold in Otago and the West Coast in the early1860's, which led to the vast influx of gold miners to those areas. Gold was then discovered six years later at the Thames, and this discovery boosted the growth of Auckland (Wilson, 2005). Also, sheep farming in the grasslands of South Island around 1861 led to a substantial investment in wool by European settlers, which made Canterbury become the wealthiest New Zealand province at that time (Wilson, 2005).

When wool prices and the production of gold fell, a new twist to the growth of New Zealand's urban areas was introduced by Julius Vogel, the colonial treasurer, in 1870, by proposing a public works loans-funded initiative (Wilson, 2005). Vogel's initiative also included assisted immigration programmes and the construction of railways. Evidence from the 1871 non-Māori census data showed a dramatic increase in the growth of New Zealand's major urban areas following investment in Vogel's initiatives (Statistics New Zealand, 2018b).

Furthermore, a prolonged economic depression which lasted till the late 1880s hit major New Zealand's urban areas following Vogel's loans-funded initiative, causing prices of farm products to slump, despite a brief boom in wheat farming (Wilson, 2005). Accordingly, the demand for land also dropped and difficult times contributed to reduced industrial labour and massive urban unemployment, causing a mass emigration of people from New Zealand's major urban areas, majorly to Australia.

However, New Zealand's frozen-meat industry anticipated future economic prosperity for some of its urban areas such as Hastings and Pātea in the heat of the economic depression, when frozen meat was successfully shipped to England in 1882 for the first time (Wilson, 2005). It also became possible to export chilled cheese and butter after addressing initial hindrances in refrigerated shipping, making the economy of New Zealand's urban areas to flourish again till the late 1920s. Following some prosperous years from the frozen meat shipping boom, a global 'Great Depression' struck New Zealand so hard that export prices fell drastically (Wilson, 2005). As farmers began to face difficulties in paying for their mortgages, urban unemployment began to soar.

The M7.8 Hawkes Bay earthquake hit the main urban area of Napier, New Zealand in 1931, killing 256 people and causing a widespread of devastation to Napier's built environment (Ingham & Griffith, 2010). The 1931 Hawke's Bay seismic event was considered New Zealand's worst natural disaster, and this prompted an in-depth review of New Zealand's building codes which were assessed as entirely inadequate at that time (Dowrick, 1998). Between the 1930s to 1940s, the rebuilding of the Hawke's Bay region with the first revised building codes contributed to the construction of Spanish Mission and Art Deco style buildings which were perceived as cheap, safe and fashionable (Willson & McIntosh, 2007). In 1936, the Reserve Bank sponsored significant public works, including state housing initiatives, leading to investment in the built environment of New Zealand's major and large urban areas.

Post-World War II, majority of New Zealand's main urban areas [i.e., major and large urban areas (Statistics New Zealand, 2018b)], started experiencing a large influx of people from neighbouring hinterlands to main urban areas. This vast migration became fortified by innovations in the transportation sector during the mid-20th century (Pool, 2013). Also, there was significant growth in the population of main urban areas in all directions following the construction of the motorway system and the corresponding reduced cost of intra-urban transportation (Gunder, 2002). Private cars also became popular during the mid-20th century and were utilised by the hinterland population to commute to main urban areas (Burayidi, 2013).

The first and second oil crises hit New Zealand in 1975 and 1978 respectively and increased the rates of unemployment and inflation in the economy of urban areas across the country leading to the floating of the New Zealand Dollar (Decker & McCracken, 2018). Accordingly, most export-led industries (i.e., whether fishing, farming, or forestry) that enabled economic growth and job opportunities in New Zealand's main urban areas suffered significant losses. Nevertheless, by the early 1980s, New Zealand diversified its export trade and other investment reforms in the educational sector, and new sets of migrants were attracted into the country mainly from Britain and China (Openshaw *et al.*, 1993).

In 2008, New Zealand was one of many other countries that were affected by the global economic recession, during which domestic spending in most urban areas was dented by high costs of living and stricter credit conditions (Ball, 2014). As New Zealand's Gross Domestic Product (GDP) shrank by 0.2 per cent, housing statistics fell by 20 per cent, which suggests a decline in economic growth and construction activities in most urban areas during the recession period (Hall & McDermott, 2016). New Zealand's economy recovered from the recession with a GDP report showing growth by 0.1 per cent during the first quarter of 2009, and 4.4 per cent during the second quarter (Wall Street Journal, 2009). However, this nascent recovery lost some momentum and was set back by disruptions and damages from the 2010/2011 Canterbury earthquake events. There was a recorded negative average growth rate of 1.4 per cent in most urban areas for the first six months following the earthquakes, which was then regained in the third year of recovery by 2.5 per cent (Hall & McDermott, 2016).

As a pragmatic regulatory mechanism put in place by the New Zealand Government to promote seismic resilience during earthquakes, owners of earthquake-prone building (EPB) are mandated through the BEPBAA to strengthen their buildings to a minimum requirement of 34 per cent NBS rating within a specified timeframe, otherwise the buildings will be demolished (MBIE, 2016a). With the inclusion of all pre-1976 buildings, other buildings are also assessed as potentially earthquake-prone in New Zealand when they score less than one-third of the New Building Standard (NBS) rating after a detailed seismic assessment has been conducted on it by certified structural engineers (NZSEE, 2017).

Impacts of the legislation on the retention of historical buildings and declining urban areas in New Zealand

A combination of building regulatory and legislative frameworks form an effective performance system for the regulation of building performance in New Zealand. Whereas the building act 2004 (MBIE, 2004) specifies a legislative framework which governs the overall building works in New Zealand, the building code specifies the minimum performance requirements that all building works must satisfy (e.g., requirements for fire safety, stability, user safety, energy efficiency, services and facilities, and access) (MBIE, 2016b). Accordingly, building regulations provide details for specific building controls such as prescribed forms, fees and infringement levies, definitions of 'moderate earthquake' and 'change of use' (MBIE, 2016b).

With a focus on the Building (Earthquake-prone Buildings) Amendment Act, it provides a legislative framework that governs the seismic retrofit works for new buildings, and the identification and strengthening of existing earthquake-prone buildings (MBIE, 2016a). Since the first-ever building seismic code introduced in 1933 after the 1931 Hawke's Bay earthquake in Napier, it has been improved over the years with lessons from building performance-based experiences gained from past earthquake disasters (MBIE, 2016a). However, a majority of historical buildings in the cores of most New Zealand main urban areas have been assessed as earthquake-prone (Cattanach *et al.*, 2008).

The Building (Earthquake-prone Buildings) Amendment Act defines an earthquake-prone building (EPB) as: a building or part that has the potential to collapse when its ultimate capacity is surpassed in the event of a moderate earthquake, and would probably injure or kill people in or near the building, or destroy other nearby properties (MBIE, 2016a). Besides, pre-1976 buildings are classified as potentially EPBs because they are mostly unreinforced masonry buildings (URM) (Russell & Ingham, 2010). A seismic vulnerability study revealed that 35 per cent of New Zealand's URM building stock is potentially EPBs due to their underperformance during earthquakes from the inadequate seismic strength of their construction materials (Ingham & Griffith, 2010). Another seismic vulnerability study with focus on Wellington which is a major urban area in New Zealand at the forefront of seismic hazard mitigation, found that 52 per cent of Wellington's overall building stock was assessed as potentially earthquake-prone (Stevens & Wheeler, 2008), with 92 per cent of the EPBs being URMs (Bothara *et al.*, 2008).

Although earthquake risks of historical buildings could be mitigated through compliance to seismic regulatory specifications, the seismic retrofit cost and other redevelopment costs to satisfy other building code requirements such as fire safety, disability access, indoor air quality, etc., are borne by building owners/investors (Aigwi et al., 2019). As most owners of inner-city historical EPBs may be unsure of the returns on investment in the strengthening and redevelopment process, they tend to abandon these buildings for demolition and relocate to suburban areas (Yakubu et al., 2017). The potential choice of historical building owners abandoning their EPBs for demolition could eventually result in changing previously vibrant urban city centres into unattractive places (Martinez-Fernandez et al., 2012). Consequently, demolition could negatively influence the economic and social vibrancy of an immediate locality, thereby causing city centre shrinkage (Wiechmann & Pallagst, 2012; Yakubu et al., 2017). Some detrimental impacts of city centre shrinkage include; loss of income from tourism; reduced tenancy; demolition of a significant proportion of the inner-city building stock; economic and population decline; reduced rateable income, and; loss of amenity and employment opportunities (Schilling & Friedman, 2002; Colvin *et al.*, 2000). With the existence of these negative impacts, a vicious loop that raises the chances of residents relocating out of a declining urban area is created (Friedrichs, 1993; Lang, 2000).

The transformation trajectories of shrinking cities

The transformation trajectories of shrinking cities are observed from past studies. Hoyt (1939) examined the continuous socio-economic decline in the growth of some American urban areas using the urban transformation life-cycle approach. The findings from the study justified the evolution of the investigated urban areas towards decline, as a direct link to the devaluation of existing derelict buildings in the inner-cities (Lang, 2000; Adams, 2005). Another study found that the growth and decline of European urban centres usually followed a regular order of development stages (Hall & Hay, 1980).

Based on the finding from Hall & Hay (1980), Van den Berg *et al.* (1982) developed an urban evolution theory which categorised the development of urban areas into four sequential stages (i.e., urbanisation, sub-urbanisation, de-urbanisation, and re-urbanisation). The urban evolution theory is linked to neoclassical economics, which reflects decline as an inevitable phenomenon caused by a sequence of economic triggers (Sassen, 2018). Nonetheless, other studies have argued that transformation trajectories cannot be restricted to a single urban evolution model because of the diverse and complex nature of urban areas (Cheshire & Hay, 1989; Buzar *et al.*, 2007).

Material and methods

This paper focuses on identifying provincial cities among New Zealand's earliest cities currently experiencing inner-city shrinkage and examining if there are links between the identified shrinking cities and impacts of the newly enforced Building (Earthquake-prone Buildings) Amendment Act 2016.

Data collection

The qualitative research method comprising of two stages: (i) document analysis; and (ii) key informant interviews; is adopted for this study to establish a pragmatic consensus between the focus of this study and reviewed literature. Application of these data collection tactics permits a comprehensive investigation into the current urban socio-economic growth trends in New Zealand's provincial cities.

(i) Document analysis

An analysis of relevant existing document was done to examine the stated research objectives. Document analysis is a systematic form of qualitative investigation that involves the discovery, appraisal and interpretation of facts or trends in existing documents (i.e., paper-based, computer-based or internet-based) by researchers (Witkin & Altschuld, 1995; Bowen, 2009), in order to develop pragmatic knowledge by eliciting meaning for a deeper understanding of an underlying research problem (Strauss & Corbin, 2008; Rapley, 2008). Accordingly, documents are capable of providing (Connell *et al.*, 2001; Bowen, 2009; Goldstein & Reiboldt, 2004): (i) background information; (ii) additional questions to be examined (i.e., during interviews as part of the enquiry); (iii) extra data from supplementary sources; (iv) an avenue for tracking deviations and growth; and (v) confirmation of discoveries from other information sources.

Notably, the document analysis approach has been chosen as one of the enquiry modes for this study because it is a cost-effective and time-efficient method of data collection from readily available sources, usually unaffected by the research procedure (Bowen, 2009). Nevertheless, some significant drawbacks in using this approach have been identified to include (Bowen, 2009): (i) insufficient details to address the entire research problem; (ii) difficulty in retrieving the documents; and (iii) possibility of biased selectivity of document sources.

In the course of this study, the document analysis procedure was achieved through the gathering of historical census data benchmarked with statistics on socio-economic and demographic indicators such as population growth, income status, employee counts from Statistics New Zealand (2018b), and Motu - a New Zealand urban population database (Grimes & Tarrant, 2013). Property prices were extracted from two of New Zealand's popular real estate websites, realestate.co.nz and qv.co.nz websites. The collected data were carefully examined to construct interpretative information based on the characteristics of the collected data. Consequently, substantial themes pertinent to this research's focus were uncovered from the analysis of the highlighted documents.

(ii) Key informant interviews

Following the process of document analysis, key informant interviews were conducted as a follow-up enquiry to examine if there are links between the identified shrinking cities and impacts of the newly enforced Building (Earthquake-prone Buildings) Amendment Act 2016. The key informant interview technique allows experts (or key informants) well known for their skills and position within an organisation or society, to provide more profound knowledge and insights into what is happening around them, and make relevant inferences about their observations (Marshall, 1996). Accordingly, this technique has been successfully and extensively used in several branches of cultural anthropology, social science, and medical research. The key informant interview technique was used in this research mainly because it is an affordable means of gathering quality data from experts within a short timeframe (Marshall, 1996). Another advantage of using this interview technique is that unanticipated new ideas are likely to emerge. However, the potential shortcomings of using this technique may include; bias if the key informants have been wrongly identified and selected, interviewers unintentionally influencing the responses of the informants, and informants divulging only politically accepted information (Marshall, 1996).

The purposeful sampling approach was used to select and screen the key informants (n=9) from different professional contexts at the local, regional and national levels, to purposefully inform an insight into the research phenomenon (Chambliss & Schutt, 2018; Yin, 2017; Creswell & Poth, 2018). The selection was made based on their expert knowledge about the research problem, willingness and level of confidence in responding to the interview questions, and official roles in their different organisations (Marshall, 1996). Also, their professional specialities and work backgrounds were specified based on their essential duties, appointment, and primary place of service regarding heritage preservation and urban regeneration in New Zealand at the time of the interview. All the key informants serve in senior roles in their organisations, such as managers, directors, principal advisers, legal advisers, chief planners, or senior administrators.

The key informants were invited by emails, followed by telephone calls, to arrange a convenient meeting place and time. Those who responded preferred to use the e-interview method in order to eliminate the need to travel, hence, saving time and money (Bampton & Cowton, 2002). However, the weakness of the e-interview approach is that it depends on the reliability of the technological device and internet connection used by both interviewers and interviewees (Deakin & Wakefield, 2014). Accordingly, whereas five of the participants preferred to use electronic mediums such as skype and zoom calls, four of them decided to use telephone interviews due to practical reasons. The length of the interviews varied between 45 to 80 minutes.

Furthermore, an interview schedule containing a defined script and outline of open-ended questions relevant to the research focus was developed to moderate the discussion processes by ensuring that all questions were answered. The richness of information and quality of ideas varied between the key informants due to their different professional backgrounds. Their emphasis varied from heritage to political, managerial, and financial perspectives regarding historical building preservation and urban regeneration. In order to maintain the consistency, quality, and efficiency of data collected across all interviews, information was compiled through note-taking and audio recording. The thematic analysis was used to develop themes from the notes and transcribed audio recordings (Braun *et al.*, 2019). After the seventh interview, thematic saturation was observed as new themes stopped to emerge. However, acceptable interpretative findings were constructed after the ninth interview (Braun et al., 2019).

Results and analysis of findings

An overview of the data gathered from the analysis of relevant existing documents and key informant interviews is provided to demonstrate the depth and breadth of useful information obtained.

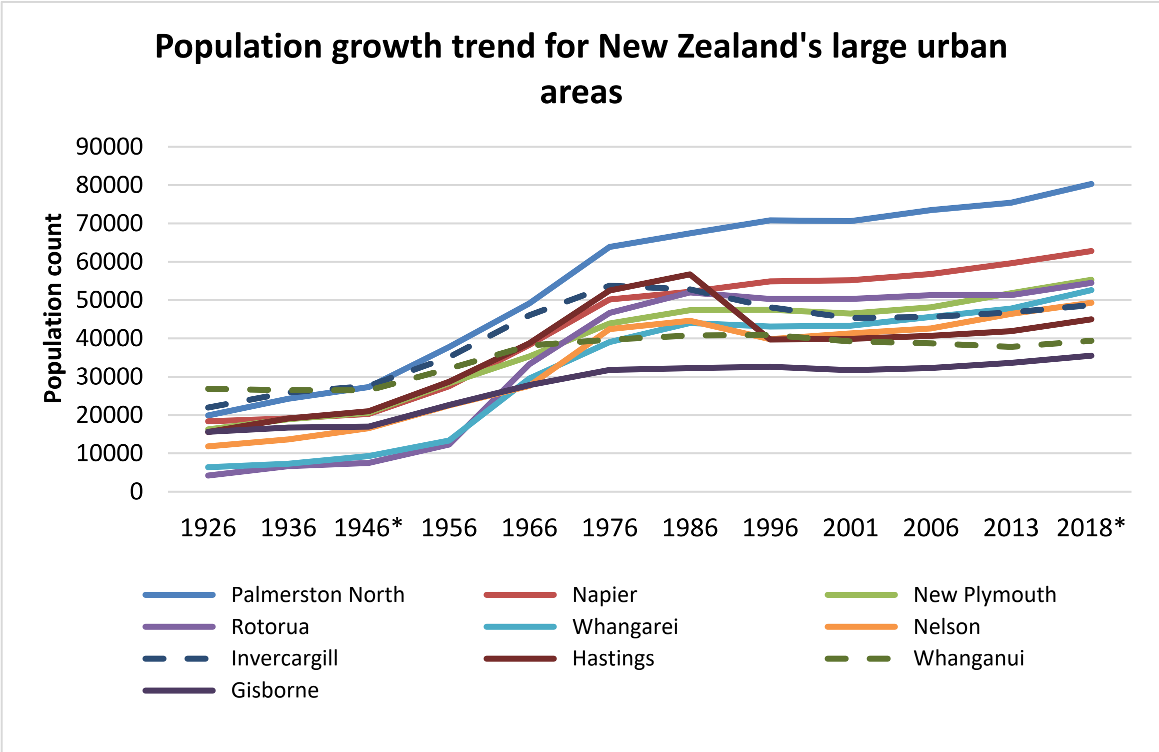
Identification of provincial cities among New Zealand's earliest cities currently undergoing decline

To identify provincial cities among New Zealand's earliest cities currently experiencing shrinkage, the following socio-economic and demographic statistics have been extracted from document analysis benchmarked with statistics on socio-economic and demographic indicators such as population growth, income status, employee counts.

(i) The population growth trend for New Zealand's large urban areas

The population data were extracted from relevant existing documents to monitor the population growth trend for New Zealand's large urban areas. The historical population data for 1926, 1936, 1946, 1956, 1966, 1976, and 1986 are extracted from Motu (Grimes & Tarrant, 2013), while that for 1996, 2001, 2006, 2013, and 2018 is gotten from Statistics New Zealand website (Statistics New Zealand, 2018b). From the total 13 large urban areas, three have been excluded due to their split from major urban areas. These excluded areas are Hibiscus Coast (split from Auckland), Upper Hutt and Porirua (split from Wellington).

Given the use of population statistics as a measurement indicator for prosperous urban areas in New Zealand, it could be noticed from Figure 1 that while some areas are experiencing a significant population increase, others are experiencing population stagnation or decline. Accordingly, it could be observed from *Figure 1* that three of New Zealand's earliest cities (i.e., Whanganui, Invercargill and Palmerston North) started with higher population counts during the 1926 census. However, over the years till 2018, while Palmerston North experienced a significant increase in population growth, Whanganui and Invercargill have been observed to have experienced population stagnancy and decline at different stages in time. The gradual decline in the population growth of Whanganui and Invercargill over the years have now placed them among the last four large urban areas in New Zealand. Hence, these two large urban areas are examined carefully in order to understand the circumstances that may have triggered their decline over the years.



* 1946 population data is from the 1945 census; * 2018 population data is estimated

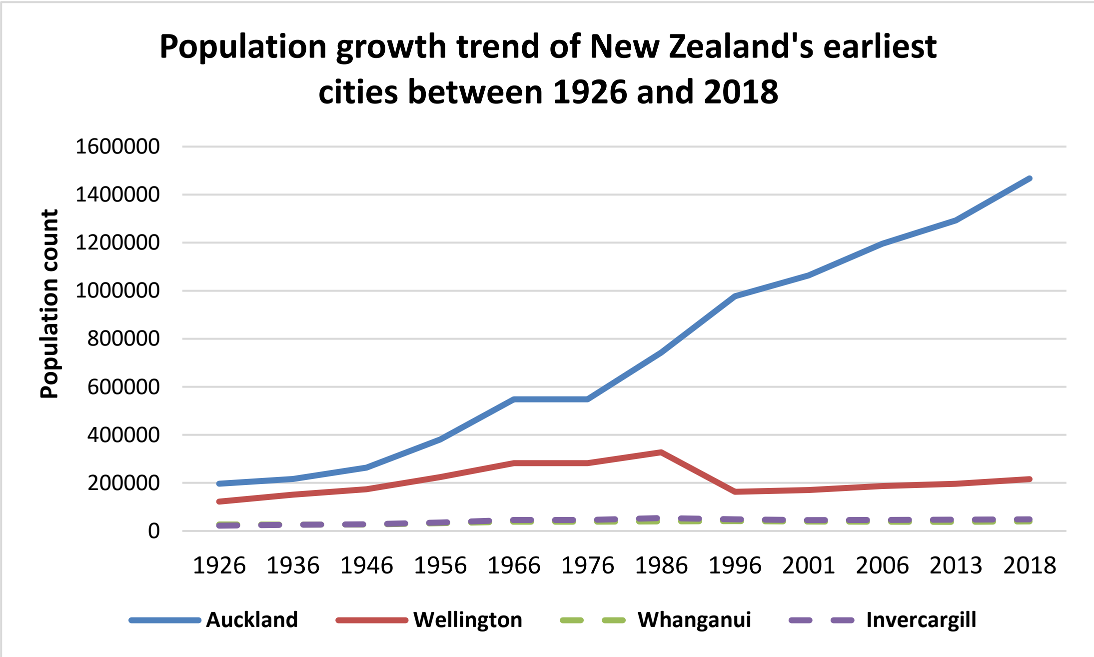
Figure 1: Population growth trend for New Zealand's large urban areas

Whanganui first experienced a gradual decline in population growth between 1926 and 1936, which coincides with the period of "great depression" that hit New Zealand in the late 1920s. Since Whanganui was a famous port town in New Zealand at that time, the drastic fall in export prices created unemployment and hard times for farmers (Wilson, 2005). Consequently, most of the population started relocating to Palmerston North which was the nearest metropolitan area that had a booming agricultural college. Next, the Whanganui flooding event that occurred on February 1940 after an episode of heavy rains caused the Whanganui river banks to collapse. Most of the low-lying areas of Whanganui city was water-logged, creating another challenging time for both motorist and pedestrians (McSaveney, 2006). This flooding catastrophe experienced by the Whanganui area justifies a further decline in its population growth between 1936 and 1946.

Many major and large urban areas in New Zealand experienced a significant rise in population between 1946 and early 1970s. This population boom was mainly due to the massive influx of people from neighbouring hinterlands to metropolitan areas. Innovations in the transportation sector (Pool, 2013), construction of motorways (Gunder, 2002), and popularity of private cars (Burayidi, 2013), have been identified as the factors that promoted this change. However, between 1976 and 1986, both major and large urban areas experienced a gradual decline in their population growth due to the first and second oil crises. The floating of New Zealand's dollar in 1985 justifies this decline in population growth (Decker & McCracken, 2018). Consequently, Whanganui and Invercargill experienced a massive decline in the number of available jobs, which led to an increase in foreclosures, unemployment, and out-migration from these areas.

A further decline in the population of Whanganui and Invercargill occurred between 2006 and 2013, which could be attributed to the 2011/2012 Canterbury earthquake sequences, and the introduction of the earthquake-prone building legislation to mitigate the impacts of earthquake-prone buildings to its users during earthquakes. However, the uncertainty in the cost-benefit implications of investing in seismic strengthening of the earthquake-prone historical buildings in the inner cores of these two city centres encouraged a mass emigration out of these areas to other bigger cities (Yakubu et al., 2017). The gradual growth in the population of Whanganui and Invercargill between 2013 and 2019 could be attributed to some community-mobilised initiatives organised by these local councils in a quest to regenerate the urban areas.

(ii) Comparing the population growth trend of New Zealand's major cities with typical provincial areas



* 1946 population data is from the 1945 census; * 2018 population data is estimated; *Wellington includes Upper Hutt and Porirua

Figure 2: Population growth trend of New Zealand's earliest cities

A comparison between the population growth trend of the two identified large urban areas in decline from *Figure 1* (i.e., Whanganui and Invercargill) with two major urban areas (i.e., Auckland and Wellington) is done to examine how these five New Zealand's earliest cities have grown differently in population size. Accordingly, *Figure 2* shows that whereas Auckland and Wellington have experienced steady population growth over the years, Whanganui and Invercargill are typical provincial areas observed to be experiencing an overlapping decline.

Provincial areas become less vibrant when specific industries move to bigger cities and the majority of the younger population move with them. The significant low proportion of the younger population in Whanganui and Invercargill may have resulted in the economic decline being experienced in these areas because the ageing population do not have enough flexibility to adapt and take advantage of demographic shifts from population decline (Jackson *et al.*, 2019).

(iii) Income status and employee growth count

The income status of an urban area and the distribution pattern of its employee growth is usually connected to the level of economic development within the area's socio-economic structure (Centre for Rural Studies, 2002; Cameron & Muellbauer, 2001). *Figure 3* shows that Auckland experienced a sharp increase in the distribution pattern of its total personal income status for the employed between 2006 and 2013. A gradual increase is also observed for Wellington. On the contrary, Whanganui and Invercargill are observed to have experienced a gradual decline in their income status between 2006 and 2013.

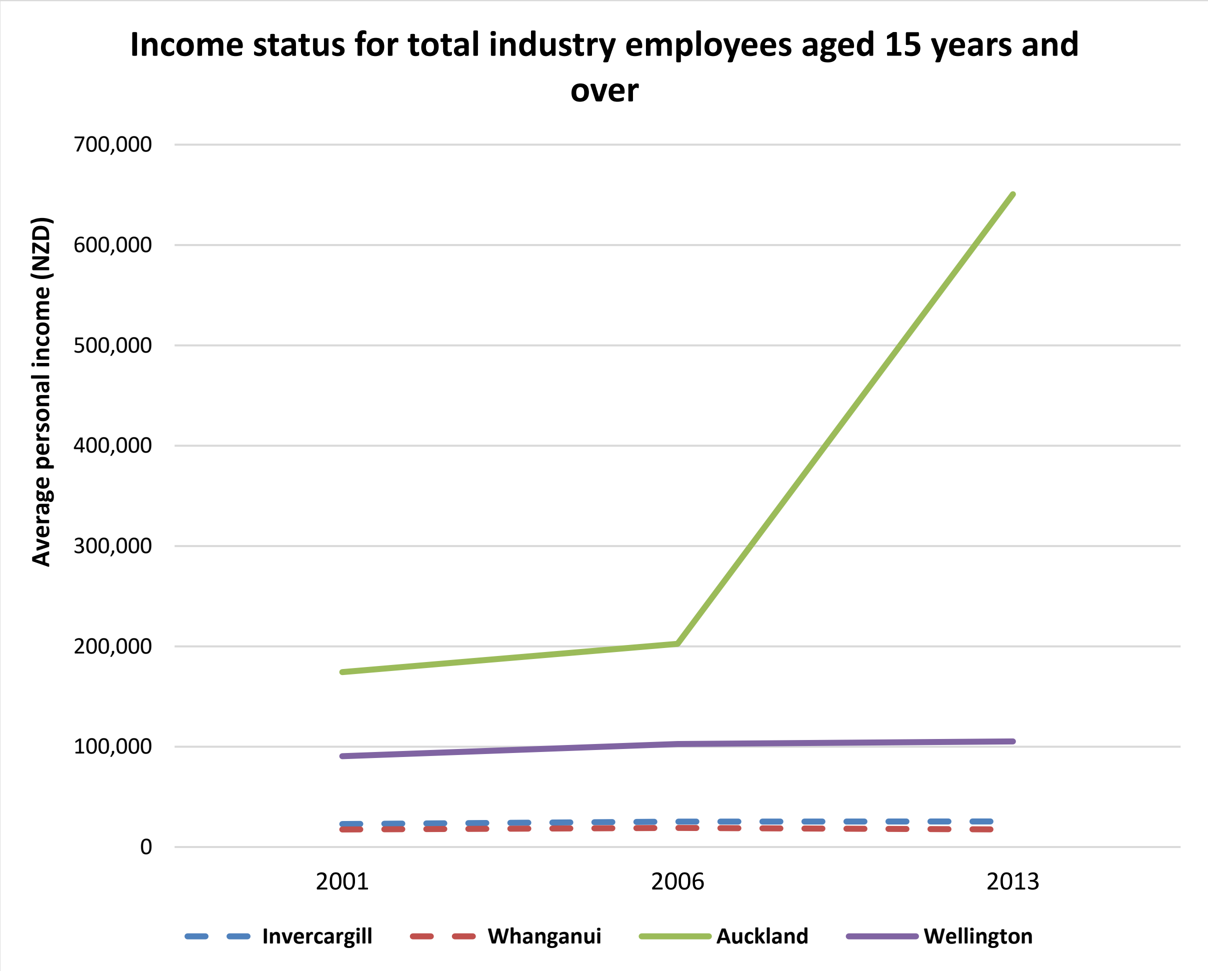


Figure 3: Total personal income for New Zealand's earliest cities

Also, the employment statistics as shown in *Figure 4*, put Whanganui and Invercargill as the least economically prosperous urban areas of the first five earliest New Zealand cities considered in this study, while Auckland and Wellington are seen to have experienced a significant increase over the years.

Figure 4: Employee growth trend for New Zealand's earliest cities

However, the employment statistics for the city centres, as shown in *Figure 5* shows that the employee growth count of urban areas largely depends on the economic activities that occur in their city centres.

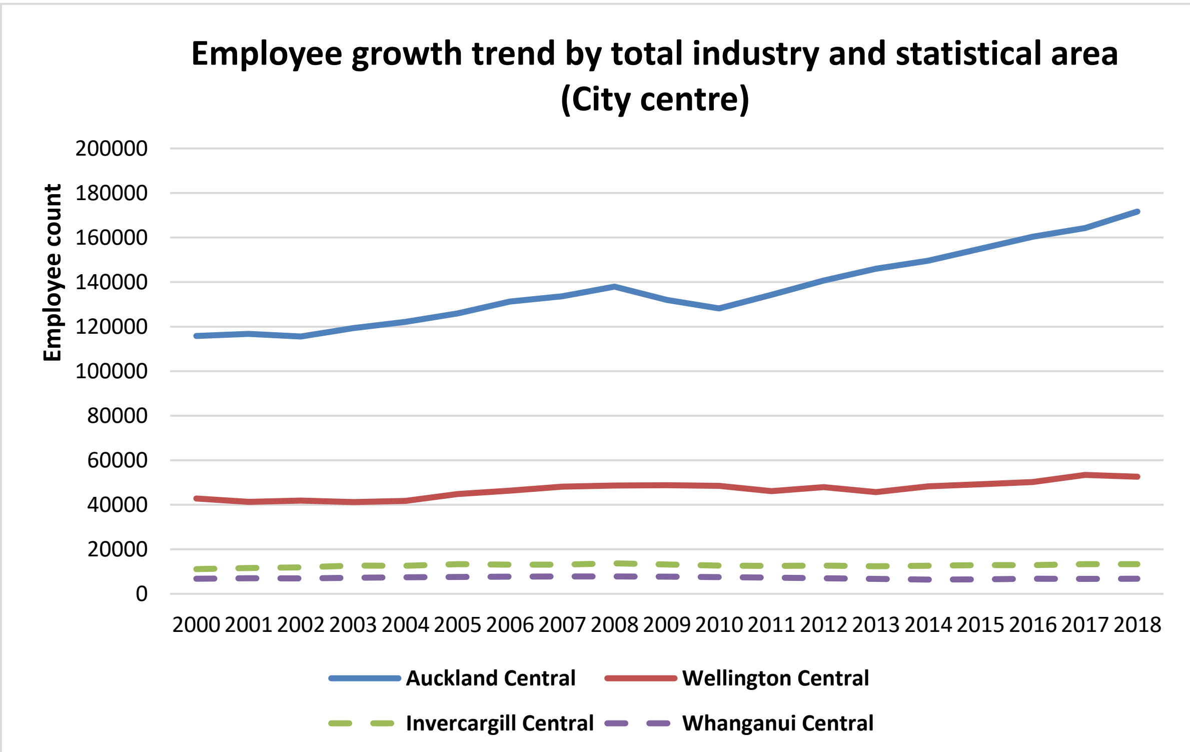


Figure 5: Employee growth trend in the city centres of New Zealand's earliest cities

Although the period between 2006 and 2013 coincides with that of the 2008 global economic recession (Bagliano & Morana, 2012), and the 2010/2011 Canterbury earthquake occurrences (Potter *et al.*, 2015), bigger cities such as Auckland and Wellington thrived in their employment and income status while provincial areas shrunk. Also, some upshots of the Canterbury earthquakes exposed how New Zealand's provincial areas differ from the bigger cities in the aspects of risks, socio-economic physiognomies, expertise, challenges, and opportunities, regarding urban resilience (Eaqub, 2014).

The implication of this narrative is that Auckland and Wellington have some specific fast-growing industries such as finance, insurance that may be absent in most provincial areas. Also, with Auckland being the economic hub of New Zealand, and Wellington the political hub, these two major urban areas have been on the right track to creating employment growth opportunities that have attracted the vibrant younger populations from provincial areas over the years (Eaqub, 2014). Invercargill and Whanganui may not have experienced the kind of substantial economic growth they had anticipated for partly due to the underperformance of their significant industries (i.e., mining, housing and manufacturing) in terms of income status and employment (Statistics New Zealand, 2018a).

(iv) Property prices

Current property prices comparisons for city centre commercial historical property listing are extracted from two of New Zealand's popular real estate websites (Realestate.co.nz, 2019; QV.co.nz, 2019). *Figure 6* shows that asking lease prices for Auckland (26 per cent) and Wellington (25 per cent) is relatively higher than that of Whanganui (14 per cent), and Invercargill (14 per cent). Also, Auckland has a significant proportion (65 per cent) of asking sale price per square metre of floor area, which has a wide margin compared to that of Wellington (16 per cent) and Invercargill (7 per cent). Whanganui (3 per cent) is the least in this category. The evaluation of actual sale price shows that Auckland and Wellington have higher prices (i.e., 44 per cent and 36 per cent respectively), while Invercargill and Whanganui have lower prices (i.e., 12 per cent and 5 per cent respectively).

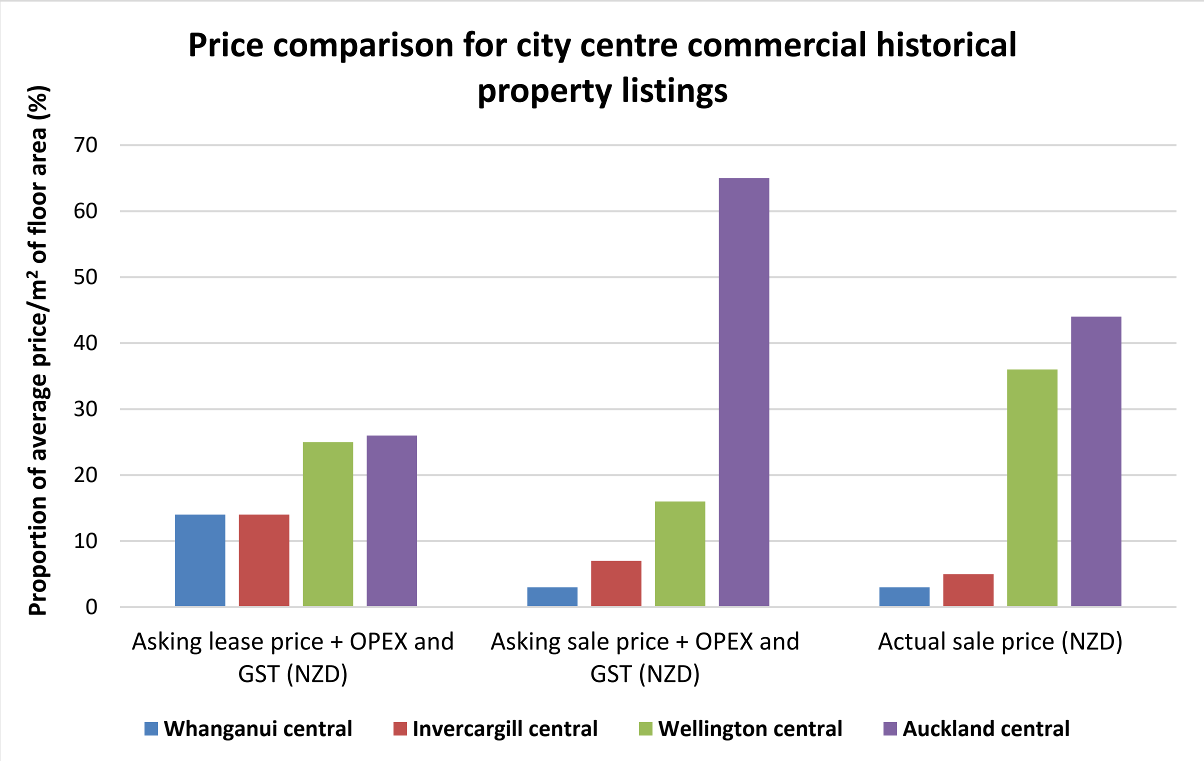


Figure 6: Property prices comparisons for commercial historical properties

Some form of inequality observed from *Figure 6* shows the disproportionate resilience of bigger cities and their socio-economic pulling force that usually tend to cause significant strain and eventual decline of provincial cities (Nel, 2015). The population growth trends could be considered a significant trigger for the fluctuations in property prices due to shifting demand for durable existing buildings in shrinking cities (Glaeser & Gyourko, 2005). Also, the link between the rise in population densities and the corresponding increase in property prices of buoyant urban areas have been emphasised through some economic pointers such as net migration, employment rate, and income growth (Agnello & Schuknecht, 2011; Winston & Eastaway, 2008). Hence, an inference connecting the decline of provincial cities with their respective property price trajectories is to be established.

Impacts of the newly enforced Building (Earthquake-prone Buildings) Amendment Act 2016.

The emphasis of findings from the key informant interviews is based on a description of the broad range of ideas obtained from the interviewees, rather than their representative or average opinions. The key informants gave their opinions on the links between the identified shrinking cities and impacts of the newly enforced Building (Earthquake-prone Buildings) Amendment Act 2016, to establish if has it raised awareness to enable more preservation of heritage buildings, created incentives for demolition, or stimulated urban regeneration or decline. Accordingly, the six themes that were identified from the thematic analysis of the interview transcripts are discussed in the following subsections:

(i) Pressure on building owners from BEPBAA compliance deadlines

The BEPBAA has put historical buildings on the spotlight. The compliance timeframes on people's mind have created more pressure for owners of EPBs. In the past, the EPB legislation that individual councils had was so variant. Some were active, and some were passive. However, with the recently amended BEPBAA after the Christchurch earthquakes, much pressure was placed on people because places that did not have compliance deadlines before now, do have deadlines now. The pressure is more on owners of EPBs who are responsible for the safety of users of their buildings. Before the introduction of the BEPBAA, there was much pressure by owners of derelict heritage buildings and developers to demolish the buildings and rebuild newer structures because of the value of land that the buildings were sited. Most owners were not inclined to preserve their buildings. Although there were already low-key conversations going on about the protection of New Zealand's heritage buildings, the introduction of the BEPBAA after the Canterbury earthquakes put heritage buildings on the spotlight because of their vast vulnerability during the seismic events.

In provincial areas, where the market forces are not sufficient to cover the cost invested in seismic retrofit, many owners of commercial historical buildings usually do a cost-benefit analysis to know what their return on investment from strengthening their buildings would be. They are usually sceptical about investing in strengthening now because they feel these buildings may need another upgrade in the future if the BEPBAA is amended. These owners believe it will cost them much money that they could never retrieve over the compliance timeframe. The outcome from a cost-benefit analysis that suggests negative return on investment often discourage owners to invest in redeveloping their EPBs. Most of the owners tend to do nothing about their buildings, collect the marginal rent back on the building while hoping it does not get empty, and at the end of the compliance timeframes would prefer to abandon the buildings. The situation becomes worse for buildings with larger floor areas where the cost of strengthening will be higher, hence, creating a scenario where the main streets of most provincial areas are characterised with decaying historical buildings due to lack of maintenance.

The situation is even more frustrating for owners of EPBs on priority routes in higher seismic hazard areas where the timeframes are practically shorter. The implication of this is that the building owners tend to search for incentives to strengthen their buildings, otherwise, abandon their buildings for demolition by the local authority when the given compliance timeframe elapses. Additionally, some investors and owners of historical buildings are too scared to maintain their buildings or make any change of use alterations because they do not want to exceed the 25 per cent threshold and trigger the seismic strengthening requirements in the building act (MBIE, 2016a).

(ii) Attitudes of councils in different seismic hazard areas

The attitude of councils usually plays a significant role in motivating people to invest in seismic strengthening of historical buildings to revitalise their areas. Sometimes councils need to make the first move to upgrade heritage buildings.

While councils in larger high seismic hazard areas like Christchurch and Wellington are predominantly at the forefront of ensuring compliance with the BEPBAA, a majority of councils in provincial low and medium seismic hazard areas usually do not have sufficient resources to ensure compliance and may still be lagging regarding their EPB profiling. Hence, these councils may prefer the 'wait and see' approach, where they do nothing and wait for what happens when the compliance timeframes are exhausted. Owners of potentially EPBs in these areas may still not have been served EPB notices. This situation is a ticking time bomb for provincial councils, considering a large number of non-compliant EPB investors in these areas. These council's hands may be entirely tied in terms of what they can do at the end of the timeframes for building owners to comply with the BEPBAA. Provincial councils have lower resources to chase building owners for compliance. They always struggle with enforcing compliance and usually end up in court, which may be too expensive for them. The risk here is that they may push back for the policy to be reviewed to allow for a longer timeframe to ensure compliance.

(iii) Risk of future amendment of the BEPBAA

There is a risk that most EPB owners become less confident about the way policy and requirements change due to review. Many EPB owners in low and medium seismic hazard areas that have between 25 to 35 years to strengthen their EPBs believe that the timeframes are so long and that any review of the BEPBAA would potentially add more time to it. For instance, if the government review the legislation in the future and introduce another timeframe that is not as short as the ones they already have, then owners will be discouraged from doing anything at all because they believe the rules will change again when the government will review the timeframes and push it further. The message this sends to building owners is that government will always push the timeframes and so they do not need to do anything to their buildings in a hurry. There is also a risk that the more policies are being reviewed with changing requirements and timeframes, the more the confidence of building owners are being undermined that the policy is going to stay in place.

For some building owners that are required to retrofit their buildings within the next 25 to 35 years, their perception would be that they may not need to do anything now because their area may be categorised under a higher seismic risk zone after the next BEPBAA review. So, they do not want to eventually re-strengthen their buildings to meet the higher NBS rating for their area. Consequently, most of these building owners believe that the smartest economic decision to make would be to defer and strengthen their building at the latest possible time, by putting their money in the bank to collect interest in the meantime, while buying more time to wait and see if there would be any new changes in the policy. Also, some other owners prefer to defer their strengthening because they believe that the newer technologies of strengthening techniques will be cheaper than the existing ones. For instance, some of the earlier strengthening projects were quite complex and more expensive compared to the new technologies.

(iv) Safety concerns and high seismic retrofit costs

Most investors in New Zealand's provincial areas believe it's too expensive to retrofit EPBs and unsafe to live in. So, they rely on the economic and health and safety arguments as justification to demolish and prefer to erect new buildings because they feel it is a cheaper option. The economic argument regarding the high cost of retrofitting the EPBs has been used by most of the building owners in provincial areas as leverage to demolish their buildings.

EPB owners in provincial areas are often discouraged from investing in strengthening their buildings because they cannot afford to charge higher rents to cover the cost of an upgrade compared to other owners who have not invested in seismic strengthening at all. These EPB owners prefer not to invest in strengthening their buildings and charge lower rents as an incentive to attract tenants. Also, most prospective tenants of commercial historical EPBs expect owners to strengthen their buildings to above 67 per cent NBS rating because they are responsible for the safety of their employees during an earthquake. Accordingly, many of older banks in provincial areas who were already planning restructuring and shutting down their branches in smaller cities due to some modern banking trends such as the advent of internet banking, have used the safety concerns as an excuse to relocate to move out since most of their buildings were historical buildings assessed to be EPB's

Besides, insurance could also be an external economic factor pushing people away from seismically strengthening and protecting their buildings. Many affected building owners are being discouraged because if they cannot secure insurance, it becomes difficult to get bank loans to develop their building or acquire a new building. However, it may be interesting to know that the cost of seismic upgrade is about the same across all regions of New Zealand depending on the alternative solution adopted, but the demand for heritage buildings varies according to different property markets in different areas.

(v) Unsophisticated investors in provincial areas

In New Zealand's provincial areas, the average age of building owners is very different from commercially active centres like Auckland and Wellington. The context has always been that the kind of investors in provincial areas are already retired and have had their buildings for 50+ years without any mortgage to pay for. This type of owners are just running their assets for marginal profits, which supplements their pensions and hobbies, and hence, they tend to quickly get startled when issues regarding compliance come up. It is very unrealistic for banks to give this category of investors loan to retrofit their EPBs. So, this category of owners settles for squeezing their buildings of the last worth and walk away when the compliance timeframe elapses. They believe they will not lose much compared to the cost of investing in strengthening.

It is usually very challenging for councils to engage this category of investors because they would consider any form of engagement from councils as barriers restricting them on what they can do with their buildings. This kind of attitude from these unsophisticated investors is often prevalent in provincial areas where the prospects of not complying with the BEPBAA to upgrade historical EPBs is a significant challenge due to the large proportion of historical buildings in these areas.

On the other hand, sophisticated investors in bigger cities usually identify the EPBs, assess their heritage values, and use cost-effective and more straightforward engineering solutions to strengthen them to the required standards at which insurance companies will agree to insure. At this point, it becomes easier for banks to give loans to buy the historical buildings from the owners and acquire incentives from funding bodies such as Heritage Equip (Heritage EQUIP, 2019).

(vi) Lack of actual seismic retrofit cost data sharing

Actual seismic retrofit cost data is challenging to get, and this has greatly influenced the barriers and motivation for building owners to invest in strengthening their historical EPBs. Most investors do not share their actual cost data. Instead, they prefer to share their designs and drawings, solutions, and estimated cost data that do not entirely represent the actual costs. As a result of these weird estimates, some engineers may overcharge, and some may undercharge. There has also been a slow uptake for some owners because they are still waiting for actual seismic retrofit cost information.

However, some owners may understate their strengthening costs because they do not want to pay higher building consent fees, which is usually based on the actual value of work. While some other owners may be very information sensitive because they may want their tenants to believe they are paying more to retrofit their buildings, and hence, increase their rent, others may be taking a loss that they do not want the public to be aware of.

Conclusion

The study in this paper has analysed some socio-economic statistics to identify provincial cities among New Zealand's earliest cities currently undergoing decline. The opinions of subject matter experts regarding how the newly amended BEPBAA may have influenced the decline of provincial areas have also been explored through key informant interviews.

Findings from the document analysis identified Whanganui and Invercargill as two typical provincial urban areas which though were among New Zealand's earliest cities are currently experiencing a decline. The statistics from the document analysis justified the decline in the population growth trend, income status, employee counts and property prices of the identified areas. Also, findings from the key informant interviews revealed the following factors as impacts of the BEPBAA that may have promoted the decline of typical provincial areas in New Zealand: (i) pressure on building owners from BEPBAA compliance deadlines; (ii) attitudes of councils in different seismic hazard areas; (iii) risk of future amendment of the BEPBAA; (iv) safety concerns and high seismic retrofit costs; (v) unsophisticated investors in provincial areas; and (vi) lack of actual seismic retrofit cost data sharing.

These findings reflect secure connections between socio-economic and policy-related influences and the population growth trends in major New Zealand's provincial areas. The implication of these findings could be useful for researchers and policy regulators to have a better understanding of the unintended, intended, and future consequences of how the BEPBAA may have promoted the prevalence of derelict and underutilised historical buildings in the inner cores of typical provincial areas in New Zealand. The occurrence of so many vacant buildings in these areas has now created opportunities for urban regeneration pursuits by concerned territorial authorities.

Acknowledgements

This study was (partially) supported by QuakeCoRE, a New Zealand Tertiary Education Commission-funded Centre. This is QuakeCoRE publication number 0479.

References

Adams, J. S. 2005, 'Hoyt, H. 1939: The structure and growth of residential neighborhoods in American cities. Washington, DC: Federal Housing Administration', *Progress in Human Geography,* vol. 29, no. 3, pp. 321-325.

Adhya, A. 2017. Introduction: The Shrinking City Phenomenon. *Shrinking Cities and First Suburbs.* Springer.

Agnello, L. & Schuknecht, L. 2011, 'Booms and busts in housing markets: Determinants and implications', *Journal of Housing Economics,* vol. 20, no. 3, pp. 171-190.

Aigwi, I. E., Egbelakin, T. & Ingham, J. 2018, 'Efficacy of adaptive reuse for the redevelopment of underutilised historical buildings: Towards the regeneration of New Zealand's provincial town centres', *International Journal of Building Pathology and Adaptation,* vol. 36, no. 4, pp. 385-407.

Aigwi, I. E., Egbelakin, T., Ingham, J., Phipps, R., Rotimi, J. & Filippova, O. 2019, 'A performance-based framework to prioritise underutilised historical buildings for adaptive reuse interventions in New Zealand', *Sustainable Cities and Society,* vol. 48,pp. 101547.

Bagliano, F. C. & Morana, C. 2012, 'The Great Recession: US dynamics and spillovers to the world economy', *Journal of Banking & Finance,* vol. 36, no. 1, pp. 1-13.

Ball, L. 2014, 'Long-term damage from the Great Recession in OECD countries', *European Journal of Economics and Economic Policies: Intervention,* vol. 11, no. 2, pp. 149-160.

Bampton, R. & Cowton, C. J. 2002, 'The E-Interview', *Qualitative Social Research,* vol. 3, no. 2.

Beauregard, R. A. 2013. *Voices of decline: The postwar fate of US cities*, Routledge.

Bothara, J., Jury, R., Wheeler, K. & Stevens, C. Seismic assessment of buildings in Wellington: experiences and challenges. Proceedings of 14th World Conference on Earthquake Engineering, Beijing, 2008.

Bowen, G. A. 2009, 'Document analysis as a qualitative research method', *Qualitative research journal,* vol. 9, no. 2, pp. 27-40.

Braun, V., Clarke, V., Hayfield, N. & Terry, G. 2019, 'Thematic analysis', *Handbook of Research Methods in Health Social Sciences,* pp. 843-860.

Burayidi, M. 2013. *Resilient downtowns: a new approach to revitalizing small-and medium-city downtowns,* New York, Routledge.

Buzar, S., Ogden, P., Hall, R., Haase, A., Kabisch, S. & Steinfiihrer, A. 2007, 'Splintering urban populations: emergent landscapes of reurbanisation in four European cities', *Urban Studies,* vol. 44, no. 4, pp. 651-677.

Cameron, G. & Muellbauer, J. 2001, 'Earnings, unemployment, and housing in Britain', *Journal of Applied Econometrics,* vol. 16, no. 3, pp. 203-220.

Cattanach, A., Alley, G. & Thornton, A. Appropriateness of Seismic Strengthening Interventions in Heritage Buildings: A Framework for Appraisal. 2008 NZSEE Conference, 2008. 6.

Centre for Rural Studies 2002. *Dalits and the State,* New Delhi, India, Concept Publishing Company.

Chambliss, D. F. & Schutt, R. K. 2018. *Making sense of the social world: Methods of investigation,* Sage Publications.

Cheshire, P. C. & Hay, D. G. 1989. *Urban Problems in Western Europe: an economic analysis*, Hyman.

Colvin, A., Fergusson, I. & Phillips, H. 2000, 'Renewing the Urban Landscape: The Dilemma of Vacant Housing', *Center for Public Policy Research–The Thomas Jefferson Program in Public Policy at the College of William Mary for The International City/County Management Association,* vol. 7.

Connell, J., Lynch, C. & Waring, P. 2001, 'Constraints, compromises and choice: Comparing three qualitative research studies', *The Qualitative Report,* vol. 6, no. 4, pp. 1-15.

Creswell, J. W. & Poth, C. N. 2018. *Qualitative inquiry and research design: Choosing among five approaches*, Sage publications.

Deakin, H. & Wakefield, K. 2014, 'Skype interviewing: Reflections of two PhD researchers', *Qualitative research,* vol. 14, no. 5, pp. 603-616.

Decker, F. & McCracken, S. 2018, 'Central banking in Australia and New Zealand: historical foundations and modern legislative frameworks', *Research Handbook on Central Banking,* pp. 245.

Dowrick, D. J. 1998, 'Damage and intensities in the magnitude 7.8 1931 Hawke's Bay, New Zealand, earthquake', *Bulletin of the New Zealand National Society for Earthquake Engineering,* vol. 31, no. 3, pp. 139-163.

Eaqub, S. 2014. *Growing apart: regional prosperity in New Zealand,* New Zealand, Bridget Williams Books.

Friedrichs, J. 1993, 'A theory of urban decline: economy, demography and political elites', *Urban Studies,* vol. 30, no. 6, pp. 907-917.

Glaeser, E. L. & Gyourko, J. 2005, 'Urban decline and durable housing', *Journal of political economy,* vol. 113, no. 2, pp. 345-375.

Goldstein, A. E. & Reiboldt, W. 2004, 'The multiple roles of low income, minority women in the family and community: A qualitative investigation', *The qualitative report,* vol. 9, no. 2, pp. 241-265.

Grimes, A. & Tarrant, N. 2013. *A New Zealand Urban Population Database: Motu Working Paper No. 13-07* [Online]. Available: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2309710.

Gunder, M. 2002, 'Auckland's motorway system: a New Zealand genealogy of imposed automotive progress 1946-66', *Urban Policy and Research,* vol. 20, no. 2, pp. 129-142.

Haase, A., Rink, D., Grossmann, K., Bernt, M. & Mykhnenko, V. 2014, 'Conceptualizing urban shrinkage', *Environment and Planning A,* vol. 46,pp. 000-000.

Hall, P. & Hay, D. 1980. *Growth centres in the European urban system*, Univ of California Press.

Hall, V. & McDermott, C. J. 2016, 'Recessions and recoveries in New Zealand's post-Second World War business cycles', *New Zealand Economic Papers,* vol. 50, no. 3, pp. 261-280.

Heritage EQUIP. 2019. *Eligibility for Heritage EQUIP funding* [Online]. Available: https://heritageequip.govt.nz/ [Accessed 11/03/2019 2019].

Hoyt, H. 1939, 'The structure and growth of residential neighborhoods in American cities'.
Ingham, J. & Griffith, M. 2010, 'Performance of unreinforced masonry buildings during the 2010 Darfield (Christchurch, NZ) earthquake', *Australian Journal of Structural Engineering,* vol. 11, no. 3, pp. 207-224.
Jackson, N., Brabyn, L., Maré, D., Cameron, M. & Pool, I. 2019. From ageing-driven growth towards the ending of growth. Subnational population trends in New Zealand. *Studies in the Sociology of Population.* Springer.
Lang, R. E. 2000, 'Did neighborhood life-cycle theory cause urban decline?', *Housing Policy Debate,* vol. 11, no. 1, pp. 1.
Langston, C. 2011. Estimating the useful life of buildings. *36th Annual Conference for Australian University Building Educators.* Bond University, Gold Coast, Australia.
Leo, C. & Anderson, K. 2006, 'Being realistic about urban growth', *Journal of Urban Affairs,* vol. 28, no. 2, pp. 169-189.
Logan, J. R. & Molotch, H. L. 2007. *Urban fortunes: The political economy of place,* Univ of California Press.
Marshall, M. N. 1996, 'The key informant technique', *Family practice,* vol. 13, no. 1, pp. 92-97.
Martinez-Fernandez, C., Audirac, I., Fol, S. & Cunningham-Sabot, E. 2012, 'Shrinking cities: Urban challenges of globalization', *International Journal of Urban and Regional Research,* vol. 36, no. 2, pp. 213-225.
Martinez-Fernandez, C., Weyman, T., Fol, S., Audirac, I., Cunningham-Sabot, E., Wiechmann, T. & Yahagi, H. 2016, 'Shrinking cities in Australia, Japan, Europe and the USA: From a global process to local policy responses', *Progress in Planning,* vol. 105,pp. 1-48.
MBIE 2004. Building Act. *In:* Department of Building and Housing (ed.). Wellington, New Zealand:Ministry of Business Innovation & Employment
MBIE 2016a. Building (Earthquake-prone Buildings) Amendment Act. Wellington:Ministry of Business Innovation & Employment.
MBIE 2016b. Building Regulatory Framework: Building Performance. *In:* Employment, M. O. B. I. (ed.). Wellington, New Zealand.
McGranahan, G. & Satterthwaite, D. 2014. *Urbanisation: Concepts and Trends*, IIED London.
McSaveney, E. 2006. *'Floods - New Zealand's number one hazard', Te Ara - the Encyclopedia of New Zealand* [Online]. Available: http://www.TeAra.govt.nz/mi/video/46853/whanganui-flood-1940.
National Business Review. 2014. *NZ has zombie towns that need to close — economist* [Online]. Available: https://www.nbr.co.nz/article/nz-has-zombie-towns-need-close-%E2%80%94-economist-ns-159124 [Accessed 14/01/2019.
Nel, E. 2015, 'Recent trends in regional and local demographic and economic inequality in New Zealand and associated regional development implications', *Local Economy,* vol. 30, no. 1, pp. 12-20.
NZSEE 2017. The Seismic Assessment of Existing Buildings:Technical Guidelines for Engineering Assessments - Initial Seismic Assessment.New Zealand Society for Earthquake Engineering.
Openshaw, R., Lee, G. D. & Lee, H. F. 1993. *Challenging the myths: Rethinking New Zealand's educational history,* Dunmore Press Palmerston North.
Pallagst, K. 2008. Shrinking Cities: Planning Challenges from an International Perspective. *In:* Rugare, S. & Schwarz, T. (eds.) *Cities Growing Smaller.* Cleveland, OH: Cleveland Urban Design Collaborative.
Pool, I. 2013. *The New Zealand family from 1840: A demographic history,* Auckland, Auckland University Press.
Potter, S. H., Becker, J. S., Johnston, D. M. & Rossiter, K. P. 2015, 'An overview of the impacts of the 2010-2011 Canterbury earthquakes', *International Journal of Disaster Risk Reduction,* vol. 14,pp. 6-14.
QV.co.nz. 2019. *The E-valuer* [Online]. Available: https://www.qv.co.nz/valuations-and-reports/the-evaluer.
Rapley, T. 2008. *Doing conversation, discourse and document analysis*, Sage.
Realestate.co.nz. 2019. *Property Listings* [Online]. Available: https://www.realestate.co.nz/ [Accessed 09/04/2019.

Reckien, D. & Martinez-Fernandez, C. 2011, 'Why do cities shrink?', *European Planning Studies*, vol. 19, no. 8, pp. 1375-1397.
Russell, A. P. & Ingham, J. M. 2010, 'Prevalence of New Zealand's unreinforced masonry buildings', *Bulletin of the New Zealand Society for Earthquake Engineering*, vol. 43, no. 3, pp. 182.
Sassen, S. 2018. *Cities in a world economy*, Sage Publications.
Schilling, J. M. & Friedman, N. 2002, 'The Revitalization of Vacant Properties: Richmond, Virginia Case Study', *Washington, DC: International City/County Management Association*, vol. 27.
Schrader, B. 2016. *The Big Smoke: New Zealand Cities, 1840–1920*, Bridget Williams Books.
Squires, G. D. 2002. *Urban sprawl: Causes, consequences, & policy responses*, The Urban Insitute.
Statistics New Zealand. 2018a. *Business Demography Statistics* [Online]. Available: http://nzdotstat.stats.govt.nz/wbos/Index.aspx?_ga=2.133971660.317407011.1547470004-133109085.1543372741# [Accessed 18/01/2019.
Statistics New Zealand. 2018b. *Population estimates tables* [Online]. Available: http://nzdotstat.stats.govt.nz/wbos/Index.aspx?_ga=2.133971660.317407011.1547470004-133109085.1543372741# [Accessed 28/11/2018 2018].
Stevens, C. & Wheeler, K. Implementing earthquake prone building policy under the Building Act 2004: Wellington City's Approach. New Zealand Society for Earthquake Engineering: Engineering an Earthquake Resilient New Zealand. NZSEE Conference, 2008.
Strauss, A. & Corbin, J. 2008. *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory* Thousand Oaks, CA, Sage Publications.
Thorns, D. & Schrader, B. 2010. *'City history and people', Te Ara - the Encyclopedia of New Zealand* [Online]. New Zealand. Available: https://teara.govt.nz/en/city-history-and-people [Accessed 29th November 2018].
Tripathi, A. D., Mishra, R., Maurya, K. K., Singh, R. B. & Wilson, D. W. 2019. Estimates for World Population and Global Food Availability for Global Health. *The Role of Functional Food Security in Global Health.* Elsevier.
UN-DESA. 2015. *Department of Economic and Social Affairs: World Population Projection* [Online]. United Nations. Available: www.un.org/en/development/desa/news/population/2015-report.html [Accessed 01/05/2019 2019].
United Nations-Habitat 2013. *State of the world's cities 2012/2013: Prosperity of cities*, Routledge.
Van den Berg, L., Drewett, R., Klaasen, L. H., Rossi, A. & Vijverberg, C. H. 1982. *Urban Europe: A study of growth and decline*, Oxford, Pergamon Press.
Wall Street Journal. 2009. *New Zealand's Economy Grows* [Online]. Available: https://www.wsj.com/articles/SB125366520990632487 [Accessed 25/04/2018.
Wiechmann, T. & Bontje, M. 2015. Responding to tough times: Policy and planning strategies in shrinking cities.Taylor & Francis.
Wiechmann, T. & Pallagst, K. M. 2012, 'Urban shrinkage in Germany and the USA: A comparison of transformation patterns and local strategies', *International Journal of Urban and Regional Research*, vol. 36, no. 2, pp. 261-280.
Wilkinson, S. & Osmond, P. 2018, 'Building Resilience in Urban Settlements', *International Journal of Building Pathology and Adaptation*, vol. 36, no. 4, pp. 334-336.
Willson, G. B. & McIntosh, A. J. 2007, 'Heritage buildings and tourism: An experiential view', *Journal of heritage tourism*, vol. 2, no. 2, pp. 75-93.
Wilson, J. 2005. *'History', Te Ara - the Encyclopedia of New Zealand* [Online]. Available: https://teara.govt.nz/en/history [Accessed 2 January 2019.
Winston, N. & Eastaway, M. P. 2008, 'Sustainable housing in the urban context: international sustainable development indicator sets and housing', *Social Indicators Research*, vol. 87, no. 2, pp. 211-221.
Witkin, B. R. & Altschuld, J. W. 1995. *Planning and conducting needs assessments: A practical guide*, Sage.
Yakubu, I. E., Egbelakin, T., Dizhur, D., Ingham, J., Sungho Park, K. & Phipps, R. 2017, 'Why are older inner-city buildings vacant? Implications for town centre regeneration', *Journal of Urban Regeneration & Renewal*, vol. 11, no. 1, pp. 44-59.
Yin, R. K. 2017. *Case study research and applications: Design and methods*, Sage publications.

KEY SOLUTIONS FOR CONSTRUCTION AND DEMOLITION (C&D) WASTE MANAGEMENT IN NSW, AUSTRALIA

Peter Davis[1], Laura Simon[1], Willy Sher[1], Patrick Tang[1], Mohammad Tanvi Newaz[1]

[1]School of Architecture and Built Environment, The University of Newcastle, Callaghan, NSW 2308, Australia

Abstract

Most recent Australian data indicates that 20.4 metric tonnes of Construction and Demolition (C&D) waste was generated in 2017, 13.6 of which was recycled. In New South Wales (NSW), to promote recycling and resource recovery, those wishing to dispose of waste are required to pay a levy per tonne of waste received at landfill sites. The NSW government aims to increase the C&D recycling rate to 80% by 2021. Current research shows that despite increased attention from government, industry practitioners and researchers, there remains scope to improve C&D waste management practices and concomitant outcomes. This research presents the second stage of a NSW Environmental Trust funded study to determine critical issues and solutions for C&D waste management in NSW. The study involved a literature review which identified potential solutions to critical waste-related issues. A purposive sample of stakeholders involved within the C&D waste stream in NSW was then invited to rank the solutions to the aforementioned issues (Stage One). Focus groups (Stage Two) were subsequently organised to discuss the ranking and identify the most appropriate solutions. This research reveals the key solutions identified by the industry specialists in NSW that would potentially help to achieve C&D waste management targets. Accordingly, the findings are valuable to managers and environmental stakeholders concerned with C&D waste management.

Keywords

Waste Management, Construction, Demolition, New South Wales

Introduction

In Australia, 17 million tonnes of waste culminated in landfill in 2002-03. This figure increased to nearly 22 million tonnes in 2016-17. A considerable portion is construction and demolition (C&D) waste (Tam et al., 2018, Productivity Commission, 2006, Pickin et al., 2018). This research focuses on C&D waste that the NSW Environment Protection Authority (2019a) define as “waste that results from the construction, demolition, repair or alteration of buildings or infrastructure”.

Recently the C&D sector generated 16.9 million tonnes of waste in 2007 and 20.4 million tonnes of waste in 2017 representing a 3.5 million tonne increase in 10 years (Pickin et al., 2018). Amongst this waste, 10.1 million tonnes were recycled in 2007, and 13.6 million tonnes were recycled in 2017. Similarly, this represents a 3.4 million tonnes increase in the same period (Pickin et al., 2018).

The literature shows that many factors that affect the efficiency of C&D waste management (Esa et al., 2017a, Ajayi et al., 2017b).

In a previous stage of this study funded by the NSW Environment Trust, the researchers interviewed 19 experts on C&D waste from the industry in NSW in order to identify the main issues of construction waste management in NSW. The following topics were identified:

Organisational topics

- Illegal dumping
- Economic values
- Waste management plan
- External waste management policy
- Construction stages
- Waste prediction, minimisation and time management
- Reporting and benchmarking
- Environment sustainability

Process topics

- Waste bin size and type / Site constraints
- On-site sorting / Sorting station
- Supply chain management

People topics

- Behaviours
- Bin availability
- Knowledge, experience and training
- Mutual obligation
- Roles and responsibilities

In this second stage, key ideas/solutions were identified for each of the factors to identify ways of improving C&D waste management in NSW, Australia. This represents the focus of the following.

Literature Review

Waste legislation in Australia

Because of the negative impact of C&D waste, the Australian federal government and the NSW state government have enacted different policies focused on the environment and on waste management (Maund et al., 2018). The Australian National Strategy for Ecologically Sustainable Development, the Environmental Protection and Biodiversity Conservation Act, the Intergovernmental Agreement on the Environment and the Commonwealth State of The Environment Reporting are Australian policies. NSW Environmental Planning and Assessment Act (EPA Act) and the NSW Protection of the Environment Operation Act are NSW policies.

In NSW, waste facilities levy a fee for each tonne of waste received. Victoria, South Australia, Western Australia and ACT also have waste levies. In Tasmania however, a levy is not compulsory. In Northern Territory, there is no waste levy (Commonwealth of Australia, 2018). In Queensland a waste levy was legislated in July 2019 (Queensland Government, 2019). The levy is a source of funding for the governments and may be invested in waste and recycling management, but mainly it represents discouragement for disposal of waste to landfill and an incentive to find good alternatives to landfill disposal (Commonwealth of Australia, 2018) (p.44-45). It has been noted that the differences in legislation can lead to suboptimal outcomes, as some industries transferred their waste to states with no levy or a lower levy for waste disposal. The Environment and Communication References Committee recommended harmonisation of “best-practice landfill standards” to overcome this (Commonwealth of Australia, 2018) (p. xi).

In recent years, NSW has focused on improving policies. In 2014, they published the NSW Waste Avoidance and Resource Recovery Strategy 2014-21, where they set the following target for 2021: 80% of the waste generated by the C&D sector to be recycled (NSW Environment Protection Authority, 2014). More recently, they received feedback from the community, industry stakeholders, planning professionals and local government, and published the Environmental Planning and Assessment Amendment Act 2017 (New South Wales Government, 2018), in order to make the EPA Act clearer and simpler (p.5). More specifically related to waste management, the NSW Environment Protection Authority (2018) published The Better Regulation Statement - Protection of the Environment Operations Legislation Amendment (Waste) Regulation. They also published the Standards for managing construction waste in NSW (2019b). They set standards about waste inspection requirements, sorting, storage and transport requirements to be followed by every C&D waste facility.

Notwithstanding a gap between the policy intent and the policy outcome, construction practitioners have been making an effort to attain good environmental policy outcomes (Maund et al., 2018). Not one, but many strategies can help practitioners to improve C&D waste management.

Solutions to critical waste related issues

The literature was reviewed in order to identify different solutions to critical waste-related topics. Key words relevant to waste management designed to focus on previously identified issues within broad databases were used. For example; Scopus, Google scholar or Web of Science were used exhaustively (Brocke et al., 2009). Thirty-two (32) papers were sourced during this traditional literature review.

The selected studies focused on the identification of strategies for waste management or minimisation (Ajayi et al., 2017b), and the categorisation of causes and challenges associated with C&D waste. Many of these studies were based on a specific location; for example China (Wu et al., 2017, Wang et al., 2017, Lu and Yuan, 2010), Jordan (Al-Rifai and Amoudi, 2016), Malaysia (Esa et al., 2017a, Esa et al., 2017b, Umar et al., 2016, Mohd Nasir et al., 2016), Australia (Udawatta et al., 2018, Udawatta et al., 2015), Spain (Villoria Sáez et al., 2014) and India (Arif et al., 2012).

Using an iterative deductive process, it was possible to identify two or three solutions for each topic. The tables below (Table 1, 2 and 3), introduce the solutions identified in the literature for each of the topics. The first table focuses on the organizational topics, the second table focuses on the process topics and the last one on the people topics. These three perspectives (organisation, process and people) were identified by Love et al. (2012). While studying error management, they used organisation, process and people views, in order to explore the mapping of dependencies and interfaces associated with projects. Studying organisation, processes and people facilitates a global view of the issue (Davis et al., 2018).

Table 1: Organizational waste management solutions

Organizational topics	Solutions identified in the literature	References
A -Illegal dumping	A1 - Harmonize state waste legislation	(Wu et al., 2017, Mohd Nasir et al., 2016, Udawatta et al., 2015, Lu and Yuan, 2010)
	A2 - Provide appropriate storage locations for materials	(Al-Rifai and Amoudi, 2016)
	A3. Conduct periodic checks on the use of C&D waste containers – introduction of 'Waste Police Officer'	(Mohd Nasir et al., 2016, Udawatta et al., 2015)
B -Economic values	B1. Develop markets for recycled products	(Mohd Nasir et al., 2016, Udawatta et al., 2015, Wang et al., 2010)

	B2. Maximise on-site reuse of materials	(Ajayi et al., 2017b, del Río Merino et al., 2010, Marinelli et al., 2014)
	B3. Sort, reuse or recycle waste	(Ajayi et al., 2017b, Hassan et al., 2012, Mohd Nasir et al., 2016)
C -Waste management plan	C1. Designate a waste management plan coordinator responsible for ensuring that WM plans are adhered to	(Umar et al., 2016, Udawatta et al., 2015)
	C2. Improve collaboration and communication between stakeholders (especially designers)	(Wu et al., 2017, Esa et al., 2017a)
	C3. Reward those who manage C&D waste effectively and sanction those who fail to do this	(Esa et al., 2017a, Arif et al., 2012)
D - External Waste management policy	D1. Strengthen regulations related to construction waste	(Wu et al., 2017)
	D2. Implement stepwise incentive system (SIS) - an award given to those who produce low levels of waste	(Esa et al., 2017a, Tam and Tam, 2008)
	D3. Implement pay-as-you-throw (PAYT) scheme, which requires construction actors to pay for the waste they produce	(Esa et al., 2017a, Barlaz et al., 2003)
E - Construction stages	E1. Incorporate WM plans into design from beginning of project	(Mohd Nasir et al., 2016)
	E2. Consider environmental aspects during design and tendering stages	(Esa et al., 2017b, Gangolells et al., 2014, Arif et al., 2012)
	E3. Simplify construction site design to enhance waste management process	(Wang et al., 2010)
F - Waste prediction, minimisation and Time management	F1. Prioritize selective disassembly, dismantling or disassembly, instead of demolition	(Esa et al., 2017a, Gangolells et al., 2014)
	F2. Identify construction activities that permit the reuse of materials from site	(Ajayi et al., 2017b, Wu et al., 2017, Al-Hajj and Iskandarani, 2012)
	F3. Accurately predict quantity of materials required to prevent long periods of on-site storage	(Umar et al., 2016)
G - Reporting and benchmarking	G1. Audit waste to monitor and record environmental performance on-site	(Ajayi et al., 2017b, Dainty and Brooke, 2004)
	G2. Set waste targets for sub-contractors	(Esa et al., 2017a, Yean Yng Ling and Song Anh Nguyen, 2013)
	G3. Utilise off site manufacturing to reduce waste	(Udawatta et al., 2015)
H Environment sustainability	H1. Select material that are fit-for-purpose. Prioritize materials that conserve raw materials and mitigate CO2 emissions.	(Esa et al., 2017a)
	H2. Adopt green procurement practice	(Lu and Yuan, 2010)
	H3. Implement life cycle approaches while using materials in building construction	(Udawatta et al., 2015, Arif et al., 2009)

Table 2: Process waste management solutions

Process topics	Solutions identified in the literature	References
J - Waste Bin Size and Types and Site Constraints	J1. Plan the number and size of containers needed for each activity	(Villoria Sáez et al., 2014)
	J2. Allocate space on site for management of C&D waste	(Esa et al., 2017a, Arif et al., 2012)
	J3. Set up temporary bins at each building zone	(Jingkuang and Yousong, 2011)
K - On-site Sorting and Sorting station	K1. Perform on-site segregation of each waste category	(Esa et al., 2017a, Gangolells et al., 2014)
	K2. Provide suitable plant and equipment (e.g. mobile crusher) on-site	(Esa et al., 2017a, Gangolells et al., 2014, Wang et al., 2010)
	K3. Provide user friendly waste categorization or chart	(Villoria Sáez et al., 2014)
L - Supply Chain Management	L1. Reduce design changes and change orders during construction stage	(Ajayi et al., 2017b, Al-Hajj and Iskandarani, 2012, Umar et al., 2016, Mohd Nasir et al., 2016, Al-Rifai and Amoudi, 2016)
	L2. Establish user friendly product market links	(Mahpour, 2018, Ajayi et al., 2017a)
	L3. Launch/innovate diverse by-product applications	(Mahpour, 2018, Ajayi et al., 2017a)

Table 3: People waste management solutions

People topics	Solutions identified in the literature	References
M - Behaviours	M1. Include waste management behaviour as part their KPI	(Silva et al., 2017)
	M2. Monitor supervisors' and labourer's attitudes	(Esa et al., 2017a, Yean Yng Ling and Song Anh Nguyen, 2013)
N - Bin availability	N1. Allocate bins for specific materials	(Ajayi et al., 2017b)
	N2. Distribute small containers in working areas	(Villoria Sáez et al., 2014)
P - Knowledge Experience Training	P1. Promote awareness and training on waste management	(Yean Yng Ling and Song Anh Nguyen, 2013, Esa et al., 2017b, Udawatta et al., 2015)
	P2. Provide / facilitate WM vocational training	(Mohd Nasir et al., 2016, Udawatta et al., 2015)
Q - Mutual Obligation	Q1. Provide a written contract among sub-contractors and workers, supervisors of construction site stating their obligations in adhering to the on-site WM plan	(Esa et al., 2017b, Li and Yu, 2011, Mohd Nasir et al., 2016)
	Q2. Build relationships among stakeholders	(Esa et al., 2017a, Gangolells et al., 2014, Udawatta et al., 2015)
R - Roles & Responsibilities	R1. Avoid confusion among supervisors and labourers as to how to manage waste	(Esa et al., 2017a, Arif et al., 2012)
	R2. Make sub-contractors responsible for waste disposal	(Domingo et al., 2009, Ajayi et al., 2017b)

Research Methodology

A panel of experts from within the construction waste stream was selected to rank the solutions identified in the literature and then to participate in focus groups to deliberate on the results.

Other studies successfully used similar methodologies to identify an optimal solution. For example, in a study about the education of caregivers, Ohns (2019) asked focus group participants to rank five methods of education and then to discuss the reasons for the rankings. This methodology helped them understand caregivers' needs. In another study on knowledge translation (Slaughter et al., 2017), a ranking exercise and focus groups allowed the identification of the best knowledge translation intervention. Accordingly, this research adopted a similar methodology.

To be part of the expert panel, participants had to satisfy these three criteria:

1. Broad experience of construction project delivery in NSW, Australia;
2. Comprehensive knowledge of C&D waste management, procedures and policies;
3. Be part of the waste stream supply-chain.

Ranking of solutions

First, the list of solutions identified in the literature review was provided to the participants in the study. The participants were asked to rank the different solutions using Survey Monkey. 13 participants answered the survey.

The survey also allowed them to add new solutions to their ranking and to justify their choice if necessary. Ranking all the solutions, instead of only choosing the best one had the advantage of providing information on the relative position of each solutions (Burns and Conchie, 2013).

The ranking was anonymous and individual prior to focus groups. Being able to answer anonymously helped the participant to give an opinion freely (Giannarou and Zervas, 2014).

The focus groups

The results of the ranking were then aggregated and presented to the panel during subsequent focus groups. Three focus groups were conducted in order to limit the number of participants per group and to allow everyone to contribute. There were 4 participants in the first group, 4 in the second and 3 in the third. Participants were asked to discuss the solutions and to collectively decide on the optimal solution. Focus groups allow researchers to facilitate interactions between participants while maximising the amount of quality information gathered in a short amount of time. The facilitators' role was to make sure the discussion was focused on the topic and that the group was trying to get to a consensus. This can work by an association of ideas, meaning that one intervention that leads to the next and would help in the formulation of different understandings. This deeper discussion improved knowledge of the topic investigated (Acocella, 2011).

During focus groups, it was important to avoid one participant having too marked an impact on discussions. Hallowell and Gambatese (2010) suggests that bias can occur if one group member dominates the debate. To avoid this situation, it was recommended that groups were homogenous, comprised of individuals with the same level of expertise (Acocella, 2011). However, this did not mean that every individual should share the same opinion.

Ranking and Focus group results

The results below report the ranking exercise and pivotal discussion during the three focus groups.

Illegal dumping

The ranking exercise before the focus groups classified "A1 - Harmonize state waste legislation", as a solution to illegal dumping.

In all focus groups, respondents agreed that harmonised legislation between the different states and between the different councils would help decrease illegal dumping. With non-harmonised legislation, construction companies are tempted to dump their waste in locations with lower fees. The three groups all concluded that the factor "A1 - Harmonize state waste legislation" was a key factor to decrease illegal dumping. The groups also discussed the factor "A2 - Provide appropriate storage locations for materials" and agreed it was also a point of interest, however they agree that it is often not practical to dedicate large spaces on a construction site to optimise waste storage.

Economic values

Respondents ranked the factor "B1. Develop markets for recycled products" just above "B2. Maximise on-site reuse of materials". In the focus groups, these two factors also seem to be identified as improving the economic value of waste management. Respondents explain that in order for companies to embrace waste management, it should be cost neutral or profitable. One participant explained: "plasterboard and stuff like that, there's just not a market for it. An inability for us to be able to make that viable". Respondents also provided the example of steel, aluminium and concrete markets which are profitable and encourage recycling of these materials. Considering maximising on-site reuse of materials, the same issue was identified by the participants, being construction companies, in as much as they would only consider it if profitable. An example of this was provided. "Recycling plasterboard […], if you could, and it cost you less than dumping it, you'd definitely do it". Both factors were considered interesting in the different discussions but concerns about viability were raised.

Waste management plan

The two first ranked factors were "C1. Designate a waste management plan coordinator responsible for ensuring that WM plans are adhered to" and "C2. Improve collaboration and communication between stakeholders (especially designers)". In the discussion when considering a waste management plan coordinator, the same issues of viability were raised. Respondents agreed, "It depends on the project as to whether or not it's going to be viable to have that person". One participant suggested that the viability of having a coordinator was contingent on the person chosen to be the coordinator: "Whether there's a financial benefit there or not depends how innovative the waste coordinator is." Two out of the three groups actually agreed that collaboration and communication could lead to a better waste management plan: "if you're working with stakeholders that you've developed that relationship with, you can sit down and design that waste management plan together […] that becomes efficient, therefore cheaper." "Collaboration could be the first choice. Speaking with - like you said, the directors; upper management - speaking with the waste management companies and all the stakeholders and developing a plan to recycle in an efficient way." Represented a pertinent example as provided.

External Waste management policy

The factor "D1. Strengthen regulations related to construction waste" was ranked higher than "D2. Implement stepwise incentive system (SIS) - an award given to those who produce low levels of waste." In the focus groups, three different opinions appeared concerning regulation. Some participants believed that regulations were strong enough: "I think we're over-regulated now", "I don't want to really hear of more regulation either". Other believed that regulations should incentivise rather than punish "I hate regulations that knock an organisation around or whatever. The stick approach regulation - hate it. Better to have regulation that encourages people." An example was provided regarding asbestos management: "All those little contractors that are putting asbestos in plastic and carting it all over the place; they get penalised by a higher waste levy fee. It should be encouraged; they should be paid to manage it." The final opinion emerging from the focus groups was that fines should be increased so companies could not prefer the fine to following the law: "Strengthening regulations is a bit of no brainer isn't it for companies that operate within the law".

In summary, participants agreed with an incentive system; however, they believed it should be a financial incentive: "So okay if you have 10 per cent of your materials in that building that's, you can prove it's recycled, you get some sort of rebate. That may work." "The financial rewards; the carrot and the stick, yeah." Noteworthy, this topic received less discussion than the first factor on legislation.

Construction stages

The primary factor ranked by the panel was "E1 - Incorporate WM plans into the design from the concept phase of the project" above "E2 - Consider environmental aspects during design and tendering stages".

During the focus groups however, the second factor was discussed more than the first and the two factors were occasionally convoluted. Participants agreed that waste management plans should be designed at the start of the project, however the same worry about viability was raised. "If you could sit there at the start of your project and estimate how much construction waste you're going to have. If you could estimate that you could put a dollar against it. If you can model to reduce it by bringing in other things, then you could make informed decisions".

In two of the three focus groups, it was agreed that if the client required waste management strategies at tendering for a project, and that this aspect was weighted in selection criteria highly enough, then construction companies would follow. This once again emphasises viability. If the client makes waste management a priority, then waste management can happen. An example was offered;

"It's generally based on what the client is saying they want to see, so if the client says that they want some sort of Green Star outcome, or they want to see certain levels, certain percentages of recycled products in the job, […] it's about what their expectations are."

In the last focus group, they believed that at the tendering phase it was already too late to have a positive impact on waste management as most of the design has already been decided. "Because I'd say for all of us being with the larger companies, by the time we actually get to tender it, the products are already locked in."

In every group, they agreed that environmental aspects should be considered during the design. "You know when they design stuff, they should consider what the standard formats of the material are that come out. So, whether it's gyprock sheets or cladding materials and actually design things so that they take the full sheets. You're not cutting off and throwing…" One group discussed modular design, and suggest, "One of the biggest things that could reduce waste would be modular construction". "I think last time I ended up with about three per cent waste. Because they had, like even like just steel stud, they had a roll former. You can see it was cutting cost."

Design was seen by the focus groups as an important way to avoid waste.

Waste prediction, minimisation and Time management

"F1. Prioritize selective disassembly, dismantling or disassembly, instead of demolition" was ranked first before "F2. Identify construction activities that permit the reuse of materials from site".

Once again, money and viability associated with the solutions was the primary issues discussed. Dismantling and disassembly can be a lot more expensive that simple demolition, and reuse of materials is not always possible or worth the effort, economically. “Say that machine's worth $150, $180 an hour. If you had a team of three that's worth $250 an hour. The machine would pull apart virtually a hundred times more than what we could pull apart as a team in a day. If you said, okay I could have one machine pulling it apart or I need a hundred guys”. If you had to actually reuse materials, and you look at the time and the cost you can say, okay it's cheaper as an end outcome to actually get new materials. If there were some incentives or you know, it may be a different story”. “The only hard thing with maximising on-site reuse is just space and time - Which is dollars.”

However, some participants were able to provide examples where their company did reuse materials: “We had a big road and we crushed it all and reused it just for access ways around site.”

The focus groups understood the ideas and their potential, but inevitably explained that money and viability associated with various solutions would always come first in the current environment.

Reporting and benchmarking

In commentary associated with reporting and benchmarking, three factors were of equal priority in the ranking exercise: “G1. Audit waste to monitor and record environmental performance on-site”, “G2. Set waste targets for sub-contractors” and “G3. Utilise off site manufacturing to reduce waste”.

According to the participants’ factors G1 and G2 were linked, as to be able to set targets a good picture of the current situation and associated audits were useful. “A lot of steps that need to be done before you get to setting waste targets and sub-contractors. You have to track their waste first.” “I guess reporting is always holding people accountable for whatever they’re committed to.” “Well from a benchmarking perspective you need to audit the waste if you want to understand what you've done on one project to try to better it on another.”

Two out of three focus groups discussed G3 and agreed that it was a good process to reduce and manage waste. “It’s just easier to control waste in a controlled environment rather than an active construction site.” “I tend to think generally, anything that's built off-site on a modular […] tends to reduce waste. Probably about pre-cast concrete and things like that, they're not doing the formwork and stuff on site, so that's a big waste creator.”

Environmental sustainability

The first factor ranked for environmental sustainability was “H1. Select material that are fit-for-purpose. Prioritize materials that conserve raw materials and mitigate CO2 emissions followed by “H2. Adopt green procurement practice”.

Respondents raised two issues for the use of green materials or recycled materials. The first issue was cost, and the second was that recycled materials could not always be relied upon to be 100% pure and clients (governments) did not want any material containing deleterious material, asbestos for example, even if the proportion was deemed safe. “Once again it becomes that economical solution. If you've got a green solution that's the same price, you can all go green. If your green solution was 10 per cent more, you wouldn't go your green solution. I don't think any of our developers, whether it be government or private enterprise, […] want to pay extra”. Further “it's within safe limits, but they're just arbitrarily saying no and I think if you want to drive the use of recycled products there needs to be some sort of acceptance that it's not going to be pure”.

Green procurement practise appeared to be a good option as the focus groups explained. They would “go green” if it were a viable option or if the client specified it. However, the group suggested the client should accept the extra costs for the green solutions. An example was provided;

“if the client tells me that they want to use a certain material, then that's what I'll do.” “A lot of this does go back to the client's expectations and I guess the government's got to lead the way”. “I don't think any of our developers, whether it be government or private enterprise, […] want to pay extra. They do want to be green, but they don't want to pay substantial prices to be green.”

Waste Bin Size and Types and Site Constraints

“J2. Allocate space on site for management of C&D waste” was ranked first before “J1. Plan the number and size of containers needed for each activity”.

Space on site had been one of the important topics during the focus groups, and participants agreed that adequate space would make waste management easier and more efficient. However, on many construction sites there was just not enough room to allocate to waste management. “You need more space outside the construction site because the construction site's too busy.”

The companies estimated the amount of waste per stage of the construction, but it was described as complex. To be very precise was countered due to unforeseen events often happening on construction sites. An estimation could help to understand the space needed for waste management. One participant suggested that waste management companies could give their expertise to construction management companies about bin sizes, location and turnover cycles.

On-site Sorting and Sorting station

The first factors were “K1. Perform on-site segregation of each waste category” followed by “K2. Provide suitable plant and equipment (e.g. mobile crusher) on-site”.

During the focus groups discussions, participants were not convinced by these factors. They explain that the waste management culture was not strong enough at the present time and some employees tend to throw waste in a proximate bin rather than determine the correct one. This contamination is a cost for the company, increasing the substantial cost of requiring several bins. In addition, the issue of room on the construction site was raised in the discussions. Suggesting;

“We've already talked about on site segregation being a cost. And […] contaminating […]. Because people just throw rubbish into anything.”

“You can have another few more bins, but you've got to have the right culture. Better to take that bin […] to someone with the technology to sort it out.”

In consideration of having the right plant on site, it was not clear to participants what kind of plant was the focus of the research. Mobile crushers, sensors to know when the bin is full, magnets to separate metals from other waste were the technologies identified during the discussions. However, some participants said that the proper equipment is very expensive. “[…] materials handling at those transfer stations - the proper ones - they're multimillion-dollar bits of gear.”

Supply Chain Management (SCM)

Regarding SCM, three factors were ranked equally; “L1. Reduce design changes and change orders during construction stage”, “L2. Establish user friendly product market links” and “L3. Launch/innovate diverse by-product applications.”

L1 was the topic most discussed. The panel considered that they had to deal with design changes every day which would consequently cause more waste. This solution was suggested as aspirational, but unrealistic. “it's the ideal world”, “it’s the dream”. In two of the focus groups, they agreed that the factor L3 was a promising one. “If you've got a use for a waste stream, then that changes it to a resource”. “Then you could put that in a bin knowing as a head builder you take that somewhere and you get money for it because someone's chasing it”.

Behaviours

In terms of behaviour factors, “M1. Include waste management behaviour as part their KPI” was ranked higher than “M2. Monitor supervisors’ and labourer’s attitudes”.

There was strong agreement on the positive possible aspects of including waste management in an employee’s KPIs. Participants intimated that it would show environment as a priority for the company. If every employee, supervisor, manager were evaluated on waste management performance against identified and measurable targets then it would “becomes a company value”. It worked well as an incentive. One respondent provided an analogy with safety: “It's like safety. Until you align safety KPIs with workers actions your safety stats didn't go down and your safety didn't improve, […]”

Bin availability

The factor N1. “Allocate bins for specific materials” was ranked preceding N2. “Distribute small containers in working areas”. The discussions showed that both were needed on a productive construction site. Getting small bins closer to the work to then feed them in to the bigger bins. Some of the respondents suggested it was a cost benefit for the company to sort their waste: “Yeah and cost benefit for you, it's concrete, it's timber, it's steel. You know the logistics of that you can manage, there's no problem”. Other respondents thought it was better to get all the waste together in one bin and let specialists take care of the sorting: “Whereas if we're still putting it in a bin the customer doesn't have to worry about it. If we go to a proper facility like [company name withheld] and then they're just stockpiling stuff, they get the benefit out of the logistics. They get the benefit out of the markets”. An issue with the small bins is that they would fill very fast.

Knowledge Experience Training

On this topic, “P1. Promote awareness and training on waste management” was ranked above of “P2. Provide / facilitate WM vocational training”. General training of all employees was ranked first as it was suggested it could help change culture and provide more employee awareness. “If you want to really develop cultural change it's a combination of that awareness and training with that leadership from the business itself.” In all focus groups, respondents agreed that training was key. If workers do not know how to manage waste properly, then they cannot do it. Vocational training was less thought-provoking to the respondents as it was suggested it took a lot of time and commitment and is not always worth it. As before, one of the respondents made a comparison with safety: “We don't all have to go out and do Certificate 4 in WHS…”

Mutual Obligation

The factor “Q1. Provide a written contract among sub-contractors and workers, supervisors of construction site stating their obligations in adhering to the on-site WM plan” was ranked higher than “Q2. Build relationships among stakeholders”. Both criteria were important. Building a good relationship with all stakeholders with communication on waste management would help to increase awareness on the topic and implant the culture in the project. However, some respondents thought that contracts could make all that more efficient. “It's that stick, so if the client gives me a contract that says I've got to do x, y, z, then I do it. If I have a similar expectation in my contract with my subbie, then I can make him accountable to achieving that so”.

Roles & Responsibilities

The factor “R1. Avoid confusion among supervisors and labourers as to how to manage waste” was ranked first before “R2. Make sub-contractors responsible for waste disposal”. However, R2 was discussed at more length during the focus groups. All the groups agree that avoiding confusion was important: “clear and concise information, no confusion”. However, there was more discussion on the second factor. Some of the respondents believed it would be complex to organise: “It could either be like one subbie that won't provide a bin and they'll be the one that upsets everybody else by putting their rubbish in theirs or something”. When other respondents thought it was appropriate if each sub-contractor were to take care of their own waste

Discussions

The literature allowed the identification of a list of factors that were ranked and discussed by experts in construction waste management in NSW, Australia (Table 1, 2, 3). During focus groups, experts discussed the different factors and explained why in their opinion one factor was better than another. Interestingly they also discussed why some factors were good from a theoretical perspective but were not used in practise. The following areas were ubiquitous in the discussions.

The first area of discussion was money. Construction is a very competitive industry (Jaśkowski and Czarnigowska, 2019) and every participant in the focus group without exception explained that money was the main obstacle to the implementation of innovative solutions for waste management. Indeed, it would be costly to implement change in their company. For example, in order to implement on site sorting, training should be provided to managers and then to the teams. Investment in new specific bins is required, and a possible loss of productivity could manifest at the commencement of revised processes while workers become familiar with the change. Construction companies would require compensation for these additional costs one way or another. If no solution to recover these costs were identified, then it appears from the foregoing discussion a construction company would tend to not implement this on-site sorting. Indeed, innovation in the construction industry is driven by maintaining competitiveness (Thorpe et al., 2009).

Respondents valued specific factors, for example; “B1. Develop markets for recycled product” (Table 1), because if there was a market for recycled products then it would be easier for construction companies to make recycling viable. This would be a way to recover the costs of recycling the product. Other factors , for example “Maximise on-site reuse of materials” (Table 1) or “Select material that are fit-for-purpose or prioritize materials that conserve raw materials and mitigate CO2 emissions” (Table 1) were described as good ideas in theory but hard to implement in practise, without costing money that the construction company could not recover in short term traditional tendering. Suggesting that more relational style through integrated project delivery (IPD) may make a difference (Walker & Rowlinson, 2019). Respondents agreed that most employees are willing to participate, do the right thing, and make efforts for waste management or the environment in general. However, if managing waste is more expensive than not taking any action, then no action is going to be taken. An extra incentive is needed for companies to take the extra step toward an efficient waste management system. Once again, an approach associated with IPD following Walker & Rowlinson (2019) is supported.

The carrot and the stick, a combination of rewards and penalty, is the solution emerging from the focus groups. External waste management policies could motivate construction companies to put more effort in waste management. Rewards can come from the client for example. The client whether it is the government, or a private entity can have a strong impact on waste management. Construction companies would follow the requests of the client, so if the client is willing to get better waste management or better environmental solutions then the construction management companies are going to put effort in it. “A lot of this does go back to the client's expectations and it appears from the research that governments should lead the way. “We do a lot of government work so they have to lead the way.” Procurement will have an impact and if the government could decide to require a minimum level of waste management from companies in order to be allowed to answer public tenders. Another possibility to show the importance of waste management would be to include it in the selection criteria with a non-negligible criteria weighting. Rewards can also come from the government deciding to incentivize the private sector to invest in waste management.

The stick or penalties can come from more regulations, motivating the construction companies to follow the rules on waste management in order to avoid financial consequences. However, it is important for governments to be prudent with legislation to avoid stifling innovation from within private companies. A good balance between rewards and penalties will help the private sectors to improve waste management (Walker & Rowlinson, 2019).

Another key point identified during this research in NSW and Australia is harmonisation of regulations (Table 1). In NSW, companies pay a levy for each tonne of waste sent to landfill, when until July 2019 the neighbouring state Queensland had no levy in place (Queensland Government, 2019). As opposed to decreasing the amount of waste, companies were tempted to send their waste away to avoid levies. The participants also identified the same issue at council level inside NSW. Harmonisation of the regulation at a federal level would deter construction companies from sending their waste away. This action would also serve as motivation to find a solution to decrease the amount sent to landfill.

A further area of notable discussion was culture. Organisational culture can be commonly defined as “the way we do things around here” (Lundy and Cowling, 1996) or more precisely “the deeply seated (often subconscious) values and beliefs shared by personnel in an organisation” (Martins and Terblanche, 2003). Several times the respondents explained that waste management is not embedded in the culture of construction companies at present. One respondent made the comparison with safety and explained that since safety is part of the organisational culture, adopting the right behaviour has been natural to many. This is because organisational culture completes management by playing a role in influencing workers behaviours (Martins and Terblanche, 2003). In order to implement some of the factors e.g. “K1. Perform on-site segregation of each waste category” (Table 2) employees need the knowledge and the determination or habit to correctly sort the waste. It has to become a natural behaviour. In order to include waste management or more generally environmental betterment in the organisational culture, the company should first articulate clearly their corporate strategy and vision concerning the environment. Then the organisational leaders should reinforce the culture by acting on the values (Sinclair, 1993). Some of the factors identified would be useful for managers to support the waste management culture like “Include waste management behaviour as part employees KPI” (Table 3) or “Promote awareness and training on waste management” (Table 3) for example. Audits on waste management (G1) (Table 1) could also serve to make employees aware of a strong waste management culture.

Technology was also discussed as a way to decrease waste generation. Participants spoke about off-site construction and even more about modular construction as a good way to decrease waste generation. It served as an efficient way to decrease waste as it considered the waste issue at its source. Wang et al. (2015) identified the use of prefabricated components (or offsite construction, Factor G3) was the best way design could affect waste reduction. The two other solutions were fewer design modifications (factor L1) and waste reduction investments. Building Information Modelling (BIM) is also a technology that can help decreasing waste generation. It allows a perfect knowledge of quantity and volumes requested for every material, and is useful to design out waste (Akinade et al., 2018). This knowledge gives a good insight into the exact quantities to order or prepare in order to avoid as much waste as possible.

Other types of technology development can also help waste management. As an example, currently most waste segregation has to be done manually. Development of technologies able to identify and automatically sort waste could help companies to save time and money for waste management.

Conclusion

C&D waste, as well as recycling, has received attention in recent research. However, it is apparent that this aspect of the construction industry remains immature. NSW waste management has been a focus since 2014 for the government. Different policies have been updated and improved. Yet, it has been shown that there can be a difference between policy intent and policy outcome. It is important to use different strategies to improve waste management in the state.

The literature review in this paper highlights the organisational, process and people solutions identified in academic literature to improve waste management in the construction industry. The study, gathering data from specialists from the construction and demolition waste stream allowed barriers and solutions to improve waste management to be identified. The financial implications of waste management should be better managed. High competition and tight margins on construction projects are barriers for companies who do not want to spend money to manage waste. Appropriate legislation could incentivise improvement, as well as clients' engagement in waste management via IPD techniques. Finally, companies could work on organisational culture to make change toward waste management easier and invest on technology.

Further studies should focus on the technologies enabling easier waste management (for example, automation of waste sorting), and on technologies that help decrease waste generation (BIM, modular construction). More attention should be given to the use and reuse of construction materials.

The study was conducted in the Australian context, more specifically NSW, so additional studies could test the possible generalisation of the findings to other countries or regions. The NSW government as well as NSW construction companies and waste management companies will be able to use the findings of this study to understand where their focus should be in order to improve waste management strategies.

Ethics Approval

This project has been approved by the Human Research Ethics Committee from the University of Newcastle, Approval No. H-2017-0053

Acknowledgement

The authors of the paper acknowledge the generous support of the NSW Environmental Trust. Without their financial support, the research project reported herein would not have been possible.

References

Acocella, I. 2011. The focus groups in social research: advantages and disadvantages. *Qual Quant,* 46**,** 1125-1136.

Ajayi, S. O., Oyedele, L. O., Akinade, O. O., Bilal, M., Akaka, H. A. & Owolabi, H. A. 2017a. Optimising material procurement for construction waste minimization: An exploration of success factors. *Sustainable Materials and Technologies,* 11**,** 38-46.

Ajayi, S. O., Oyedele, L. O., Bilal, M., Akinade, O. O., Alaka, H. A. & Owolabi, H. A. 2017b. Critical management practices influencing on-site waste minimization in construction projects. *waste management,* 59**,** 330-339.

Akinade, O. O., Oyedele, L. O., Ajayi, S. O., Bilal, M., Alaka, H. A., Owolabi, H. A. & Arawomo, O. O. 2018. Designing out construction waste using BIM technology: Stakeholders'expectations for industry deployment. *Journal of Cleaner Production,* 180**,** 375-385.

Al-Hajj, A. & Iskandarani, T. 2012. Reducing Waste Generation on the UAE Construction Sites. . *7th International Conference on Innovation in Architecture, Engineering & Construction, São Paulo, Brazil*.

Al-Rifai, J. & Amoudi, O. 2016. Understanding the key factors of construction waste in Jordan. *Jordan Journal of Civil Engineering,* 10.

Arif, M., Bendi, D., Toma-Sabbagh, T. & Sutrisna, M. 2012. Construction waste management in India: an exploratory study. *Constr Innov Inf Process Manag,* 12**,** 133-155.

Arif, M., Egbu, C., Haleem, A., Kulonda, D. & Khalfan, M. 2009. State of green construction in India: drivers and challenges. *J Eng Des Technol* 7**,** 223–234.

Barlaz, M., Cekander, G. & Vasuki, N. 2003. Integrated solid waste management in the United States. *J Environ Eng,* 129**,** 583-584.

Brocke, J., Simons, A., Niehaves, B., Reimer, K., Plattfaut, R. & Cleven, A. 2009. Reconstructing the giant: On the importance of rigour in documenting the literature search process. *ECIS 2009 proceedings*.

Burns, C. & Conchie, S. 2013. Risk information source preferences in construction workers. *Employee Relations,* 36**,** 10-81.

Commonwealth of Australia 2018. Environment and Communications References Committee - Never waste a crisis: the waste and recycling industry in Australia. *In:* SENATE, T. (ed.). Parliament House, Canberra, Australia.

Dainty, A. R. J. & Brooke, R. J. 2004. Towards improved construction waste minimisation: a need for improved supply chain integration? . *Struct. Surv. ,* 22**,** 20-29.

Davis, P., Sher, W., Tang, P. & Newaz, M. T. 2018. Factors affecting waste management on New South Wales construction sites. *COBRA 2018.* London, United-Kingdom.

Del Río Merino, M., Izquierdo Gracia, P. & Weis Azevedo, I. S. 2010. Sustainable construction: construction and demolition waste reconsidered. . *Waste Management & Research,* 28**,** 118-129.

Domingo, N., Osmani, M. & Price, A. D. 2009. Construction waste minimisation in the UK healthcare industry. *In:* DAINTY, R. J. (ed.) *25th Annual ARCOM Conference.* Albert Hall, Nottingham: Association of Researchers in Construction Management.

Esa, M. R., Halog, A. & Rigamonti, L. 2017a. Developing strategies for managing construction and demolition wastes in Malaysia based on the concept of circular economy. *Journal of Material Cycles and Waste Management,,* 19**,** 1144-1154.

Esa, M. R., Halog, A. & Rigamonti, L. 2017b. Strategies for minimizing construction and demolition wastes in Malaysia. *Resources, Conservation and Recycling,* 120**,** 219-229.

Gangolells, M., Casals, M., Forcada, N. & Macarulla, M. 2014. Analysis of the implementation of effective waste management practices in construction projects and sites. *Resour Conserv Recycl,* 93**,** 99-111.

Giannarou, L. & Zervas, E. 2014. Using Delphi technique to build consensus in practice. *International Journal of Business Science and Applied management,* 9**,** 66-82.

Hallowell, M. & Gambatese, J. 2010. Qualitative research: Application of the Delphi Method to CEM Research. *Journal of Construction Engineering and Management,* 136**,** 99-107.

Hassan, S. H., Ahzahar, N., Fauzi, M. A. & Eman, J. 2012. Waste management issues in the northern region of Malaysia. *Procedia-Soc. Behav. Sci,* 42**,** 175-181.

Jaśkowski, P. & Czarnigowska, A. 2019. Contractor's bid pricing strategy: A model with correlation among competitors' prices. *Open Engineering,* 9**,** 159-166.

Jingkuang, L. & Yousong, W. 2011. Establishment and application of performance assessment model of waste management in architectural engineering projects in China. *Syst. Eng. Procedia,* 1**,** 147-155.

Li, J. & Yu, K. 2011. A study on legislative and policy tools for promoting the circular economic model for waste management in China. *J. Mater. Cycles Waste Manage. ,* 13**,** 103-112.

Love, P. E. D., Lopez, R., Edwards, D. J. & Goh, Y. M. 2012. Error begat error: Design error analysis and prevention in social infrastructure projects. *Accident Analysis and Prevention,* 48**,** 100-110.

Lu, W. S. & Yuan, H. P. 2010. Exploring critical success factors for waste management in construction projects of China. *Resources Conservation and Recycling,* 55**,** 201-208.

Lundy, O. & Cowling, A. 1996. *Strategic Human Resource Management*, Cengage Learning Emea.

Mahpour, A. 2018. Prioritizing barriers to adopt circular economy in construction and demolition waste management. *Resources, conservation and recycling,* 134**,** 216-227.

Marinelli, M., Dolan, M., Spillane, J. & Konanahalli, A. Material waste in the Northern Ireland construction industry: on-site management, causes and methods of prevention. *In:* RAIDEN, A. B., ABOAGYE-NIMO, E. , ed. 30th Annual ARCOM (Association of Researchers in Construction Management) Conference, 1–3 September 2014 2014 Portsmouth, UK, . 113-122.

Martins, E. C. & Terblanche, F. 2003. Building organisational culture that stimulates creativity and innovation. *European Journal of Innovation Management,* 6**,** 64-74.

Maund, K., Gajendran, T. & Brewer, G. 2018. Key Issues for Implementation of Environmental Planning Policy: Construction Management Practice. *Sustainability,* 10**,** 2156.

Mohd Nasir, S. R., Othman, N. H., Mat Isa, C. M. & Che Ibrahim, C. K. 2016. The challenges of construction waste management in Kuala Lumpur. *Jurnal Teknologi,* 78**,** 115-119.

New South Wales Government 2018. Environmental Planning and Assessment Amendment Act 2017: Public Exhibition Report. *In:* GOVERNMENT, N. S. W. (ed.). Sydney, Australia,.

Nsw Environment Protection Authority 2014. NSW Waste Avoidance and Resource Recovery Strategy 2014-21. *In:* AUTHORITY, N. E. P. (ed.). Sydney, NSW, Australia: Environment Protection Authority.

Nsw Environment Protection Authority 2018. Better Regulation Statement - Protection of the Environment Operations Legislation Amendment (Waste) Regulation 2018. *In:* AUTHORITY, N. E. P. (ed.).

Nsw Environment Protection Authority 2019a. Standard for managing construction waste in NSW - factsheet. *In:* EPA, N. (ed.).

Nsw Environment Protection Authority 2019b. Standards for managing construction waste in NSW. *In:* AUTHORITY, N. E. P. (ed.).

Pickin, J., Randell, P., Trinh, J. & Grant, B. 2018. National Waste Report 2018. *In:* ENERGY, D. O. T. E. A. (ed.).

Productivity Commission 2006. Waste management: Productivity Commission Draft Report. *In:* GOVERNMENT, P. C. A. (ed.). Melbourne, Australia.

Queensland Government 2019. Queensland Waste levy fact sheet.

Silva, A., Rosano, M., Stocker, L. & Gorissen, L. 2017. From waste to sustainable materials management: Three case studies of the transition journey. *waste management,* 61**,** 547-557.

Sinclair, A. 1993. Approaches to Organisation Culture and ethics. *Journal of Business Ethics,* 12**,** 63-73.

Slaughter, S. E., Bampton, E., Erin, D. F., Ickert, C., Wagg, A. S., Jones, C. A., Schalm, C. & Estabrooks, C. A. 2017. Knowledge translation interventions to sustain direct care provider behaviour change in long-term care: A process evaluation. *Journal of Evaluation in Clinical Practice,* 24**,** 159-165.

Tam, V. & Tam, C. 2008. Waste reduction through incentives: a case study. *Build Res Inf* 36**,** 37-43.

Tam, V. W. Y., Le, K. N., Wang, J. Y. & Illankoon, C. 2018. Practitioners Recycling Attitude and Behavious in the Australian Construction Industry. *Sustainability,* 10**,** 1212.

Thorpe, D., Ryan, N. & Charles Michael, B. 2009. Innovation and small residential builders: an Australian study. *Construction Innovation,* 9**,** 184-200.

Udawatta, N., Zuo, J., Chiveralls, K., Yuan, H., Zillante, G. & Elmualim, A. 2018. Major factors impreding the implementation of waste management in australian construction projects. *Journal of Green Building,* 13.

Udawatta, N., Zuo, J., Chiveralls, K. & Zillante, G. 2015. Improving waste management in construction projects: An Australian study. *Resources, Conservation and Recycling,* 101**,** 73-83.

Umar, U. A., Shafiq, N., Malakahmad, A., Nuruddin, M. F. & Salihi, I. U. 2016. Ranking of principal causes of construction waste for malaysian residential project. *Engineering Challenges for Sustainable Future - Proceedings of the 3rd International Conference on Civil, offshore and Environmental Engineering, ICCOEE 2016***,** 163-168.

Villoria Sáez, P., Del Río Merino, M. & San-Antonio González, A. 2014. Success strategies for on-site waste management in spanish construction sites. *Construction and Building Research.*

Walker, D. and Rowlinson, S., 2019. *Routledge Handbook of Integrated Project Delivery*. London, Routledge.

Wang, H., Xiong, W., Wu, G. & Zhu, D. 2017. Public–private partnership in Public Administration discipline: a literature review. *Public Management Review***,** 1-24.

Wang, J., Li, Z. & Tam, V. W. Y. 2015. Identifying best design strategies for construction waste minimization. *Journal of Cleaner Production*, 92**,** 237-247.
Wang, J., Yuan, H., Kang, X. & Lu, W. 2010. Critical success factors for on-site sorting of construction waste: A china study. *Resources, Conservation and Recycling,* 54**,** 931-936.
Wu, Z., Ann, T. & Shen, L. 2017. Investigating the determinants of contractor's construction and demolition waste management behavior in Mainland China. *Waste Management,,* 60**,** 290-300.
Yean Yng Ling, F. & Song Anh Nguyen, D. 2013. Strategies for construction waste management in Ho Chi Minh City, Vietnam. *Built Environ Project Asset Manag,* 3**,** 141-156.

FACTORS LIMITING PERFORMANCE OF THE CONSTRUCTION INDUSTRY: A NEW ZEALAND PERSPECTIVE

James Olabode Bamidele Rotimi[1], Israr Wahid[1], Wajiha Shahzad [1]

[1] School of Built Environment, Massey University, Albany, New Zealand

Abstract

The construction industry plays a significant role in the economic activities of a country. An in-depth understanding of the construction industry is therefore essential, in particular, how businesses within the industry perform and how they combine to shape the growth and development of the national economy. The market in which construction businesses operate is highly complex and competitive. An understanding of the nature of the market is important in determining the performance of construction firms. A review of the literature suggests that in New Zealand, there are peculiar issues and challenges that limit the performance of the construction businesses. An in-depth literature review has been conducted and the data from other sources including from industry reports, government documents and industry surveys has been reviewed to understand these problems. A few rich interviews with subject matter experts have assisted in the collation of perspectives on potential solutions. The research proposes various possible solutions for government, the construction industry and for individual construction firms that will enhance the performance of the industry as whole.

Keywords

Construction industry; Construction firm performance; New Zealand construction industry; New Zealand construction industry problems; New Zealand construction industry risks; Risk-sharing construction;

Introduction

The construction industry is of crucial importance to the economy of any country. It contributes directly and indirectly to various other sectors for example, the manufacturing sector, service sectors and provides various employment opportunities in a country. A healthy performing construction industry can therefore generate various job opportunities, higher wages, and enhanced tax revenues for a country's economy, thus benefiting society as a whole (Vogl & Abdel-Wahab 2014). The literature suggests that the output from construction industries averages around 3-8 % of national GDP for most of the countries worldwide (Arditi & Mochtar 2000). Data from the United Nations Economic Commission for Europe (UNECE) shows a spread of contribution by construction companies to national GDP in Europe from 2-10 % for the year 2018 (UNECE 2019). Hence a good or bad performing construction sector can directly affect the socioeconomic development of a country.

In business performance domain, Neely, Adams and Kennerley (2002) argued that effectiveness and efficiency are important dimensions in understanding business performance. "Effectiveness" refers to the level of stakeholder's satisfaction with the output of an organisation, in relation to their requirements, while efficiency is how economically an organisation meets the requirement of stakeholders. Thus an organisation which meets its objectives economically and efficiently can be considered of better performance in relation to its competitors (Neely 1998). This research therefore conceptualizes 'construction firm performance' as measurement of efficiency and effectiveness of different mechanism adopted to meet the stated objectives of the firms. Some of the possible objectives of construction firms can be high quality of end products, enhanced profit margins and satisfied customers among others (Kagioglou, Cooper & Aouad 2001). The end product of the construction industry is the 'built environment' which can account for around 66-90 % of a nation's wealth (Pearce 2003). Therefore, there has been an increased interest in understanding the dynamics of this industry and to ultimately improve its performance.

The reports by PWC (2016) and Page and Norman (2014) noted that, in New Zealand, the construction industry has a significant effect on the overall economy, more so than any other industry. It is estimated that around 4.6 % and 8 % of GDP in year 2013 and 2015, respectively, was contributed by the construction industry to the New Zealand economy. In year 2015, the construction sector contributed NZ $18.9 billion to New Zealand's GDP. The same reports estimate that NZ $1 invested in construction industry results in around NZ $2.51 to NZ $3.11 worth of economic activity, which is relatively high compared to other industries in New Zealand. This implies that a better performing construction industry has a carryover effect on other industries, such as, the mining, manufacturing sectors and so forth. However, New Zealand's construction industry is also a highly volatile industry and in the last 20 years, the construction sector has shown both a double-digit growth and decline, which is the sign of a highly volatile nature that of an industry and a similar phenomenon is not observed in other sectors of economy (PWC 2016). Official statistics show a strong outlook for the industry, with construction activity of over NZ $300 billion, projected for over the next six years up until 2023 (Ministry of Business Innovation and Employment 2018).

Considering the enormous value of New Zealand's construction industry, there is a need to understand the reasons for its high volatility and the various risks that are involved in the construction business in the country. Hence, improvement in the performance of this sector offers a range of benefits to different stakeholders. For individual firms, this means better profitability for owners and more earning opportunities for the work force, and for end users this means a decrease in construction costs, a better quality in terms of the end product, fewer project delays and more value for money. Recently, a large number of high-profile construction firms have gone bankrupt, which has had a negative effect upon overall industry (Edmund 2018). It is therefore pertinent to explore the problems that the industry is currently facing.

This research aims to identify the critical issues the construction industry in New Zealand currently faces and to explore possible way forward. The scope of this research is to identify issues that pertain to the whole construction industry. In this research the firm and project level issues have not been discussed in-depth.

Study approach

In order to understand the problems in New Zealand's construction industry, the research was conducted in two main phases. In the first phase, an in-depth literature review was conducted. Two powerful search engines i.e., 'Scopus' and 'Google Scholar' were used to search for the relevant literature. The search for the literature was carried out by using the relevant titles and keywords in the search engines. In order to gain more relevant literature in the New Zealand context, different filters, such as, 'subject area' (business, engineering, management), 'document type' and 'keyword', were used in the Scopus search engine. Afterwards, abstracts were scanned to select relevant papers. Various researchers have followed this approach in the construction management literature (Hong & WM Chan 2014; Ke, Wang, Chan & Cheung 2009). A few of the keywords used were, "New Zealand construction industry", "New Zealand construction industry problems", "New Zealand construction industry risks", "construction business risks" and so forth. Although, a few relevant research papers were selected, little success was achieved in finding literature relevant to New Zealand's construction context. Therefore, various Government documents, publications from the Building Research Association of New Zealand (BRANZ), construction industry reports, various construction industry related surveys, construction magazines and newspaper articles were reviewed to understand the specific industry problems. This step enabled the researcher to identify the main problem areas, that the construction industry is currently facing. After developing a preliminary scope of the problem areas, confirmatory interviews were conducted for the purpose of validation. A total of five interviews have been conducted with industry experts who are currently working in New Zealand construction industry and had an experience of 15-20 years in New

Zealand, at various decision-making roles in their respective firms. The profile of the interview respondents is shown in Table 1 below. Semi-structured, face-to-face interviews were conducted to obtain open ended responses from the respondents regarding the issues identified. The data gathered from the interviews was analyzed using thematic analysis, which is considered as an acceptable form of qualitative data analysis. (Dansoh, Frimpong & Oppong 2019; Sattineni & Schmidt 2015). This method is useful for identifying and describing the patterns in the qualitative data (Braun & Clarke 2006). The identified themes were then associated with the problem areas that were highlighted in the first step.

Table 1 Interview respondents profile

Interviewee	Role in organisation	Years of experience
A	CEO	20
B	CEO	20
C	Principle quantity surveyor	15
D	Project manager	20
E	Project manager	15

Study findings and discussion

The literature review revealed that labor and skill shortage, unfair risk allocation, sub-optimal procurement approaches, less economies of scale, low labor productivity and low profit margins, were the main problems the New Zealand construction industry is faced with. In order to confirm or refute the highlighted issues, the interviewees were asked about the question related to each highlighted problem area. The findings are discussed in detail below:

Labor and skill shortage

The construction industry is dealing with labor and skill shortage in many countries including in the UK (Dainty, Ison & Briscoe 2005), Northern Ireland (McGuinness & Bennett 2006) and Australia (McGrath-Champ, Rosewarne & Rittau 2011) and the New Zealand construction industry is also dealing with the same problem of labor and skill shortages. Results from a number of industrial surveys, highlight the issue of the unavailability of skilled labor as one of the main problems hindering the performance of the construction industry. Skill shortage is more pronounced for the design function and other technical skills (PWC 2016). The (AECOM 2019) survey notes that , 43 % industrial practitioners identified the skill shortage as the biggest industry challenge, while 69 % of industrial professionals identified it as the main issue for industry in the Civil Contractors New Zealand (CCNZ) survey (CCNZ & Teletrac Navman 2017). The research report by BRANZ, also highlighted the inability of the industry to attract people with the required level of skills for the construction industry, as one of main hindrances affecting its performance. This is probably based on the fact that there is less job security in the construction sector due to the boom-bust cycle that is one of the usual characteristics of this industry. The same report, however, also observed that, staff retention (an important parameter for skill development) was not adequately monitored by the majority of the firms (Page & Norman 2014).

When the interviewees were asked to give their opinions about labor and skill shortage in New Zealand construction industry, the respondents were of the opinion that small population of the country and huge demand for infrastructure were reasons for the shortage of skilled labor. The shortage of skilled labour can have an impact on overall firm performance from tendering to the project execution stage. Similarly, sometimes there is also the issue of the inability to pass drug tests by personnel who are currently available for work. Commenting on the possible solutions three interviewees held the opinion that employers should go to different countries where adequate skilled labor supply is available and hire employees directly for short and long term or on a project basis based on the model of the construction industry in the gulf states, for example in the United Arab Emirates (UAE), Qatar and so forth. However, such approaches often lead to language barriers. Therefore, in such instances, a supervisor fluent in English and in the primary language of the labour force, should be appointed where possible. Other interviewees opined that small improvements in the workplace setting, such as, the availability of coffee/tea and steps, for example occasional get togethers for employees, can boost the morale and enhance the commitment to stay with a firm/industry, which generally leads to skill enhancement. The (PWC 2016), report also notes that government and industry should work in collaboration by investing jointly for the purpose of upskilling and training the skilled labour force. Also, initiatives could be devised to attract the relevant skilled workforce, such as, project managers from other sectors, for example from manufacturing and so on. Another possible solution could be to relax immigration policies to attract more skilled construction professionals. The same view was shared by industrial professionals during the CCNZ survey (CCNZ & Teletrac Navman 2017).

Unfair risk allocation

The construction business inherently involves more risk due to the involvement of many parties, i.e., designers, consultants, engineers, contractors, suppliers and so forth (El-Sayegh 2008). Similarly, risk allocation is an important concern for the construction industry since there are generally no established rules for the allocation of the risks in construction business. Unfair risk allocation has also been cited as an important factor that is negatively affecting the construction industry (Lam, Wang, Lee & Tsang 2007). This means that the stakeholders who are most able to control the risk do not bear the consequences of this risk. Instead, the risk is transferred to some other stakeholder, who may not be in a best position to mitigate the risk. Generally, most of the risk is transferred to the contractor (Cheung, Ng, Wong & Suen 2003). However, the ability of a stakeholder which is taking the risk, to actually manage that risk affects the overall project performance (Roumboutsos & Anagnostopoulos 2008). New Zealand’s construction industry is also dealing with the problem of the unfair risk allocation to the different parties during the execution of the project (Mbachu & Taylor 2014). The (PWC 2016) report notes that, in New Zealand’s construction industry, there is a trend to pass most of the risk to the supplier/contractor through highly complex contracts (sometimes additional variations of over 100 pages to the standard contract), which leads to the increase in the overall cost of the construction, as the supplier tends to include the costs of the risk in the estimates and this includes the associated legal costs. This same issue is highlighted in the AECOM report that the risk in not equally shared among stakeholders, with the contractors sharing a higher risk as compared to the client. This approach leads to frequent litigation. Sometime high-profile firms have failed for the same reason. Carillion in the UK and RCR Tomlinson in Australia are two recent examples (AECOM 2019). A lot of criticism is also directed at the rule of “joint and several liability”, which states that two or more persons who have caused a particular loss will each be liable for the full extent of the loss. (LawCommison 2011; PWC 2016). This means that the risk is shared by all of the parties involved in the construction, even those who have little control to mitigate it.

Commenting on the question, that how serious the issue of unfair risk allocation, was affecting the performance of construction firms, all the interviewees agreed that risk management deserves significant attention by all the stakeholders as it was hindering the performance of industry as a whole. From discussions it also came to notice that during tendering process, inadequate documents are usually provided by the clients, where it is difficult to completely understand the risks that are involved in the contract. Only a highly skilled team at the contracting firm can foresee such risks and lookout for any clauses which may be detrimental to the firm during the project execution stage. From discussion, it also emerged that most of the contractors were taking an unfair amount of the risks with little understanding of risks. In some cases, only a few problems during project execution exposed them to risks they were unable to mitigate which led them to bankruptcy. The interviewees suggested that, before undertaking a contract, the contractors should properly workout the risks and price them accordingly. Additionally, the clients should try to provide adequate drawings and other relevant documentation so that the scope of the work and the risks involved are clearly understood by all of the stakeholders. The reports (AECOM 2019; PWC 2016) also argued that one of the possible solution around the problem could be partnership, alliancing and collaborative working approaches, which could improve the risk allocation and sharing practices. Similarly, the industry and government can investigate the use of the "Proportionate liability approach", that is frequently used in Australia as a possible alternative to 'Joint and several liability rule'. According to this approach, the liability for the loss is divided among the stakeholders as per their share of responsibility (McNair 2016).

Sub-optimal procurement approaches

The traditional procurement method in construction involves the preparation of the design documents by the client and then various bidders are invited to bid for the project, based on a lump sum contract amount. The bidder with the lowest quoted price is awarded the project. This approach is known as Design-bid-build approach (DBB) (Eriksson 2008). However, this approach often does not lead to the best results in terms of quality, time and the whole life cycle cost for the project (Cheung et al. 2003).

The (AECOM 2019) report argues that the preference for the traditional procurement practices, for example the lowest cost tender bidding, is a significant problem in New Zealand's construction industry. There seems to be too much of a preference on the lowest price contracting method, without proper consideration of the quality or the life cycle costs. A trust deficit is also prevalent among the client and the contractor. The report also estimates that around NZ $50 million per year, is lost due to poor procurement practices and potentially NZ $525 million in cost savings can be achieved over a period of 15 years up to 2030, by using other innovative procurement approaches, such as, design-build procurement methods (DB).

The government sector is one of the biggest clients for the construction industry. However, in order to manage the risk, the government tends to go for the traditional DBB mode of procurement, whereby the contract is awarded to the lowest bidder. However, this is not always the best approach to contracting as is evident from the research (Eriksson & Westerberg 2011; Pesämaa, Eriksson & Hair 2009). Due to the separation of the design and build function, during DBB procurement methods there is a separation of the contractor and design team, which limits the valuable input in terms of the construction management and project execution details (Ruparathna & Hewage 2015). This is especially relevant during a big project, where sometime the designer is unable to understand the practical implications of the project.

Then there is also an issue of using nonstandard contracting practices i.e., custom/ tailored contracts which have additional variations. For example, the Standard Conditions of Contract for Building and Civil Engineering (NZS 3910) is well understood by all industry stakeholders, however any variation that is added leads to uncertainly since such variations can be interpreted in different ways by different stakeholders which may lead to a litigation process and hinder standardization and mass production. This shows that procurement practices have not matured enough in the industry especially for government procurement (PWC 2016).

In order to gain more insight around the problem, the interview respondents were asked about their satisfaction with the procurement approaches currently prevailing in the industry in terms of delivering the value for money. The interview respondents unanimously agreed that procurement practices prevalent in industry were not optimal and should be changed. During the discussions around the issue it also came to notice that sometimes the contractors are underbidding intentionally in anticipation that they would cover the costs with additional work which usually happens during the execution of project and then charge a high premium for those additional works. Therefore, clients should lookout for such practices and should consider other aspects as well before the award of contract such as previous experience of a contractor, satisfied customers and so forth in addition to price. Two interview respondents also opined that the innovative procurement approaches such as Design-build method (DB) and Target cost contracting (TCC), could be a viable alternative to DBB method of procurement for construction firms operating in New Zealand. The target cost contracting (TCC) approach with gain-share/pain-share arrangements, could be followed for big projects, which has been successful in other countries (Chan, Lam, Chan & Wong 2010) while literature points to a number of benefits of Design-build (DB) procurement method. (Ilori & Talukhaba 2017; Ruparathna & Hewage 2015). Industry professionals also feel that the use of standardized contractual documents should be promoted. In addition, it was agreed by all of the interviewees that alliancing /partnership/ public private partnerships are the best ways to achieve value for money. 90 % of the respondents also agreed that partnership approaches are a better alternative to achieve value for money in the (AECOM 2019) survey.

Regulations and associated costs

Regulation and Compliance costs are also perceived as one of the major challenge confronting the industry (AECOM 2019). Accordingly, 31 % respondents considered these costs as one of the major issues, while 42 % considered increasing regulatory compliance costs as one of the main issues for the construction industry (CCNZ & Teletrac Navman 2017). Furthermore, these regulation costs are also considered to be one of the reasons for the high construction costs in New Zealand (AECOM 2019; ANZ 2017; Page & Norman 2014). Usually the regulations are imposed by the government for the betterment of the general public and to manage the business risks for the different stakeholders. For example, the government may implement some laws to promote health and safety practices, ensuring safety for those working in a particular industry or for general public. However, the quality of such regulations can hinder or support the overall performance of industry. The (PWC 2016) report notes that industry stakeholders opine that the government should perform a detailed cost-benefit analysis, before imposing a new regulation, in order to assess its suitability. In addition, regular evaluations should be carried out in order to assess the impact of a regulation, and improvements should be made where needed.

An example of such a scenario could be the analysis of "retention regulations", imposed in 2017, which were intended to reduce losses for the various stakeholders in the case of a firm failure. However, (PWC 2016) report estimates that the new regulation costs to be around NZ $30 million per annum for the industry. This is a significant cost, even more than the total risk it intends to address. The additional costs are ultimately transferred around the entire supply chain, thus increasing the cost of the end product and shrinking the profit margins. Similarly, Health and safety regulations, although of the utmost importance to ensure safe workplaces, have also been criticized for having high compliance costs and confusion around their proper implementation (PWC 2016). In New Zealand, an approval for any type of construction needs to be obtained by building consent authorities (BCAs). This approval process by building consent authorities also needs improvement. The current issues involve delayed approval times, variations in procedures among the various BCAs at the different locations in New Zealand and varying consenting costs (PWC 2016).

When the interview respondents were asked to give their opinions around the quality of rules and regulation for construction industry, the interviewees argued that building codes and health and safety regulations were necessary for a functional building industry. Some interview respondents also felt that it was the responsibility of the construction companies to understand the regulations and how they will affect their business to avoid any unfavorable circumstances. The setting up of special courts to resolve construction related disputes such as, in the UK construction industry was also proposed by some of these experts. The interview respondents also opined that BCAs needed more resourcing in order to improve its functioning. The (PWC 2016) report proposed a similar solution that for better functioning BCAs, more standardized processes across all the BCAs should be implemented, which will help create a more efficient consenting process and a consistent interpretation of the building code.

Economies of scale

The concept of the economies of scale imply that as the operational and production capacity of an organization increases, its efficiency increases (Ambrose, Highfield & Linneman 2005). From the perspective of construction this means that as the volume of the construction work increases, a construction firm is able to deliver better quality products at a reduced price.

The (PWC 2016) report notes that due to the isolated geographic location and the small population, large scale development is often a challenge in New Zealand's construction industry, and thus there is a difficulty in achieving economies of scale. In Australia, the workforce is 7.3 times larger than in New Zealand, enabling it to achieve much better economies of scale. This is especially true for the residential sector, where there is a huge demand, however there are fewer large-scale development opportunities. In comparison, Australia has large brown field development opportunities, while few such opportunities are available in New Zealand. In addition, government procurement policies are also viewed as sub optimal by industrial players, for example Housing New Zealand Corporation, usually divides the large projects in small packages, (possibly to reduce risk), causing a hindrance to achieve economies of scale, which can help in reducing the overall construction costs.

When interview respondents were asked to comment on possible solution to the economies of scale, they were of the opinion that problem with economies of scale will continue to affect the overall industry for some years in the future, as the issue is also related to the low population and the corresponding demand for the infrastructure. A few respondents suggested that the problem could be addressed to some extent by taking advantage of global supply chains for example, by ordering pre-fabricated components or modular buildings from countries where they are available at a cheaper price and hence the advantage of the economies of scale of other countries can be achieved in New Zealand. Some expert also suggested that government can address the problem by initiating a large-scale projects package, instead of dividing large projects, into smaller multiple projects. Such large-scale development opportunities will also attract many international players.

Labor productivity

Official statistics suggests that the productivity in New Zealand's construction industry has not improved considerably over time A 1 % increase in labour productivity for the construction industry translates into an addition of around NZ $139 million in terms of GDP (PWC 2016). The report (Page & Norman 2014) notes that the traditional measure of productivity including labor, capital and multi factor productivity (MFP) has not improved, compared to the demand in the sector. This essentially means that little progress has been made related to worker skill improvement, application of better processes and efficient use of capital. Most of the rise in productivity is due to more labor units (worked hours) compared to the value added to each hour.

However, it appears that industry professionals are now more concerned about the productivity of their firm. The CCNZ survey indicates that over 55 % of businesses are measuring their productivity, which can be further improved (CCNZ & Teletrac Navman 2017). On an individual firm level Jaffe, Le and Chappell (2016), suggest that labor productivity has increased by 1.7 % and MFP by 0.5 % annually, as compared to 0.5 and 0.1 % for the industry over-all.

The interview respondents were asked to comment on current productivity levels in the industry and the possible solution to it, the respondents argued that, in order to improve labor productivity, it should be monitored continuously during the execution of the project and any instances of low productivity from usual practice should be investigated immediately. More innovative approaches to construction, such as, the use of pre-fabrication and 3D printing should be looked into to improve the productivity of the industry. Similarly, a need to invest in training and in the up skilling of the workforce, was also discussed by a few of the respondents. The (PWC 2016) report notes that, too many small players in the industry also hinders the productivity, thus more collaborative working should be promoted.

Low-profit margins

The construction firms in New Zealand are facing the pressure of reduced profit margins (Edmund 2018). Gross margins have reduced across sectors while worker's wages have been increased (Page & Norman 2014). The financial report by Australia and New Zealand Banking Group, estimated the profit after tax to be around 2 % for year 2017 for construction firms in New Zealand, which is quite low (ANZ

2017). In comparison construction companies in Australia are making around 4 % profit after tax (Balatbat, Lin & Carmichael 2010). Similarly, a large number of small firms were not making any profit at all in New Zealand (Curtis & Page 2014). This is quite alarming and a possible predictor of bankruptcy for several firms currently operating in New Zealand. Many high-profile companies such as Ebert and Mainzeal have gone into receivership recently (Edmund 2018).

The interview respondents were asked to comment of finical performance of construction firms in New Zealand. All of the respondents agreed that most of the firms were not making healthy profits due to several reasons. Some of these reasons were preference of the client on lowest price, poor project management practices by contractors, and their inability to understand the risks involved. Similarly, it was also argued by interviewees that many small and medium sized firms were not monitoring their cash flows and other financial indicators and hence were losing money without realizing it. Also, some contractors especially small sized companies were not properly pricing their work efforts and hence are finding it difficult to survive for longer duration. Commenting on possible solutions, some respondents were of the view that contractors should make around 5 % of profit after tax in in order to grow and sustain the business. In addition, the companies should do extensive review of risks involved and price those risk accordingly. Similarly, finical aspects should also be monitored regularly, and good project management practices should be adopted to ensure long term survivability of the business.

Conclusion

This research has explored various problems that the New Zealand construction industry is currently facing. The findings from the literature review and in-depth interviews with industry experts revealed that the labor & skill shortage, unfair risk allocation, problems during procurement, the impact of government regulations, failure to achieve the economies of scale and dwindling profit margins are the main problems affecting the industry. Several possible actions for government, the construction industry and individual construction firms were discussed. Among others few of such possible solutions are providing large scale development opportunities to industry players, a review of the building regulations, understanding and pricing of risk by the contractors. However, this was an exploratory study and more in-depth research will be conducted by the researchers in next phase to assess the impact of each of the issues discussed on the overall performance of construction firms currently operating in the industry. Similarly, more insights will be obtained by conducting questionnaire surveys, case studies and interviews on a larger sample set that includes contractors, sub-contractors, clients and designers who are involved in residential, commercial/industrial, transportation and heavy/civil construction, to understand the unique problems of each of the different sub-sectors.

References

AECOM 2019, *Sentiment Infrastructure And Buildings Construction Survey New Zealand 2019*.

Ambrose, BW, Highfield, MJ & Linneman, PD 2005, 'Real estate and economies of scale: the case of REITs', *Real Estate Economics*, vol. 33, no. 2, pp. 323-50.

ANZ 2017, *New Zealand Construction Residential & Non-Residential Market Update*, Australia and New Zealand Banking Group.

Arditi, D & Mochtar, K 2000, 'Trends in productivity improvement in the US construction industry', *Construction Management & Economics*, vol. 18, no. 1, pp. 15-27.

Balatbat, MC, Lin, Cy & Carmichael, DG 2010, 'Comparative performance of publicly listed construction companies: Australian evidence', *Construction Management and Economics*, vol. 28, no. 9, pp. 919-32.

Braun, V & Clarke, V 2006, 'Using thematic analysis in psychology', *Qualitative research in psychology*, vol. 3, no. 2, pp. 77-101.

CCNZ & Teletrac Navman 2017, *Construction Survey 2017*.

Chan, DW, Lam, PT, Chan, AP & Wong, JM 2010, 'Achieving better performance through target cost contracts: The tale of an underground railway station modification project', *Facilities*, vol. 28, no. 5/6, pp. 261-77.

Cheung, S-O, Ng, TS, Wong, S-P & Suen, HC 2003, 'Behavioral aspects in construction partnering', *International Journal of Project Management*, vol. 21, no. 5, pp. 333-43.

Curtis, M & Page, I 2014, *Small construction firms in New Zealand*, BRANZ.

Dainty, AR, Ison, SG & Briscoe, G 2005, 'The construction labour market skills crisis: the perspective of small–medium-sized firms', *Construction management economics*, vol. 23, no. 4, pp. 387-98.
Dansoh, A, Frimpong, S & Oppong, GD 2019, 'Exploring the dimensions of traditional authority influencing stakeholder management at the pre-construction stage of infrastructure projects', *Construction Management and Economics*, pp. 1-18.
Edmund, S 2018, 'Razor-thin margins push New Zealand construction firms over the edge', *STUFF*.
El-Sayegh, SM 2008, 'Risk assessment and allocation in the UAE construction industry', *International Journal of Project Management*, vol. 26, no. 4, pp. 431-8.
Eriksson, PE 2008, 'Procurement effects on coopetition in client-contractor relationships', *Journal of construction engineering and management*, vol. 134, no. 2, pp. 103-11.
Eriksson, PE & Westerberg, M 2011, 'Effects of cooperative procurement procedures on construction project performance: A conceptual framework', *International Journal of Project Management*, vol. 29, no. 2, pp. 197-208.
Hong, Y & WM Chan, D 2014, 'Research trend of joint ventures in construction: a two-decade taxonomic review', *Journal of facilities management*, vol. 12, no. 2, pp. 118-41.
Ilori, BO & Talukhaba, AA 2017, 'Evaluating the practice of the design-build procurement method in South Africa', *International Journal Of Construction Supply Chain Management*, vol. 7, no. 3, pp. 110-23.
Jaffe, AB, Le, T & Chappell, N 2016, 'Productivity distribution and drivers of productivity growth in the construction industry', *Motu Economic and Public Policy Research*.
Kagioglou, M, Cooper, R & Aouad, G 2001, 'Performance management in construction: a conceptual framework', *Construction Management and Economics*, vol. 19, no. 1, pp. 85-95.
Ke, Y, Wang, S, Chan, AP & Cheung, E 2009, 'Research trend of public-private partnership in construction journals', *Journal of construction engineering and management*, vol. 135, no. 10, pp. 1076-86.
Lam, KC, Wang, D, Lee, PT & Tsang, YT 2007, 'Modelling risk allocation decision in construction contracts', *International Journal of Project Management*, vol. 25, no. 5, pp. 485-93.
LawCommison 2011, *Joint and Several Liability*, 15/08/2019, https://www.lawcom.govt.nz/our-projects/joint-and-several-liability.
Mbachu, J & Taylor, S 2014, 'Contractual risks in the New Zealand construction industry: Analysis and mitigation measures', *International Journal of Construction Supply Chain*, vol. 4, no. 2, pp. 22-33.
McGrath-Champ, S, Rosewarne, S & Rittau, Y 2011, 'From one skill shortage to the next: The Australian construction industry and geographies of a global labour market', *Journal of Industrial Relations*, vol. 53, no. 4, pp. 467-85.
McGuinness, S & Bennett, J 2006, 'Examining the link between skill shortages, training composition and productivity levels in the construction industry: evidence from Northern Ireland', *The International Journal of Human Resource Management*, vol. 17, no. 2, pp. 265-79.
McNair, D 2016, *Proportionate liability*, PricewaterhouseCoopers.
Ministry of Business Innovation and Employment 2018, *The National Construction Pipeline Report*.
Neely, A 1998, 'Three modes of measurement: theory and practice', *International journal of business performance management*, vol. 1, no. 1, pp. 47-64.
Neely, AD, Adams, C & Kennerley, M 2002, *The performance prism: The scorecard for measuring and managing business success*, Prentice Hall Financial Times London.
Page, IC & Norman, D 2014, *Measuring construction industry productivity and performance*, BRANZ.
Pearce, DW 2003, *The Social and Economic Value of Construction: The Construction Industry's Contribution to Sustainable Development, 2003*, Construction Industry Research and Innovation Strategy Panel.
Pesämaa, O, Eriksson, PE & Hair, JF 2009, 'Validating a model of cooperative procurement in the construction industry', *International Journal of Project Management*, vol. 27, no. 6, pp. 552-9.
PWC 2016, *Valuing the role of construction in the New Zealand economy*, PricewaterhouseCoopers, Construction Industry Council, BRANZ.
Roumboutsos, A & Anagnostopoulos, KP 2008, 'Public–private partnership projects in Greece: risk ranking and preferred risk allocation', *Construction Management and Economics*, vol. 26, no. 7, pp. 751-63.
Ruparathna, R & Hewage, K 2015, 'Review of contemporary construction procurement practices', *Journal of Management in Engineering*, vol. 31, no. 3.
Sattineni, A & Schmidt, T 2015, 'Implementation of mobile devices on jobsites in the construction industry', *Procedia Engineering*, vol. 123, pp. 488-95.
UNECE 2019, *UNECE Statistical Database*.
Vogl, B & Abdel-Wahab, M 2014, 'Measuring the construction industry's productivity performance: critique of international productivity comparisons at industry level', *Journal of construction engineering and management*, vol. 141, no. 4, p. 04014085.

IS A DEATH THE KEY FOR POLICY CHANGE IN NSW CONSTRUCTION?

John Smolders [1], Willy Sher [2]

[1]School of Computing Engineering and Mathematics, University of Western Sydney, NSW, Australia

[2]School of Architecture and Built Environment, University of Newcastle, NSW, Australia

Abstract

The recent spate of defective buildings highlighted by the news media has ignited a call by property owners for effective controls to be implemented to ensure purchasers of apartments are assured that (for some) their biggest investment has some form of warranty to protect them against defects and expensive rework. Several investigations by government to improve productivity and compliance have had some beneficial impact but problems still persist. This paper highlights recommendations investigated by and for government that have not been put into practice. This paper investigates past Royal Commissions, Inquiries and Reports commissioned by State and Federal governments. Whilst their overall conclusions are similar, the following aspects have been either specifically neglected or overlooked: design documentation, licencing and professional practice for high rise construction, compliant building materials and effective regulatory control. This paper establishes a link to the causations of rework as a direct result of the above omissions through two case studies. The case studies were examined using mixed method research using a qualitative questionnaire administered to key stakeholders associated with the projects.

Keywords

Rework, Policy, Non-Compliant Building Products, Documentation and Skilling.

Introduction

It has taken three decades for the NSW government to take action to combat a developing crisis that has been looming within the construction industry. The specific area in question is the proliferation of apartments being constructed across the State. Of concern is the manner they are constructed in and the legacy these buildings leave behind.

This developing crisis unfolded when a number of apartment occupiers were forced to evacuate their homes when cracking noises became evident within a block of apartments known as the Opal Tower. The Minister took action, blaming certifiers for the problems that had occurred. It was later discovered via a report commissioned by government that faulty engineering design and placement of precast panel(s) were the causes of the problems. Within a short space of time, another apartment building at Mascot was the subject of news broadcasts. The building was apparently sinking, with occupiers being ordered to evacuate. Erskineville, an apartment complex constructed over contaminated land, followed. Its residents were forced out of their homes (Fellner et al., 2019). Fellner et al quoted the Minister for Better Regulation as saying there was *no "great cause for alarm*". The NSW Premier defended her government, saying that they had appointed a Building Commissioner to oversee change and reinstate confidence in the residential apartment market (Robinson, 2019). To understand how the apartment market was able to grow over the past few decades with some buildings demonstrating considerable defects, this paper draws upon two case studies conducted between 2014 and 2015 (Smolders 2016).

The two case studies explored in this paper demonstrate failures within the system currently being used. At first glance these case studies lead to the conclusion that both contractors disregarded 'good' practises as well as regulations. However, as the investigation delved deeper, it was evident that gaps within the system allowed these contractors free rein to build as they liked. These same gaps were highlighted as areas for reform in a number of inquiries and Royal Commissions but were not enacted.

Complexities

For clarity, the (media-induced) crisis within the construction industry is a phenomenon solely centred around apartment construction. The housing industry and commercial sector are not the focus of attention. However, governments seem to view construction as a single entity and regulate accordingly. One of the regulatory requirements is Home-Owners Warranty Insurance (HOWI). The policy around HOWI only applies for single/two storey homes to protect the consumer against defective work. With the collapse of HIH insurance in 2001(HIH was a major provider for HOWI), the NSW government decided to exempt apartment buildings over three storeys to minimise any possible financial exposure back to the government. One of the reasons for this decision was the debt legacy caused by mounting insurance claims. The government needed to manage this insurance debt. They formed the view that owners of apartments could use civil proceedings against developers/builders and therefore did not require HOWI (Parliament of Australia, n.d.). In early 2000, construction was predominately made up of 'walk-up' 3 storey apartments. Over the following two decades, the trend changed, and apartments averaged 9-12 storeys and higher. During this time, the government made no significant changes to licensing or insurance. The NSW State elections of 2011 saw a major swing from Labour to Liberal government. The State was financially strained compared to other states and required revitalising. It embarked on a program of infrastructure development and housing to boost the economy. Red tape and planning laws were eased to aid the construction of apartments. In return, the government saw windfall revenue from stamp duty and other taxes averaging 44% ($268,000) of the purchase price according to recent reports (HIA, 2019). With this increasing income stream, government would have been reluctant to interfere. As a result, *"Law abiding citizens pay their stamp duty and their taxes – they expect government to regulate to protect them. It is a massive breach of public trust"*, Ms Hearn of the Owners Corporation Network (OCN) recently stated on national television (T, 2019) in relation to defective apartments.

The Current Building System

Prior to 1989, the construction industry faced mounting bureaucratic obstacles in having developments approved for construction by local government. Some projects took years for local councils to respond to development applications. The state government intervened; private certification was introduced, allowing developers to engage directly with private certifiers to speed up the approval process. The benefit to the state was a marked increase in stamp duty revenue desperately needed for the NSW economy at the time (HIA, 2019).

Before 1989, architects played the leading role in design and supervision on behalf of their clients. To assist the delivery process, a 'Clerk of Works' (employed by the architect) oversaw the entire building process to ensure compliance and quality. This model has disappeared over the past three decades. In addition, emphasis on technical knowledge in architectural education has reduced compared to pre-1989. Architects currently rely on builders' knowledge to complete designs, reducing their exposure to foreseeable risks.

The building construction industry is amongst the largest sectors within Australia in terms of employment and contribution to Gross Domestic Product (GDP). As already mentioned, the current crisis is the apartment sector. According to Nichols, 650,000 apartments have been constructed across the country in the last two decades (Nicholls, 2019). The situation in NSW is somewhat different to other states in that the only requirement for a contractor is for a builder's license. That license was introduced in the early 1970's to combat 'cowboys' in the housing sector. The license equips individuals to build domestic one to two storey houses and was not intended to extend to apartment complexes, which is the case today. NSW has no requirement for licensing builders to construct commercial buildings in excess of three stories. Therefore, it can be argued that a number of the builders constructing apartments over three storeys may not be qualified to do so.

The predominant method of procurement is currently the Design and Construct model. Here developers seek an architect of choice to complete the initial documentation to secure pre-sales. Once the sales have been completed (a requirement from the banks to secure funding), developers generally source other designers to complete the documentation for tendering. 'Designers' in this context means architects, architectural designers, drafting services, services from abroad and / or tradespeople. Tenders are let and contractors are charged with responsibility to complete the documentation for final approvals within their budgetary constraints. Part of this process, depending on the completeness of the secondary design, entails that detailed design could be left solely to tradespeople to complete. This means that the original documentation approved for a project's development consent is simply marked up to contain additional details sufficient to satisfy the issuing of a Construction Certificate. Construction details are conveniently left off the drawings and simply left to those who may not be competent enough to execute the work. This gives rise to non-compliance and poor quality.

Legislation

The framework established for developments in NSW is covered under the Environmental Planning and Assessment Act 1979 (EPA Act). The Act provides a framework for land use and provides for the creation of

- Environmental Planning Instruments (i.e. State Environmental Planning Policies (SEPP), Local Environmental Plans (LEP).
- Development Control Plans (DCP)
- A process for development assessment and approval.

The objectives of the EPA Act are as follows,

- Promotion of **social and economic welfare of the community** by managing the environment and the States natural resources.
- Facilitation of ecologically sustainable development.
- Promotion of orderly and economic use and development of land.
- Promotion of **good design** and amenity of the built environment.
- Promotion of the **proper construction and maintenance** of buildings (NSW Government, 1979).

Upon receipt of a development consent, applicants are required to seek a Construction Certificate under section 6.7(1) of the EPA Act. No work is to commence on site until such time as a **principal certifier** has been appointed and the local council has been advised. A certifier can be council, or an accredited certifier (a person who is accredited under the Building Professionals Act 2005). The responsibilities of the certifier prior to the issuing of an Occupation Certificate are to ensure,

- The development consent is in force.
- A construction certificate has been issued.
- The building has been constructed in accordance with the NCC/BCA and is fit for occupation.
- All the relevant requirements of the legislation have been met.

Deficiencies within the legislation

Chief Justice BJ Preston of the Land and Environment Court recently stated *"the statutory scheme relating to building and construction certification has been recently amended to address concerns relating to private certification and that inconsistencies between the development approval by the development consent and the development carried out pursuant to the construction certificate were increasingly common"* (Justice Preston, 2019). Maltabarow observed during the transition period to private certification that only 25% of certifiers had some form of qualification (Maltabarow, 2013). Saulwick and Rabe recently quoted the Premier who conceded self-regulation has failed (Rabe, 2019). The problems facing the (apartment) construction industry have been apparent for some considerable time. A number key deficiencies were identified in the two case studies described in this paper (Smolders, 2016). These included, poor documentation, poor skilling, lack of professionalism, unsatisfactory regulatory control and non-complying building products (NCBPs). Smolders investigated how this situation was allowed to occur despite the recomm3endations of government inquiries and Royal Commissions conducted over an extended period. These include:

1. The Winneke and Gyles Royal Commissions into Union activities- 1982-1992
2. The Campbell Inquiry investigating Quality of Buildings-2002 (Building Code of Australia)
3. The Cole Royal Commission-2003
4. Collins Inquiry of Construction Insolvency-2012
5. Hanger Royal Commission into the Home Insulation Program 2013
6. Heydon Royal Commission into Trade Union Governance and Corruption. 2014
7. Elliott Inquiry into Skills Shortage in NSW. 2014

These inquiries have had the following impacts on the Building Construction Industry (BCI).

1. Winneke and Gyles (1982-92) investigated unlawful and disruptive practices by unions, in particular the Builders Labourers Federation (BLF) and their general secretary. The BLF was subsequently deregistered and for a period and the costly troubles associated with union activities settled down.
1. In 2002 Campbell was instrumental in creating a national building code - the Building Code of Australia (BCA). This was originally intended as a guide but as a result of legal disputes, the judiciary view the document as a legal document verbatim. For a long period of time, the BCA was renewed each year, costing approximately $450. This was major stumbling block for most builders. In addition they found it challenging to interpret. The BCA is now incorporated into a suite of volumes known as the National Construction Code (NCC) and is freely available online. Campbell also recommended Building License categories for low, medium and high-rise buildings but this was not acted upon by the NSW government. In addition, he also recommended that practitioners engage in continuing professional development (CPD) on the BCA to improve quality, but this was also **overlooked** by the NSW government.
2. Cole in 2003 was instrumental in ascertaining the decline in productivity in the Australian construction industry. He uncovered a litany of lawlessness by unions resulting in large corporations abrogating their risk to smaller sub-contractors. This resulted in the establishment of the Australian Building Construction Commission (ABCC) acting to curb unlawful union actions on building sites. The CFMEU still refute the rule of law on major construction sites.
3. Collins in 2012 examined insolvencies in NSW and determined that monies collected by builders were used for unintended purposes (i.e. paying sub-contractors and suppliers). One of his recommendations was to establish a rating scheme for contractors to highlight their professional ethics when paying sub-contractors. This recommendation **was not** taken up.
4. Hanger in 2013 was commissioned to investigate the management of the 'Pink Batts' program (introduced to offset the Global Financial Crisis). Unfortunately, there were some deaths as result of poor training and Hanger highlighted the need for appropriate training and adherence to on-site occupational health and wellbeing. The question of adequate training is still of major concern compounded by the way 'licenced' apartment builders are exempted from

using individually licensed trade people with the exception of plumbers, electricians and specialist service providers.

5. Heyden in 2014 conducted a royal commission, investigating union slush funds after it became evident a union health official had committed an offence. It was later determined that motor-cycle gangs were operating through the CFMEU on construction sites. This has become a fact of life as Labour Senator Doug Cameron says *"The politician who has done more to defend the honour of the Construction, Forestry, Mining and Energy Union, a union which, in part, exists to protect the rights of workers but also, in part, operates outside the law, is Labor"* (MBA, 2014b,1).
6. Elliott in 2014 was commissioned to investigate a perceived skills crisis potentially caused by the attraction of workers to the mining industry. This was not proven. However, Elliott recognised the importance of schools and TAFE in delivering and promoting trade-based apprenticeships. The NSW government has not taken serious notice of these recommendations. TAFE funding has been in crisis for some time and there has been no concerted effort to lift apprenticeships in NSW. This has become one of the major concerns of quality delivery of buildings today.

Methodology

Johnson, Onwuegbuzie and Turner (2007a) refer to mixed method research (MMR) as "attempts to consider multiple viewpoints, perspectives, positions, and standpoints" (Johnson and Onwuegbuzie, 2004). Silverman states, *"by having a cumulative view of data drawn from different contexts, we may, as in trigonometry, be able to triangulate the 'true' state of affairs by examining where the different data intersect"* (Silverman, 2010). MMR has also been encouraged by scholars as Creswell and Clark (Creswell and Clark, 2010) and Fielding (Fielding, 2010). Data was sourced off-site, on-site and from literature (Fig 1). Using these as the basis for the methodology, two case studies were selected within close geographical proximity to one another. Both projects were frequently a topic of interest in local media for a number of reasons, particularly the time they took to complete (SCICLUNA, 2008). Twelve participants were invited for a semi-structured interview. The participants were balanced for on and off-site viewpoints (Fig 2).

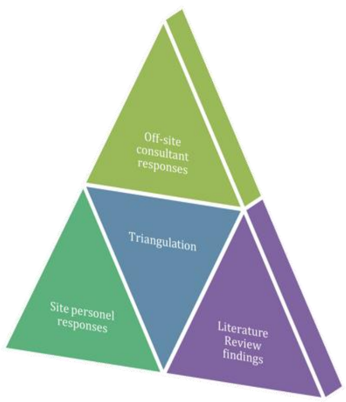


Figure 1-Triangulated inter-relationship

No.	On-Site	Off-Site	Profession
1			Certifier-BCA Consultant
2			Sub-Contractor-Fire services
3			Architect-Prepared initial concept plan and DA Submission.
4			Builder – Builder No 2 now based in China.
5			Client – Developer
6			Site Clerk - Administration
7			Quantity Surveyor- Cost Planner on behalf of the financier.
8			Building professional
9			Superintendent-Overseer on behalf of financier.
10			Union Rep-workers representative.
11			Contracts Administrator-rework.
12			Development Manager-Pre DA.

Figure 2-Case study Stakeholders

Taking into consideration the findings from government inquiries, four interview themes were selected. A summary of these themes is shown in Fig 3.

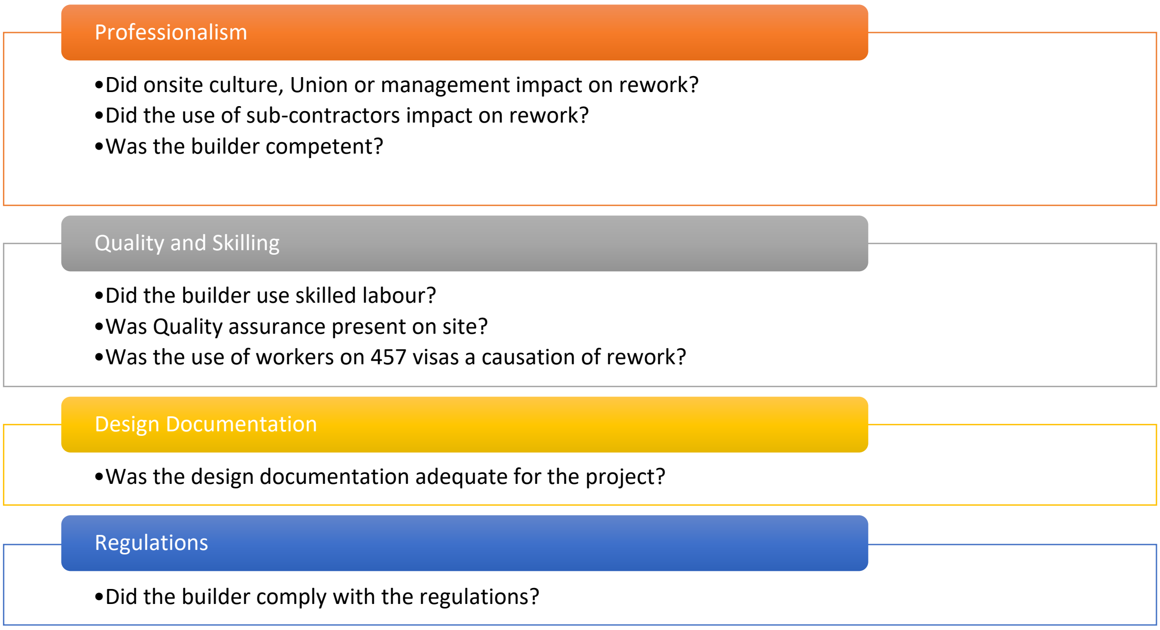


Figure 3-Summarised Literature Review Questions and Themes

Both of the case studies were deemed financially distressed and required external intervention to ensure completion by their respective financiers. The study adopted phenomenological hermeneutic approach, that, according to Sher, has been popularised in some domains as “lived experience studies” (Sher, 2014). Responses obtained from the selected stakeholders have provided for the “lived experience” viewpoint. Data collection was managed using NVIVO software.

Background of the Case Studies

Case Study 1 (CS1)

A development application for a serviced apartment building was lodged in 2000. A contract was signed in 2005. The original documentation was completed for a lump sum tender but was ultimately altered for the winning tenderer as a design and construct contract. This was to allow the builder to redesign the structure to accommodate pre-finished wet area modules in the form of kitchens, laundries and bathrooms. As a consequence, the revised documentation was incomplete, uncoordinated and not in accordance with the BCA. Prior to intervention, the project sustained financial hardship caused by slow payment to sub-contractors and disgruntled on-site workers. The project required substantial rework including a complete redesign of the hydraulics and fire services, replacement of all non-compliant fire doors, and rectification of fire breaches to inter-tenancy walls and floors. The builder was permitted to complete the works under strict supervision. The project was completed in 2010.

Case Study 2 (CS2)

This project was in close proximity from CS1. Both contractors were from overseas. CS2 was similar in size and cost at tender (~$24m) and on completion (~$50m). This project had extensive issues with the CFMEU (McCarthy, 2009). Due to adverse media coverage, only three participants were willing to be interviewed. The project sustained a number of flaws and was highlighted for the use of unskilled illegal workers (McCarthy, 2009).

Findings

A semi-structured questionnaire was used to interview the stakeholders. It comprised three components, a yes/no section (Fig. 4), a Likert response (Fig.5) section and an open reflective comment. The overwhelming response to all of the questions indicated a negative view of both contractors. In addition, all of the comments received substantiated findings from the literature review (Fig 6).

Q #	CS1	CS2	Remarks
12	8/10	3/3	confirmed direct labour was used on site.
13	10/10	1/3	confirmed the contractor was in-experienced.
23	6/10	2/3	confirmed client's influence did not hamper site management
24	7/10	3/3	confirmed client involvement hampered the project.
25	6/10		noted no payment difficulties from the client.
29	6/10		could not confirm the presence of consultants on site.
31	7/10		confirmed that there was no quality assurance on site.

Figure 4-Case Study Yes/No responses

Q #	CS1	CS2	Remarks
14	9/9	2/3	Rated Workmanship as poor.
16	8/9	2/3	Rated Documentation as poor.
17	7/9	1/3	Rated Payments by contractor as poor.
18	8/9	2/3	Rated Site Management as poor.
19	7/9	3/3	Rated WHS on site as poor.
20	5/9	0/3	Rated Working conditions as fair whilst 4/9 rate it as poor.
21	5/9	2/3	Rated Relationship as fair whilst 4/9 rated it as poor.
22	8/9	2/3	Rated the overall quality of the project as poor.

Figure 5-Likert response findings

Literature **Causation of rework**	**Case Study 1 & 2** **Findings**
Poor design documentation and control	Yes
Poor management skills i.e. Site management	Yes
Lack of financial skills i.e. On-site financial control Budget estimating	Yes
Poor workmanship i.e. Lack of QA	Yes
Cultural differences i.e. Communication and language barriers.	Yes
Poor regulatory building control i.e. Non Compliance	Yes

Figure 6-Case Study Preliminary findings

Quality Assurance did not play a significant role on either of the projects nor did compliance with the BCA (particularly on CS1). The role of the certifier and council became very evident. The number of defects was allowed to mount to such a point that complete sections of 'completed' works had to be removed and replaced. In addition, the builders were regarded as unprofessional in their management of the projects and used incomplete documentation.

Recent Cases

In 2018, Opal Tower at Sydney's Olympic Park had their 392 apartments evacuated when cracks and noises became apparent (Boucher, 2019). The Government falsely blamed the certifiers (Hair, 2018). In an attempt to pacify adverse comment towards the government, the NSW government stated that they would accept all of the recommendations of the Shergold Weir Report, which was recently prepared for the Building Ministers Forum dealing with faulty cladding. It should be noted that Michael Lambert prepared a report for the Building Professionals Board in 2015 (Lambert, 2015). There are considerable similarities between the Shergold Weir and Lambert reports. However, the government did little to address the report's concerns and recommendations. It is pertinent to question why the Minister responsible was changed six times in a period of eight years and no attempt was made to acknowledge or make improvements. Mascot Towers (Lewis-Boucher, 2019) followed soon after Opal, then projects at Zetland, Erko and Alexandria. Within seven months, five buildings became uninhabitable (Farrelly, 2019). Dr. Nicole Johnston's recent study of rework identified a considerable number of apartments as having defects emanating from water ingress and poor adherence to fire prevention regulations (Johnston and Reid, 2019). Due to intense media pressure, the government announced the appointment of a Building Commissioner, a recommendation made by the Master Builders Association (MBA, 2019). However, a current parliamentary inquiry into faulty buildings headed by greens Senator, Shoebridge, questioned the newly appointed commissioner, as to how he could address their concerns as well as those of industry considering the commissioner has no budget nor staff to assist him (Gorrey, 2019).

Conclusion

Defects in construction are a fact of life. Until such time as the process of construction is fully automated and possibly derived from an assembly line, defects of some description will prevail. However, the defects depicted in the case studies examined here and the cases that have emerged recently are too significant to ignore. The ultimate loser has been the homeowner. Governments have been on notice for a considerable time. Numerous reports and six ministers in the space of eight years and yet another inquiry at the time of writing attest to this wicked problem. Reform is urgently needed in the apartment sector. The government has benefited from record amounts of income emanating from taxes applicable to construction activities. Key improvements are required in the certification process, documentation, recognition and registration of professionals at every level, control to stop the importation of non-compliant building products and the lifting of skills through education and mentoring. Apartment owners need protection. Government and industry alike must take the responsibility and address the complex issues that have been allowed to grow over the past few decades. Williams and Thompson rightly say that "Someone will have to die before the NSW Government properly fixes the system" (Williams and Thomson, 2019).

About the Authors

John Smolders AM FAIB is a licenced and chartered builder with more than 40 years in construction.

Willy Sher FCIOB has experience as a site engineer, planner and estimator. He has been a construction academic for over three decades.

References

Boucher, D., L., 2019. Biggest Overhaul of Building Laws in NSW Following Opal [WWW Document]. URL https://theurbandeveloper.com/articles/biggest-overhaul-of-building-laws-in-nsw-following-opal (accessed 2.12.19).

Creswell, J.W., Clark, V.L.P., 2010. Designing and Conducting Mixed Methods Research. SAGE.

Farrelly, E., 2019. Sydney's stupidest building boom was born in a bonfire of regulation [WWW Document]. Syd. Morning Her. URL https://www.smh.com.au/national/nsw/sydney-s-stupidest-building-boom-was-born-in-a-bonfire-of-regulation-20190725-p52aq7.html (accessed 8.29.19).

Fellner, C., Chung, L., Saulwick, J., 2019. Zetland apartments abandoned in secret evacuation over "severe" defects [WWW Document]. URL https://www.smh.com.au/national/zetland-apartments-abandoned-in-secret-evacuation-over-severe-defects-20190709-p525lk.html#comments (accessed 7.10.19).

Fielding, N., 2010. Mixed methods research in the real world. Int. J. Soc. Res. Methodol. 13, 127–138. https://doi.org/10.1080/13645570902996186

Gorrey, J.S., Megan, 2019. Building commissioner keen on government loans for distressed buildings [WWW Document]. Syd. Morning Her. URL https://www.smh.com.au/national/nsw/building-commissioner-keen-on-government-loans-for-distressed-buildings-20190816-p52hx9.html (accessed 8.30.19).

Hair, J., 2018. NSW Government vows to "throw the book" at dodgy building certifiers after Opal Tower fiasco [WWW Document]. ABC News. URL https://www.abc.net.au/news/2018-12-30/opal-tower-damage-sparks-nsw-government-crackdown/10673968 (accessed 8.29.19).

HIA, 2019. Housing industry update [WWW Document]. URL https://hia.com.au/business-information/economic-information/industry-updates (accessed 8.20.19).

Johnson, R.B., Onwuegbuzie, A.J., 2004. Mixed Methods Research: A Research Paradigm Whose Time Has Come. Educ. Res. 33, 14–26. https://doi.org/10.3102/0013189X033007014

Johnston, N., Reid, S., 2019. Examining Building Defects-Research Report.

Justice Preston, B.J., 2019. Legal Responsibility for Building and Construction.

Lambert, M., 2015. Independent Review of the Building Professionals Act 2005 [WWW Document]. URL http://bpb.nsw.gov.au/sites/default/files/public/Information%20sheets%20%26%20practice%20advice/BP%20Act%20review%20Discussion%20Paper.pdf (accessed 6.25.15).

Lewis-Boucher, D., 2019. 'Builder Couldn't Read Construction Plans': NSW Commissioner on Mascot Towers [WWW Document]. URL https://theurbandeveloper.com/articles/builder-couldnt-read-construction-plans-nsw-commissioner-mascot-towers?utm_medium=email&utm_campaign=200819%20NSW&utm_content=200819%20NSW+CID_959da1cd8c4ad2d02963330ba03fbbab&utm_source=email (accessed 8.20.19).

Maltabarow, G., 2013. BUILDING CERTIFICATION AND REGULATION – SERVING A NEW PLANNING SYSTEM FOR NSW [WWW Document]. URL https://majorprojects.affinitylive.com/public/4699af15dd6daca40c4a59f1b91f4a86/Maltabarow_report.pdf (accessed 7.21.15).

MBA, 2019. MBA Submission Building Stronger Foundations.

McCarthy, J., 2009. Union boss call to kill "phoenix." Herald 2.

Nicholls, S., 2019. Cracking Up-Four Corners ABC. Australian Broadcasting Corporation.

NSW Government, 1979. Environmental Planning and Assessment Act 1979 No 203 - NSW Legislation [WWW Document]. URL https://www.legislation.nsw.gov.au/#/view/act/1979/203 (accessed 8.27.19).

Parliament of Australia, C., n.d. HIH Insurance Group collapse [WWW Document]. URL https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/Publications_Archive/archive/hihinsurance (accessed 8.21.19).

Rabe, J.S., Tom, 2019. Immediate reforms: Triguboff's Meriton wants building industry change [WWW Document]. Syd. Morning Her. URL https://www.smh.com.au/national/nsw/immediate-reforms-triguboff-s-meriton-wants-building-industry-change-20190712-p526re.html (accessed 7.15.19).

Robinson, J., 2019. David Chandler appointed NSW building commissioner [WWW Document]. URL https://www.propertyobserver.com.au/forward-planning/investment-strategy/property-news-and-insights/102121-david-chancellor-oam-appointed-nsw-building-commissioner.html (accessed 8.1.19).
SCICLUNA, S.-K., 2008. Finishing touches; $30m facelift gives new look to ugliest building. Newctle. Her. 3.
Sher, W., 2014. Tertiary construction management education: the lived experience of academic staff in Australia. (PhD). The University of Newcastle, Newcastle.
Silverman, D., 2010. Doing Qualitative Research, Third. ed. SAGE.
Smolders, J., 2016. Consequences of unforeseen rework on Australian construction projects - a case study approach | NOVA. The University of Newcastle's Digital Repository, Consequences of unforeseen rework on Australian construction projects - a case study approach.
T, J., 2019. OCN blasts "hands-off" regulations after Four Corners TV report. FLAT CHAT. URL https://www.flat-chat.com.au/ocn-blasts-hands-off-regs-after-four-corners-tv-report/ (accessed 8.26.19).
Williams, S., Thomson, J., 2019. Only a death will make government fix the problem of high-rise safety [WWW Document]. Aust. Financ. Rev. URL https://www.afr.com/news/only-a-death-will-make-government-fix-the-problem-of-highrise-safety-20190102-h19mz3 (accessed 1.8.19).

THE CURRENT STATE OF PRODUCTIVITY IN THE NZ CONSTRUCTION INDUSTRY

Stephan van de Linde[1], Linda Kestle[1]

[1]School of Building Construction, Unitec Institute of Technology, Auckland, New Zealand

Abstract

The construction sector in New Zealand is considered to have a continuing low level of productivity. The industry has been contributing less to the National GDP than construction industries in America, Australia and the United Kingdom. This research aimed to determine via document analysis and survey questionnaires, whether New Zealand's construction industry might accomplish a 20% increase in GDP contribution (ie 5.4% to 6.48% by 2020) as set by the Productivity Partnership in 2012. Publications suggested that the construction industry's contribution to the National GDP follows the average profit-based productivity trend of four of the NZX listed construction or construction related companies. If true, it is forecasted that the target of a 20% increase will not be reached. Since 2017, the four selected NZX listed construction or construction related companies' productivity has plateaued, or decreased, over the last eighteen months. A survey was undertaken as well, by 15 selected Auckland based commercial construction related employees focussed on gauging whether the respondents' companies placed an emphasis on productivity measures and reporting. In addition, the survey responses included the respondents' perceptions of the influence of productivity inhibitors and enhancers in their own companies and the wider NZ construction industry. The companies and respondents 'showed their cards', and their true productivity issues were pinpointed.

Keywords

construction sector, enhancers, GDP, inhibitors, NZX, productivity

Introduction

New Zealand's construction productivity has not performed well during the past 40 years and labour productivity is currently similar to what it was during the 1970's, (De Serres 2013). Productivity is a key concept for the economy of any country (Abdel-Wahab & Vogl, 2011). In terms of industries and their contribution to the economy (and GDP), construction's contribution has been lacking during the past three to four decades in New Zealand. When comparing New Zealand's construction GDP contribution of 5.4%, with the United Kingdom's 8%, America's 9% and Australia's 7%, it is evident there is significant potential for improvement, (BRANZ 2013).

The Productivity Partnership formed in 2010 by the New Zealand government and industry, agreed to a common goal to improving construction productivity by 20%, by the year 2020, (Productivity Partnership 2012). The suggested areas of improvement were: Skills; Evidence; Procurement; and Construction Systems, (Productivity Partnership 2012). In addition, 'The Research Strategy for the Building and Construction Industry', produced by BRANZ in June 2013, compiled a list of research areas to be investigated to improve the construction industry, and this essentially extended the Productivity Partnership list. The suggested research topics were: Industry structure; Productivity measures; Industry processes; Skills; Technology; Client value; Operating environment; Canterbury re-build and Auckland's growth, (BRANZ 2013).This research has been undertaken to gauge how the initiative has been tracking, and if we can expect to reach the goal of a 20% productivity increase, and how that has been and will be evidenced and measured. The Research Question therefore was - "What measurable movement has there been in NZ's commercial construction related industry, over the last 5-10 years?" and refers to the goals set by the Productivity Partnership (2012), approximately 7-8 years ago. This research is an indicator of how the productivity initiative has performed, and he possible results that could be expected by 2020. It also shed light on the local commercial construction industry's understanding of productivity influencers, and their internal use of productivity reporting. The results in this research relate to national and construction and industry specific GDP contributions over the past 10 years, and summarises the publicly available published financial statements of four NZX (publicly) listed construction or construction related companies. These financial statements were compared in terms of Revenue, Profit and the Assumed Staff Hours of Work during the past 5 years. In addition, an analytical survey was completed by 15 respondents working in mid to large scale commercial sector construction companies in Auckland, and that survey focussed on potential productivity inhibitors and enhancers.

Literature Review

Defining productivity

Differing definitions were found in the reviewed literature, and one that closely aligns with how the Productivity Commission viewed construction sector productivity, was in the Oxford dictionary, "*The effectiveness of productive effort, especially in industry, as measured in terms of the rate of output per unit of input*".

The Oxford dictionary also identified the following synonyms: "*efficiency, production, productiveness, work rate, output, yield, capacity, productive capacity*", (http://dictionary.oed.com 2018).

The most common line of thought in published literature was to measure productivity by dividing output by input. This could be in relation to a product sold and the corresponding man hours utilised to produce the product for sale. Teicholz (2013), gave two formulae, the first for a given task, being output per hour worked, e.g. 3.5 pre-nailed roof trusses per hour at a predefined specification and grade. The second for the greater construction industry, "*However, when measuring the output of entire industry rather than a task, output is defined in dollars of revenue (for a given base year) per work hour*", (Teicholz (2013), p.1).

Similarly, it has been emphasised that productivity is a relative concept and is measured over time (i.e. per hour worked etc.), or between multiple operational units of comparable nature (Tran & Tookey, 2011), who defined it as being- Output obtained per input utilised, promoting both output and input in monetary value, or any other relevant unit. This core idea was supported by Durdyev & Mbachu (2011), saying "*the concept draws upon the output-input paradigm - the amount or quantity of output of a process per unit of resource input*" (p.19), and by Czumanski & Lšdding (2012). Although, Czumanski & Lšdding (2012) differed by saying - "*relation of the output of a process to the used capacity given in time units or the number of persons involved*" (p.55).

Abdel-Wahab & Vogl (2011) reported completely different definitions – firstly, productivity being a measure of output (value added) by labour input (number of workers; hours worked), and secondly, economists focused on in-depth productivity analysis, via multi-factor production functions in which the most prolific contributing factors to productivity growth are identified and incorporated. For example, labour quality and capital inputs like information and communication technology (ICT).

Productivity levels

Looking at a recent history and the current state of productivity, labour costs have stayed the same (correlating with inflation %-change). However, GDP per hour worked has dropped over the last 40 years according to De Serres (2013) when comparing New Zealand's growth indicators, with 16 Organisations for Economic Cooperation and Development, (OECD) countries.

The results show New Zealand was approximately 4% below the OECD countries in 1970, but dropped to almost 40% below in 2011. Anderson (2013), calculated the Multi-Factor Productivity (MFP) for 1982-1990, reporting the MFP index to be above 1.0, but after 1990 it has not risen beyond 0.95 – ie the MFP has shown little to no real improvement in New Zealand construction in that time. It is further suggested that based on empirical analysis, the second year following the start of an economic boom, the MFP index drops, meaning, as construction demand increases, MFP (or productivity) decreases, given that there is a lag period. Tran & Tookey (2011), reported that the average working New Zealander's wage almost doubled from 1988 to 2009, but compared to inflation (approximately 3% average per annum) over the same period, wage increases did not lead to any additional disposable income for workers. As per a number of productivity definitions, it means that the cost of labour would not have played a significant role in the decrease of productivity over the same period of time.

Measurement and evaluation of productivity

How is productivity measured and evaluated? and how is it compared with the productivity levels of other industries, and/or over time? If looking nationally, the GDP contribution, as suggested by Durdyev & Mbachu (2011), is "*an improvement in efficiency of the building and construction sector – defined as a reduction in the cost of work put in place – will have a positive effect on every other sector, and consequently on the national economy*", (p.18).
Looking locally, measures of gross output or extra value-added is relevant as "*an increase in output per worker can be observed either by requiring workers to produce more in the hours they work, or if they work longer hours*" (Tran & Tookey 2011, p.44).

Two popular output measurements are: Gross Output or Value-added. Labour productivity is frequently calculated as output per worker, or output per hour worked, (Tran and Tookey 2011). Productivity measures are not all equal, along with there often being major methodological differences, (Chancellor et al. 2015). The methodologies can include calculated productivity indicators and statistical models for example, econometrics, linear programming (i.e. optimisation and regression), Total Factor Productivity (TFP) and Data Envelopment Analysis (DEA), as described by Czumanski & Lšdding (2012).

Data envelopment analysis

The two-staged Data Envelopment Analysis (DEA) method was designed to establish the main drivers of productivity; Firstly, DEA evaluates efficiency in terms of output/input across similar units (for example, companies, departments, projects.), or could compare the same unit over time (i.e quarterly or annually). There could be multiple inputs and outputs, causing complex mathematical problem-solving. However, DEA is a non-parametric statistical method, meaning that there are no assumptions made on the distribution/origin of the data being used (i.e. no strings attached). Another advantage of DEA is that it does not rely on output/input prices. Secondly, conducting a '2-stage DEA', means using the results from the original DEA, and working back to loosely determine which industry or economic factors influence efficiency (i.e. productivity) the most. The process involves using regression analysis, estimating the dependent variable (the DEA ratio calculated in the first step above) by suggesting a range of (measured) independent variables from real life, (Chancellor et al. 2015).

Total factor productivity (TFP)

TFP – seldom if ever, includes all relevant factors in the analysis (Shackleton 2013). TFP assumes a strict Neoclassical economic system (i.e. economy depends on supply, customer demand and therefore the customer ultimately dictates pricing), (Ruddock 2011).

TFP can be explained in the following ways:

- keeping input constant, and as time passes observe how output changes;
- it is the part of output growth that cannot be explained by input growth, (Kohli 2015).

Lack of productivity

In previous studies by Tran & Tookey (2011); Chancellor et al. (2015); Fulford & Standing (2014); Teicholz (2013); Fuemana, et al. (2013); Anderson (2013); and Durdyev & Mbachu (2011), management, and particular aspects of project and site management were found to be some of the leading causes of inefficient productivity. Some of the factors were - the lack of communication, lack of strategic planning, lack of management training and practices, lack of reviews of past projects, lack of risk assessment, and a lack of coordination of the project. Fuemana et al. (2013), noted that New Zealand has a large number of small construction companies (3-10 staff commonly), who find it difficult at times to attract suitably qualified managers to lead and run the company(s) efficiently. This leads to in-house, on-the-job training, that can lead them to them being less efficient/productive. Teicholz (2013), came to a similar conclusion when undertaking a USA investigation.

Fragmentation of the supply-chain can cause poor productivity as well, according to Fulford & Standing (2014), due to poor communication channels and a lack of information sharing. Anderson (2013), reiterated the importance of the client's skill level, and how improving their knowledge and communication skills and timing would reduce final design timeframes, and improve productivity. Design management is considered to be a collaborative construction management approach, offering significant potential to improve productivity, as it is "*concerned primarily with value generation, integration of specialist knowledge, and the critical timing of key decisions*" (Kestle 2009, p.12). Fuemana et al. (2013), added that the traditional Lowest Price Conforming (LPC) procurement process is still widely used, even though it is extremely sensitive to designer mistakes, client variation orders and construction quality issues. In addition to this, LPC can lead to adversarial relationships, all of which can affect productivity negatively.

The most important resources on a construction site, are the people constructing the project, and therefore it is logical that this aspect of construction, could in fact be key to improving productivity. Up till now, research has showed that the local market had, and still has a trade skills shortage, and that the current labour skills on offer are insufficient or inappropriate. A suggestion for this, is the poor handling of the boom-bust cyclical nature of construction and retention of skilled workers during a downturn (Durdyev & Mbachu (2011). The current construction boom in New Zealand, has further increased the levels of unskilled labour, according to Fuemana et al.(2013), and this combined with low apprenticeship uptake has added to inefficient productivity. Fuemana et al. (2013), listed building regulations as a negative productivity driver in New Zealand, as it reduces construction activity and innovation, and increases cost. This was confirmed by Chancellor et al. (2015, p.64), who stated that "*regulatory impediments hinder productivity growth".*

Potential mitigation of low productivity

Fulford & Standing (2014), suggested communication is key to sustain and enhance good productivity, and that this could lead to better collaboration, and trusted industry relationships. Fulford & Standing (2014), also recommended retrospective project reviews, as a continuous improvement method via project debriefing and analysis. Another suggestion was that whilst a project is on-going, management should undertake on-site productivity measurements, that are compared over time (Durdyev & Mbachu 2011). Teicholz (2013), focused on Building Information Modelling (BIM) as an innovative system, for example, to overlay different facets of the building design (i.e. architectural, structural, services et al.) in order to facilitate construction buildability, integration and clash detection for example.

Lean construction principles and tools, specifically the Last Planner System (LPS), have been suggested to improve construction productivity (Bosnich & Kestle 2015; and Fuemana et al. 2013), having been originally introduced by Ballard (2000), in an attempt to improve construction productivity at a project level. Lean's focus is on *"the continuous process of eliminating waste, meeting or exceeding all customer requirements, focusing on the entire value stream, and pursuing perfection in the execution of a constructed project."* (Bosnich & Kestle 2015, p.4).

Methodology

Data collection

The Research Question was - "What measurable movement has there been in NZ's commercial construction related industry, over the last 5-10 years?" attempt to establish what local commercial construction companies know about their own productivity and whether managers are monitoring productivity levels. An additional aim was to establish what these companies know about New Zealand's construction sector productivity nationally. There were basically two sub-questions focii underpinning the main question, "Which productivity inhibitors, accelerators, and productivity measurement methodologies are being used by commercial construction related companies in Auckland".

Given the nature of the research question – a mixed method research approach was undertaken that involved qualitative survey questionnaires, and quantitative document analysis. Data collection for this research focussed on current construction practice, innovation and the opinions and thoughts of relevant stakeholders, a qualitative survey method or approach would be most appropriate. Fellows and Liu (2009) argue that survey research, when conducted correctly, has the ability to yield effective data collection in a short timeframe, making it a feasible option for this research.

Denscombe (2010) states that official documents present "authoritative, objective and factual information." (p.217), therefore a document analysis was conducted on both published statistics information, using freely available online NZ Statistics databases, and 4 of the large NZX construction or construction related companies' financial statements, to identify how the construction industry has been tracking since the Productivity Commission's report in 2013.

As noted earlier, the Commission called for a 20% improvement by 2020 (being 6.48% up from 5.4%). The NZ Statistics data set- 'Gross Domestic Product: March 2018 quarter – supplementary, as presented in Table 5, provided the Annual NZ National GDP information, including the construction industry contribution to the National GDP. The analyses tracked the GDP contributions by the construction industry, in conjunction with the 4 large NZX companies' financial statements over the past 5 years', (i.e. revenue and profit after tax, divided by assumed man hours worked per annum).

The information collected was numerical, and was utilized to calculate productivity levels (i.e. $s earned / hours used to create the $s), from their publicly reported revenue and profit figures Denscombe (2010, p.217), stated that official documents of such as discussed above deliver "authoritative, objective and factual" information.

Survey data were gathered using a survey questionnaire and using purposive sampling to select 15 Auckland-based respondents that included directors, commercial managers, project managers, design managers, quantity surveyors, and engineers using individual survey questionnaires to identify current in-house productivity practice, and national productivity influencers (refer *Figure 5*). The survey questionnaire comprised a set of questions that had to be completed in such a way that the respondents' knowledge and corresponding company practices' were collected and described. Gray (2004), and Fellows & Liu (2009), confirmed that this form of qualitative research aims to understand people's perceptions of the world they work and function within.

Results

Document analysis: NZ Statistics

The NZ construction industry contributes a small percentage of the overall contribution (see red bars on *Figure 1* below) to the National GDP. It is worth noting that the construction contribution to the National GDP has grown yearly (since 2011). The National GDP has increased every year as displayed on both *Figure 1* and *Figure 2*, below. The year-on-year net effect has been positive for most of the past 9 years. Construction had a decrease (i.e. negative growth) at 2011, however has shown positive growth since.

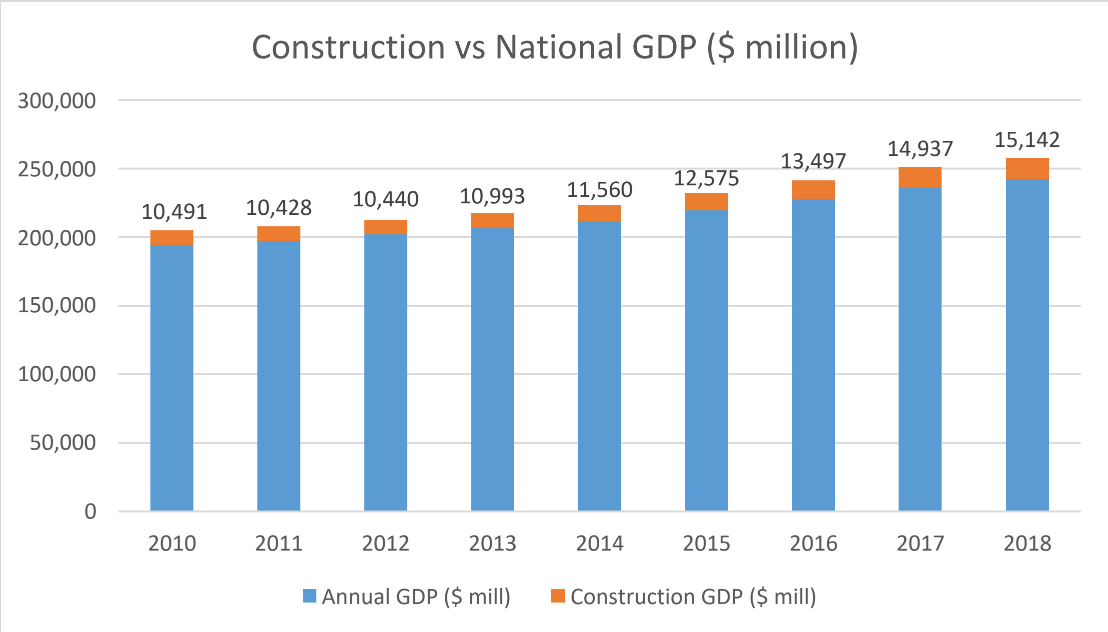


Figure 1 - Construction contribution to National GDP

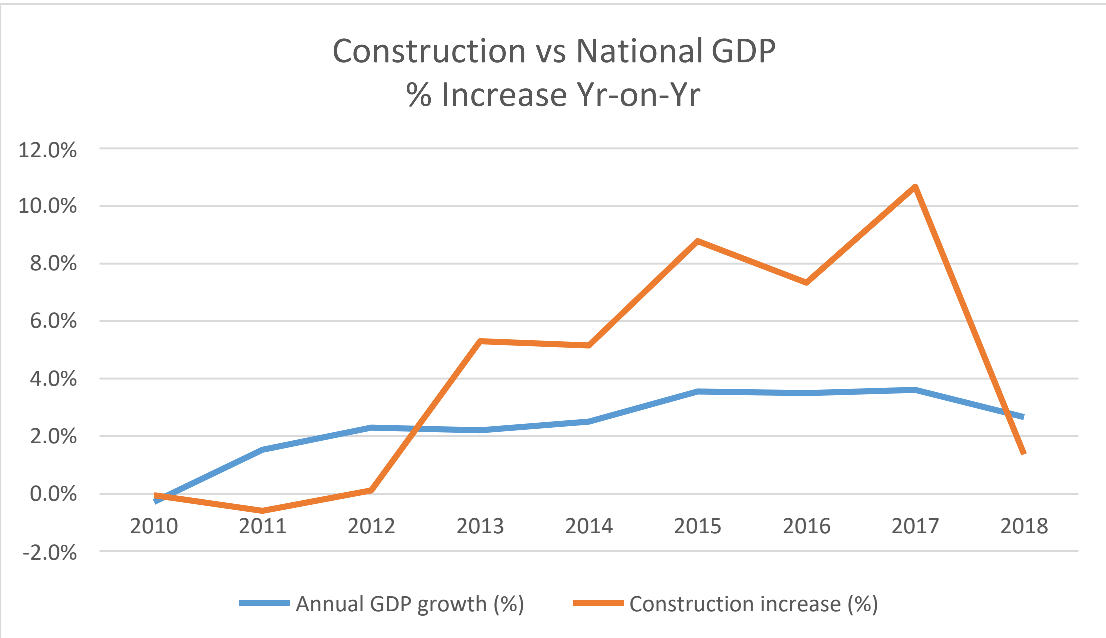


Figure 2 - Year on year percentage increase of GDP (National and Construction contribution)

Document analysis: NZX Companies

Productivity, when calculated using company revenue, shows a slowing or negative growth. In *Figure 3* and *Figure 4* the average trend of the 4NZX companies was negative from 2017, and the associated productivity calculated using company profit is much more pronounced compared to the revenue for the period. *Figure 4* shows negative growth, except for Company D. The average trend of the 4NZX companies was negative from 2016.

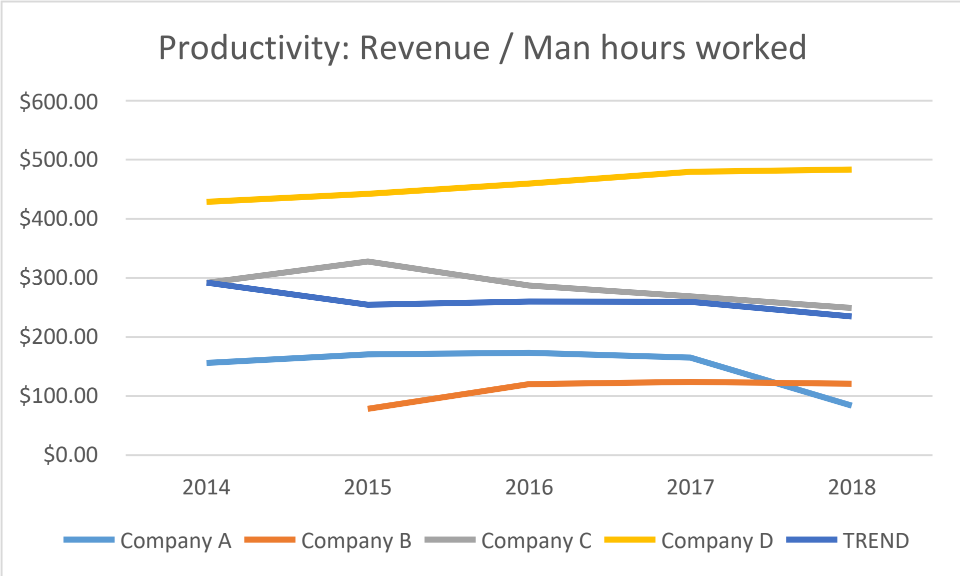


Figure 3 - Revenue productivity measure of the 4NZX commercial construction or construction related companies

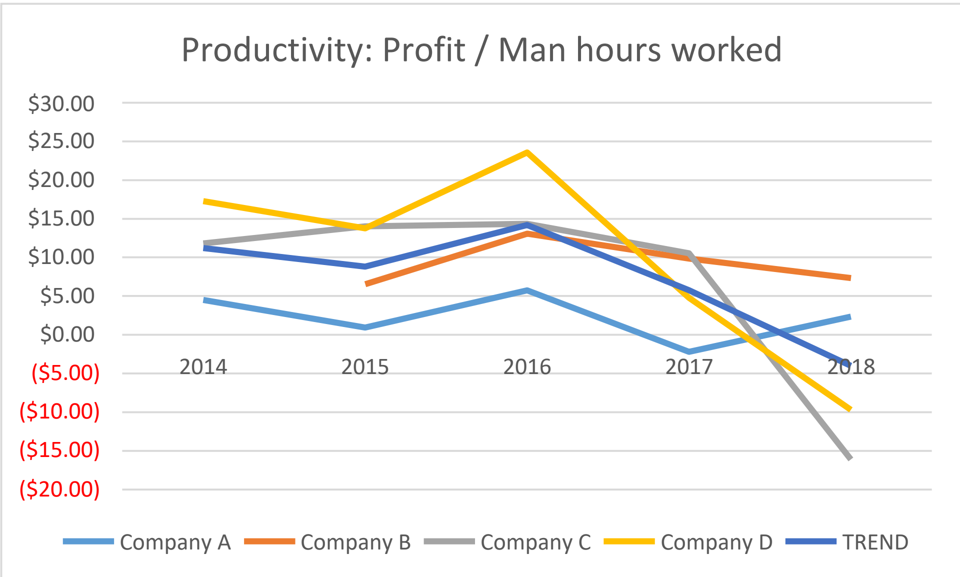


Figure 4 - Profit productivity measure of the 4NZX commercial construction or construction related companies

Survey Questionnaire

The majority of the selected respondents were directors, project managers, design managers, commercial managers, digital engineers and quantity surveyors. The average periods of NZ work experience across the respondents was 13.6 years, with 95% of respondents having between 2 and 20 years of experience.

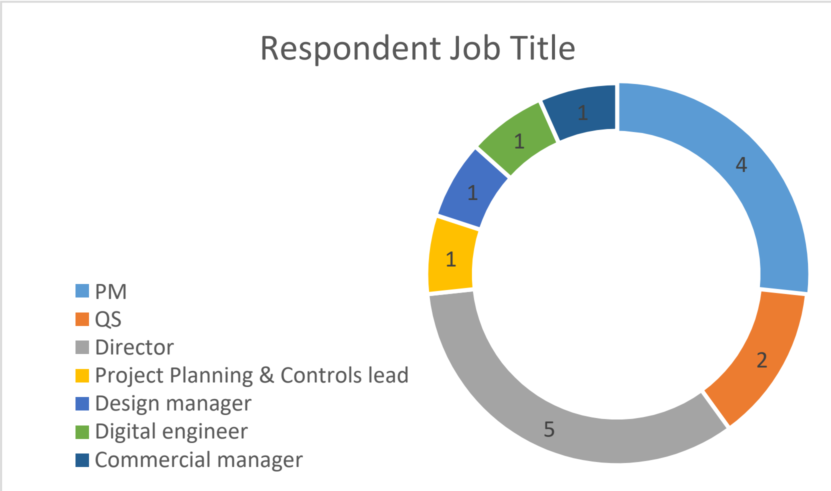


Figure 5 - Job titles of the 15 respondents

Productivity-reporting results - 11 of the 15 respondents reported that their companies do measure and report on productivity, where it was being recorded, and to whom it was reported. The following was recorded and noted (all appropriate options were to be selected by the respondents):

Table 1: Level of Productivity measured and reported

Who measured	*At what levels measured?*			*To whom reported?*	
Shareholders	*N/A*	*N/A*		*6*	*18%*
Financials	*9*	*29%*		*N/A*	*N/A*
Leadership	*4*	*13%*		*7*	*21%*
Senior management	*6*	*19%*		*11*	*33%*
Middle management	*4*	*13%*		*6*	*18%*
Workers	*7*	*23%*		*3*	*9%*
Other: Sub-contractors	*1*	*3%*		*0*	*0%*
Total	*31*	*100%*		*33*	*100%*

Table 2: Productivity measurement methodology as explained by the respondents

Extensive cost control with incorporated labour utilized duration of projects against outgoings and cost
Predominantly labour consumption compared with tendered values
Site based QS measure amount of work done per week; this is measured against the baseline (set at project initiation)
Comparison of fees earned to the time spent & cost incurred
Quality of work / time spent to deliver it
Performance review for personal growth & business unit reporting of cost vs expenses monthly
$ expenditure / $ received <= 1
Labour constants budgeted vs actual trading - per zone/ work package & cost plan reporting (committed cost trading)
Self-performing work: actual man hours / budgeted man hours
Meeting KPI's. Targets set for leadership reached. Site reporting

The following two *Tables 3 and 4*, report on the respondents' opinions regarding both productivity inhibitors and enhancers, within their own company as well as in the wider NZ industry. Note: 12 respondents completed each section, as 3 individuals declined to complete either or both sections.

Table 3: Respondents' opinions on productivity inhibitors

Inhibitors	Company				New Zealand wide		
	If no.1	If no.2	If no.3		If no.1	If no.2	If no.3
Managerial							
Bad communication	8%	15%	5%		8%	10%	5%
Lack of strategic planning	18%	5%	5%		18%	3%	8%
Lack of managerial training	0%	5%	3%		0%	3%	3%
No review of past projects	3%	5%	0%		3%	5%	0%
Weak risk assessment	0%	0%	8%		0%	8%	5%
Weak project coordination	5%	3%	13%		5%	5%	13%
Design							
Lack of consultant coordination	8%	14%	8%		11%	11%	8%
Poor buildability design	11%	8%	6%		14%	6%	6%
Late client influence after construction started	11%	6%	8%		6%	11%	11%
Tender under bidding	3%	6%	11%		3%	6%	8%
Human resources							
Lack of skilled workers retention (during an economic downturn)	18%	5%	3%		18%	5%	3%
Unskilled labour increase in market	8%	8%	8%		10%	13%	5%
Low apprenticeship / cadetship uptakes	5%	3%	3%		3%	5%	8%
Lack in upskilling current labour	3%	13%	5%		3%	8%	8%
Exorbitant labour rates	0%	5%	15%		0%	3%	10%
Regulation							
Delays construction activity	5%	11%	8%		5%	8%	15%
Reduces innovation	8%	11%	5%		8%	10%	5%
Increases cost of construction	13%	8%	8%		10%	13%	3%
Prevents change	8%	5%	11%		10%	3%	10%
Economic influences							
Production cost increases	3%	3%	0%		3%	3%	0%
Inflation	3%	6%	6%		3%	8%	3%
Constant industry growth	6%	3%	11%		6%	0%	14%
Economies of scale irrelevant	3%	3%	6%		3%	3%	6%
Weak investment quality in NZ	8%	6%	3%		8%	6%	3%
Fragmented construction industry communication	6%	8%	6%		6%	14%	0%
Fragmented supply chain	6%	6%	3%		6%	0%	8%

The respondents were asked to rank the 3 factors they believed have the most prominent *negative* effect on productivity. These factors could differ between the respondent's company and the wider NZ construction industry i.e 1 – being most influential and 3 – being least influential of the 3 selected:

Table 4: Respondents' opinions on productivity enhancers

Enhancers	*Company*				*New Zealand wide*		
	If no.1	*If no.2*	*If no.3*		*If no.1*	*If no.2*	*If no.3*
Management							
Improvement in communication and information sharing	*15%*	*0%*	*8%*		*8%*	*3%*	*5%*
Promote collaborative networks	*3%*	*5%*	*3%*		*5%*	*8%*	*5%*
Retrospective project reviews	*3%*	*3%*	*10%*		*5%*	*3%*	*13%*
Continual on-site productivity measure and reporting	*10%*	*3%*	*8%*		*10%*	*3%*	*3%*
Understanding construction industry behavioural triggers	*3%*	*5%*	*0%*		*5%*	*5%*	*0%*
Constant training and development	*0%*	*18%*	*5%*		*0%*	*13%*	*8%*
Systems							
Standardization across industry	*13%*	*5%*	*3%*		*13%*	*8%*	*0%*
Increased innovation	*10%*	*3%*	*15%*		*10%*	*3%*	*18%*
Embrace new technologies (e.g. BIM)	*10%*	*8%*	*8%*		*10%*	*8%*	*10%*
Encouraging prefabrication	*0%*	*5%*	*5%*		*0%*	*5%*	*5%*
Incorporate LEAN construction methodologies (e.g. Last Planner System)	*0%*	*13%*	*3%*		*0%*	*10%*	*0%*
Human resources							
Upskilling workers and employees	*10%*	*5%*	*15%*		*10%*	*5%*	*13%*
Encouraging professional development	*8%*	*8%*	*8%*		*8%*	*13%*	*3%*
Careful integration of low-skilled labour	*3%*	*3%*	*0%*		*0%*	*3%*	*5%*
Appropriate allocation of tasks to correct level of experienced workers	*8%*	*5%*	*3%*		*10%*	*3%*	*3%*
Developing an experienced work force	*5%*	*13%*	*8%*		*5%*	*10%*	*10%*

An observation when comparing the opinions between the respondents' companies and the wider NZ industry, is that they tend to follow the same pattern when looking at the highest percentages (highlighted blocks on *Table 3* and *Table 4*).

All of the possible factors listed were selected from previously published research papers. All of the factors have been selected at least once, meaning there is still a wide range of issues in the construction sector today and none of these can be removed from the list.

Document analysis: NZ Statistics and the 4NZX construction or construction related companies

A basic but useful Document Analysis Framework was set up to collect relevant quantitative statistical data to complement the qualitative data being collected via the survey questionnaire, and to add to the subsequent data analysis -refer *Table 5* below.

Table 5 – Statistics NZ and NZX data collection framework

Source	Type of Data	Purpose
Statistics NZ	Current and historical GDP contributions (specifically for the construction industry)	Extracting GDP information to relate to the literature review and as a comparison to the NZX selected companies' productivity movement.
4 of the NZX listed company website / financial reports	Data related to company productivity – Revenue /numbers of permanent staff x1960hrs pa	Productivity trends compared to national construction GDP contribution
4 of the NZX listed company website / financial reports	Data related to company productivity – Profit/ numbers of permanent staff x1960hrs pa	Productivity trends compared to national and construction GDP contribution

Discussion and analysis

NZ GDP

In *Figure 1*, it was clear just how small the construction contribution (the top red bar) makes to the National GDP. Representing this in Table format (*Table 6* below), it became clear what the exact contribution has been:

Table 6 –Nine-year GDP record

	2010	2011	2012		2013	2014	2015	2016	2017	2018
Annual NZ GDP ($ m)	194.25	197.27	201.89		206.43	211.74	219.53	227.48	236.00	242.45
Constn GDP contrib ($ m)	10.491	10.428	10.440		10.993	11.560	12.575	13.497	14.937	15.142
Constn GDP contrib (%)	5.4%	5.3%	5.2%		5.3%	5.5%	5.7%	5.9%	6.3%	6.2%

In *Figure 2* - Year on year percentage increases of GDP (National and Construction contribution), show nett increases in national and construction GDP contributions during the past 10 years. This was to be expected in a healthy and growing economy, and was in line with the Productivity Partnership (2012) expectations.

There are however, two ways to assess whether the 20% increase in GDP construction contribution in 10 years will be reached, or whether it has already been achieved or not. Firstly, the 2010 construction contribution percentage was 5.4%, and a 20% increase on this would expect to see a 6.48% (additional 1.08 percentage points) contribution by 2020. This takes both the year-on-year growth of the national economy and construction industry into account. Currently then, the target is still 0.24 percentage points below the target, sitting at 6.24%. Secondly, by disregarding the National GDP growth and only focusing on the construction contribution, that contribution has increased between 2010 and mid-2018 by $4,651 million, or 44.3%. That is more than double the growth goal, and given that the national economy growth over the same time has only been 24.8%, this is a reasonable growth result to date in terms of meeting /working toward the construction productivity 2020 GDP target ?

NZX companies

Two forms of productivity were calculated for each of the selected 4NZX listed construction or construction related companies. Firstly - Revenue / number of permanent staff x 1960 hours of work per year. Secondly - Profit / number of permanent staff x 1960 hours of work per year. Combining these trend lines with the construction GDP over the past 5 years, (divided by $100 million to fit on the same graph for a visible trend analysis) - showed that the construction GDP lags 1-2 years behind the 4NZX trend lines. Refer *Figure 6* below where – the 4NZX companies' productivity trends were compared with the construction GDP contribution. For example, as profit increased between 2015-2016, this was visible in the GDP between 2016-2017. However, as profit dropped between 2016-2017, GDP plateaued between 2017-2018, and is expected to witness a drop in GDP between 2018-2019 as Profit continues to fall during 2017-2018.

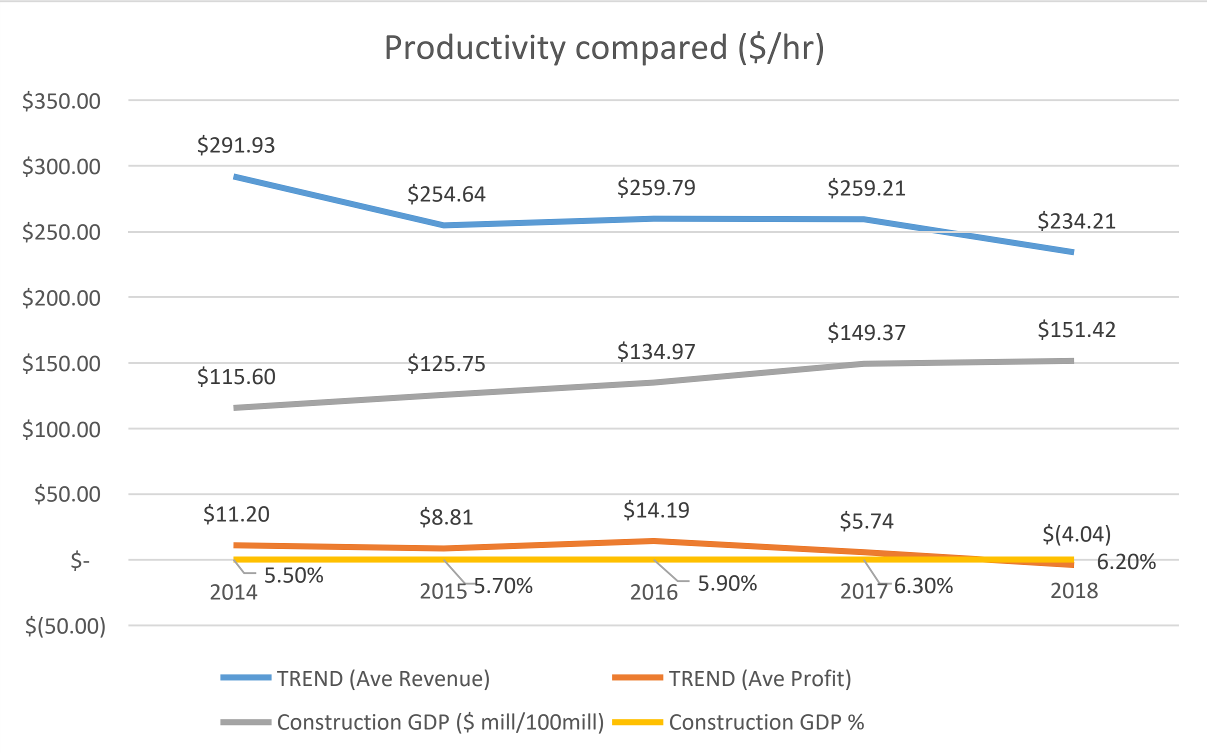


Figure 6 – the 4NZX companies' productivity trends compared to construction GDP

Survey questionnaire

The questionnaire was completed by a diverse range of 15 respondents in the industry - directors, commercial managers, project managers, design mangers, quantity surveyors and engineers. In terms of Abdel-Wah Vogl's (2011) definition of Productivity, 11/15 of the respondents agreed with the definition where: Productivity = Value-added to the Product and Process Divided By the Time Taken to Add the Added-Value. However, 4/15 disagreed, believing instead that Productivity = Output Divided by Input.

The majority of the respondents said their companies measured and reported productivity, (refer *Table 1 and Table 2*), and believed that both productivity inhibitors and enhancers were likely to be similar (though not 100% the same) to other companies in the NZ construction industry. The survey questionnaire brought to light the fact that not all of the respondents' companies measure and report productivity. It is therefore recommended that this becomes mandatory, as unknown productivity levels cannot proactively be improved. It was also surprising to discover that productivity data and results are seldom reported back to those who are being asked to record and report on productivity, (even within the same company). Circular and transparent loops of communication and information sharing would certainly assist in improving these inefficiencies.

Conclusions and recommendations

The NZ GDP has increased during the past 5-10 years, as did the construction average contribution to the GDP. Even though the construction contribution has increased by approximately 44% over the past 9 years. Unfortunately, when using the first method of evaluation, productivity seems to be on a trajectory to miss the 20% improvement by 2020 of 6.48% of NZ GDP, promoted as being the contribution goal by the Productivity Partnership (2012). Four of the NZX listed construction or construction related companies, were reviewed in this research, and it was noted that the NZ GDP tends to follow the combined trend-lines of these 4 NZX listed companies' profit productivity lines for the past 5 years, given the 1-2 year lag. The productivity inhibitor results from the survey questionnaires, evidenced that there are managerial and human resources plaguing the construction industry. The management and systems enhancers were seen by the surveyed respondents to be the most likely factors needed to improve productivity in the construction industry.

Recommendations

After conducting this particular research investigation, there are a few recommendations going forward :

1. Construction industry inefficiencies were not seen to be effectively targeted as a country-wide issue, and the nation-wide growth is most likely due to there being a growing economy, not a more productive industry. It is therefore recommended that the Productivity Partnership continue efforts beyond 2020, with an aim to get better buy-in and fuller reporting by stakeholders, to increase the impact on construction industry productivity, to potentially realise even greater efficiencies.
2. The productivity of sub-contractors was not the primary focus of this research, and would be a relevant and related future research project. It is recommended that sub-contractors be monitored and productivity recorded and reported. The data and analysis would complement and expand the current research investigation outcomes.
3. It is recommended that government initiate/support the regular, maybe annual, preparation of a national productivity report, compiled using all of the NZX listed companies, as it would be a great reporting and benchmarking tool across all industries, but also within industries, and incentivise top performers. This concept would encourage higher productivity and efficiency in the construction industry (and all of the other NZ GDP contributing industries).
4. It is recommended that all companies actively work to rid themselves of their most prominent productivity inhibitors. It is further recommended that as companies focus on productivity enhancers, the inhibitors will diminish. For example, improving communication and information sharing, would mitigate the lack of strategic planning. In addition, continuous training and development/upskilling of workers should lead to more skilled workers in the market, and mitigate overpriced labour rates, and applying LEAN principles and practice would improve overall efficiencies in the construction industry.

References

Abdel-Wahab, M., & Vogl, B. 2011, 'Trends of productivity growth in the construction industry across Europe, US and Japan'. *Construction Management and Economics*, vol.29, no.6, pp. 635-644.

Anderson, H., 2013, 'Construction productivity – the devil's in the detail', *Productivity Hub Symposium*, Te Papa, Wellington, NZ.

Ballard, H.G., 2000, 'The last planner syste of production control', *Unpublished PhD thesis* The University of Birmingham, UK.

Bosnich, A. & Kestle, L. 2015, 'How will NZ's construction industry escalate productivity to meet the largest predicted construction demand in decades - is a lean approach one of the magic

bullets?' *Asia Pacific Institute of Advanced Research (APIAR)- 1st International Conference of Theory into Practice-conference proceedings,* Adelaide, Australia, pp.1-10.
Chancellor, W., Abbott, M., & Carson, C. 2015, 'Factors promoting innovation and efficiency in the construction industry: a comparative study of New Zealand and Australia', *Construction Economics and Building,* vol.15, no.2, pp.63-80.
BRANZ. 2013, 'The research strategy for the building and construction industry'. Building and Construction Sector Productivity Partnership. 2012, 'Productivity Roadmap'.
Czumanski, T. & Lšdding, H. 2012, 'Integral analysis of labour productivity', *Procedia CIRP*, vol.3, pp.55-60
Denscombe, M., 2010, 'The good research guide', 4th edition, *Open University Press*, UK.
Durdyev, S., & Mbachu, J. (2011). On-site labour productivity of New Zealand construction industry: Key constraints and improvement measures. Construction Economics and Building, 11(3), 18-33.
Fuemana, J., Puolitaival, T. & Davies, K. 2013, 'Last Planner System – a step towards improving the productivity of New Zealand construction', *21st Annual Conference of the International Group for Lean Construction – IGLC 21,* Fortaleza, Brazil, pp. 679-688.
Fulford, R., & Standing, C. 2014, 'Construction industry productivity and the potential for collaborative practice', *International Journal of Project Management*, vol.32. pp.315-326.
Gray, D. E., 2004. 'Doing research in the real world', *Sage Publications*, London, UK.
Kestle, L. 2009, 'Remote Site Design Management', *(Unpublished PhD thesis).* University of Canterbury, New Zealand.
Kohli, U. 2015. 'Explaining total factor productivity', retrieved from: https://www.business.unsw.edu.au
Oxford English Online Dictionary. 2018, 3rd edition, retrieved from http://dictionary.oed.com
Ruddock, S. & L. 2011, 'Modelling productivity and growth patterns in the construction industry using the EU KLEMS Database', *COBRA 2011 Proceedings of RICS Construction and Property Conference,* Manchester, UK.
Shackleton, R. 2013, 'Total factor productivity growth in historical perspective - CBO Working Paper 2013–01', *Congressional Budget Office ,* Washington DC. USA, 19pps.
Teicholz, P. M. 2013, 'Labour-productivity declines in the construction industry: causes and remedies (another look)', *AECbytes Viewpoint Issue 67*,. retrieved from http://scholar.google.co.nz
Tran, V.D. & Tookey, J. 2011, 'Labour productivity in the New Zealand construction industry: a thorough investigation', *Australasian Journal of Construction Economics and Building*, vol. 11, no. 1, pp. 41-60.

BLOCKCHAIN TECHNOLOGY AND ITS POTENTIAL FOR THE CONSTRUCTION INDUSTRY

Samudaya Nanayakkara[1], Srinath Perera[1], H.M.N. Dilum Bandara[2], G. Thilini Weerasuriya[1], and Jason Ayoub[1]

[1]School of Computing, Engineering and Mathematics, Western Sydney University, Australia

[2]Data61, CSIRO, Australia

Abstract

Blockchain was introduced as the underlying technology to enable cryptocurrency transactions among untrusted parties. Today, its transformative potential is often compared to that of the World Wide Web, and both practitioners and researchers across all domains are exploring how to utilise blockchain technology to address long-standing problems around data integrity, transparency, and trust. A significant number of research and case study findings indicate many industries are already exploring the diverse benefits of blockchain technology. Analysis of how other industries adopt blockchain could help to understand how to solve similar types of problems in the construction industry. This paper critically analyses the potential to use blockchain in the construction industry. Research findings show that the blockchain technology and its capabilities are mature enough to support many use cases in the construction industry, and the industry's inertia in adopting new technologies seems to be the only hurdle. Two major sectors where blockchain technology could have a greater and immediate impact include the building information modelling and supply chain management.

Keywords

Blockchain; Construction Industry; Smart Contract; Supply Chain Management; Technology Adaptation;

Introduction

The blockchain is an innovative technology first introduced in 2008 through the emergence of Bitcoin (Nakamoto, 2008; Abeyratne and Monfared, 2016). Due to the mainstream attention on Bitcoin, blockchain was first seen as a way to create new digital currencies where people could anonymously transact among untrusted participants transcending geographical boundaries (Wang et al., 2017). However, as time went on, new use cases were explored as industry professionals began to see the significant benefits of blockchain.

The key properties of blockchains include the immutability, consistency, transparency, and disintermediation where data stored on the blockchain cannot be tampered with or deleted (Efanov and Roschin, 2018; Underwood, 2016; Gupta, 2017; Iansiti and Lakhani, 2017). Because blockchains are distributed ledgers, anyone can view the data, which therefore removes the need for trust between transacting parties, as no secrets can be kept on a public blockchain (Guegan, 2017). Permissioned blockchains were introduced to solve the privacy and confidentiality problems in public blockchain networks (Guegan, 2017). The decentralised nature of blockchain overcomes many problems of traditional software due to systems being centralised and controlled by a single entity. These traditional systems are prone to easy tampering and hacking, as well as lack trust and transparency as they are administered by a single entity (Iorio, 2017; Underwood, 2016).

Capabilities of blockchain technology can be extended far beyond cryptocurrencies. It could not only transform existing applications and services, but also lead to many novel use cases such as blockchain-powered elections, power grids, supply chains, property management, and agri-insurance (Rosic, 2017;

Iansiti and Lakhani, 2017). Similarly, blockchain can potentially bring many benefits to the construction industry. In this research, the authors identify several pressing problems experienced in the contemporary construction industry and determine whether the blockchain technology could potentially help in addressing them. Some examples of these problems in the construction industry include, but are not limited to, lack of trust among stakeholders, supply chain continuity, non-payments and delays, fraud, and large amounts of administrative work that can be prone to human errors (Wang et al., 2017).

Research methodology

Even though a decade has passed since the launch of Bitcoin, blockchain is still a rapidly evolving technology, and cryptocurrency is the prominent use case. Blockchain is difficult to understand as it is an amalgamation of several disciplines such as cryptography, mathematics, computer science, finance, economics, and politics. Thus, there are limited applications and case studies in many sectors, including the construction industry. Moreover, due to the limited availability of experts, it is impractical to conduct interviews, questionnaire surveys, or any other data gathering method. Also, due to the infancy of blockchain technology, meaningful primary data sourced from surveys and questionnaires would not be possible due to the general lack of understanding of blockchain amongst the general public. Due to this practical limitation, following four steps were followed to gather qualitative research data from a wide variety of secondary sources such as case studies from other industries:

i) Carry out an in-depth literature review to understand blockchain technology using journal and conference papers, textbooks, technical whitepapers, and reliable Internet sources.

ii) Analyse literature and Internet sources to identify how blockchain is being used in a variety of industries while focusing on other industry use cases and industrial applications which are based on blockchain technologies.

iii) Critically analyse literature and published expert reviews to identify common problems in the construction industry.

iv) Map blockchain solutions in other industries to common problems in the construction industry and identify potential applications of blockchain to help solve these problems.

Scope

This research explores how blockchain as a technology can be used in the construction industry rather than how cryptocurrencies can be applied to the construction industry. The primary scope of this research is to focus on how blockchain can be used to solve common problems encountered in the construction industry through lessons from blockchain solutions implemented in other industries.

Blockchain

Industry 4.0 and the FinTech era are changing the composition of the financial sector and many other sectors rapidly. The most prominent FinTech application is decentralised transaction handling through cryptocurrencies such as Bitcoin, Ripple, Ethereum, LiteCoin, EOS. More than two thousand currencies are available presently (Underwood, 2016; Rodrigo et al., 2018).

The technology underpinning cryptocurrencies is known as blockchain or digitalised distributed ledger (DDL) (Abeyratne and Monfared, 2016; Underwood, 2016; Efanov and Roschin, 2018). The first cryptocurrency, 'Bitcoin' was introduced by Satoshi Nakamoto in 2008 in his whitepaper (Nakamoto, 2008), and the first cryptocurrency was implemented in 2009 (Nomura Research Institute, 2016). Blockchain is a secure and transparent technology to share and store data between users through a Peer-to-Peer (P2P) network, without a central point of control, avoiding the middleman and ensuring the trust in a trustless environment (Guegan, 2017; Rodrigo et al., 2018).

In 2013, Buterin (2013) proposed the Ethereum blockchain. Ethereum is not just a cryptocurrency and has the capability to develop applications on top of the blockchain network called decentralised applications or DApps. In 2015, Ethereum made a new programming paradigm with the DApp concept by introducing ‘smart contracts’ as the first practical distributed processing model on top of a blockchain network (Dannen, 2017).

Blockchain is a mechanism to replicate, share, synchronise, and process data spread across different geographical locations such as multiple sites, countries, or organisations. Accordingly, the main property of blockchain technology is the lack of a central administrator or centralised data storage (Walport, 2016). A blockchain contains records of transactions ordered as a chain of data blocks that are shared with other members of the network. Each transaction is confirmed by the consensus of the members to eliminate fraudulent transactions, e.g., to prevent the double-spending of an asset. Once a transaction is confirmed by the members and accepted by the blockchain, it can never be altered or deleted (Efanov and Roschin, 2018; Underwood, 2016; Gupta, 2017; Iansiti and Lakhani, 2017). While several consensus algorithms with varying properties are used in practice, they share the common characteristic of making it computationally and cost-prohibitive for an attacker to alter the data stored on the blockchain. In terms of data storage, Table 1 explains the problems of traditional data storage that blockchain could potentially solve (Crofts et al., 2018). Applications with less sensitive data can use public blockchain platforms, while private and consortium blockchain platforms are suitable for enterprise-level sensitive data (Rodrigo et al., 2018).

The growing popularity of cryptocurrencies among traders and its impact on multiple domains have led to heightened curiosity to discover other technologies, capabilities, and applications of blockchains. Consequently, several commercial and proof of concept solutions based on blockchains have emerged in domains such as power, supply chain, property, food, health, waste, identity management, elections, and collectibles (Iorio, 2017; Iansiti and Lakhani, 2017; Underwood, 2016).

Table 1: Traditional vs. blockchain data storage

Traditional, Centralised Data Storage	**Blockchain Data Storage**
Prone to hacking due to single point to attack.	Hard to hack due to the decentralised network.
Lack of transparency as the administrator of the network can decide how much information people can view.	The public has full access to the blockchain, meaning that no information can be kept secret. This offers full transparency and eliminates the need for trust.
The central body has full control of the data.	The network is run by users, which reduces the corruption often seen in centralised networks
Prone to tampering of data as there is no way of verifying that data has not been tampered with	Cannot be manipulated or tampered

Technology Concepts Behind Blockchain

A blockchain network consists of several to thousands of peers called nodes. A P2P network forms a distributed and flat topology without a hierarchy, central authority, or the main server where nodes share similar responsibilities and ownership (Kaushik et al., 2017; Weernink et al., 2017). Such a topology provides better resilience, where even if several nodes are compromised by attackers, rest of the nodes in the P2P network can maintain blockchain network in an appropriate state (Nomura Research Institute, 2016). Nodes’ main task is to validate the ‘transactions/operations’ on data and persistently store results of those transactions while preserving data consistency and immutability (Guegan, 2017). Each transaction is digitally signed (Diffie and Hellman (1976), ensuring only the authorised users can update data stored on the blockchain. A set of valid transactions form a ‘block’, and a chain of interlinked blocks form the ‘ledger’. Nodes that form a block is referred to as a ‘miner/validator/producer’. As seen

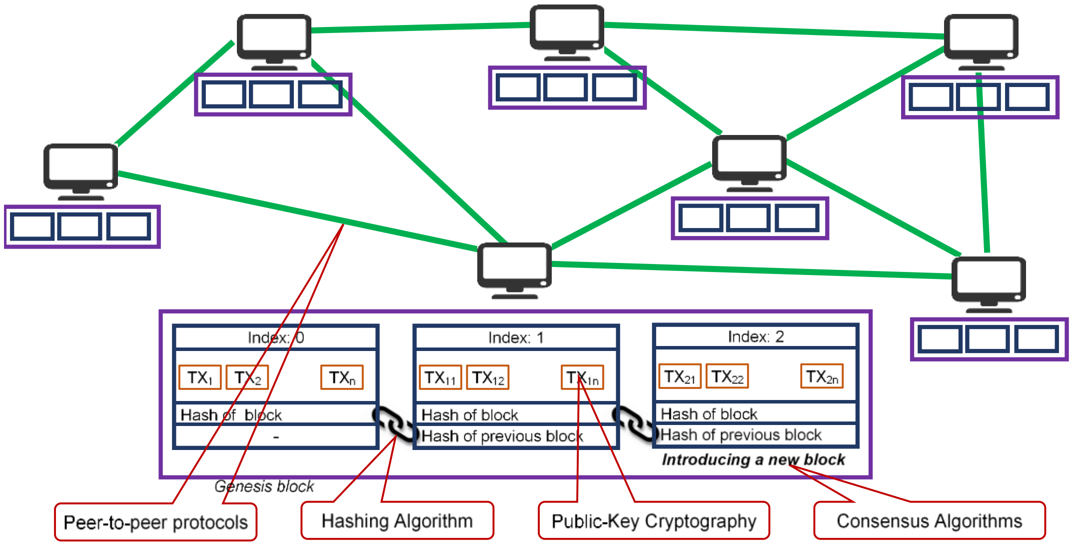


Figure 1: Technologies and concepts behind a blockchain network

in **Error! Reference source not found.**, a miner collects a set of valid transactions (TXs) into a block, links it to the previous block by appending hash of the previous block's data, calculate hash of all data in the block, and then appends it to the ledger (Lewis et al., 2017). A 'hash' value is the digital fingerprint of any data such as text, number, document, or file. Similar to a fingerprint is unique to each human; the hash value is unique to each input dataset (Efanov and Roschin, 2018; Rodrigo et al., 2018).

Blockchains use a consensus algorithm to determine a valid block and which node could create it. For example, in many public blockchains, the first miner that calculates a block with certain cryptographic properties can form a new block. This process is computationally expensive and referred to as 'Proof of Work (PoW)'. Then the block is broadcasted to all other nodes in the blockchain network. Nodes receiving the block further validate it before appending it to their copy of the ledger. Another alternative is 'Proof of Stake (PoS)' where nodes stake assets to become a miner. Then a miner is selected to build a block in each round based on a distributed lottery scheme. If a miner creates an invalid block and gets caught (as other nodes validate a mined block), its stake is removed. Presently, commercial blockchains use over 20 different consensus algorithms with varying scalability, security, and decentralisation properties.

Miners are usually compensated in cryptocurrency for their mining effort; hence, incentivise the participation of many miners making it difficult for a few fraudulent nodes to tamper or modify the data stored on a blockchain. Such attacks become extremely difficult as an attacker needs to modify not only a single block, but all the subsequent blocks as each block is cryptographically linked to the previous block (Nofer et al., 2017). For example, PoW can provide one of the highest levels of security among consensus algorithms, as long as no single miner controls more than 50% hash power of the network (Vranken, 2017). Ultimately, the blockchain network provides a single source of truth.

Notable Properties of Blockchain

Blockchain technology provides a set of unique and enhanced features that increases the trust, usage, and applicability of IT (Information Technology) systems in many sectors (Iorio, 2017; Iansiti and Lakhani, 2017; Underwood, 2016). Blockchain technology has the potential to enhance trust, transparency, auditability, accountability, anonymity, security, robustness, resilience, performance, and equality on Internet-based information systems (Nanayakkara et al., 2019; Rodrigo et al., 2018).

Level of acceptance of any software system depends on both the level of compliance with the Functional Requirements (FRs) and Non-Functional Requirements (NFRs). A Turing-complete blockchain platform can equally satisfy the FRs (Buterin, 2013) without depending on the environment similar to any general-purpose, high-level programming language. Therefore, a blockchain-based software system can equally satisfy all FRs of any business application, just like a traditional software system. That means compliance of NFRs will ultimately increase the level of acceptance of any blockchain-based software system compared to traditional software systems. A significant number of positive features arise from the blockchain properties such as a) functional features such as accuracy, interoperability, non-physicality, self-contentedness, and suitability; b) reliability features such as accessibility, availability (no single point of failure), fault tolerance, robustness, and stability; c) efficient read, write, and execute operations; and d) trust and security features such as accountability, auditability, disintermediation (no single point of trust), fraud resistance, and integrity (Nanayakkara et al., 2019; Rodrigo et al., 2018; Anjum et al., 2017; Buterin, 2016). Developability and maintainability are negative features of blockchain-based systems.

In addition, modern blockchain networks support smart contracts. A 'smart contract' is a self-executing contract or set of rules between two or more parties is directly written into the system and exists across the blockchain network (Rudolf, 2017; Silverberg et al., 2016; Nanayakkara et al., 2019). A smart contract can be used to satisfy common contractual conditions such as payment terms and compliance requirements without a central authority or external enforcement while minimising malicious and accidental errors (Rudolf, 2017; Silverberg et al., 2016).

Blockchain Applications

Blockchain is considered as one of the most disruptive technologies applicable to many disciplines. Both blockchain technologies and applications can be classified in three generations as Blockchain 1.0 for the digital currency, Blockchain 2.0 for digital finance, and Blockchain 3.0 for digital society (Swan, 2015; Zhao et al., 2016). Bitcoin is considered as the first blockchain application that was introduced to the financial industry (Mingxiao et al., 2017). In addition to Bitcoin, presently there are over 2600 cryptocurrencies with a total market capitalisation over USD 265 billion (Coin Market Cap, 2019). Ethereum, Ripple, Litecoin, Tether, Monero, and Cardano are some of the other popular cryptocurrencies (Li et al., 2017).

Economic, marketing and financial applications such as stocks, bonds, smart property, and smart-contract-based applications are defined as Blockchain 2.0 by Swan (2015). Further, Turing-complete blockchain platforms or universally computational programming languages enabling the users to develop smart contracts also belong to the era of Blockchain 2.0 (Li et al., 2017; Xu et al., 2018). Smart contracts strengthen mutual trust among blockchain users as the core technology behind Blockchain 2.0 (Lu, 2018). Blockchain 2.0 platforms started with the smart-contract-enabled Ethereum DApps. Some of the other popular platforms include Hyperledger Fabric, Iroha, Sawtooth, EOSIO, R3 Corda, Quorum, Tron, Stellar, NEM, and Neo (Alharby and Moorsel, 2017; Luu et al., 2016).

Blockchain applications beyond cryptocurrency, finance, and markets such as public services, healthcare, gaming, food and agriculture, science, art, culture, and intellectual property belong to the Blockchain 3.0 era (Swan, 2015; Wang et al., 2017). Gaggioli (2018) mentioned that there is a significant number of potential business applications that can be developed in the Blockchain 3.0 era. Examples of Blockchain 3.0 applications related to public services are the BitFury land registry and the Horizon State online voting system. Blockchain applications in supply chain management are OriginChain for food, Everledger for diamonds, and CSIRO's Data61 blockchain for the beef supply chain management. Healthcare-related applications of blockchain include OmniPHR – a personal health record application, MedRec – a medical records management system, and Konfido – a cross-border electronic health data sharing application. Usizo is a platform where blockchain technology has been applied to manage foreign aid crowdfunding. TravelBlock, Travel Grid, TravelChain, and Aeron are air-ticket and travel planning related blockchain solutions. The music industry uses blockchains such as Ujo, Viberate, and Mycelia for decentralised ownership management. Blockchain in the gaming and collectables industry has many examples, including CryptoKitties, World of Ether, EOS Knights, MegaCryptoPolis, Blockchain Cuties, Mythereum, and MonsterEOS (Crofts et al., 2018; Gaggioli, 2018; Nomura Research Institute, 2016; Rosic, 2017; Underwood, 2016). Some of the contemporary issues faced by the construction industry are also common to other industries, and the authors are already seeing the emergence of blockchain-based solutions to address similar problems in those industries. Potential case studies are discussed next.

Supply chain management

A supply chain is a network of different processes of multiple firms, which are linked as upstream (i.e., suppliers) and downstream (i.e., customers) to deliver products or services to the ultimate consumer (Christopher, 1992). The supply chain is one of the key challenge areas of the construction industry (Hewavitharana et al., 2019; Nanayakkara et al., 2015). Most common supply chain issues are the lack of trust among supply chain members, difficulty in tracking the origin of a product, and difficulty in planning given less transparency in the network. Lack of trust and information across the entire supply chain are common issues in the construction supply chains (Nanayakkara et al., 2013). Therefore, smart contacts based, enhanced trust and immutability features could solve these two key issues to a greater extent (Wang et al., 2017). Moreover, smart contracts and immutability can solve other issues in construction supply chains (Wang et al., 2017) such as difficulty in tracking the origin of a product across a large supply chain (Perera et al., 2012), lack of quality validate (Wang et al., 2017), and difficulty in controlling lengthy supply chain workflow operations (Cox et al., 2006).

Financial services

The financial sector is the first and most successful domain to adopt blockchain (Underwood, 2016). Danuri et al. (2006) mentioned that the construction industry has a significant number of finance-related issues. Ramachandra and Rotimi (2011) mentioned that the construction industry has a chained payment settlement culture, and default settlement durations are much higher than in other industries. Besides the long settlement period, there is a substantial amount of payment delays in the construction industry (Danuri et al., 2006). There is a considerable number of partial payments and non-payments in the construction industry that worsens the financial status of upstream members of the construction supply chain, and sometimes this impact will close down companies (Ansah, 2011). Existing inefficient financial business models and applications are being replaced by highly efficient, blockchain-based financial platforms (Nofer et al., 2017). As an example, Ripple addresses these problems by providing a global, blockchain-based platform for the settlement of transactions across financial institutes (Koch and Pieters, 2017). Another major concern on the traditional financial structure is the middlemen which delay and add additional costs to transactions. Bitcoin was the first cryptocurrency aimed to address this by allowing users to do transactions directly between each other without the need for a middleman or bank (Vranken, 2017). Traditional financial business processes have another drawback where it is hard to transfer value without currencies. Blockchain can define its own digital assets (or digitalised versions of assets) called Tokens. Tokens could be used by any business application to define its own digital assets to perform transactions (Catalini and Gans, 2018). Most financial sector blockchain solutions could be integrated with many information and financial systems in other sectors, including the construction industry, to overcome their financial challenges, reduce costs, and add agility (Zainuddin, 2018).

Compliance and assurance management

Ashworth and Perera (2018) stated that compliance and assurance management is one of the most significant challenging areas for the construction industry. There are many different approaches to ensure compliance and quality assurance. A common technique is to monitor and check an organisation's practices using an audit process. An 'audit' is the internal or external process of examining business records and practices to ensure compliance with specific quality and regulatory standards Karapetrovic and Willborn (2000). Once an audit was completed, a record will be kept for future references and actions will be taken to correct any issues found through the audit process. An audit ensures that the quality and compliance of a product or service are up to standard (O'Dwyer, 2017).

An immutable and distributed blockchain-based system can solve issues related to compliance and assurance management to a great extent in the construction industry (Anjum et al., 2017).

Asset management and maintenance

Proper asset management and maintenance are challenging in any sectors, and even more so in the project-based construction industry (Nanayakkara et al., 2015). The purpose of maintenance is to ensure that a product or service is always running at its intended efficiency and effectiveness. Maintenance is extremely important, especially when it is for a product that is regularly used by the workers and the public, as it ensures safety while using the product or service (Perera et al., 2014). Schedules and records of maintenance are often used to track when an asset requires maintenance, as well as when an asset has received maintenance. Three key issues in asset management and maintenance are accessibility issues of record (Lemieux, 2016), inaccurate records, challenge to execute on-time maintenance schedules (Perera et al., 2013). Lemieux (2016) mentioned the blockchain system could solve issues related to inaccuracy and availability of data, while smart contracts can solve issues related on-time execution of maintenance tasks to a great extent.

Sustainability management

Rodrigo et al. (2019) stated that sustainability management is one of the essential sectors of the modern construction industry. The rise of global warming, climate change, and waste increase the demand for better sustainable operations for almost every domain, including manufacturing, construction, food and agriculture, transportation, and many others. Davidson (2009) mentioned that it is essential to monitor the sustainability of the product or service that they provide in both the private and public sector in any domain. Sustainability monitoring such as monitoring energy use, carbon emission management, and waste management are key focuses for many domains (Davidson, 2009; Ratnasabapathy et al., 2019). Pacheco-Torgal and Jalali (2012) highlighted that the construction industry makes a significant impact on environmental pollution and stress the importance of addressing it. Rodrigo et al. (2019) stated inaccurate record, loss of data, and unavailability of data are among the key challenges in sustainability management and monitoring. Blockchain-based systems can solve these data-related issues to a significant level.

Potential Blockchain Applications for Construction Industry

Blockchain technology can be applied to many areas of the construction industry including construction supply chains, building information modelling, design management, sustainability and waste management, property and land titles, asset management and maintenance, and others. These potential construction applications will be briefly discussed in the next sub-sections.

Construction supply chain management

Blockchain can have many different applications in a construction supply chain. For example, smart contracts could be used to automatically purchase, track, and verify items in a construction supply chain in real-time (Nanayakkara et al., 2019). Furthermore, current procedures in the construction industry heavily rely on contractual agreements. Kinnaird et al. (2017) stated that digital contracts or smart contracts that can be stored and executed securely on a blockchain reduce counter-party risks for suppliers or contractors as they add certainty needed to carry on with a job. Furthermore, blockchain can be used to improve payment settlements, compliance management, material planning, and many other supply chain management operations with better efficiency, trust, and transparency among transacting parties (Nanayakkara et al., 2019).

Building Information Modelling

One of the major potential applications of blockchain in the construction industry is the space of Building Information Modelling (BIM). A major limitation of current BIM models is that they can only provide pre-set information on building components and not live information (Kinnaird et al., 2017). Another issue is that these models often generally stop being updated once the construction is completed due to information is maintained by single or limited parties. Blockchain could be applied to solve these issues by information sharing among present and future information owners to a great extent. Blockchain applications in building information modelling are vast, including integration with the Internet of Things (IoT), Asset Management, Augmented Reality (AR), Virtual Reality (VR), Artificial Intelligence (AI), and many other potential solutions (Heiskanen, 2017).

Design management

In the construction industry, many contractors and consultants come together to design and deliver a one-off project. This can often cause a fragmented approach to design as a different group of contractors and consultants. Usually, each construction discipline is kept separately during the design phase of the project. In recent years, the design management phase has been advanced by BIM to ensure that the design of the building meets the expectations of the client (Wang et al., 2017; Heiskanen, 2017). Blockchain could be utilised to truly enhance the benefits of BIM by allowing all architects and engineers to design on the same BIM model with their respective components with clear ownership (Kinnaird et al., 2017). Moreover, persistent recording on design and construction decisions could be useful in future cases analysis, e.g., to find out who is at fault for designing or building a collapsed bridge.

Sustainability and waste management

Sustainability is one of the highest priorities in the built environment today due to the external demand from governments, customers, and the general public (Pitt et al., 2009). Blockchain technology can be used to properly calculate embodied and operation carbon in the construction industry and assist in optimising carbon management or even carbon trading (Rodrigo et al., 2019). Furthermore, blockchain technology can be used for proper energy management in the built environment (Imbault et al., 2017). The construction industry produces a significant portion of waste worldwide, and a blockchain could be utilised for proper waste management, including waste trading and circular economy (Ratnasabapathy et al., 2019).

Asset management and maintenance

According to the PAS-55 specification of the British Standards Institution (2008), all the necessary data and information related to the built asset needs to be tracked at every stage of the asset life cycle. However, project nature and the involvement of a high number of parties make asset management and maintenance nearly impossible. Blockchain-based, construction asset management systems would allow tracking and access to all the necessary data throughout the asset life cycle. It could provide better asset life cycle while minimising challenges and providing better maintenance performance (Wang et al., 2017).

Conclusion

Blockchain has evolved drastically over the last decade as a generic platform for reducing counterparty risks since its beginnings as the underlying technology for cryptocurrency. There is little research on blockchain adoption in the construction industry at present. Therefore, this study aimed to analyse the current use cases of blockchain in other industries and determine its potential to solve contemporary challenges in the construction industry. The research suggests that blockchain is a persistent, immutable, and secure system that is effective in eliminating the middleman and automating processes due to its prominent disintermediation, transparency, and consistency features. A key finding was that attempts are widely being made to implement blockchain-based solutions in many industries, including food and agriculture, healthcare, entertainment, foreign-aid, advertising, and public services. At the same time, it was noted that both research and commercial attempts are relatively poor in the construction industry. Nevertheless, the authors found that the construction industry could adopt blockchain technology to solve long-standing problems, including trust issues among parties, lack of transparency in the construction supply chain, payment related issues, asset maintenance issues, a large amount of administrative paperwork, compliance issues, collaboration issues especially in design management, and others. Therefore, there is a significant potential for blockchain applications in the construction industry, especially in the areas of supply chain management, building information modelling, asset management, and sustainability.

The authors propose a blockchain maturity model in Figure 2 for the construction industry. The maturity model is based on the present status of research, publications, blockchain platforms, its application development, anticipated developments in core blockchain technologies and adopting maturity model was published by Nguyen et al. (2019). The authors suggest five key stages for blockchain in the construction industry, including ideation, experimentation, pilot, commercialisation, and adoption. The few blockchain research and industrial projects in the construction industry are soon heading to their pilot stage according to their academic, news, and whitepaper publications. With the maturity of blockchain technology, adoption practices, and relevant policy enhancements the construction industry will soon be able to solve several long-standing problems with high efficiency, transparency, agility, and low cost.

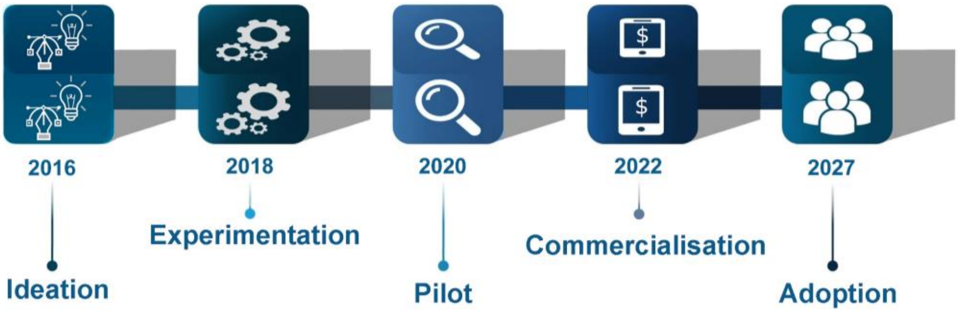


Figure 2: Blockchain maturity in the construction industry

References

Abeyratne, S. A. & Monfared, R. P. 2016. Blockchain ready manufacturing supply chain using distributed ledger. *International Journal of Research in Engineering and Technology,* 5.

Alharby, M. & Moorsel, A. V. 2017. Blockchain Based Smart Contracts : A Systematic Mapping Study. *Computer Science & Information Technology (CS & IT).*

Anjum, A., Sporny, M. & Sill, A. 2017. Blockchain standards for compliance and trust. *IEEE Cloud Computing,* 4**,** 84-90.

Ansah, S. K. 2011. Causes and effects of delayed payments by clients on construction projects in Ghana. *Journal of Construction Project Management and Innovation,* 1**,** 27-45.

Ashworth, A. & Perera, S. 2018. *Contractual procedures in the construction industry,* London, Routledge.

British Standards Institution 2008. PAS 55-1: 2008, Part 1: Specification for the optimized management of physical assets. British Standards Institution.

Buterin, V. 2013. Ethereum (Technical white paper). Available: https://github.com/ethereum/wiki/wiki/White-Paper.

Buterin, V. 2016. *Privacy on the Blockchain* [Online]. Ethereum Blog. Available: https://blog.ethereum.org/2016/01/15/privacy-on-the-blockchain/ [Accessed 7 September 2018].

Catalini, C. & Gans, J. S. 2018. Initial coin offerings and the value of crypto tokens. National Bureau of Economic Research.

Christopher, M. 1992. *Logistics and supply chain management*, London, the United Kingdom Pitman Publishing.
Coin Market Cap. 2019. *All Cryptocurrencies* [Online]. CoinMarketCap. Available: https://coinmarketcap.com/all/views/all/ [Accessed 2019-09-07 2019].
Cox, A. W., Ireland, P. & Townsend, M. 2006. *Managing in construction supply chains and markets: reactive and proactive options for improving performance and relationship menagement*, Thomas Telford.
Crofts, B., Lam, D. & Kosmatos, J. 2018. *Solving real world problems with blockchain* [Online]. Digital Pulse. Available: https://www.digitalpulse.pwc.com.au/solving-real-world-problems-blockchain [Accessed 5 March 2019].
Dannen, C. 2017. *Introducing Ethereum and Solidity*, Springer.
Danuri, M. M., Munaaim, M. C., Rahman, H. A. & Hanid, M. Late and non-payment issues in the Malaysian Construction Industry-Contractor's perspective. International Conference on Construction, Culture, Innovation and Management (CCIM), 2006.
Davidson, K. 2009. *Monitoring systems for sustainability: what are they measuring?*
Diffie, W. & Hellman, M. 1976. New directions in cryptography. *IEEE transactions on Information Theory,* 22**,** 644-654.
Efanov, D. & Roschin, P. 2018. The All-Pervasiveness of the Blockchain Technology. *Procedia Computer Science,* 123**,** 116-121.
Gaggioli, A. 2018. Blockchain Technology: Living in a Decentralized Everything. *Cyberpsychology, Behavior, and Social Networking,* 21**,** 65-66.
Guegan, D. 2017. Public Blockchain versus Private blockhain. *Documents de Travail du Centre d'Economie de la Sorbonne***,** 1-6.
Gupta, M. 2017. *Blockchain for dummies*, USA, A Wiley Brand.
Heiskanen, A. 2017. The technology of trust: How the Internet of Things and blockchain could usher in a new era of construction productivity. *Construction Research and Innovation,* 8**,** 66-70.
Hewavitharana, T., Nanayakkara, S., Perera, A. & Perera, J. 2019. Impact of Enterprise Resource Planning (ERP) Systems to the Construction Industry. *International Journal of Research in Electronics and Computer Engineering,* 7**,** 887-893.
Iansiti, M. & Lakhani, K. R. 2017. The truth about blockchain. *Harvard Business Review,* 95**,** 118-127.
Imbault, F., Swiatek, M., De Beaufort, R. & Plana, R. The green blockchain: Managing decentralized energy production and consumption. 2017 IEEE International Conference on Environment and Electrical Engineering and 2017 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe), 2017. IEEE, 1-5.
Iorio, E. D. D. 2017. *17 Blockchain Applications That Are Transforming Society* [Online]. Blockgeeks. Available: https://blockgeeks.com/guides/blockchain-applications/ [Accessed 07 March 2017].
Karapetrovic, S. & Willborn, W. 2000. Quality assurance and effectiveness of audit systems. *International Journal of Quality & Reliability Management,* 17**,** 679-703.
Kaushik, A., Choudhary, A., Ektare, C., Thomas, D. & Akram, S. 2017. Blockchain - Literature Survey. *2nd IEEE International Conference On Recent Trends in Electronics Information & Communication Technology (RTEICT).* India: IEEE.
Kinnaird, C., Geipel, M. & Bew, M. 2017. Blockchain Technology, How the Inventions Behind Bitcoin are Enabling a Network of Trust for the Built Environment. London: Arup.
Koch, C. & Pieters, G. C. 2017. Blockchain Technology Disrupting Traditional Records Systems.
Lemieux, V. L. 2016. Trusting records: is Blockchain technology the answer? *Records Management Journal,* 26**,** 110-139.
Lewis, R., McPartland, J. & Ranjan, R. 2017. Blockchain and financial market innovation. *Global Commodity Applied Research Digest,* 7.
Li, X., Jiang, P., Chen, T., Luo, X. & Wen, Q. 2017. A survey on the security of blockchain systems. *Future Generation Computer Systems*.
Lu, Y. 2018. Blockchain: A survey on functions, applications and open issues. *Journal of Industrial Integration and Management,* 3**,** 1850015.
Luu, L., Chu, D. H., Olickel, H., Saxena, P. & Hobor, A. 2016. Making Smart Contracts Smarter. *ACM SIGSAC Conference on Computer and Communications Security - CCS'16.*
Mingxiao, D., Xiaofeng, M., Zhe, Z., Xiangwei, W. & Qijun, C. 2017. A Review on Consensus Algorithm of Blockchain. *IEEE International Conference on Systems, Man, and Cybernetics (SMC).* Banff, Canada: IEEE.
Nakamoto, S. 2008. Bitcoin: A peer-to-peer electronic cash system (Technical white paper). Available: https://bitcoin.org/bitcoin.pdf.
Nanayakkara, S., Perera, P. & Perera, A. 2013. Factors Influencing Selection and Effective Implementation of ERP Systems in Medium Sized Organizations in Developing Countries. *International Journal of the Computer, the Internet and Management,* 21**,** 7-14.

Nanayakkara, S., Perera, P. & Perera, A. 2015. Factors Incompatibility of Selection and Implementation of ERP Systems for Construction Organizations. *International Journal of Computer Science and Technology,* 6**,** 9-15.

Nanayakkara, S., Perera, S. & Senaratne, S. 2019. Stakeholders' Perspective on Blockchain and Smart Contracts Solutions for Construction Supply Chains. *CIB World Building Congress.* Hong Kong.

Nguyen, B., Buscher, V., Cavendish, W., Gerber, D., Leung, S., Krzyzaniak, A., Robinson, R., Burgess, J., Proctor, M., O'Grady, K. & Flapper, T. 2019. Blockchain and the built environment. London: Arup Group Limited.

Nofer, M., Gomber, P., Hinz, O. & Schiereck, D. 2017. Blockchain. *Business & Information Systems Engineering,* 59**,** 183-187.

Nomura Research Institute 2016. Survey on Blockchain Technologies and Related Services. Nomura Research Institute.

O'Dwyer, M. 2017. *How Blockchain Will Impact The Auditing World* [Online]. Available: https://blog.ipswitch.com/how-blockchain-technology-will-change-the-audit-world [Accessed 2019-08-05].

Pacheco-Torgal, F. & Jalali, S. 2012. Earth construction: Lessons from the past for future eco-efficient construction. *Construction and building materials,* 29**,** 512-519.

Perera, P., Nanayakkara, S. & Perera, A. Benefit of Implementing a National Level ERP system for Health Sectors in Sri Lanka through Stock Optimization. The Second International Congress of Interdisciplinary Research and Development, 2012 2012. Thailand.

Perera, P., Nanayakkara, S. & Perera, A. 2013. Critical Evaluation on ERP Applications for Defence Sector of Sri Lanka. *International Journal of the Computer, the Internet and Management,* 21**,** 4.1-4.16.

Perera, P., Nanayakkara, S. & Perera, A. 2014. Application of Proper Asset Management Methodology and Technology. *International Journal of Computer Science and Technology,* 5**,** 33-41.

Pitt, M., Tucker, M., Riley, M. & Longden, J. 2009. Towards sustainable construction: promotion and best practices. *Construction innovation,* 9**,** 201-224.

Ramachandra, T. & Rotimi, J. O. 2011. The nature of payment problems in the New Zealand construction industry. *Construction Economics and Building,* 11**,** 22-33.

Ratnasabapathy, S., Perera, S., Alashwal, A. M. & Lord, O. 2019. Assessment of Waste Generation and Diversion Rates in Residential Construction Projects in Australia. *CIB World Building Congress.* Hong Kong.

Rodrigo, M. N. N., Perera, S., Senaratne, S. & Jin, X. 2018. Blockchain for Construction Supply Chains: A literature Synthesis. *Proceedings of ICEC-PAQS Conference 2018.* Sydney, Australia.

Rodrigo, M. N. N., Perera, S., Senaratne, S. & Jin, X. 2019. Embodied Carbon Mitigation Strategies in the Construction Industry. *CIB World Building Congress.* Hong Kong.

Rosic, A. 2017. *17 Blockchain Applications That Are Transforming Society* [Online]. Blockgeeks. Available: https://blockgeeks.com/guides/blockchain-applications/ [Accessed 07 March 2017].

Rudolf, T. H. 2017. Smart Contracts. Zurich: Walder Wyss Ltd.

Silverberg, K., French, C., Ferenzy, D. & Berg, S. V. D. 2016. Getting Smart: Contracts on the Blockchain. Washington: The Institute of International Finance.

Swan, M. 2015. *Blockchain: blueprint for a new economy,* United States of America, O'Reilly Media Inc.

Underwood, S. 2016. Blockchain beyond bitcoin. *Communications of the ACM,* 59**,** 15-17.

Vranken, H. 2017. Sustainability of bitcoin and blockchains. *Current Opinion in Environmental Sustainability,* 28**,** 1-9.

Walport, M. 2016. Distributed Ledger Technology : Beyond Blockchain. *UK Government Office for Science*.

Wang, J., Wu, P., Wang, X. & Shou, W. 2017. The outlook of blockchain technology for construction engineering management. *Frontiers of Engineering Management,* 4.

Weernink, M. O., Engh, W. V. D., Francisconi, M. & Thorborg, F. 2017. The Blockchain Potential for Port Logistics. Netherlands.

Xu, L. D., Xu, E. L. & Li, L. 2018. Industry 4.0: state of the art and future trends. *International Journal of Production Research,* 56**,** 2941-2962.

Zainuddin, A. 2018. *Coins, Tokens & Altcoins: What's the Difference?* [Online]. Master the Crypto. Available: https://masterthecrypto.com/differences-between-cryptocurrency-coins-and-tokens/ [Accessed 31 August 2019].

Zhao, J. L., Fan, S. & Yan, J. 2016. Overview of business innovations and research opportunities in blockchain and introduction to the special issue. *Financial Innovation,* 2.

ARCHITECTURAL DESIGN FOR TOWN PLANNERS – LESSONS LEARNT AT THE UNIVERSITY OF JOHANNESBURG

Trynos Gumbo[1], Nischolan Pillay[2]

[1]Department of Town and Regional Planning/ School of Engineering and the Built Environment, University of Johannesburg, Johannesburg, South Africa

[2] Department of Town and Regional Planning/ School of Engineering and the Built Environment, University of Johannesburg, Johannesburg, South Africa

Abstract

The South African higher and tertiary national department implemented a raft of changes to phase-out Non-Higher Education Qualification Sub-Framework (HEQSF) such as the National Diploma's, Bachelor of Technology Degrees, between 2016 and 2019 and introduce new bachelor's degree programs for roll out more particular in Universities of Technology across the country. Consequently, the Department of Town and Regional Planning at the University of Johannesburg, implemented a Bachelor of Urban and Regional Planning degree in 2017, in the process introducing completely new modules that sought to prepare graduates for the world of work. To develop town planning students holistically, one of the crucial practical modules that was introduced is Architectural Design that is offered in the second semester of the first year of study. Since a basic understanding of drawing is critical for students to comprehend concepts of architectural design and drafting, the module is preceded by Drawing for Planners, in the first semester, which introduces such basic concepts. This paper focuses particularly on the Architectural Design module and the lessons learnt from this course regarding pedagogical approaches and student understanding of key concepts of architectural design. The research makes use of a mixed method approach utilizing both secondary and primary sources of data that include a distillation of literature and auto-ethnographic inquiry and interviews that were administered to students to collected data that assisted in understanding appropriate teaching and learning approaches for the module. Findings noted a clear transfer of knowledge, skill and understanding of architectural design concepts and overall critical thinking processes through the aid of a variety of teaching methods, but mostly anchored on learning by doing since it's a hands-on module. The paper concludes by recommending a fusion of a myriad of teaching styles to suit the learning needs of the first-year town planning students who have different backgrounds from their high schools.

Keywords: Architecture; Town Planning; Pedagogy; Skill Transfer; Education

Introduction

In early 2016, the government of South Africa implemented a change in tertiary education that sought to change the structure of technical degrees to a full traditional degree. This change affected all previous Technikons, including the University of Johannesburg. However good this change was, it affected continuing students in the old National Diploma and Bachelor of Technology programmes and meant that those students had to finish their studies by the end of 2019. Reflecting back onto the previous system, it had beneficial impact on students in terms of experience through Work Integrated Learning (WIL) within the degree structure, which is tradition of a Technikon or University of Technology. This working experience meant that students were capable of performing minor duties post qualification. Students of the previous system were employed much quicker as they possessed skills from the industry, which made the old system unique in a way. The new development followed the traditional sense of a University system and the degrees disregarded any form of WIL. This change in pedagogy negatively effects the training of students attending a former technical university. The change in the degree structure affects all courses at Universities of Technology and the Department of Town and Regional Planning was not spared with this occurrence. This paper will concentrate primarily on the lessons learned in the Architectural Design course. Architectural Design 1B, as its convention states is a module based on

Architectural Design, however this course is a minor subject only implemented in one semester of the three-year degree.

The paper starts presenting a literature review and conceptual synopsis section that presents the main aspects of architectural design and the different teaching and learning methods appropriate for tertiary and higher education students. It then goes on to highlight the research methodology that was adopted and applied in the study, where the research design, research approaches as well as the data collection and analysis instruments are discussed. Thereafter, the paper presents the research findings that emanated from the study and it ends by presenting the recommendations and conclusions.

Literature Review and Conceptual Synopsis

This section presents the architectural design concepts as well as the different teaching and learning methods as they are applied to impart knowledge to university students, particularly the learners that are studying town and regional planning.

Teaching and learning strategies and styles

Teaching is the process of imparting knowledge into the learners, while learning is the process of grasping, organizing, and making meaning the taught knowledge and the delivered concepts. The process of teaching and learning is dialectically constituted as both processes that presuppose each other. Teaching approaches entail the broad categories of methodologies that are applied by teachers as they impart knowledge in learners. The inductive-deductive dichotomy in teaching and learning also guides the choice of teaching methods to be adopted in the teaching and learning experiences.

Inductive teaching approaches focus more on experiential acquisition of knowledge by learners through intensive interaction with the content. In this regard, our teaching approach in the architectural design is informed by philosophical underpinnings from pragmatists such as John Dewey that emphasizes putting theory into practice (Dewey, 1904). According to Dewey (1904), experience is the best teacher. The reason why we adopt the inductive approach to teaching and learning is because architectural design concepts are very practical in nature. They relate to student's lived experiences of the everyday.

On the other hand, we also employ the deductive approach to teaching and learning. According to Felder (1993), the deductive approach entails teaching methodologies that emphasize well-structured presentation of concepts to be taught through introducing concepts to students followed by practical activities. Using the deductive methods enable me to introduce concepts at any level of operation of our students since the module is in the First Year of study.

In implementing the inductive and the inductive approaches in teaching and learning, we seek to strike a balance – the middle range – of the two approaches in order to reach optimum output in meeting the objective to be achieved. The module demonstrates that an eclectic approach that triangulates the strengths of the inductive and deductive approaches to teaching and learning promotes deeper understanding of concepts and knowledge retention, as well as generates confidence and problem-solving abilities in learners (Fedler, 1993).

On the other hand, teaching methods refer to the general principles, pedagogy and strategies we employ in delivery of concepts in the classroom situation. The choice and adoption of any teaching method is determined by an array of existing factors both inside and outside the Planning School. Students operating at different levels of learning therefore require not only a diversity of teaching approaches in the learning and teaching process; but also, a diversity of these methods (Fedler, 1993). Briggs and Wager (1989), also stress the teaching methods applied in any learning and teaching situation should be configured to match the level of development and operation of the students. This means that, in principle, the various teaching methods can be adopted in any teaching and learning situation, but the implementation of these methods

Lecturing is the most popular method of teaching that we employ in all our teaching sessions. We employ lecturing because it caters for large classes, and it enables me to introduce concepts. The lecture technique also promotes a face to face interaction with my students. Through the lecture method, we beam all the lecture presentations using an overhead projector as a form of visual presentation that allows students to follow the debates under discussion. Problem based learning links concepts with professional activities. Thus, the problem-based learning techniques is very useful in architectural design discourses because they seek solution to design problems. For example, we use the lecture method to introduce concepts, and the Problem Based Learning technique to enable students engage with the learning content and challenge the planning problems in a collaborative way. Thus, Problem Based Learning is about students connecting disciplinary knowledge to real-world problems. This is one of the core values the architectural design module seeks to achieve.

Discovery learning is a teaching technique that puts emphasis on students finding out ‘things’ for themselves through introspecting into the existing problems or concepts, as well as asking questions about the existing phenomena. Discovery learning is essentially about students constructing their own knowledge through structures and sequenced presentation of concepts, generate their own conclusions through reflecting on tasks given, and intuitively asking why scenarios present themselves the way they do. As soon as student make these enquiries, new knowledge is developed and generated. We therefore use the discovery learning technique because it is an innovative, thought-provoking, and interesting way of knowledge creation in my students. Inquiry based learning, is a teaching technique based on inquiry or asking questions. After every lecture presentation, we ask students challenging questions so that they develop deeper understanding of the concepts under discussion. This way, our students are intrinsically motivated to find answers to these questions through exploring the learnt concepts thereby creating new knowledge and insights in architectural design.

Coaching involves guiding students in the learning process. As lecturers, we maintain my role of imparting knowledge to my students while at the same time I ensure that my students learn and work on their own. Coaching assumes a traditional perspective of teaching of knowledge transmission from the knowledgeable other. Thus, coaching adopts two levels, that is, teacher-student coaching through face to face lectures; as well as student-student coaching through tutorials and group work. From a constructivist perspective, coaching therefore entails laddering and scaffolding my students until they reach their Zone of Proximal Development (ZPD) (Vygotsky, 1978). In our case, laddering and scaffolding takes form of support in the teaching and learning process. Discussion is a generic technique in teaching and learning. We use this technique in almost every lecture as a way of exploring planning concepts, sorting relevant facts, and developing conclusions from the topics presented. In most instances, discussion presents me and my students with a platform to revisit work done, as well as an opportunity to argue, analyse and interpret specific issues in architectural design.

In our teaching, visual presentations take form of simple illustrations, diagrams, sketches, and drawings. On the other hand, videos take form of short films that usually last between three and ten minutes. These techniques create a sense of wonder and natural curiosity in the teaching and learning process as my students are motivated to learn. Complex phenomena are visually represented in form of sketches and in motion. We use whiteboards in the lecture rooms to make visual presentations in writing. Through the use of videos, complex concepts are explained. This enhances flexibility in teaching and learning, as well as provides clarity on concepts. Students remain focused. This approach, to teaching and learning enables students to acquire knowledge and skills through structured sequence of complex concepts in architectural design. In our teaching, we also use case studies. We realized that case studies are a powerful, and student-oriented teaching technique that imparts knowledge and critical thinking skills particularly in solving planning problems. According to Angelo and Boehrer (2002), case studies enable students to work through complex, ambiguous, real world problems through engaging with the course material, and through practical interaction with the learning experiences rather than presenting an analysis from a distance. Case studies by nature are multidisciplinary, and enable students to bridge the gap between theory and practice. We also use seminars as a method of teaching Urban and Regional Planning concepts. According to Gibbs (1999), seminars are a method of teaching that brings together small groups of students for a meeting to discuss a common concept. Through seminars, we enable our students to focus on a particular theme. This enables my students not only to grasp concepts but, also to discuss and actively participate in the learning process. We also use group tutorials in our teaching. According to Gibbs (1999), group tutorials are a relaxed way of bringing together students of various capability to learn often difficult questions. They are a form of laddering (Vygotsky, 1978). Unlike seminars, group tutorials bring students from the same class together. Through group tutorials, student revise concepts learnt in a more relaxed manner.

Research Methodology

This research aims to investigate the methods, challenges and solutions related to the Architectural Design Course which forms part of the Bachelor of Urban and Regional Planning syllabus at the University of Johannesburg. The research employed a case study design approach and also implemented a qualitative research approach.

Task 1: Review of Literature

In this task, the authors conduct an extensive and critical review of literature of; Learning by doing and Modes of Learning, Mode 2. The literature forms the theoretical and conceptual framework for this research and the lens in which the authors interpret the empirical data.

Task 2: Primary Data

For this study, the authors utilised semi-structured interviews for the primary methods and data collection. The authors intended to interview 30 respondents, this was successful and we had a 100% turn out. Further to the interviews, the authors hare their Auto-Ethnographic interpretations of the course’s methods and challenges.

Analysis of Data

The analysis of data for this research is by far the most important aspect of this paper. The data was collected from 30 interviewees from various levels within the Bachelor of Urban and Regional planning. This qualitative data was analysed using an interpretivist paradigm aiming to understand the participants perceptions of the course and further the authors relate their own experience in the 3 years that the course has been implemented.

Discussion and Findings

In 2017, The Department introduced for the first time, a Bachelor’s degree in Urban and Regional Planning. This degree was an overhaul of the previous National Diploma programme, with it came various courses to compliment the Town Planning Profession. Although a major change in pedagogy has occurred within the tertiary education sector in South Africa, the Department of Town and Regional Planning strived to keep parts of the course practical to give students experience of the real-world examples, even though the pursuit is now an academic one. This phenomenon has occurred as Town and Regional Planning or Urban and Regional Planning is a highly technical field with most students pursuing a career in industry.

Table 1: Table comparing the old and new programme structures.

Old Structure	New Structure
National Diploma Town and Regional Planning Technical Planner (Professional, Accredited)	**Bachelor’s Degree** Urban and Regional Planning Planner (Accreditation in 2022)
Bachelor of Technology Degree Town and Regional Planning Professional Planner (Accredited)	**Honours Degree** Urban and Regional Planning Professional Planner (Accreditation in 2022)

Source: Authors 2019

Taking into consideration the industry needs, the Department of Town and Regional introduced various courses within the degree structure to give a holistic training to their students. The course includes modules in Architectural Design, Civil Engineering, Land Surveying, Building Economics and Property Valuation, and Environmental Science as part of the syllabus. This approach allows students to learn beyond planning. The aim of the course is to introduce Architectural Design to Town Planning students to allow them basic knowledge of the various aspects of Architecture and its relationship with Town Planning. The course therefore had to be structured to cover various aspects of Architectural Design, more especially the technical aspects. Due to time constraints of the course, the knowledge transfer had to be compressed but powerful and relevant to industry. The course started with an introduction to architecture and the built environment and its need, thereafter quickly proceeding to the technical aspects of submission and working drawings.

The Architectural Design course, therefore, is primarily a technical transfer of skills more than designing, however students are expected to show some design thinking. The entire syllabus is based on a small-scale residential house. This project was chosen as it is complex but also easy enough to relate to. Students are expected to study the provided drawings for one week, thereafter a discussion of the building takes place. The course then introduces students to architectural drafting techniques and introduction into layering drawings from walls, windows, doors, etc. to annotations and dimensions. We also introduce students to basics services such as sewer, storm water, electrical and water supply. The overall important aspect in the course is to introduce students to reading the plans and producing area schedules with related town planning controls. The table below illustrates the course structure over the semester.

Table 2: Table outlining the structure of the course.

Assignment	**Outcome**	**Time limit**
Introduction to Architectural Design	To understand what Architecture, Architectural Design and Architectural Drafting means and their relevant uses in the industry.	1 Week
Introduction to Site Plans	To understand what is the purpose of a site plan, furthermore to draft a site plan with relevant services, setbacks and features.	1 Week
Floor Plans	To understand what is the purpose of a floor plan, furthermore to implement understanding through drawing a floor plan with all technical details.	3 Weeks
Basic Services	To understand what role services, play in a building. Students are required to produce a services layout of sewers and stormwater.	1 Week
Building Sections	To understand the need for building sections in a set of working drawings. Students are required to produce sections of the building provided.	2 Weeks
Elevations	To understand the need for building elevations. Students are required to draft elevations with all building features and site features.	2 Weeks
Electrical Layouts	To understand the need for electrical layouts in small domestic projects and to draft a basic electrical layout.	1 Week

Source: Authors 2019

The need for the course of Architectural Design provides fundamental understanding of Architectural Design and the related technical aspects. This course is vitally important for Town Planners, especially those who will work in the development planning sector. The authors have had personal experience with lack of understanding in drawings submitted to local municipalities and believe the implementation of Architectural Design for Town Planners will give students added edge in the working world.

Students responses and the level of understanding of Architectural Design

In this section of the research, the authors made use of qualitative interviews to assess students' views and opinions on the course. The authors probed the following areas to understand the benefits and challenges of the course;

In this topic, we asked students what did they understand by Architectural design as a whole. The following typical responses were noted as reflected in box 1 below.

> *"The art and science of designing buildings"*
>
> *"To understand the different scales of the built environment, from macro to micro development"*
>
> *"The process of designing buildings"*
>
> *"Architectural design forms part of Planning, it is a vital component in the process of Building"*
>
> *"A profession that concentrates on the structure of Buildings"*

Although 30 students were interviewed for the study, the above responses were typical answers that were received. The students seem to have rudimentary knowledge of what architectural design is. Some of the views are less inclined to being a correct definition of architectural design however the understanding is what is important and 80% of the responses were a correct or limited understanding of Architectural Design. Through this exercise, the authors note that an area of concentration in the initial lecture is to stress the definition of architectural design and an understanding of architectural design in the built environment. Although the authors have somewhat introduced the definition of architectural design, more will have to be done so that students can have a deeper understanding of what architectural design is.

Skills and Knowledge gained in the Course

In this area of research, we asked students what skills and knowledge they gained in the course. The following typical answers were provided by students as reflected in box 2 below.

> *"The skills learnt from the module include the ability to read plans and understand the different components of a building"*
>
> *"The skills and knowledge gained from the course is beneficial to town planners as it is something that we need when we enter practice, I have gained knowledge of how to draft plans and produce various different services layouts"*
>
> *"I now understand that architecture and town planning are disciplines that work together to construct a development of any kind. The skills I have gained help me to have an understanding of the entire scale of the built environment"*
>
> *"Architectural design has improved my critical thinking and problem-solving skills"*

The above answers were typical of students throughout the interview process. Most students have gained understanding, skills and knowledge from the course. It was discovered that all students understand that buildings are made up of components, although we did not explicitly imply that buildings are made out of components, students made this discovery by themselves, possibly so when we layered different components while drafting the various layers. Students furthermore discovered that through the course, they learned the necessary skills of drafting, many of the students further stated that due to this they gained knowledge which could be implemented when they enter practice. The authors take this as a positive and will implement further strategies to develop the students drafting skills. From this research, the authors discovered that the course in architectural design opened up their knowledge of the greater built environment.

Students expressed that their knowledge is not limited to town planning but has further overlapped into other professions which they have basic understanding of, further to this, students were cognisant of the different scales of the built environment. The authors do believe that knowledge has been gained by students in terms of the consultants that will be involved with built environment projects, furthermore the students gained knowledge and understand that town planning does not operate in a silo and various components comprise the built environment. By far, the most important skill gained by students was the improvement of critical thinking and problem-solving skills. This comment by majority of students remains true to the testament that architectural design requires high levels of critical thinking and problem-solving abilities. Throughout the course, the challenges and situations are intended to foster critical thinking and problem solving. For example, students are expected to design and fit their drawings on a page, although rudimentary this pushes students to thinking further than what is in front of them. This methodology occurs deep into the course were students have to plan and execute various strategies in order to complete a drawing perfectly.

Implementation of Architectural Design throughout the 3-year course

In this section of the research, Students were asked if they gained basic skills and knowledge in the course and if it was worthy implementing it throughout that course so that the knowledge and skill set expanded further. The following typical responses were noted from students as reflected in box 3 below.

"Yes, I think this course should be implemented over the three years because of the broad skills and knowledge we have to gain"

"Yes, Architectural design can be implemented so that we have time to understand the course more, we have too much to learn in only one semester"

"Yes, it will help me with furthering my design skills and problem-solving skills"

"No, it may sacrifice our time as our main objective is town planning"

When posed with this question, there was an overwhelming "Yes" response. The typical response from students was the need to expand their knowledge and skills further in architectural design as one semester was not enough for them to learn more than just basics. Students further commented that the knowledge had to be compressed into one semester and the time allocation for learning everything was simply not enough. Students further commented that if architectural design was implemented throughout the three-year course, it would greatly help in improving their design skills and problem-solving skills. By far, students kept mentioning the need for advancing their problem-solving skills. This comment must be taken into consideration when implementing the course further to foster both design and problem-solving skills.

Challenges in the Module

In this section of the research, we asked students what challenges they faced in the module. This question was critical as we needed this data to better the module for future students. The following response were typical from students as reflected in box 4 below.

"Drafting of the drawings using line weights, line types and conventions"

"Learning to draw with drafting pens"

"Annotations and Dimensions using lettering techniques"

"Understanding how a building fits together and the construction it"

"The work load for this course was heavy and we need more time"

"Access to the studio, after hours and when we have free time"

Through interviews with students, the common challenges were found to be drafting challenges. Although in lectures and in their previous module of drawing, students were taught drafting skills thoroughly. However, students found challenges in using the drafting pens, admittingly drafting is difficult for the first timer and the skills take many years to perfect. The second challenge that students faced was the understanding of how a building is put together. Although this was taught to students, one semester is challenging to fully grasp these concepts. Like all architecturally related courses, the work load to produce drawings is always heavy, especially if one is drafting by hand. Although students were allocated enough time to produce the drawings, some struggle with time management. In future classes, the authors believe that more efforts should be placed on time management for students.

One of the biggest issues for students is access to the venue when they have free time and afterhours. Although the lecturers make concerted efforts to make the venue available, the university policies states otherwise. Lecturers and students alike are not allowed to use the venues after hours unless by special application to the university. Over a semester of 17 allocated lecture slots, access to the venue is limited to that. Students are allowed to use the venue during the normal university working times, as the studio belongs to the Department of Town and Regional Planning, however afterhours use becomes the discretion of the University and is causing tremendous stress on students and lecturers.

Course Structure for deeper understanding

In this part of the research, we asked students, in their opinion, how the course can be structured better to gain a deeper understanding of the course. The following typical responses were noted as reflected in box 5 below.

"Increasing the tutorial time of architectural design"

"Examples of other drawings, so that we may gain more knowledge"

"Video tutorials on drawing and drafting"

"Measuring an existing building and drawing it"

From the responses of students, various different recommendations have been put forward by students. The majority of students requested more time for tutorials. Although the lecturers would like to give more time to students, due to the course being a minor subject, time allocated is only 10 hours per week. It is in this situation, the need for studio time afterhours becomes crucial. Some students requested to engage with other drawings to further understand the concepts of architectural design. This is noted and the authors will further provide more examples in future years. One major theme realised through this research is the issues with drafting. Students have requested more time for learning drafting and furthermore have requested video tutorials going forward. The authors see this as a good recommendation and will implement this in future years. One other recommendation put forward by students is the measuring and drawing of a building. By far this recommendation by students is vitally important, the authors wish to introduce this concept to students and implement it in future years. In the authors opinion and with relation to the literature, learning by doing is a powerful method of teaching.

Lecturers skills, expertise and portrayal of course content

In the final question posed to students, we asked, in their opinion, if the lecturer possessed the adequate skills and expertise and if the lecturer portrayed the content in a manner which was understandable to students. The students, overwhelmingly responded "Yes" to this question. It is good to note that the lecturer from the belief of students is knowledgeable and has the expertise to teach and portray information in a manner that students understand and enjoy. In the next section, the authors wish to expand on this area from an auto ethnographic enquiry.

Auto- Ethnographic Enquiry and Lecturers Responses

In light of the introduction of various different modules into the Urban and Regional Planning Degree to improve the overall holistic training of future Town/Urban and Regional Planners, the architectural design module seeks to build on the knowledge of the student. The course, short and to the point gives information to the student in a manner which allows for critical thinking, creativity and problem solving. It was our hope that students gain knowledge and understanding more than any other skill from the course. Through a learn by doing approach, the course utilises a set of completed architectural drawings for students to read understand and draw. Within the course, small tutorials are used to further their ability of design.

Challenges

During the course, the lecturer had three major challenges. The table below illustrates these challenges.

Table 3: Table outlining the structure of the course.

Year 1 (29 Students)	**Year 2** (52 Students)	**Year 3** (48 Students)
Lack of drawings tables for students. Access to Venue	Lack of drawings tables for students. Access to Venue	Access to Venue
Lack of Drawing Equipment at the start of the course	Lack of Drawing Equipment at the start of the course	Lack of Drawing Equipment at the start of the course
None	Individual Attention to students	Individual Attention to students

Source: Authors 2019

The table above, illustrate the three major challenges faced by the lecturer in the course. By far our greatest challenge in the first two years of study was the lack of drawing boards, either boards were broken or a board would not be available for a student to use because of the numbers. This negatively affected the student’s ability to finish work on time. However, in the third year of the course, new drawings boards were provided by the university and this problem has been solved. Our challenge of the venue being available at all times seems to still be a major issue. Although various talks with the university’s management, the issue of access still remains an issue. Due to the safety of students, the venues are closed after hours and special permission must be granted for use. However, the Department of Town and Regional Planning will make concerted efforts to make after hour use a reality for students.

Year on Year, the common problem by students is their ability to procure equipment for the course. Due to financial reasons and funding, some students only procure their equipment 5 weeks into the semester. The students require basic drawings instruments which include four drafting pens, set squares, scale rule, circle stencil and an eraser. Although this equipment may seem easy to acquire, students sometimes don’t have the resources to.

Since the beginning of the programme, the student numbers have increased significantly to almost double. This is due to the universities policies and not the departments requirements nor the South African Council for Planners (SACPLAN). It is a well-known fact that studio subjects such as architectural design require at least a few tutors to handle the load of students. The course currently caters for 48 students with 2 tutors and 1 studio master, making it difficult to give each student individual attention. The authors view on this scenario is that more tutors should be employed for this particular subject to give more attention to students, this way one students can have the individual attention they need. The following sections are our recommendations going forward.

Recommendations

The following table outlines the authors recommendations taking into consideration both students and lecturers views of the current scenario;

Table 4: Table outlining the issues and recommendations for the course.

Issue	Recommendation
Understanding of Basic Concepts related to Architectural Design	Employ a more in depth understanding of the course in the form of theory notes. Test if required.
Skills and Knowledge Transfer	Introduce smaller exercises for students to understand the content better. Then gradually move to more complex exercises.
Drafting	Introduce more drafting techniques in the first semester, this includes drawing with pens.
Understanding Building Construction	Introduce more video and pictures into lectures so that students learn how components fit together. The use of VR can also further stimulate learners experience.
Studio Access	Request special access of the venue from the University through the entire semester.
Tutorial Time	Increase the time and frequency of tutorials
Video Tutorials	Introduce video tutorials into the syllabus to further enhance the lecture slides, notes and critique sessions.
Additional Knowledge	Introduce the measurement of buildings and foster a learning by doing atmosphere.
Procurement of Equipment	Have the list of equipment written into the year book for students as well as the learners guide. The Department can procure the equipment and students can buy the equipment from the department.
Students numbers	Employ more tutors to give more attention to students.

Source: Authors 2019

Conclusion

This paper has demonstrated that town planning students can comprehend and learn new essential practical skills through the adoption and use of a variety of teaching and learning styles. However, more attention and emphasis must be placed on the learning by doing techniques that support the mastering of the practical skills as the students are given opportunities to keep practising the concepts overtime. The challenges noted are not impossible issues to resolve but require effort from various parties, especially the universities higher management. The authors do believe that some of the issues will be resolved in the next 2-3 years. Although challenges exist, opportunities also exist.

References

Alaiwi, Z., Sagoo, A., Georgy, M., Ul Haq, I. & Khalfan, M. 2016, 'An overview of a conceptual model for improving planning and scheduling stages of construction projects in United Arab Emirates', *The 40th Australasian Universities Building Education Association (AUBEA) Conference proceedings*, Central Queensland University, Cairns, Australia, pp. 408-22.

Angelo, T. and Boehrer, J. (2002). *Case learning: How does it work? Why is it effective*? University of California: Santa Barbara.

Biggs, J and Tang, C. (2007). *Teaching for quality learning. United Kingdom*: McGraw-Hill.

Briggs, L.J. and Wager, W.W. (1989). *Handbook of procedures for the design of instruction*. (2nd Ed.). New Jersey: Educational Technology Publications.

Brown, S. and Knight, P. (1994) *Assessing learners in higher education*. London: Kogan Page.

Dewey, J. (1904). *The relation of theory to practice in education*. New York: Macmillan.

Gibbs, G. (1999). *Using Assessments Strategically to Change the Way Students Learn*. In: Assessment Matters in Higher Education edited by Brown, S, and Glasner, A. Buckingham: SRHE and Open University Press.

Giddens, A. (1984). *The constitution of society. Outline of the theory of structuration*. Cambridge: Polity Press.

EXTRINSIC AND INTRINSIC DRIVERS OF BIM ADOPTION IN THE AUSTRALIAN AEC INDUSTRY

Shadi Batarseh[1,3], Imriyas Kamardeen[2], Mohammad Mojtahedi[1]

[1] Faculty of Built Environment, University of New South Wales, Sydney, Australia

[2] School of Architecture and Built Environment, Deakin University, Geelong, Australia

[3] Mott MacDonald, 383 Kent Street, Sydney, Australia

Abstract

The use of Building Information Modelling (BIM) in the Architecture, Engineering and Construction (AEC) industry is recognised with potential for improving process efficiency and savings for clients, consultants and builders. Nonetheless, resistance to BIM adoption in the AEC industry continues to exist. Using the Unified Theory of Acceptance and Use of Technology (UTAUT) this research investigates extrinsic and intrinsic motivation drivers and the individual's willingness to adopt BIM. An online questionnaire survey was conducted in the AEC industry of Australia, which received 177 responses from BIM users. Canonical Correlation Analysis (CCA) techniques was used to empirically analyse the associations among the motivating drivers and BIM adoption. The research found that performance expectancy is strongly associated with individual's willingness to use BIM whereas the actual use of BIM at work is strongly associated with facilitating conditions. In addition, effort expectancy has a moderate association with both willingness to use and actual BIM use. The research offers a practical framework for overcoming obstacles and establishing supportive organizational design for BIM adoption. The framework would also assist AEC organizations to conduct "health-checks" for their employees' readiness for BIM adoption, and willingness to increase BIM use at work.

Keywords

BIM adoption; Australian AEC industry; extrinsic and intrinsic drivers; unified theory of acceptance and use of technology (UTAUT); personal innovativeness; willingness for BIM adoption.

Introduction

Building Information Modelling (BIM) has been promoted as the ultimate solution for advancing the Architecture, Engineering, and Construction (AEC) industry. Though it is agreed by researchers and practitioners that BIM has many potential benefits, it is still unclear why BIM has not been accepted and adopted to a significant extent in the AEC industry (Lee et al., 2013). Previous research has identified three groups of BIM adoption challenges: "technology itself", "business processes", and "people and culture" (Bew and Underwood 2009; Owen et al. 2010; Rekola et al. 2010; Sacks et al. 2010; Grilo and Jardim-Goncalves 2010; Stapleton et al. 2014).

It has been recognised that the failure of AEC organizations to adopt BIM is more than simply an issue of technology itself (Wainright and Waring 2004), rather it extends into the domain of "people and culture". Likewise, the adoption of BIM is not a simple case of approval or rejection. Various researchers have proposed diverse factors that can influence technology adoption and how individuals reach acceptance. For instance, Davies and Harty (2013) identified that an individual's beliefs and expectations regarding the consequences of using BIM have important roles in successful adoption. Deutsch et al. (2011) discussed three change drivers of technology adoption which are people, business, and the technology itself. Brewer and Gajendran (2011) stated that decisions for investing in a technology are subjected to a range of factors, which are; human influences, business process influences, technology-related influences, and personal considerations (Brewer and Gajendran, 2011). Venkatesh et al. (2003) attested that performance expectancy, effort expectancy, social influence and facilitating conditions determine individuals' attitudes towards technology use. In addition, the technology acceptance model (TAM), proposed by Davis (1989), posited that the individual's behavioural intention to use new technology is determined by two beliefs, that is its "perceived usefulness" and "perceived ease of use". Jacobsson and Linderoth (2012) confirmed that occupational skills and nature of work tasks also influence ICT technology adoption. Based on these facts, there is an indication that the acceptance of BIM in the AEC industry can possibly be influenced by individual prerequisites. There is a variety of research that has explored the business aspects of BIM as well as the technology itself in terms of challenges and obstacles. There is limited research that explored the human aspect related to BIM adoption.

The aim of this research is to explore extrinsic and intrinsic drivers of individuals' willingness to adopt BIM within the Austrlian AEC context. The extrinsic motivation drivers are the perception that the user will use technology because it is perceived to be instrumental to achieve valued outcome, while the intrinsic motivation driver is the perception that the user is using the activity for personal traits not work performance reasons (Davis et al. 1992).

Theoretical background

Venkatesh et al. (2003) proposed the Unified Theory of Acceptance and Use of Technology (UTAUT) building on eight technology acceptance and behaviour-related theories, namely: Technology Acceptance Model (TAM) (Davis, 1989), and its later version TAM2 (Venkatesh and Davis, 2000), Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975), Motivation Model (MM) (Davis et al., 1992), Theory of Planned Behaviour (TPB) (Ajzen, 1991); Model of Personal Computing Utilization (MPCU) (Thompson et al., 1991); Innovation Diffusion Theory (IDT) (Moore and Benbasat, 1991), and Social Cognitive Theory (SCT) (Compeau et al., 1999). The relationships between the various constructs in the UTAUT are described in Figure 1. Venkatesh et al. (2003) defined four constructs that influence individuals' intention to adopt technology, which are: (1) performance expectancy - the degree to which individuals believe that the new technology or system would assist them in increasing their work performance; (2) effort expectancy - the degree to which individuals believe that the new technology or system would be easy to learn and use; (3) social influence - the degree to which key people surrounding the individual believe that it is important to use the new technology or system; and (4) facilitating conditions - the degree to which individuals believe that the needed support to use the new technology or system is provided by their organization or management. The model also contains four moderators which would have an indirect effect on the relationships between the constructs, which are: gender, age, experience and voluntariness of use.

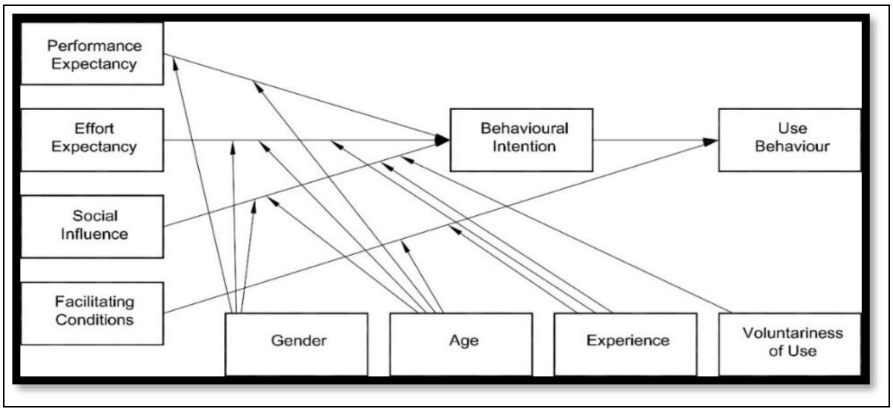


Figure 1: Unified Theory of Acceptance and Use of Technology (Venkatesh et al. 2003)

The UTAUT was used as the underpinning theory in this research. Accordingly, a research framework was developed, as shown in Figure 2, to explain the relationships between BIM adoption and motivational drivers. The UTAUT constructs were contextualized to BIM. The four extrinsic motivational drivers were considered; BIM Performance Expectancy (BPE), BIM Effort Expectancy (BEE), Social Influence on BIM (SIB), and Facilitating Conditions for BIM (FCB). Unlike the UTAUT, the research framework contains five constructs and the fifth construct is personal innovativeness for information technology. Agarwal and Parasad (1998) defined Personal Innovativeness for Information Technology (PIIT) as the willingness of an individual to try out any new information technology. Hence, the framework replaced voluntariness of use as moderator with Personal Innovativeness for Information Technology (PIIT) as an independent construct, which is considered an intrinsic motivational driver. Third, the age moderator was removed because BIM is considered a specialized ICT for specific purposes, not a general use system. In addition, the gender moderator was removed due to the limited scope of the study, and the experience moderator was removed because BIM is considered new technology or innovation for the AEC industry. Variables that characterise the five constructs in the research framework are detailed in the following sections.

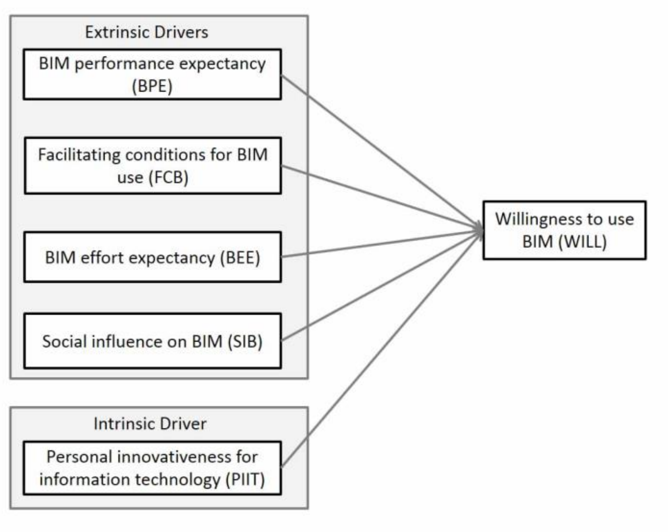


Figure 2: Research framework

BIM Performance Expectancy (BPE)

Performance expectancy is defined in the Technology Acceptance Model (TAM) as the degree to which an individual believes that using the system will help him or her to attain gains in job performance (Davis 1989). Six varaibles / indicators were identified in different technology adoption theories (Davis et al. 1992; Thompson et al. 1991; Moore and Benbasat 1991; Compeau et al. 1999), which characterise technology performance expectancy and these were contextualised to BIM adoption as follows:

- BPE-1: Using BIM in my job would enable me to accomplish tasks more quickly
- BPE-2: Using BIM would improve my job performance
- BPE-3: Using BIM in my job would increase my productivity
- BPE-4: Using BIM would enhance my effectiveness on the job
- BPE-5: Using BIM would make it easier to do my job
- BPE-6: I would find BIM useful in my job

BIM Effort Expectancy (BEE)

Effort expectancy is defined in Technology Acceptance Model (TAM) as the degree of ease associated with the use of the system (Davis 1989). Six varaibles / indicators were identified in different technology adoption theories (Thompson et al. 1991; Moore and Benbasat 1991; Venkatesh et al. 2003), which characterise technology effort expectancy and were contextualised to BIM adoption as follows:

- BEE-1: Learning to operate BIM would be easy for me
- BEE-2: I would find it easy to get BIM to do what I want it to do
- BEE-3: My interaction with BIM would be clear and understandable
- BEE-4: I would find BIM to be flexible to interact with
- BEE-5: It would be easy for me to become skilful at using BIM
- BEE-6.: I would find BIM easy to use

Social Influence on BIM (SIB)

Social Influence is defined in Unified Theory of Acceptance and Use of Technology (UTAUT) as the degree to which an individual perceives that how important others believe that he or she should use the new system (Venkatesh et al., 2003). Four varaibles / indicators were identified in different technology adoption theories (Thompson et al. 1991; Venkatesh and Davis 2000; Venkatesh et al. 2003), which characterise social infleunce on technology adoption and were contextualised to BIM adoption as follows:

- SIB-1: I use the system because of the proportion of co-workers who use the system.
- SIB-2: The senior management of this business has been helpful in the use of the system.
- SIB-3: My supervisor is very supportive of the use of the system for my job.
- SIB-4: In general, the organization has supported the use of the system.

Facilitating Conditions for BIM (FCB)

Facilitating conditions is defined in the Unified Theory of Acceptance and Use of Technology (UTAUT) as the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system (Venkatesh et al., 2003). Drawing from Venkatesh et al. (2003), Thompson et al. (1991) and Moore and Benbasat (1991), the following indicators are contextualised to measure facilitating conditions for BIM adoption:

- FCB-1: Guidance was available to me in the selection of BIM.
- FCB-2: Specialized instruction concerning BIM use was available to me.
- FCB-3: A specific person (or group) is available for assistance with BIM difficulties.
- FCB-4: Using BIM is compatible with all aspects of my work.
- FCB-5: I think that using BIM fits well with the way I like to work.
- FCB-6: Using BIM fits into my work style.

Personal Innovativeness for Information Technology (PIIT)

Innovativeness is defined by Rosen (2005) as the degree to which an individual is relatively earlier in adopting new ideas than other members of a social system. Personal innovativeness is defined as the willingness of an individual to try out any new ICT (Lee et al., 2013). Agarwal and Prasad (1997) stated that personal innovativeness helps in identifying the individuals who are likely to adopt ICT innovations earlier than others. The statements below measure the personal innovativeness of an individual as suggested by Rosen (2005):

- PIIT-1: I find trying a new information technology to be enjoyable.
- PIIT-2: If I hear about a new information technology, I would look for ways to experiment with it.
- PIIT-3: Among my peers, I am usually the first to try out new information technologies.

Willingness to use BIM

Individual's willingness to use BIM at work is the dependent variable. It can be measured using a numerical percentage response that reflects the user's judgment.

Research method

This research embraced the quantitative deductive approach. The survey strategy was deemed suitable because the research required data collection from professionals working in various organizations within the Australian AEC industry. The questionnaire survey method was chosen for data collection because it has been seen to achieve an acceptable response rate and fulfils a number of requirements, such as: (1) it is anonymous, which allows employees to feel comfortable in giving information related to their perceptions of their organization's efficiency in connection with innovation, their BIM skills, and their general views about BIM itself; (2) it can target a wide range of organizations within the industry, rather than being confined to specific ones; and (3) it can be flexible in providing the respondent with an option to complete the survey online either with a conventional computer or with a smart phone which encourages participants to complete the survey at their own time.

Survey instrument

An online questionnaire was designed to test the research framework. The questionnaire contained three sections. The first section gathered respondents' background information. The second section collected respondents' level of aggreement using a seven-point Likert-scale, with 1 meaning 'strongly disagree' and 7 meaning 'strongly agree', on the indicators of the five BIM adoption drivers; i.e. BIM performance expectancy (6 statements), BIM effort expectancy (6 statements), social influence on BIM (4 statements), facilitating conditions for BIM use (6 statements), and personal innovativeness for information technology (3 statements). The third section measured the respondent's judgment of the percentage of paticipant's willingness to use BIM in their work. A numerical percentage response was recorded that reflected the user's judgment of BIM use.

Survey administration

The questionnaire survey was conducted online with professionals from various sectors of the Australian AEC industry. The survey was administered for a period of five months from June to October 2017, and used a stratified random sampling technique to select participants after checking if they used BIM at work, were employees in AEC companies, and worked in Australia. Participants were approached through different channels to request participation in the survey. Individual employees were approached directly via email requests with the link to the online survey. Additionally, employees with AEC organizations, which had been identified by BuildingSMART Australasia, were sent requests via corporate communications. A total of 592 professionals were invited with 177 responding, resulting in a response rate of around 30%. This is within the acceptable range of response rates for organizational research as suggested by Baruch and Holtom (2008).

Survey participants

Table 1 presents the participants' profiles. Seventy six per cent of the respondents provided their personal details (N = 135), which gives a general indication that participants were comfortable in revealing their identity, maybe because they wanted to have a copy of results as indicated in the survey. Regarding AEC industry experience, 67.6% had more than 10 years, 27.2% between 3 and 10 years, and 5.2% less than 3 years, which suggests that overall, the participants had a high level of experience in the AEC industry. With BIM experience, 33.3% had more than 8 years, 52.3% had between 3 and 8 years, and 5.2% had less than 3 years' experience. This suggests that, overall, the participants had a medium level of BIM knowledge, possibly because BIM is still relatively a new approach, only around 15 years old and it takes time to overtake the old CAD systems. Finally, regarding the role, 13.9% were top management participants, such as directors and owners, 36.4% were senior architects and engineers, 11% junior architects and engineers, and 38.7% BIM managers and technicians.

Table 1: Survey participants' profile

Characteristic	Statistic (%)
Total participants	177
Respondents identity provided	135 provided their identity out of 177 (76.3%)
AEC industry experience	173 provided job role (97.7%)
Less than 3 years	9 (5.2%)
Between 3 - 10 years	47 (27.2%)
More than 10 years	117 (67.6%)
BIM experience	174 provided job role (98.3%)
Less than 3 years	25 (14.4%)
Between 3 - 8 years	91 (52.3%)
More than 8 years	58 (33.3%)
Job Title/Role	173 provided job role (97.7%)
BIM technician / manager	67 (38.7%)
Junior architect / engineer	19 (11%)
Senior architect / engineer	63 (36.4%)
Top management	24 (13.9%)

Data analysis method

Canonical correlation analysis (CCA) was performed using SPSS V24. CCA is the most appropriate statistical method to examine the relationship between two multi-variate sets (Newton and Rudestam, 2012; Sherry and Henson, 2005). The first set of variables is identified as the predictor, and the second set of variables is identified as the criterion based on a researcher's expectations about predictive causality. CCA can be conceptualized as a simple bivariate correlation between two synthetic variables because the CCA examines the correlation between a synthetic criterion and synthetic predictor variable that are weighted based on the relationships between the variables within the sets (Yoo et al., 2012).

Results

A series of canonical correlation analysis (CCA) was conducted between each of the independent variables: BIM Performance Expectancy (BPE), BIM Effort Expectancy (BEE), Social Influence on BIM (SIB), Facilitating Conditions for BIM use (FCB), and Personal Innovativeness for Information Technology (PIIT); and the dependent variable: Willingness to use BIM (WILL). The results are presented in Table 2.

Table 2: Test of canonical correlations between constructs

	Correlation	Eigenvalue	Wilks Statis.	F	Num D.F	Denom D.F.	Sig.
BPE and WILL	.668	.804	.554	22.385	6	167	.000
BEE and WILL	.532	.394	.717	10.909	6	166	.000
SIB and WILL	.136	.019	.981	.800	4	169	.527
FCB and WILL	.631	.662	.602	18.096	6	164	.000
PIIT and WILL	.284	.088	.920	4.902	3	168	.003

H0 for Wilks test is that the correlations in the current and following rows are zero

The results of the canonical correlation analysis between perceived BIM Performance Expectancy, variable set 1: BPE1 BPE2 BPE3 BPE4 BPE5 BPE6 and the Willingness to use BIM at work, variable set 2: WILL, is shown in Table 2. The results are statistically significant based on the Wilks's λ=.554 criterion, F (6, 167) = 22.385, sig. =.000. Because Wilks's λ represents the variance unexplained by the model, 1- λ yields the full model effect size in an eigenvalue.

The results of the canonical correlation analysis between perceived BIM Effort Expectancy, variable set 1: BEE1 BEE2 BEE3 BEE4 BEE5 BEE6 and the Willingness to use BIM at work, variable set 2: WILL, is shown in Table 2. The results are statistically significant based on the Wilks's λ=.717 criterion, F (6, 166) = 10.909, sig. =.000. Because Wilks's λ represents the variance unexplained by the model, 1- λ yields the full model effect size in an eigenvalue.

The results of the canonical correlation analysis between perceived Social Influence on BIM, variable set 1: SIB1 SIB2 SIB3 SIB4 and the willingness to use BIM at work, variable set 2: WILL, is shown in Table 2. The results are statistically not significant based on the Wilks's λ=.981 criterion, F (4, 169) = .800, sig. =.527.

The results of the canonical correlation analysis between perceived Facilitating Conditions for BIM, variable set 1: FCB1 FCB2 FCB3 FCB4 FCB5 FCB6 and the willingness to use BIM at work, variable set 2: WILL, is shown in Table 2. The results are statistically significant based on the Wilks's λ=.602 criterion, F (6, 164) = 18.096, sig. =.000. Because Wilks's λ represents the variance unexplained by the model, 1- λ yields the full model effect size in an eigenvalue.

The results of the canonical correlation analysis between perceived Personal Innovativeness for IT, variable set 1: PIIT1 PIIT2 PIIT3 and the Willingness to use BIM at work, variable set 2: WILL, is shown in Table 2. The results are statistically significant based on the Wilks's λ=.920 criterion, F (3, 168) = 4.902, sig. =.003. Because Wilks's λ represents the variance unexplained by the model, 1- λ yields the full model effect size in an eigenvalue.

The CCA results validated that all the driver, except Social Influence on BIM (SIB), were associated with willingness for BIM use at work, and it demonstrated an association hierarchy of the drivers, as presented in Table 3. BIM Performance Expectancy (BPE) became as the most influential driver with correlation (0.668), then followed by Facilitating Conditions for BIM (FCB), BIM Effort Expectancy (BEE), and last Personal Innovativeness for Information Technology (PIIT) with correlations (0.631), (0.532), and (0.284). SIB found to be not significance.

Table 3: CCA between drivers and willingness to use BIM results

Driver	Correlation	Sig.
BIM Performance Expectancy - BPE	.668	.000
Facilitating Conditions for BIM - FCB	.631	.000
BIM Effort Expectancy - BEE	.532	.000
Personal Innovativeness for IT - PIIT	.284	.003
Social Influence on BIM - SIB	.136	.527

Correlation is significant at the 0.01 level

The five independent variables are proven to be significantly associated/correlated with the dependent variable, Willingness to use BIM (WILL). Performance expectancy had the highest correlation, followed by facilitating conditions, then personal innovativeness. Social influence was found not to be significant.

Discussion

The results show that BIM performance expectancy is the most powerful driver for users' willingness to use BIM. As stated in TAM literature, the measures of performance expectancy is significantly associated with behavioural intentions (Lee et al., 2013), which suggests that individuals consider BIM as a facilitator to enhance their job performance. Elaborating on the research results, individuals perceived that BIM would enhance their job performance for the actual and applicable work only if the necessary facilitating conditions were provided by management. This is reasonable because it is the management's responsibility to choose the proper BIM hardware and software, and allow for the additional time required to do the same tasks using BIM, especially in the early adoption phase. The results also showed that enhancing user performance is what motivates the individuals to be willing to use BIM.

Facilitating condition for BIM use is the second most powerful driver for users' willingness to use BIM. This emphasises the importance for AEC organizations to create a supportive environment for facilitating the users' satisfaction with BIM. Doing so should promote improved user performance by increasing quality and reducing resources and cost, and decreasing the individual's effort in doing their usual tasks.

The results show that BIM effort expectancy is the third most powerful driver for willingness to use BIM is. It means that the greater the effort that individuals perceive they have to employ in doing their work using BIM, the poorer they would consider using BIM. Based on the results, effort expectancy has a moderate association on BIM use, coming in third place with a medium correlation value. This may mean that effort has an indirect relationship with accepting BIM, since users tend to consider it as a temporary tool in the early stage of adoption, based on their previous CAD experience. Maybe this means that individuals would consider BIM as work requirement for employment, not a personal preference of selecting the ICT system to be used.

The results show that personal innovativeness is the fourth influential driver with a low correlation, while social influence did not have a significant relationship. Personal innovativeness is a newly added driver to the research framework based on the ICT literature. Results have shown its invalidity in its current definition and further study is recommended to test the validity of the relationship between organizational innovativeness and technology acceptance, with validated scales for them.

Conclusion

The research revealed what motivates individuals to increase their willingness to use BIM at work and to make them active contributors to the adoption process. This would decrease the adoption cost and time and increase its return on investment. Understanding employees' perception of BIM would help

AEC organizations' BIM managers to improve their adoption strategies. BIM adoption may face three types of challenges and obstacles which could be technical difficulties, operational process difficulties and employees' attitudes difficulties. Technical difficulties and operational processes difficulties can be observed and measured. Employee attitudes difficulties can be understood by the framework proposed in this research. One of the research recommendations to organizational management during the BIM adoption process is to employ recourse to explain BIM advantages for each employee according to their job role. This will help the employees to increase their understanding of BIM benefits, which would BIM rejection and resistance behaviour.

The research findings must be interpreted within the following limitations: First, the research context was the Australian AEC industry, which may not be applicable to other countries. Second, the study did not distinguish what BIM adoption stage applied since an individual's satisfaction and expectation levels may change from the pre-adoption stage, to the adoption stage, and so through to the post-adoption stage.

The research finding for facilitating conditions suggests that further studies should be conducted on organizational support and the specific managerial role and methods most suitable for adopting BIM. The unexpected finding for social influence and personal innovativeness, though they have been validated by the literature, suggests that further studies should be conducted as there may be multidimensional variables.

References

Agarwal, R. and Prasad, J., (1997). "The role of innovation characteristics and perceived voluntariness in the acceptance of information technologies". *Decision sciences*, *28*(3), pp.557-582.

Agarwal, R. and Prasad, J., (1998). "A conceptual and operational definition of personal innovativeness in the domain of information technology". *Information systems research*, *9*(2), pp.204-215.

Ajzen, I., (1991). "The theory of planned behaviour". *Organizational behavior and human decision processes*, *50*(2), pp.179-211.

Baruch, Y. and Holtom, B.C., (2008). "Survey response rate levels and trends in organizational research". *Human relations*, *61*(8), pp.1139-1160.

Bew, M. and Underwood, J., (2009). "Delivering BIM to the UK Market, Handbook of Research on Building Information Modeling and Construction Informatics: Concepts and Technologies", *IGI-Global December 2009*. ISBN 978-1-60566-928-1.

Brewer, G. and Gajendram, T., (2011). "Attitudinal, behavioural, and cultural impacts on e-business use in a project team: A case study". *Journal of Information Technology in Construction (ITcon)*, *16*(37), pp.637-652.

Compeau, D., Higgins, C.A. and Huff, S., (1999). "Social cognitive theory and individual reactions to computing technology: A longitudinal study". *MIS quarterly*, pp.145-158.

Davies, R. and Harty, C., (2013). "Measurement and exploration of individual beliefs about the consequences of building information modelling use". *Construction Management and Economics*, *31*(11), pp.1110-1127.

Davis, F.D., Bagozzi, R.P. and Warshaw, P.R., (1992). "Extrinsic and intrinsic motivation to use computers in the workplace 1". *Journal of applied social psychology*, *22*(14), pp.1111-1132.

Davis, F.D., (1989). "Perceived usefulness, perceived ease of use, and user acceptance of information technology". *MIS quarterly*, pp.319-340.

Deutsch, R., (2011). BIM and integrated design: strategies for architectural practice. *John Wiley & Sons.*

Fishbein, M. and Ajzen, I., (1975). *Belief, attitude, intention and behavior: An introduction to theory and research*.

Grilo, A. and Jardim-Goncalves, R., (2010). "Value proposition on interoperability of BIM and collaborative working environments". *Automation in construction*, *19*(5), pp.522-530.

Jacobsson, M. and Linderoth, H.C., (2012). "User perceptions of ICT impacts in Swedish construction companies:'it's fine, just as it is'". *Construction management and economics*, *30*(5), pp.339-357.

Lee, S., Yu, J. and Jeong, D., (2013). "BIM acceptance model in construction organizations". *Journal of Management in Engineering*, *31*(3), p.04014048.

Moore, G.C. and Benbasat, I., (1991). "Development of an instrument to measure the perceptions of adopting an information technology innovation". *Information systems research*, *2*(3), pp.192-222.

Newton, R.R. and Rudestam, K.E., (2012). *Your statistical consultant*. Sage.

Owen, R., Amor, R., Palmer, M., Dickinson, J., Tatum, C.B., Kazi, A.S., Prins, M., Kiviniemi, A. and East, B., (2010). “Challenges for integrated design and delivery solutions”. *Architectural engineering and design management*, *6*(4), pp.232-240.

Rekola, M., Kojima, J. and Mäkeläinen, T., (2010). “Towards integrated design and delivery solutions: pinpointed challenges of process change”. *Architectural Engineering and Design Management*, *6*(4), pp.264-278.

Rosen, P.A., (2005). *Effect of Personal Innovativeness on Technology Acceptance and Use* (Doctoral dissertation, Oklahoma State University).

Sacks, R., Koskela, L., Dave, B.A. and Owen, R., (2010). “Interaction of lean and building information modeling in construction”. *Journal of construction engineering and management*, *136*(9), pp.968-980.

Sherry, A. and Henson, R.K., (2005). “Conducting and interpreting canonical correlation analysis in personality research: A user-friendly primer”. *Journal of personality assessment*, *84*(1), pp.37-48.

Stapleton, K.A., Gledson, B.J. and Alwan, Z., (2014). Understanding technological interoperability through observations of data leakage in Building Information Modelling (BIM) based transactions.

Thompson, R.L., Higgins, C.A. and Howell, J.M., (1991). “Personal computing: toward a conceptual model of utilization”. *MIS quarterly*, pp.125-143.

Venkatesh, V., Morris, M.G., Davis, G.B. and Davis, F.D., (2003). “User acceptance of information technology: Toward a unified view”. *MIS quarterly*, pp.425-478.

Venkatesh, V. and Davis, F.D., (2000). “A theoretical extension of the technology acceptance model: Four longitudinal field studies”. *Management science*, *46*(2), pp.186-204.

Wainwright, D. and Waring, T., (2004). “Three domains for implementing integrated information systems: redressing the balance between technology, strategic and organisational analysis”. *International Journal of Information Management*, *24*(4), pp.329-346.

Yoo, S.J. and Wen-Hao, H., (2012). “The impact of employee’s perception of organizational climate on their technology acceptance toward e-learning in South Korea”. *Knowledge Management & E-Learning*, *4*(3), p.359.

EVALUATION OF GREEN BUILDING RESEARCH IN 2015-2019

Xianbo Zhao[1], Josua Pienaar[1]

[1] School of Engineering and Technology, Central Queensland University, Australia

Abstract

Green building is economically, socially, and environmentally sustainable, and useful to lower down the greenhouse gas emissions from buildings. This study aims to undertake a scientometric review of green building research in 2015-2019. A total of 644 articles from Web of Science core collection database were analysed. The most productive researchers as well as the research institutions and countries/regions active in green building research were identified. Hot research themes detected through keyword co-occurrence analysis and cluster analysis included: urban heat island, urban sustainability, cost performance of green buildings, green building technologies, rating tools, energy saving behaviour, occupant health and comfort, policies, multi-criteria decision making techniques, green building performance and building information modelling for green building. The articles with high citations were also introduced in this study and showed the most recent trend of green building research.

Keywords

Green building; scientometric review; sustainability

Introduction

The building and construction industry unavoidably have impact on environment. Commercial and residential buildings has contributed 20%-40% to the global energy consumption (Pérez-Lombard et al., 2008) and accounted for a great portion of global greenhouse gas (GHG) emissions, increasing global concerns about the climate change mediated by GHG (Shanmugam et al., 2019; Shanmugam et al., 2018; Wu et al., 2014). Green or sustainable building practices have great potential of reducing the global energy consumption and GHG emissions (Darko and Chan, 2016). Hence, a great number of researches have been undertaken in this field. By definition, green building is designed and constructed with ecological principles (Kibert, 2012) and has minimal influence on natural environment and human health (Yudelson, 2010).

Green buildings are believed to consume less resources than non-green building, and offer occupants improved indoor air quality and comfort (Darko et al., 2017; Zhao et al., 2019). In the existing researches, the terms “green building” and “sustainable building” have been used interchangeably. The development of green building has been facilitated by rating systems, such as Leadership in Energy and Environmental Design (LEED, USA), Building Research Establishment Environmental Assessment Method (BREEAM, UK), Green Building Council of Australia Green Star (GBCA, Australia), Green Mark Scheme (Singapore), etc. These systems provide practical guide in terms of the supply recognition and verification of commitment and measurements (Adler et al., 2006; Wu and Low, 2010).

Green building researches are still active in the past five years. Zhao et al. (2019) performed a bibliometric review of green building research in 2000-2016, while few have reviewed the most recent green building research. This study aims to undertake a scientometric review of the global green building research from 2015 to 2019. Scientometrics is considered as the discipline of measuring science, technology, innovation, and the impact of scientific work (Matusiak and Morzy, 2012), including measuring the authors, source journals, countries and institutions, and maps scientific fields and the production of indicators for use in policy and management contexts (Leydesdorff and Milojević, 2015). This study outlines the most recent research trends and identifies the collaborative network in the field of green building with an objective view.

Method

The Web of Science (WOS) core collection database contains the most important and influential journals, and is therefore recognized as the most authoritative data source for studying publications of most subjects (Pouris and Pouris, 2011; Song et al., 2016). Pre-analysis and comparison was undertaken first, and then the following retrieval code was used: TI=(green building OR sustainab building). Here, TI means the title of a publication. Using the title to search articles will help identify the most relevant articles, saving time spent on screening the irrelevant ones in the database.

In this review, only journal articles were used because journal articles usually present higher-quality and more comprehensive information than other types of publications. The time span of the articles was set as 2015-2019. Hence, a preliminary list of 644 bibliographic records were collected in August 2019. After the screening, all these records were relevant to green building and used for the further analysis. Each record contains the authors and affiliations, publication year, source journal, title, country/region, abstract, keywords, as well as the references. Figure 1 shows the distribution of the 644 records in 2015-2019.

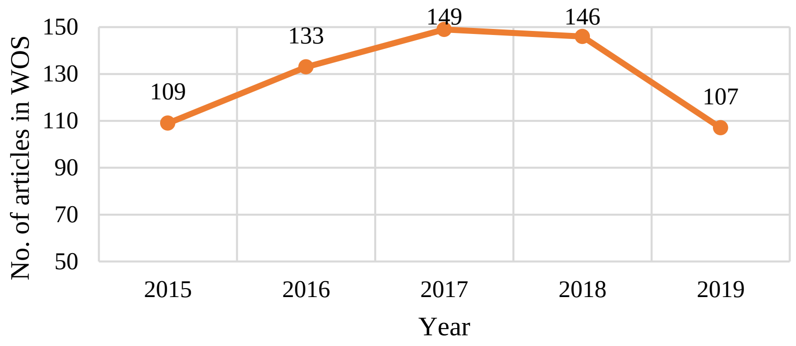


Figure 1: No. of green building articles in 2015-2019

A scientific knowledge domain can capture the notion of a logically and cohesively organized body of knowledge (Chen, 2016). Domain analysis is an advantageous scientometric approach to discovering the implications hidden in a vast amount of information and tracing development frontiers (Hjørland and Albrechtsen, 1995; Song et al., 2016). CiteSpace was used to analyze the literature of green building. In this study, several scientometric techniques were adopted, such as co-authorship analysis, countries/regions and institutions co-occurrence analysis, keyword co-occurrence analysis, subject category co-occurrence analysis, and document co-citation analysis.

Results

Co-authorship network

According to the number of journal articles in 2015-2019, the productive authors were identified. In terms of the number of articles co-authored by researchers from WOS database, Amos Darko (Hong Kong Polytechnic University) was the most productive author in the green building filed in 2015-2019 with 11 articles. Albert PC Chan (Hong Kong Polytechnic University) was the second productive author with 10 articles. The third position was shared by Zhonghua Gou (Griffith University), Bon-Gang Hwang (National University of Singapore) and Ayokunle Olubunmi Olanipekun (Federal University of

Technology, Akure; formerly Hong Kong Polytechnic University), who co-authored 8 articles in 2015-2019.

In academia, co-authorship has been the most visible and accessible indicator of scientific collaboration and can be used to measure collaboration activities (Abbasi et al., 2012). A co-authorship network is shown in Figure 2, where each node denotes an author and the inter-author links mean the collaboration through the co-authorship in the articles. The network pruning was used to delete excessive links through Pathfinder (Chen and Morris, 2003). Finally, there were 102 nodes and 175 links in the co-authorship network. The level of collaboration is represented by the thickness of the links in a given year. The links' colors (e.g., blue, purple, red, orange and yellow,) correspond to the years from 2015 to 2019, respectively.

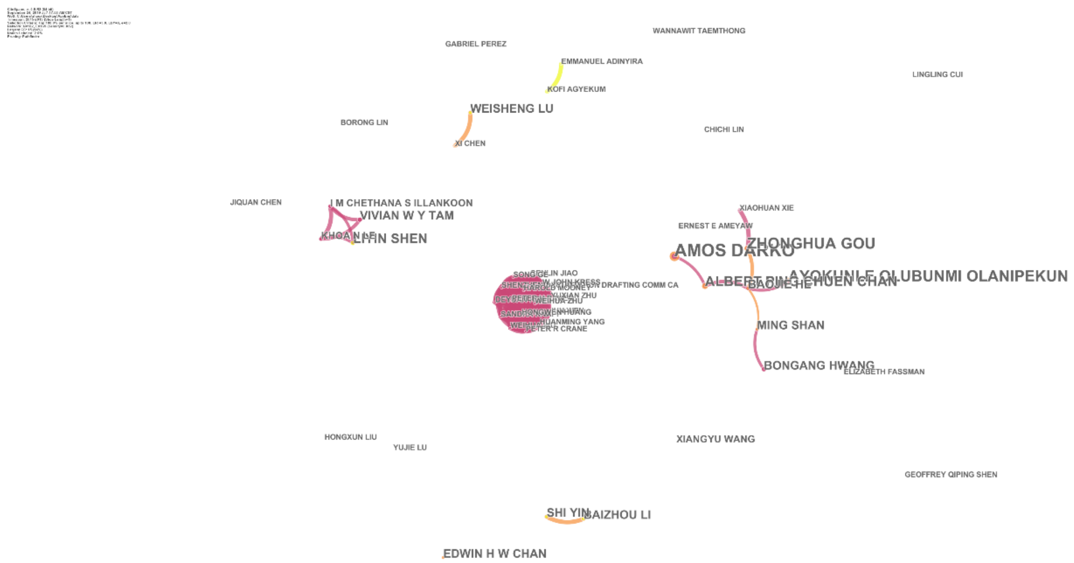


Figure 2: Co-authorship network

In terms of the collaboration, several closed-loop circuits can be found in Figure 2, indicating that strong collaboration relationships have been established among the researchers within the circuits, such as the circuit of Vivian WY Tam, Liyin Shen, JM Chethana S Illankoon and Khoan Le. In addition, research communities were detected, where authors collaborated with productive authors. For example, a productive community was found to consist of Amos Darko, Albert PC Chan, Ayokunle Olubunmi Olanipekun, Boajie He, Ming Shan, Bon-Gang Hwang, etc. It is a very productive research community with several productive researchers. A citation burst indicates a most active area of research and represents notable increases in citations over a short period, thus attracting an extraordinary degree of attention from the relevant scientific community. Jian Zuo received a citation burst in 2015-2016, with a burst strength of 2.02.

Countries/regions and institutions network

A network was generated to explore the distribution of the articles on green building. This network includes 148 nodes and 489 links. The node size denotes the total number of articles published in 2015-2019. As shown in Figure 3, China (179 articles), the USA (107 articles), Australia (65 articles), Malaysia (45 articles) and England (41 articles) makes major contributions to the articles on green building. The large number of journal articles indicated that green building research had been advanced in these countries/regions. The contributions of institutions were also detected. The following institutions have been the most active in the green building research progress in 2015-2019: Hong Kong Polytechnic University (31 articles), National University of Singapore (24 articles), and Universiti

Teknologi Malaysia (15 articles). These institutions can be recognized as the centres for green building publications in the world.

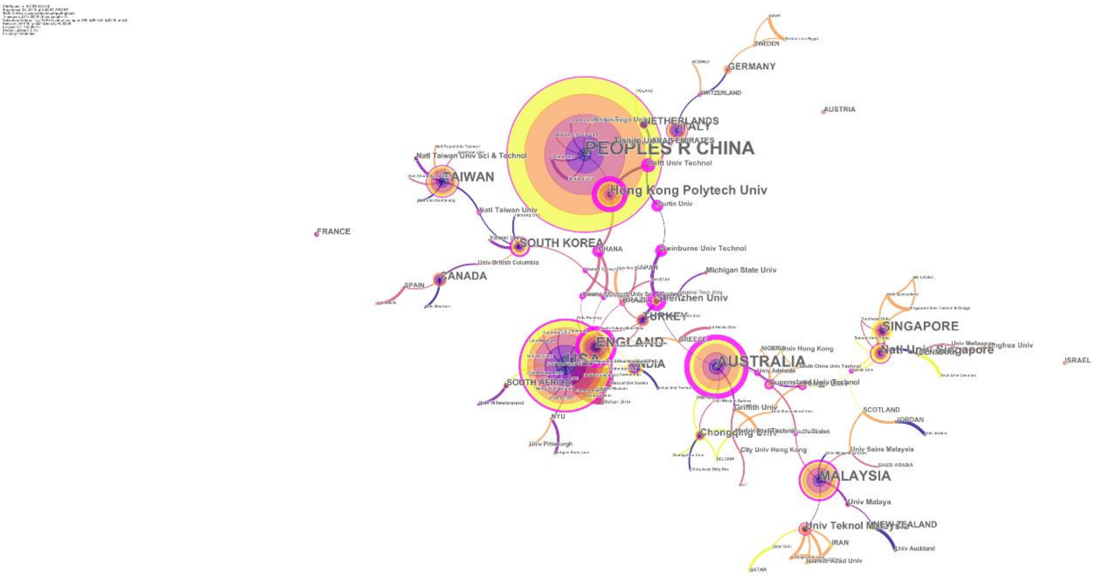


Figure 3: Countries/regions and institutions network

In graph theory, betweenness centrality measures the number of times a particular node lies between other nodes in the network (Freeman, 1979). Betweenness centrality can be calculated as the portion of the number of the shortest paths (between all pairs of nodes) that pass through the given node divided by the number of the shortest path between any pair of nodes (Abbasi et al., 2012). The nodes with high betweenness centrality serve as a bridges between two or more large groups of nodes, and thus tend to control information flows within the network (Burt, 1995). As shown in Figure 4, the nodes with high betweenness centrality are marked by purple circles. Countries/regions such as Australia (centrality=0.82), England (centrality=0.76), Ghana (centrality=0.71), South Korea (centrality=0.32), and Malaysia (centrality=0.29), and institutions such as Shenzhen University (centrality=0.95), Delft University of Technology (centrality=0.89), and Hong Kong Polytechnic University (centrality=0.84) took the key positions in the network and linked green building research activities between different countries/regions and institutions. Furthermore, citation bursts were found in Canada (burst strength=1.99, 2015-2016) and South Africa (burst strength=1.85, 2051-2016). These indicated that the articles published by these countries/regions and institutions received great attention in the corresponding years.

Subject category co-occurrence network

In the WOS core collection database, one or more subject categories were allocated to each journal publication. A network of the co-occurring subject categories in green building research, consisting of 63 nodes and 255 links, was produced to analyze the emerging trends (Figure 4). Hence, green building research covered 113 subject categories, suggesting that it was a multi-disciplinary research. The node size represents the number of articles in each category. Engineering (242 articles), construction & building technology (166 articles), environmental sciences & ecology (162 articles), science & technology-other topics (144 articles) and green & sustainable science and technology (132 articles) were found to have the most abundant articles.

Several nodes obtained high betweenness centrality, as shown by purple rings, such as the categories of environmental sciences (centrality=1.16), engineering (centrality=1.07), environmental engineering (centrality=0.94), and environmental studies (centrality=0.85). They were the turning points linking the research in different stages together and greatly affected the development of green building research in 2015-2019. In addition, a citation burst was found in public, environmental & occupant health (burst strength=1.81, 2015-2016), implying that occupant health had attracted great attention in this period.

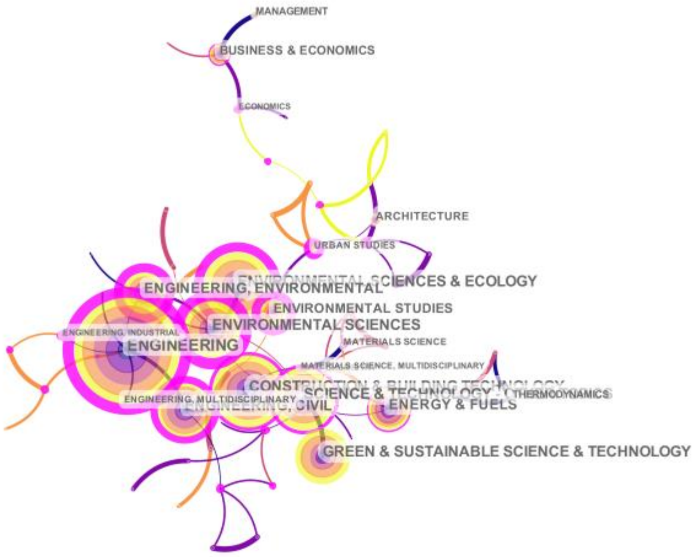


Figure 4: Subject category co-occurrence network

Keyword co-occurrence network

In the WOS database, there are "author keywords" supplied by authors and "keywords plus" identified by journals. Both types of keywords from the 644 records were employed to produce a network of co-occurring keywords. Figure 5 shows the network of co-occurring keywords with 346 nodes and 1,931 links. Similar keywords, such as "green building" and "sustainable building" were merged into "green building". The node size represents the occurrence frequency of keywords. The top 10 high-frequency keywords were "green building" (frequency=209), "performance" (frequency=95), "sustainability" (frequency=77), "construction" (frequency=74), "system" (frequency=67), "design" (frequency=64), "energy" (frequency=58), "model" (frequency=52), "energy efficiency" (frequency=49), and "China" (frequency=44).

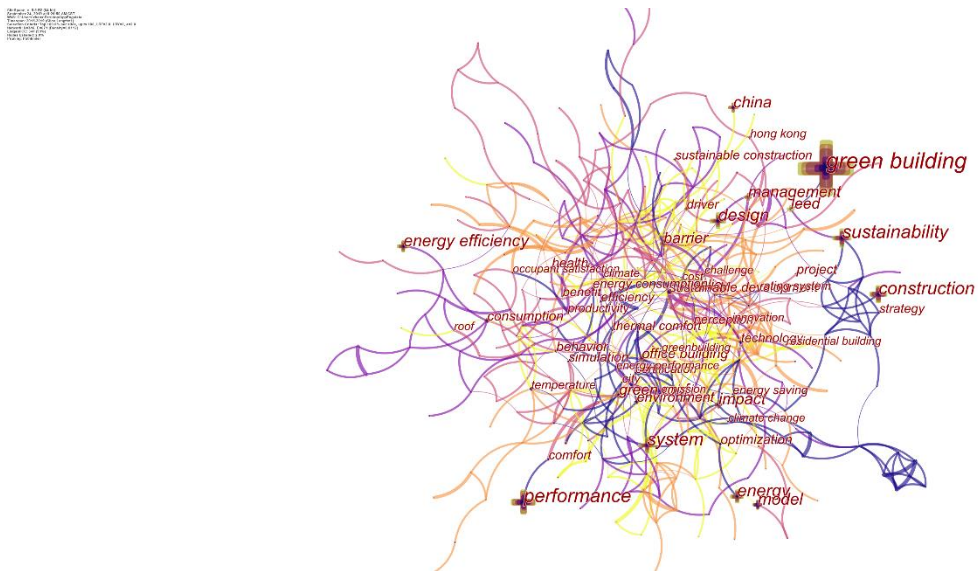


Figure 4: Keyword co-occurrence network

In addition, in 2015-2019, five keywords were found to be citation bursts: “exposure” (burst strength=2.04, 2015-2016), “quality” (burst strength=2.11, 2015-2016), “green building material” (burst strength=2.03, 2015-2016), “comfort” (burst strength=2.89, 2015-2016), and “Hong Kong” (burst strength=2.63, 2017-2019), indicating that these were the hot topics in green building research in the corresponding years. It merits attention that green building in Hong Kong was the most recent citation burst. Several researches based in Hong Kong have been well cited in 2015-2019. For instance, Wong and Baldwin (2016) studied the feasibility of using a double-skin green facade, to high-rise residential buildings in Hong Kong, which aimed to reduce energy consumption for cooling in hot and humid summer in Hong Kong, and found that it was possible to save energy using this technology; and Chen and Yang (2015) developed a hybrid daylight, airflow network and building energy simulation of a public rental housing development in Hong Kong that fulfilled the requirement of the green building guidance.

Document co-citation network

Document co-citation analysis explores the potential intellectual structures of a knowledge domain and demonstrates the quantity and authority of references cited by articles. Co-citation clusters were detected. According to the WOS citation metric, the top 10 cited documents are summarized in Table 1, whose citations range from 65 to 40. Wei et al. (2015) 65 citations, occupying the top position. Wei et al. (2015) analyzed how and to what extent indoor air quality was taken into account in green building certifications in 31 green building certifications from 30 countries worldwide and found that the average contribution of indoor air quality to global green building schemes was around 7.5%. Magno et al. (2015) also received 65 citations, sharing the top position. Magno et al. (2015) focused on the lighting system in buildings and propsoed an inexpensive, wireless, easy to install, adaptable, and smart Light-emitting diode (LED) lighting system to automatically adjust the light intensity, saving energy and achieving user satisfaction.

Table 1: 10 most cited green building articles in 2015-2019

Article	Citation	Article	Citation
Wei et al. (2015)	65	Lu et al. (2017)	47
Magno et al. (2015)	65	Costanzo et al. (2016)	45
Coma et al. (2016)	52	Wu and Issa (2015)	42
Azkorra et al. (2015)	52	Illankoon et al. (2017)	41
Coma et al. (2017)	48	Pei et al. (2015)	40

A network of document co-citations, consisting of 472 nodes and 2,137 links, is shown in Figure 5. Each node denotes a document and is labeled with the name of the first author and the publication year, and each link represents the co-citation relationship between the two corresponding documents. The node size denotes the co-citation frequency of the document. The node documents were among the 22,343 valid documents cited in the 644 bibliographic records, and may not be included in the 644 articles. Zuo and Zhao (2014), Zhang et al. (2011) and Hwang and Tan (2012) were the top three and received 60, 33 and 33 co-citations, respectively.

Around 20 documents had high betweenness centrality, shown by the purple circles. Examples were Bianchini and Hewage (2012) (centrality=0.42), Hwang and Leong (2013) (centrality=0.2) and Gou et al. (2013b) (centrality=0.16), etc. These were the significant articles that influenced the development of green building research in 2015-2019.

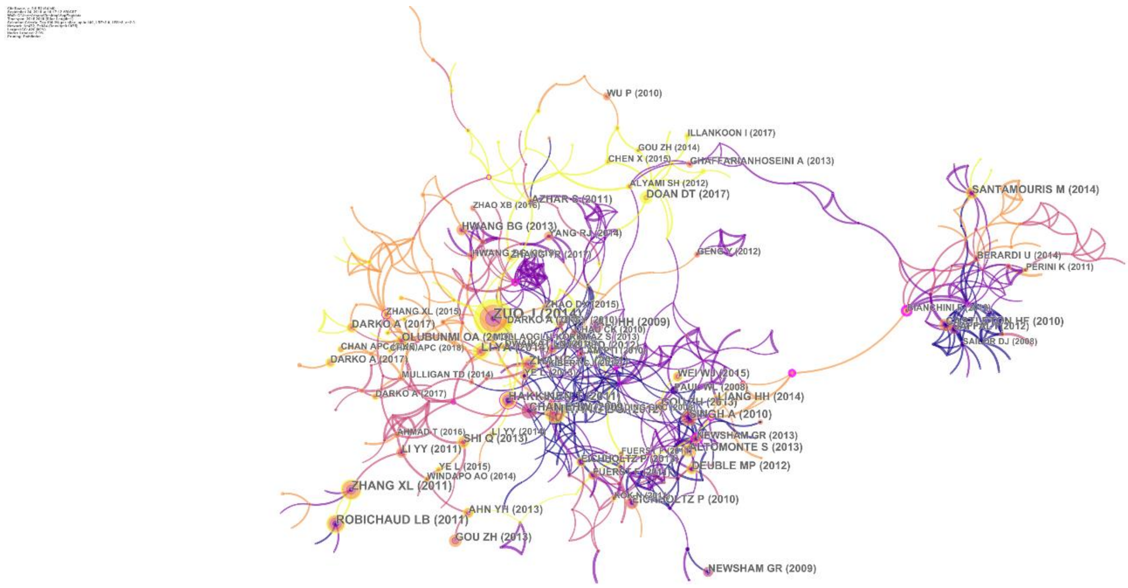


Figure 5: Document co-citation network

Additionally, citation bursts were detected in 17 documents as shown in Figure 6., and the top three citation bursts were: Paul and Taylor (2008) (burst strength=5.11, 2015-2016), Ding (2008) (burst strength=3.93, 2015-2016) and Sailor (2008) (burst strength=3.93, 2015-2016). Most of them received bursts in 2015-2016 while Gou et al. (2013a) (burst strength=3.25) got the burst in 2017-2019. Although all these burst articles were published before 2015, they still had impacts on the recent green building research in 2015-2019.

Top 17 References with the Strongest Citation Bursts

References	Year	Strength	Begin	End	2015 - 2019
UNEP (, 2011, GREEN EC PATHW SUST, V0, P0	2011	2.7447	**2015**	2016	
SCOFIELD JH, 2009, ENERG BUILDINGS, V41, P1386, DOI	2009	2.7447	**2015**	2016	
CIDELL J, 2009, PROF GEOGR, V61, P200, DOI	2009	1.9584	**2015**	2016	
PAUL WL, 2008, BUILD ENVIRON, V43, P1858, DOI	2008	5.1136	**2015**	2016	
KIBERT CJ, 2012, SUSTAINABLE CONSTRUC, V0, P0	2012	1.8363	**2015**	2016	
JAFFAL I, 2012, RENEW ENERG, V43, P157, DOI	2012	1.9919	**2015**	2017	
MILLER N, 2008, J REAL ESTATE PORTFO, V14, P385	2008	1.9584	**2015**	2016	
YANG J, 2008, ATMOS ENVIRON, V42, P7266, DOI	2008	1.9584	**2015**	2016	
KIBERT CJ, 2008, SUSTAINABLE CONSTRUC, V0, P0	2008	2.3513	**2015**	2016	
TURNER C, 2008, ENERGY PERFORMANCE L, V0, P0	2008	2.3513	**2015**	2016	
SAILOR DJ, 2008, ENERG BUILDINGS, V40, P1466, DOI	2008	3.9273	**2015**	2016	
NEWSHAM GR, 2009, ENERG BUILDINGS, V41, P897, DOI	2009	2.2595	**2015**	2017	
DING GKC, 2008, J ENVIRON MANAGE, V86, P451, DOI	2008	3.9273	**2015**	2016	
ALEXANDRIA E, 2008, BUILD ENVIRON, V43, P480, DOI	2008	3.1384	**2015**	2016	
SAADATIAN O, 2013, RENEW SUST ENERG REV, V23, P155, DOI	2013	1.7953	**2016**	2017	
ALI HH, 2009, BUILD ENVIRON, V44, P1053, DOI	2009	3.5813	**2016**	2017	
GOU ZH, 2013, J GREEN BUILD, V8, P162, DOI	2013	3.2547	**2017**	2019	

Figure 6: Document citation bursts

This study detected 14 co-citation clusters according to the keywords of the documents cited in each cluster, using the log-likelihood ratio (LLR) algorithm. This was because the LLR method is able to provide the best cluster labels with respect to uniqueness and coverage (Chen, 2014). The cluster size is measured by the number of member documents. The sizes of the 14 clusters ranged from 52 to 10. Cluster #0 had the most members and was labeled “urban heat island”. “Green building technologies”, “urban sustainability”, “project cost performance” and “energy saving behavior” were the labels of clusters #1, #2, #3 and #4, respectively. This indicated that these topics were the hot research themes in 2015-2019.

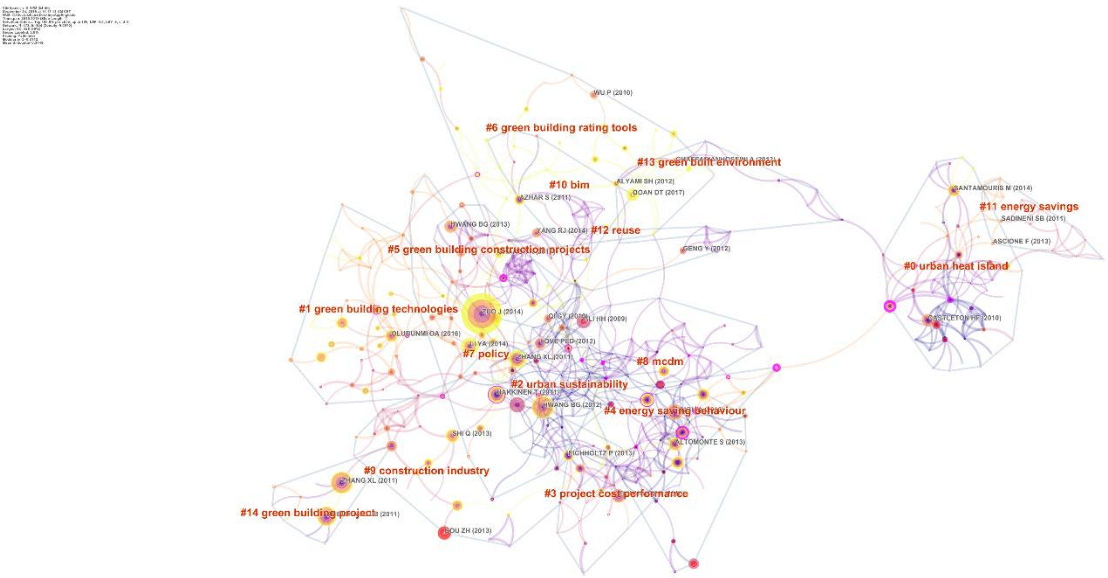


Figure 6: Document co-citation clusters

Conclusions

Green building is economically, socially, and environmentally sustainable, and useful to lower down the GHG emissions from buildings. This study aims to undertake a scientometric review of green building research in 2015-2019. A total of 644 articles collected from Web of Science core collection database were analysed.

The most productive researchers were identified. The research institutions and countries/regions active in green building research were also explored. Hot research themes detected through keyword co-occurrence analysis and cluster analysis included: urban heat island, urban sustainability, cost performance of green buildings, green building technologies, rating tools, energy saving behaviour, occupant health and comfort, policies, multi-criteria decision-making techniques, green building performance and building information modelling for green building. The articles with high citations were also introduced in this study and showed the most recent trend of green building research.

References

Abbasi, A., Hossain, L. & Leydesdorff, L. 2012, 'Betweenness centrality as a driver of preferential attachment in the evolution of research collaboration networks', *Journal of Informetrics,* Vol. 6, No. 3, pp. 403-412.

Adler, A., Armstrong, J., Fuller, S., Kalin, M., Karolides, A., Macaluso, J. & Walker, H. 2006, *Green Building: Project Planning and Cost Estimating,* R.S. Means, Kingston, MA.

Azkorra, Z., Perez, G., Coma, J., Cabeza, L. F., Bures, S., Alvaro, J. E., Erkoreka, A. & Urrestarazu, M. 2015, 'Evaluation of green walls as a passive acoustic insulation system for buildings', *Applied Acoustics,* Vol. 89, No., pp. 46-56.

Bianchini, F. & Hewage, K. 2012, 'How “green” are the green roofs? Lifecycle analysis of green roof materials', *Building and environment,* Vol. 48, No., pp. 57-65.

Burt, R. S. 1995, *Structural Holes: The Social Structure of Competition,* Harvard University Press, Cambridge, MA.

Chen, C. 2014, "The CiteSpace Manual", available at: http://cluster.ischool.drexel.edu/~cchen/citespace/CiteSpaceManual.pdf (accessed 1st March 2017).

Chen, C. 2016, *CiteSpace: A Practical Guide for Mapping Scientific Literature,* Nova Science Publishers.

Chen, C. & Morris, S. Year, "Published. Visualizing evolving networks: Minimum spanning trees versus pathfinder networks". *IEEE Symposium on Information Visualization 2003*, IEEE, pp. 67-74.

Chen, X. & Yang, H. X. 2015, 'Combined thermal and daylight analysis of a typical public rental housing development to fulfil green building guidance in Hong Kong', *Energy and Buildings,* Vol. 108, No., pp. 420-432.

Coma, J., Perez, G., de Gracia, A., Bures, S., Urrestarazu, M. & Cabeza, L. F. 2017, 'Vertical greenery systems for energy savings in buildings: A comparative study between green walls and green facades', *Building and Environment,* Vol. 111, No., pp. 228-237.

Coma, J., Perez, G., Sole, C., Castell, A. & Cabeza, L. F. 2016, 'Thermal assessment of extensive green roofs as passive tool for energy savings in buildings', *Renewable Energy,* Vol. 85, No., pp. 1106-1115.

Costanzo, V., Evola, G. & Marletta, L. 2016, 'Energy savings in buildings or UHI mitigation? Comparison between green roofs and cool roofs', *Energy and Buildings,* Vol. 114, No., pp. 247-255.

Darko, A. & Chan, A. P. C. 2016, 'Critical analysis of green building research trend in construction journals', *Habitat International,* Vol. 57, No., pp. 53-63.

Darko, A., Zhang, C. & Chan, A. P. 2017, 'Drivers for green building: A review of empirical studies', *Habitat international,* Vol. 60, No., pp. 34-49.

Ding, G. K. C. 2008, 'Sustainable construction - The role of environmental assessment tools', *Journal of Environmental Management,* Vol. 86, No. 3, pp. 451-464.

Freeman, L. C. 1979, 'Centrality in social networks conceptual clarification', *Social Networks,* Vol. 1, No. 3, pp. 215-239.

Gou, Z., Lau, S. S.-Y. & Prasad, D. 2013a, 'Market readiness and policy implications for green buildings: Case study from Hong Kong', *Journal of Green Building,* Vol. 8, No. 2, pp. 162-173.

Gou, Z., Prasad, D. & Lau, S. S.-Y. 2013b, 'Are green buildings more satisfactory and comfortable?', *Habitat International,* Vol. 39, No., pp. 156-161.

Hjørland, B. & Albrechtsen, H. 1995, 'Toward a new horizon in information science: domain‐analysis', *Journal of the Association for Information Science and Technology,* Vol. 46, No. 6, pp. 400-425.

Hwang, B. G. & Leong, L. P. 2013, 'Comparison of schedule delay and causal factors between traditional and green construction projects', *Technological and Economic Development of Economy,* Vol. 19, No. 2, pp. 310-330.

Hwang, B. G. & Tan, J. S. 2012, 'Green building project management: obstacles and solutions for sustainable development', *Sustainable development,* Vol. 20, No. 5, pp. 335-349.

Illankoon, I. M. C. S., Tam, V. W. Y., Le, K. N. & Shen, L. 2017, 'Key credit criteria among international green building rating tools', *Journal of Cleaner Production,* Vol. 164, No., pp. 209-220.

Kibert, C. J. 2012, Sustaination: Green Building Design and Delivery. 3rd ed. Hoboken, NJ: John Wiley and Sons.

Leydesdorff, L. & Milojević, S. 2015, "Scientometrics", In Wright, J. D. (Ed.) *International Encyclopedia of Social and Behavioral Sciences.* 2nd ed, Oxford, UK, Elsevier, pp. 322-327.

Lu, Y. J., Wu, Z. L., Chang, R. D. & Li, Y. K. 2017, 'Building Information Modeling (BIM) for green buildings: A critical review and future directions', *Automation in Construction,* Vol. 83, No., pp. 134-148.

Magno, M., Polonelli, T., Benini, L. & Popovici, E. 2015, 'A Low Cost, Highly Scalable Wireless Sensor Network Solution to Achieve Smart LED Light Control for Green Buildings', *Ieee Sensors Journal,* Vol. 15, No. 5, pp. 2963-2973.

Matusiak, A. & Morzy, M. Year, "Published. Social network analysis in scientometrics". *2012 Eighth International Conference on Signal Image Technology and Internet Based Systems*, IEEE, pp. 692-699.

Paul, W. L. & Taylor, P. A. 2008, 'A comparison of occupant comfort and satisfaction between a green building and a conventional building', *Building and Environment,* Vol. 43, No. 11, pp. 1858-1870.

Pei, Z. F., Lin, B. R., Liu, Y. C. & Zhu, Y. X. 2015, 'Comparative study on the indoor environment quality of green office buildings in China with a long-term field measurement and investigation', *Building and Environment,* Vol. 84, No., pp. 80-88.

Pérez-Lombard, L., Ortiz, J. & Pout, C. 2008, 'A review on buildings energy consumption information', *Energy and buildings,* Vol. 40, No. 3, pp. 394-398.

Pouris, A. & Pouris, A. 2011, 'Scientometrics of a pandemic: HIV/AIDS research in South Africa and the World', *Scientometrics,* Vol. 86, No. 2, pp. 541-552.

Sailor, D. J. 2008, 'A green roof model for building energy simulation programs', *Energy and Buildings,* Vol. 40, No. 8, pp. 1466-1478.

Shanmugam, S., Sun, C., Chen, Z. & Wu, Y.-R. 2019, 'Enhanced bioconversion of hemicellulosic biomass by microbial consortium for biobutanol production with bioaugmentation strategy', *Bioresource Technology,* Vol. 279, No., pp. 149-155.

Shanmugam, S., Sun, C., Zeng, X. & Wu, Y.-R. 2018, 'High-efficient production of biobutanol by a novel Clostridium sp. strain WST with uncontrolled pH strategy', *Bioresource Technology,* Vol. 256, No., pp. 543-547.

Song, J., Zhang, H. & Dong, W. 2016, 'A review of emerging trends in global PPP research: analysis and visualization', *Scientometrics,* Vol. 107, No. 3, pp. 1111-1147.

Wei, W. J., Ramalho, O. & Mandin, C. 2015, 'Indoor air quality requirements in green building certifications', *Building and Environment,* Vol. 92, No., pp. 10-19.

Wong, I. & Baldwin, A. N. 2016, 'Investigating the potential of applying vertical green walls to high-rise residential buildings for energy-saving in sub-tropical region', *Building and Environment,* Vol. 97, No., pp. 34-39.

Wu, P. & Low, S. P. 2010, 'Project management and green buildings: lessons from the rating systems', *Journal of Professional Issues in Engineering Education and Practice,* Vol. 136, No. 2, pp. 64-70.

Wu, P., Xia, B. & Zhao, X. 2014, 'The importance of use and end-of-life phases to the life cycle greenhouse gas (GHG) emissions of concrete - a review', *Renewable and Sustainable Energy Reviews,* Vol. 37, No., pp. 360-369.

Wu, W. & Issa, R. R. A. 2015, 'BIM Execution Planning in Green Building Projects: LEED as a Use Case', *Journal of Management in Engineering,* Vol. 31, No. 1, pp.

Yudelson, J. 2010, *The Green Building Revolution,* Island Press, Washington, DC.

Zhang, X., Shen, L. & Wu, Y. 2011, 'Green strategy for gaining competitive advantage in housing development: a China study', *Journal of Cleaner Production,* Vol. 19, No. 2, pp. 157-167.

Zhao, X., Zuo, J., Wu, G. & Huang, C. 2019, 'A bibliometric review of green building research 2000-2016', *Architectural Science Review,* Vol. 62, No. 1, pp. 74-88.

Zuo, J. & Zhao, Z. Y. 2014, 'Green building research–current status and future agenda: A review', *Renewable and Sustainable Energy Reviews,* Vol. 30, No., pp. 271-281.

PUBLIC-PRIVATE PARTNERSHIP IN THE CONTEXT OF SMART CITIES: REVIEW OF CONTEMPORARY LITERATURE

Tuan Son Nguyen[1], Tingting Liu[1], Sherif Mohamed[1], Sherif Mostafa[1]

[1]School of Engineering and Built Environment , Griffith University, Gold Coast, Australia

Abstract

Previous studies have made critical contributions to the theory and practice of Public-Private Partnership (PPPs) in the context of smart cities. A literature review plays an essential role in supporting scholars to better understand the topic, helping researchers identify the boundaries of the current body of knowledge and research trends, and shaping future research. Therefore, this paper analyses the latest research developments in PPPs within the context of smart cities. It examines papers published between 2001 and 2019 and discusses the relevant trends regarding PPPs and industrial sectors in the context of smart cities. The paper reveals that innovation and co-research in PPP projects are the main trends recently.

Keywords

Smart cities; Public-private partnership; Literature review.

Introduction

With the advancement of information and communication technology (ICT) and the Internet of Things (IoT), the concept of smart cities emerged. Many cities around the globe, such as Barcelona, New York, and Toronto have adopted a “smart” approach to renovate and develop their urban systems. As an integral part of the “smart cities” initiative, cities’ core infrastructure systems integrate digital technologies to build intelligent buildings, transport networks, and water treatment plants. There is a growing trend of incorporating smart technologies and components in the design of new infrastructure and the upgrade of existing infrastructure. The need for developing smart infrastructure has been highlighted by users, regulators, and governments. As stated by the Royal Academy of Engineering, smart infrastructure enables information gathering and processing, and ultimately facilitate informed decisions. Cruz and Sarmento (2017) further claimed that smart infrastructure allows efficient use of energy and resources and is intelligently responsive to changes in the environment. Building smart infrastructure can be seen as an effective mechanism to facilitate effective and efficient delivery of infrastructure and its associated services.

PPPs have been widely used in infrastructure development and delivery. PPPs serve as important mechanisms to alleviate a government’s budgetary constraints, increase the service quality, reduce life-cycle costs and achieve optimum risk allocation. However, smart cities and smart infrastructure development have their characteristics and requirements, and traditional PPP models may not be suitable for these types of projects. For example, since the innovation in smart infrastructures, such as software and hardware gathering and processing big data, the private sector, acting as a technology provider, will leverage the big data for commercial use. If traditional PPP models are adopted, the public safety issue could arise because of the disclosure of public information and data to a private sector partner. It, therefore, remains uncertain whether the existing PPP models can be used in smart infrastructure development to accommodate the special characteristics and requirements of these types of projects. This paper conducts a critical literature review of PPPs in the context of smart cities based on papers published from 2001 to 2019 to answer the research question: what is the development status of PPPs in the context of smart cities?

This paper begins by discussing the fundamentals of smart cities and PPPs. It then goes on to present the research method that was adopted. The following sections review selected publications under different types of PPPs applied in the context of smart cities. A brief discussion is presented after that, with the final section of the paper concluding and making suggestions for future studies.

Background

Smart Cities

Due to the rapid evolution of smart cities, there is no consensus on the definition of *smart cities* (Stone et al. 2018). The smart cities concept proposed by Giffinger and Gudrun (2010) includes a wide range of aspects in cities' development, such as smart economy, smart people, smart governance, smart mobility, smart environment, and smart living. There are also diverse smart domains included, such as smart infrastructures and behaviour communities (Rantakokko 2012). The concept of smart cities has also been mentioned in the context of public engagement and government, for instance, for cities developing web-based and technological methodologies to increase public participation in discussions (Diaz-Diaz & Perez-Gonzalez 2016). Deakin and Al Waer (2011) suggested that smart cities can be defined by the application of diverse technologies to transform life and working environments in cities.

Cities can be seen as smart when investments in the human and social capital, and traditional and ICT-based infrastructure, fuel sustainable economic growth and high quality of life, with a wise management of natural resources, through a participatory government (Rantakokko 2012). There are also different definitions of smart cities, for instance, Rantakokko (2012) stated that smart city is often defined as one with spatial intelligence and innovation, based on sensors, embedded devices, large data sets, and real-time information and response. Being a smart city brings new and better services to individuals, as well as cost savings to the city in the provision of services and operating the city (Rantakokko 2012). Most people agree that smartening of cities involves innovation in energy management, mobility services and practices, building design and management, health-care design and management, infrastructure development and use, technology implementation and governance and citizen knowledge and behaviour (Stone et al. 2018). Given the development speed of new technologies, the smart city is best considered not as an end-point but an unending process (Stone et al. 2018).

The smart cities approach being applied in city planning is a current trend, and two possible approaches may provide a methodology to move smart cities implementation forward: the technology-driven method and the human-driven method (Kummitha & Crutzen 2017). There is a consensus that a technology-based "smart" approach is fundamental to overcome the challenges of urbanisation (Cruz & Sarmento 2017). The human-driven method is that smart cities are for individuals, and these people make their cities smarter. Smart cities also attract more key stakeholders to the city, such as companies, professionals, students, and create new business opportunities (Rantakokko 2012). The existing stakeholders, for instance, local government, citizens and businesses, living labs, and research and technology communities, have different roles in contributing to the development of smart cities (Rantakokko 2012). The involvement of these key stakeholders plays a critical role in making smart cities, especially regarding attracting funds and knowledge. Dupont et al. (2015) stated that urban sustainability needs efforts to enhance human dimensions collaboratively. It seems innovative sustainable solutions need innovative collaborations. PPPs can be seen as one of the critical aspects of smart cities.

Public-Private Partnerships

PPPs are most commonly used as a mechanism to leverage private funding to compensate for a loss in public funding based on the theoretical principle that private sector expertise can increase efficiency and cost reductions in public services (Cruz & Sarmento 2017).

Regarding PPP model, for a project, the private sector calculates the required capital expenditure (CAPEX) and operating expenditure (OPEX), and it also estimates revenue, which is facilitated by the existence of several existing similar systems. The level of project risk is measured; then, the model calculates the expected return (Cruz & Sarmento 2017). The design, structuring, and assessment of PPPs are based on an estimation of revenues, costs, and a risk assessment to determine a risk-adjusted return on investment. One of the advantages of the collaboration of the private sectors is reducing CAPEX and OPEX. However, the cost of private finance is often higher than public borrowing, whereas the efficiency of construction is to be expected, decreasing the overall CAPEX. Depending on these estimations, a project's net present value and internal rate of return – which are the most commonly used decision-making criteria – can be calculated (Cruz & Sarmento 2017). Based on the project risk level and revenues, the private sector often requires some guarantee mechanism from the public authority to minimise the risk in case of insufficient revenue and potential bankruptcy. In the scenario when the real demand or consumption is lower than a threshold level, compensation from the public is required. In some scenarios, the PPP remuneration mechanisms do not require any demand risk; and the private sector is paid a fixed sum depending on the availability of the infrastructure or service (Cruz & Sarmento 2017).

The PPP model has both potential benefits and drawbacks. A number of potential benefits can be listed: 1) the possibility of an overall decrease in life cycle costs, due to the bundling of different stages of the project; 2) the ability to leverage private capital to finance the construction and operation of public infrastructure; 3) freeing-up public resources that can be used for alternative investments; 4) allowing the government to focus on its core functions; and 5) promoting innovation and gathering the best available know-how from private international operators (Cruz & Sarmento 2017). However, PPPs do have a high value of risk, especially when taking into account the negative effects of ex-post renegotiations, which occur when new circumstances appear, such as lower-than-expected demand, a change in the project design by the government, or fiscal and legal changes (Cruz & Sarmento 2017).

The PPP model is one of the four critical key drivers of smart cities (Veselitskaya et al. 2019). These key divers include mature infrastructure, wide use of ICT, the involvement of citizens in the city development, and the expansion of PPPs. There are a number of studies that emphasised the importance of reforming the traditional PPPs to support smart cities (Dupont et al. 2015; Cruz & Sarmento 2017). A number of specific networks were reported (Dupont et al. 2015), for example, the university partnerships for co-designing and co-producing urban sustainability.

Research method

There are two stages in the review process in this paper, including paper collection and content analysis. The paper collection stage was guided by the collection protocol (Table 1), which presents information about the criteria's inclusion and exclusion and search strategy (Jasinski et al. 2015; Nguyen et al. 2018). The content analysis allows authors to identify the focused subjects (Elo & Kyngäs 2008). This section also highlights overview information regarding the collected papers, for instance, 1) the number of publications per year and 2) the reported countries and industrial sectors that adopt PPPs the most in the context of smart cities.

Paper collection

Table 1 shows the inclusion/exclusion criteria and a literature survey. The inclusion and exclusion criteria were identified based on review questions that represented the objectives of the literature review. Only peer-reviewed papers were collected for this comprehensive literature review. The review had only studies reported in English, and it minimised the risk of language bias in the results (Pickering & Byrne 2013; Nguyen et al. 2018). ISI Web of Science and Scopus databases were used to search papers because both of them cover the major literature sources across the different discipline areas and fields (Thomas 2014). The keyword search terms were 'smart city', 'smart cities', 'PPP', and 'public private partnership'. The timeframe for searching was not limited but was later revised to 2001−2019, as the earliest paper that satisfied the research rules was 2001. In total, there were 56 collected papers, of which 21 were from Web of Science and 35 were from Scopus. Among these papers, some of them were overlapped. To eliminate duplicated papers, all papers' references (56 papers) were collected and stored in EndNote. By doing so, the duplicated papers could be easily eliminated, resulting in a total of 44 papers. In addition, a number of collected papers did not satisfy the research rules. For instance, some only had a title and an abstract in English, and others were not referred papers. Those papers were removed, which left a total of 32 for analysis.

Table 1: Collection protocol designed for the literature review process (Adapted from Nguyen et al. (2018))

Step	Research method
Inclusion criteria	Population: Peer-reviewed papers representing the PPPs and smart cities Language: English
Exclusion criteria	Editorials and book reviews
Searching the literature	Method: Database searching Databases: ISI Web of Science and Scopus Terms for searching: 'PPP' or 'public private partnership' and 'smart cities' or 'smart city'

Content analysis

This literature review adopted content analysis, which is a systematic and structural process to identify the main research themes for literature reviews. Content analysis allows scholars to examine huge quantities of documents in a systematic manner for identifying the focused subjects (Elo & Kyngäs 2008).

Overview of collected papers

There has been an increasing trend in the number of publications in the last four years (2016 to 2019), indicating a significant growing research interest in the topic of PPPs in the context of smart cities (see Figure 1). This growth may reflect an increasing number of PPP projects regarding smart cities, as the PPP model is one of the key drivers of smart cities (Veselitskaya et al. 2019).

Interestingly, the implementation of PPP projects in the context of smart cities was mostly reported in the EU countries, including Finland, France, Spain, Denmark, Italy, Netherlands, Belgium, UK, and Austria. In terms of country frequency, the top country which reported adopting PPPs into smart cities is Italy, following by the USA and Spain (see Table 2).

From the review, it appears that there is a diversity of industrial sectors that have adopted PPPs in the context of smart cities (see Table 3). *Infrastructures* and *ICT* are the fields in which most PPP projects are being reported, followed by *health* and *services*. The infrastructure includes housing, water, and transportation (bus, railway, and electric vehicle). ICT includes IoT, social media, IT-based product and services, data, and information management. The services include parking service, waste removal/recycling, smart garbage collection, public service improvement, banking, urban mobility, and mobility as a service.

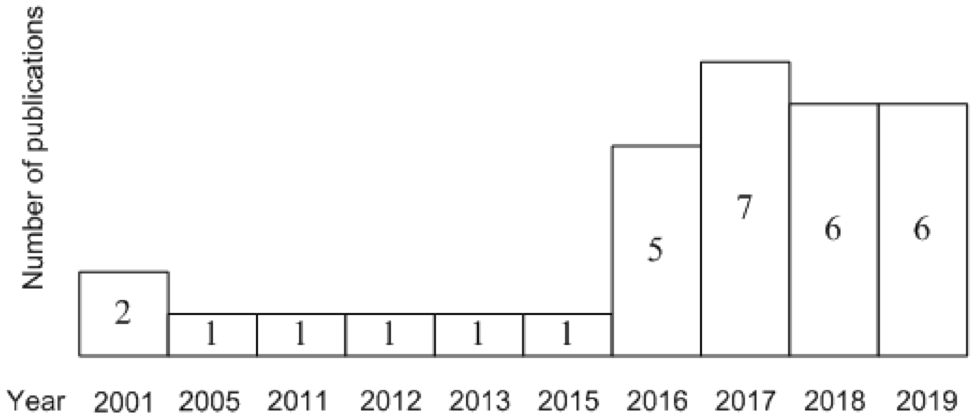


Figure 1: Number of publications per year

Table 2: Reported countries adopting PPP in the context of smart cities

No.	Countries	Number of papers	Percentage of papers (%)[1]
1	Italy	4	13
2	USA	3	9
3	Spain	3	9
4	UK	2	6
5	Finland	2	6
6	France	2	6
7	China	2	6

[1]The total percentage does not equal 100% as only countries reported in more than two papers are shown.

Table 3: Industrial sectors

No.	Industrial sectors	Number of papers	Percentage of papers (%)[2]
1	Infrastructures: Housing, water, transportation, energy	16	50
2	Information communication technology	15	47
3	Health	9	28
4	Services	7	22

[2]The total percentage is higher than 100% because a number of papers have more than one industrial sectors.

Literature review

PPP models in the development of smart cities

To illustrate how PPPs are being used in different levels of technological innovation, Cruz and Sarmento (2017) classified three types for PPP development: business-as-usual PPPs, incremental innovation PPPs, and ground-breaking innovation PPPs. This classification is based on the level of innovation in PPP projects. In this paper, the authors classified the PPP projects based on four different types, business-as-usual, incremental innovation, ground-breaking innovation, and co-research PPP projects (see Table 4).

Table 4: PPP project classification

No.	PPP types	Authors
1	Business-as-usual PPPs	Farris (2001); Antoniucci et al. (2015); Diaz-Diaz and Perez-Gonzalez (2016); Baruah and Gogoi (2017); Cruz and Sarmento (2017); Anwar et al. (2017); Offenhuber and Schechtner (2018); Smigiel (2019)
2	Incremental innovation PPPs	Horan (2001); Snow et al. (2016); Dameri and Benevolo (2016); Cruz and Sarmento (2017); Nesti (2017); Alvarez-Cedillo et al. (2017); Ferraris et al. (2018); Stone et al. (2018); Kim (2018); Selim et al. (2018); Grimaldi and Fernandez (2019); Smigiel (2019); Cooper et al. (2019); (He et al. 2019)
3	Co-research PPPs	Iida et al. (2005); Vinekar (2011); Rantakokko (2012); Dupont et al. (2015); Bull and Azennoud (2016); Abella et al. (2017); Ok and Yoo (2017); Kim (2018); Smigiel (2019); Veselitskaya et al. (2019)
4	Ground-breaking innovation PPPs	Ojasalo and Kauppinen (2016); Cruz and Sarmento (2017)

Business-as-usual PPPs

Business-as-usual PPPs can be referred to as the standard PPP approach (Cruz & Sarmento 2017). There are a number of particular PPP types, including 1) management and operating contracts, 2) leases, 3) concessions, 4) build-operate-transfer (BOT), 5) design-build-operate (DBO), and 6) joint venture (World Bank 2019). These generally involve long-term contracts and a significant level of financing by the private sector (Cruz & Sarmento 2017).

It is noted that the classification of standard PPPs does not mean that there is no innovation in these projects (Cruz & Sarmento 2017). However, the solution was used before and was essentially prescriptive, in which the public sector can determine, and specify the level of technological incorporation (Cruz & Sarmento 2017). For instance, in 2014, the Land Transport Authority (LTA) in Singapore proposed a new bus contracts model to be able to provide a better response to ridership and commuter needs. The LTA owns the assets, such as vehicles and depots, and leases them to the operator; and the operators bid for the management of the system, and receive a fixed fee (Cruz & Sarmento 2017).

One would expect that innovations regarding the smart sensing of infrastructure (e.g., in tunnels, pavements, or bridges), or in the signalling and management of Metro and rail operations, would be incorporated, as they can represent a gain in efficiency. However, the solution is essentially prescriptive, whereby the public sector determines, and specifies the level of technological incorporation that it expects, and in which systems and subsystems that innovation must be integrated (e.g. the Hohoot Metro

Line 1 in Mongolia). The systems are updated with tested technology but without a structural change in the level of development of such systems. The LTA is responsible for the planning of routes and services. The process includes a number of different packages. The first three included 5 year contracts plus 2 years extra for good performance; and the remaining nine have 2 to 10 year contracts (Cruz & Sarmento 2017).

Another example is the New Railway BOT – North-South Railway project ─ in the Philippines (Cruz & Sarmento 2017). The project is a 650 km new railway, which was launched in 2015, linking the Manila Metro (the capital region) with Legaspi City (capital of Albay province). The contract involves the design, construction, financing, operation, and maintenance of the system. The contract has a 34-year duration. (Cruz & Sarmento 2017).

Incremental innovation PPP

'Incremental innovation' PPPs can be referred to as a project that establishes PPPs for specific sets of subsystems, for instance, ticketing systems, vehicles, communication, and control system (Cruz & Sarmento 2017). The use of PPPs has been more related to 'hard' infrastructure development, for example, roads, airports, water systems, and dams. It is reported that there has been a growing trend towards increasing the use of PPPs in 'soft systems', especially information communication technology (ICT) systems. An example of this is the electronic ticket system in Athens (Cruz & Sarmento 2017). The PPP project aims to implement an integrated electronic fare system. The contract is for 12 years and includes the funding, design, installation, operations support, maintenance, and technical management of the system. The operator is remunerated through a payment mechanism linked to the quality of services (Cruz & Sarmento 2017).

Co-research PPP

Universities and research centres play an increasing role in an innovation project regarding smart cities (see Table 4). For example, the Oulu Innovation Alliance was established in 2007, consisting of the City of Oulu, the University of Oulu, the Oulu University of Applied Sciences, the VTT Technical Research Centre of Finland and Technopolis (Rantakokko 2012). The alliance' objective is to evaluate the city's potential from the global perspective to draw up a regeneration proposal for the Oulu innovation ecosystem in order to better meet the challenges of business and innovation (Rantakokko 2012).

Ground-breaking innovation PPP

'Ground-breaking innovation PPPs' can be referred to as a project that is more linked to isolated exploratory pilot actions, and the project proves the possibility of being able to test 'proof of concepts' (Cruz & Sarmento 2017). Ojasalo and Kauppinen (2016) referred to this type of PPP project as the creation or re-creation of new business. They stated that this option is initiated by companies and aims to create something new. It is supported by using cities as a platform for new ideas, where a plurality of stakeholders, ideas, and knowledge come together. The cities are a source of ideas and collaborative methods between systems and communities. New business opportunities come from innovative outcomes (Ojasalo & Kauppinen 2016).

Discussion

The literature review indicates that the previous studies focused more on the corroboration of different parties in the PPP projects as well as the innovation aspects of these projects in the context of smart cities, whereas the mechanism of PPP projects regarding the financial aspect in the context of smart cities is less discussed. This opens the door for future research. The further studies should pay more attention to develop a new PPP mechanism for smart cities where innovation is emphasised which create more risks, and thus, the new PPP model should consider this aspect to balance the opportunities and risks for both public and private parties.

Even though PPP is one of the key drivers for smart cities, the public opinions are sometimes still sceptical about whether or not the private parties are making more profit on the existing public system than what they offer/benefit to the taxpayers. For instance, the incremental PPP projects are built up based on the hard systems that existed before, so the citizens will need to pay more to access these facilities because they now offer more convenience for them. However, the critical point here is how much the users are willing to pay for the new system. Even though this issue can be addressed by the transparency of PPP projects, people should keep in mind that the purpose of private parties is to make profits. Future studies should address these problems.

There is evidence suggesting that there is a requirement for different options for public services and their future innovation and production in the context of smart cities. Public-private–people partnerships (PPPP) is an increasingly popular approach for this purpose. Collaborative innovation enhances PPPP in general, which may bring many advantages to all individuals. It is critical for individuals to understand each other's concerns as well as their demands. The engagement has to be regular and open in nature in order to build trust (Ojasalo & Kauppinen 2016). Through the involvement of people in a PPP model, PPP projects in the context of smart cities will be more transparent and get more support from the citizens.

Conclusion

PPP in the context of smart cities has received attention from both academia and industry because of the increase in the demand of building up smart cities, while there is a shortage of public funding. This paper has presented a comprehensive literature review of PPPs in the context of smart cities, focusing on papers published from 2001 to 2019. The review aimed to advance understanding of this topic as well as highlight the current study status and trends. The review discovered the EU countries which have adopted PPPs in the context of smart cities the most. Infrastructures and ICT are where the PPP projects take place more commonly in developing smart cities. Regarding PPP project types, the incremental innovation and co-research PPP projects are the most commonly applied in the context of smart cities.

Some research trends for the PPP models in developing smart cities should be focused on. First, developing a new PPP model and mechanism will suit projects that require a high level of innovation. Secondly, public engagement in the development of an individual PPP project should be explored to create more transparency and trust among public and private parties.

Acknowledgements

The work described in this paper was fully supported by the Cities Research Institute, Griffith University.

References

Abella, A., Ortiz-De-Urbina-Criado, M. & De-Pablos-Heredero, C. 2017. 'A Model for the Analysis of Data-Driven Innovation and Value Generation in Smart Cities' Ecosystems', *Cities*, vol. 64, pp. 47-53.

Alvarez-Cedillo, J., Acosta-Gonzaga, E., Aguilar-Fernández, M. & Pérez-Romero, P. 2017. 'Internet Prospective Study', *Bulletin of Electrical Engineering and Informatics*, vol. 6, pp. 235-240.

Antoniucci, V., D'alpaos, C. & Marella, G. 2015. 'Energy Saving in Tall Buildings: From Urban Planning Regulation to Smart Grid Building Solutions', *International Journal for Housing Science and Its Applications*, vol. 39, pp. 101-110.

Anwar, B., Xiao, Z. D., Akter, S. & Rehman, R. U. 2017. 'Sustainable Urbanization and Development Goals Strategy through Public-Private Partnerships in a South-Asian Metropolis', *Sustainability*, vol. 9.

Baruah, M. & Gogoi, B. 2017. Urban Mobility and Economic Development of Tinsukia, Assam. *In:* SHARMA, P. & RAJPUT, S. (eds.) *Sustainable Smart Cities in India: Challenges and Future Perspectives.*

Bull, R. & Azennoud, M. 2016. 'Smart Citizens for Smart Cities: Participating in the Future', *Proceedings of the Institution of Civil Engineers-Energy,* vol. 169, pp. 93-101.

Cooper, P., Tryfonas, T., Crick, T. & Marsh, A. 2019. 'Electric Vehicle Mobility-as-a-Service: Exploring the “Tri-Opt” of Novel Private Transport Business Models', *Journal of Urban Technology,* vol. 26, pp. 35-56.

Cruz, C. O. & Sarmento, J. M. 2017. 'Reforming Traditional Ppp Models to Cope with the Challenges of Smart Cities', *Competition and Regulation in Network Industries,* vol. 18, pp. 94-114.

Dameri, R. P. & Benevolo, C. 2016. 'Governing Smart Cities: An Empirical Analysis', *Social Science Computer Review,* vol. 34, pp. 693-707.

Deakin, M. & Al Waer, H. 2011. 'From Intelligent to Smart Cities', *Intelligent Buildings International,* vol. 3, pp. 133-139.

Diaz-Diaz, R. & Perez-Gonzalez, D. 2016. 'Implementation of Social Media Concepts for E-Government: Case Study of a Social Media Tool for Value Co-Creation and Citizen Participation', *Journal of Organizational and End User Computing,* vol. 28, pp. 104-121.

Dupont, L., Morel, L. & Guidat, C. 2015. 'Innovative Public-Private Partnership to Support Smart City: The Case of "Chaire Reves"', *Journal of Strategy and Management,* vol. 8, pp. 245-265.

Elo, S. & Kyngäs, H. 2008. 'The Qualitative Content Analysis Process', *Journal of Advanced Nursing,* vol. 62, pp. 107-115.

Farris, J. T. 2001. 'The Barriers to Using Urban Infill Development to Achieve Smart Growth', *Housing Policy Debate,* vol. 12, pp. 1-30.

Ferraris, A., Santoro, G. & Papa, A. 2018. 'The Cities of the Future: Hybrid Alliances for Open Innovation Check Tor Projects', *Futures,* vol. 103, pp. 51-60.

Giffinger, R. & Gudrun, H. 2010. 'Smart Cities Ranking: An Effective Instrument for the Positioning of the Cities?', *Architecture, city and environment,* vol. 4.

Grimaldi, D. & Fernandez, V. 2019. 'Performance of an Internet of Things Project in the Public Sector: The Case of Nice Smart City', *Journal of High Technology Management Research,* vol. 30, pp. 27-39.

He, B. J., Zhu, J., Zhao, D. X., Gou, Z. H., Qi, J. D. & Wang, J. S. 2019. 'Co-Benefits Approach: Opportunities for Implementing Sponge City and Urban Heat Island Mitigation', *Land Use Policy,* vol. 86, pp. 147-157.

Horan, T. A. 2001. 'Digital Places: Design Considerations for Integrating Electronic Space with Physical Place', *DISP,* vol. 144, pp. 12-19.

Iida, E. E., Springer, J. F., Pecora, P. J., Bandstra, E. S., Edwards, M. C. & Basen, M. M. 2005. 'The Sess Multisite Collaborative Research Initiative: Establishing Common Ground', *Child and Family Social Work,* vol. 10, pp. 217-228.

Jasinski, D., Meredith, J. & Kirwan, K. 2015. 'A Comprehensive Review of Full Cost Accounting Methods and Their Applicability to the Automotive Industry', *Journal of Cleaner Production,* vol. 108, pp. 1123-1139.

Kim, K. G. 2018. Implementation of Climate Smart City Planning: Global Climate Smart City Platform Solution. *Low-Carbon Smart Cities: Tools for Climate Resilience Planning.*

Kummitha, R. K. R. & Crutzen, N. 2017. 'How Do We Understand Smart Cities? An Evolutionary Perspective', *Cities,* vol. 67, pp. 43-52.

Nesti, G. 2017. Living Labs: A New Tool for Co-Production? *Secondary 'Living Labs: A New Tool for Co-Production?'.*

Nguyen, T. S., Mohamed, S. & Panuwatwanich, K. 2018. 'Stakeholder Management in Complex Project: Review of Contemporary Literature', *Journal of Engineering, Project, and Production Management,* vol. 8, pp. 75-89.

Offenhuber, D. & Schechtner, K. 2018. 'Improstructure - an Improvisational Perspective on Smart Infrastructure Governance', *Cities,* vol. 72, pp. 329-338.

Ojasalo, J. & Kauppinen, H. 2016. 'Collaborative Innovation with External Actors: An Empirical Study on Open Innovation Platforms in Smart Cities', *Technology Innovation Management Review,* vol. 6, pp. 49-60.

Ok, J. A. & Yoo, S. 2017. 'Directions and Improvements of the Future Smart City Development: A Case of Gyenggi Province', *Spatial Information Research,* vol. 25, pp. 281-292.
Pickering, C. M. & Byrne, J. A. 2013. 'The Benefits of Publishing Systematic Quantitative Literature Reviews for Phd Candidates and Other Early-Career Researchers', vol.
Rantakokko, M. 2012. 'Smart City as an Innovation Engine: Case Oulu', *Elektrotehniski Vestnik/Electrotechnical Review,* vol. 79, pp. 248-254.
Selim, A. M., Yousef, P. H. A. & Hagag, M. R. 2018. 'Smart Infrastructure by (Ppps) within the Concept of Smart Cities to Achieve Sustainable Development', *International Journal of Critical Infrastructures,* vol. 14, pp. 182-198.
Smigiel, C. 2019. 'Urban Political Strategies in Times of Crisis: A Multiscalar Perspective on Smart Cities in Italy', *European Urban and Regional Studies,* vol. 26, pp. 336-348.
Snow, C. C., Håkonsson, D. D. & Obel, B. 2016. 'A Smart City Is a Collaborative Community: Lessons from Smart Aarhus', *California Management Review,* vol. 59, pp. 92-108.
Stone, M., Knapper, J., Evans, G. & Aravopoulou, E. 2018. 'Information Management in the Smart City', *Bottom Line,* vol. 31, pp. 234-249.
Thomas, S. 2014. 'Blue Carbon: Knowledge Gaps, Critical Issues, and Novel Approaches', *Ecological Economics,* vol. 107, pp. 22-38.
Veselitskaya, N., Karasev, O. & Beloshitskiy, A. 2019. 'Drivers and Barriers for Smart Cities Development', *Theoretical and Empirical Researches in Urban Management,* vol. 14, pp. 85-110.
Vinekar, A. 2011. 'It-Enabled Innovation to Prevent Infant Blindness in Rural India: The Kidrop Experience', *Journal of Indian Business Research,* vol. 3, pp. 98-102.
World Bank. 2019. *Ppp Arrangements* [Online]. Available: https://ppp.worldbank.org/public-private-partnership/agreements [Accessed 19 Sep 2019].

AN OVERVIEW CHALLENGES OF BIM AND LEAN CONSTRUCTION IMPLEMENTATION IN NEW ZEALAND CONSTRUCTION INDUSTRY

Ayuba Jerry Likita[1], Mostafa Babaeian Jelodar[1]

[1]School of Built Environment, Massey University, New Zealand

Abstract

BIM is a digital representation of a building geometric and non-geometric data, used as a reliable, shared knowledge platform to make decision on a facility throughout its lifecycle. On the other hand the focus in Lean construction is reduction of waste, increase of value of the customer, and continuous improvement for sustainable outcomes. Hence BIM can be the platform or facilitator of lean philosophy in construction. The aim of this paper, is to review and discuss the challenges of BIM, Lean construction in implementation globally and within New Zealand construction sector. A systematic and comprehensive review of relevant literature was used to identify various stages of challenges in the adoption and implementation of BIM and lean construction. Twenty-nine previous articles on BIM, Lean construction have been discussed, and challenges involved in implementation of these tools and concepts were documented. The findings indicate that BIM is successfully practice in Australia, Hong Kong, Canada, Japan, Singapore, United Kingdom and North America. In conclusion the barriers of BIM, Lean construction for more sustainable and productive construction was classified in three layers of project, organization and industry.

Keywords

Building Information Modelling, Lean Construction, Sustainable Principles, Productivity

Introduction

Building Information Modeling (BIM) and Lean construction are considered two of the most relevant drivers of change in the construction industries according to Sacks *et. al. (*2010). More, so Bolpagni *et.al*. (2017) further stated that lack of a unique definition of BIM and Lean construction often generate confusion and misunderstanding in the construction industry as well as in academia. However, BIM has been identified by the New Zealand Productivity Partnership as a new technology which integrates data and knowledge management to minimize inefficiencies and enhance the value delivered during design, build and operation.

According to Meyer & Thumell. (2016) BIM is a digital representation of a building geometric and non-geometric data, used as a reliable, shared knowledge resource to make decisions on a facility throughout its lifecycle while Rahman *et.al*. (2013) explain Lean construction as a production management philosophy that seems to suit sustainability principles in terms of waste minimization, resource optimization, continuous improvement resource, end user satisfaction and so forth. Sustainable construction as another popular concept has been recognized as a driver for societal transformation. Accordingly the construction industry in general has started to study and implement joint effort, i.e. lean construction and BIM to better manage projects Bolpagni *et.al. (*2017) although lean construction and BIM are quite different initiatives, but both are having profound impacts on the construction industry.

Construction industry is behind most industries in terms of quality productivity. In general, the construction process is carried out in various stages for instance pre-construction, construction and post-construction stages. For the overall construction process to be successful, continuity between these stages must be achieved positively (Hardin & McCool, 2015). This has been the major setback of construction productivity improvement for decades now. According to Sacks *et.al.* (2010) the goal would be to minimize waste and move toward more sustainable construction and stated that lean construction, BIM can accommodate such goals and play a role in production, representation and requirement creation for the building and construction sector. They also demonstrate the approaches and interactions between lean construction, BIM and sustainable construction, which can be an opportunity to change the perception of the Architecture, Engineering and Construction (AEC) industry for better. More, so Wang *et.al*. (2011) study indicates by recognizing the benefits of BIM all over the world found that the New Zealand construction industry has made significant points towards accepting BIM as a future application process for the construction industry.

However, Trans *et.al*. (2012) in the quest of establishing framework for further BIM research the study found some significant issues/challenges relating to uptake of BIM, Lean construction in the New Zealand construction. Some of these industry challenges have been identified as insufficient BIM application in New Zealand and lack of post-construction facilities management, the study further indicate three reasons BIM has not been widely accepted and used in New Zealand, which are; (1) slow uptake by New Zealand construction companies (2) lack of focus on BIM initiatives (led by government and industry bodies), and (3) lack of BIM-based building life cycle considerations. More, so (Stanley & Thurnell. (2014) identify perceptions regarding barriers to the implementation of 5D BIM in Auckland, there is lack of integrated models which are essential pre-requisite for full inter- operability and hence collaborative working in the industry.

Problem statement

According to Tran *et al*. (2012) study for establishing a BIM research framework in New Zealand, three reasons why BIM has not been widely used such as: slow acceptance by companies; lack of New Zealand-focused creativities; and a lack of BIM-based building life cycle considerations. Despite interest in BIM from policy makers, it appears there is no real taste by political leaders to initiate BIM implementation at a policy level. The study identified insufficient BIM application in New Zealand, and lack of post- construction facilities management. Studies and governmental reports in New Zealand have resurrected the picture of declining performance in the construction sector. It appears the productivity and performance of the construction sector has remained static or very low for the past 50 years were other industries have enjoyed significant advances and growth Durdyev & Mbachu. (2011). There is also lack of integrated approaches at conceptual level to link BIM and Lean philosophy in construction to uphold sustainable principles over the entire lifecycle of a project Rahman *et.a*l. (2013). The aim of this paper, is to review and discuss the challenges of BIM, Lean construction in implementation globally and within New Zealand construction industry. This is to create an accurate picture of the challenges and barriers involved in BIM implementation as a platform of lean philosophy in construction.

Methodology

To achieve aim of the paper: literature review of previous studies on BIM, Lean construction and sustainable principles in construction industry were performed and summarized. This study uses a methodological approach proposed by Jelodar, *et.al*. (2016) where a two-stage methodology was designed and implemented to achieve research aims. The two-stages were; a theoretical review as stage 1, and Practical exhaustive investigation for stage 2. However, this study adopted a theoretical and comprehensive review of relevant literature used in identifying various challenges in the adoption and implementation of BIM in the New Zealand construction industry. A pool of 150 articles were considered initially using keywords; such as BIM, lean construction, sustainable construction, BIM adoption, and construction industry. After a thorough investigation of articles; twenty-nine (29) relevant articles and research work, with the theme of BIM, lean construction and sustainable principles in construction industry locally and globally were identified to be relevant to the goal of this; these articles were considered carefully in order to outline the pool of possible challenges in the implementation of BIM, lean construction for the purpose of sustainable principles in New Zealand construction industry. Nine out of the twenty-seven articles and research work were New Zealand based studies, and focused on challenges of implementing BIM and lean approaches mainly in New Zealand. It is very important to identify and explore the nature and causes of these challenges. Hence the results of the studies were discussed and compared in the following sections.

Global BIM Lean construction implementation research

Table 1. Shows summary and contributions of previous researches on BIM, Lean construction and sustainable principles in construction industry globally. It shows thirteen previous researches that applied BIM, Lean construction principles in construction industry. Details on the research were discussed in subtopic below.

UK BIM Strategy Report (2012) made a thoughtful description on BIM as the first truly global digital construction technology and concluded that the technology will soon be deployed in every country in the world. The study recorded that the UK Government has to some extent mandated BIM into the UK construction industry and the original estimated savings to UK construction and its clients is £2billion per annum through the widespread usage of BIM and hence viewed as a significant tool for government to reach its target of 15-20% savings on the costs of capital projects by 2015. In an internet survey performed by Smart Market Report (2010) on the frequency of BIM use by the professionals in the U.S construction industry, it was found that 56% of firms using BIM are using it on 50% of their projects, with only 34% of the total respondents using it on less than one quarter of their projects.

Regardless of the current global interest and publicity around BIM, it is original idea has been around for quite a while; in fact it could be dated back to the 1970's Eastman *et al.(*2008). McGrath R.G. (2010) indicate that it has taken almost 40 years for current digital tools to emerge and have commercial viability and appeal in the construction sector. Bernstein. (2005) says the best evidence of its value to the construction industry is the extensive acceptance by practitioners, researchers and engineers, in addition to the fact that major developed construction industries such as the United States, United Kingdom, Denmark, the Netherlands, Finland, and Australia have all accepted and are uptake new technologies as a result to these advancements.

Smith. (2014) reveals key global trends in relation to BIM implementation, it also shows initiative and approaches that are being used by countries leading the way in the field, and it further proves that BIM implementation has gained considerable momentum over the past few years. Accordingly, the study also demonstrates several countries that are developing a successful implementation strategy with North America, United Kingdom, Singapore, Hong Kong and Australia. Therefore, the key global trends verified the importance of coordinated government support and leadership as a critical driver for BIM implementation. Figure 1 shows an illustration for integrated framework using BIM, Lean construction and sustainable construction: Adopted from Rahman A. *et. al.* (2013).

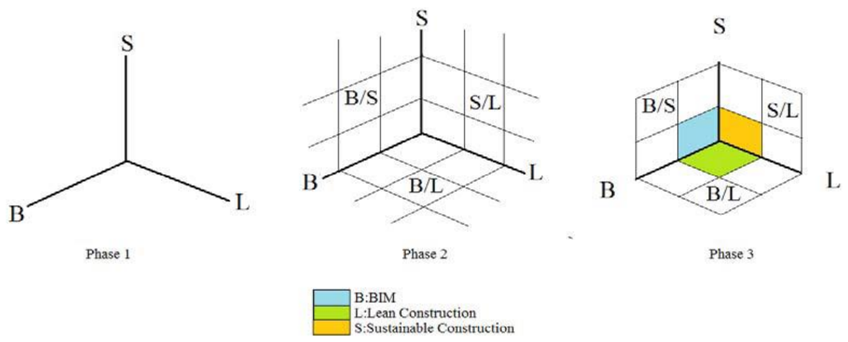


Figure 1 Integrated framework of BIM, Lean Const. and Sustainable Construction; Adopted from Rahman A. *et.al. (*2013)

Table: 1 Summary BIM, Lean Construction application in construction industry globally

Author/Year	**Title**	**Purpose**	**Findings**
Sacks et.al. (2010)	The interaction of Lean and BIM in construction	It was to investigate different ways of conceptualizing Lean construction and BIM presenting literature were examined.	Base on the investigation carried out a framework of analyses was created for assessing interconnections of Lean and BIM in construction industry.
Smith. (2014)	BIM Implementation- Global Strategies	To investigate the initiative and approaches that are being used by countries leading the way in the field.	The key findings were the importance of coordinated government support and leadership as a critical driver for BIM implementation.
Bolpagni. *et.al.* (2017)	Integration of Lean construction and Building Information Modelling in a large organization in Massachusetts	Was to establish strategies to be adopted and use for large client organization who would like to integrate BIM and Lean in all operational approach	It indicate that (1) internal change is needed in the client organization,, (2) clients need to drive the process in order to maximize benefits (3) BIM does not fit in the traditional procurement process and (4) existing contracts need to be modified to support BIM and Lean
Porwal and Hewage (2013)	BIM Partnering framework for public construction projects	To establish a widespread of BIM adoption in construction industry	Change is required in BIM adoption in the existing work practice, in order to improved productivity, better coordination, and reduce error and rework.
Wong *et. al*. (2014)	Review of cloud-base BIM technology in the construction sector.	Is to identify the substantive work on cloud – BIM particularly on building life cycle management, to provide valuable insight for practitioners and propose avenues further researchers	Findings suggested that more research to be directed towards operation, maintenance, facility management, energy efficiency, demolition and deconstruction stages of building life cycle management
Jorgensen and Emmitt. (2008)	Lost in transition- The transfer of Lean manufacturing/production from the Japanese manufacturing industry to the construction sector in the west.	To explore the transfer of Lean manufacturing/production from the Japanese manufacturing industry to the construction sectors in the west	It revealed a number of characteristics that are specific to Lean construction, most notably recognitions that critical research findings have been slow but appear to be gaining momentum
Ricardo *et.al.* (2013)	BIM-FM implementation; An exploration investigation.	Purpose was to identify key deliverables for the establishment of level of integration.	Findings indicate lack of awareness related to the benefits BIM can offer to FM process, it reveals gap of knowledge exists in relation to the value design and construction BIM can generate after construction is finished.
Sarhan *et.al*. (2018)	Barriers to implementing Lean construction practices in the Kingdom of Saudi Arabian construction industry	To identify barriers affecting Lean construction practices in the Kingdom of Saudi Arabia	It reveals 22 barriers to Lean construction implementation in KSA construction industry.
Yaakob *et. al*. (2014)	A propose study of developing BIM framework in Malaysian construction industry	To highlight fragmentation issues, discuss the definition concept and potential for BIM implementation as an integrated tool that will minimize the issue in Malaysian construction industry	It reveals related problems such as reworks, time delay, rising cost, lack of communication, coordination and wastages

Latiffi A.A *et.al*. (2013)	BIM application in Malaysia construction industry	To explore previous BIM studies on definitions and history of BIM, construction issues, application of BIM and BIM tools in construction projects as well as benefits of BIM	Findings reveals that, BIM technology implementation is expected to become more widespread in Malaysian construction industry because of the government support and efforts in promoting BIM
Roshana *et. al.* (2013)	BIM: a NEW Paradigm for quality of life within Architectural, Engineering and Construction industry.	To identify determinant factors and implementation gap of BIM in the AEC industry.	Findings reveals various determining factors and gaps existed at the national and organizational levels.
Rahman *et.al*. (2013)	Exploring the synergies between BIM and Lean construction to deliver highly integrated sustainable projects	Adversarial and non-collaborative behaviors in different sustainable construction approaches was adopted for delivering sustainable projects	The study shows exploration of an integrated approach at conceptual level that links BIM and Lean construction was adopted to uphold sustainable principles over the entire life cycle of a project.
Trans *et.al.* (2012)	Shaving BIM: Establishing a framework for future BIM research in New Zealand	To reviews and analyses issues relating to the uptake of BIM in the New Zealand construction industry	It reveals three reasons why BIM has not been widely accepted and use in New Zealand construction industry; (1) slow uptake by NZ construction industry, (2) lack of kiwi-focused in BIM initiatives (led by the government and industry bodies) and (3) lack of BIM- based building life cycle considerations
Soetanto. *et.al* (2014)	Defining the sustainable building design process: method for BIM execution planning in the UK	To develop a building information modelling (BIM)-enabled sustainable design process model that identifies critical decisions actions in the design process along with the information and level of detail that facilitate an informed timely decision.	The study shows that project delivery method have a significant effect on the sustainable outcome of buildings. The development of a structure process can assist sustainable design practice among building professional
Matarneh R. & Hamed S. (2017)	Barriers to the adoption of BIM in the Jordanian building industry	To explore the adoption of within the Jordanian construction industry	Findings reveals that the adoption of BIM in Jordan is still in a very primitive phase and faces a number of critical barriers such as , but not limited to, the absence of government incentives, lack of BIM standard, lack of BIM awareness, lack of BIM need, cost and resistance to change.
Hosseini *et.al*.(2016)	Building Information Modeling (BIM) in Iran: An Exploratory study	To present an account on the current state of BIM with focus on barriers and drivers associated with its adoption in Iran based on the perceptions of Iranian construction practitioners	It showed that the highest ranked barriers to adoption of BIM in Iran are almost entirely associated with the structure of Iranian market, the nature of the construction industry and predominant business environment in the country as well as lack of attention by policy makers and the government.
Stanley R.& Thurnell D. (2014)	The benefits of and barriers to implementation of 5D BIM for quantity surveying in New Zealand	To identify perceptions regarding the benefits of, and barriers to the implementation of 5D BIM by quantity surveyors in Auckland by increasing efficiency, improving visualization of construction details, and earlier risk identification.	It reveals perceived barriers to 5D BIM implementation within the construction industry; lack of software compatibility, prohibitive se- up costs, lack of protocols for coding objects within BIM, lack of an electronic standard for coding BIM software, and lack of integrated models which are essential pre-requisite for full inter-operability and hence collaborative working in the industry.
Ghaffarian Hosseini *et. al.* (2017)	Amplifying the practicality of contemporary BIM implementations for New Zealand Green building certification (Green Star)	BIM is expected to aid designers to shift the construction industry towards more environmentally and economically sustainable construction practice.	It reveals BIM supports the practitioners to achieve the majority of Green star criterion (75%) Energy efficiency criterion is the key factor affecting the assessment process of Green star and National Australian Built Environment rating system in New Zealand.

Therefore, Figure 1 shows the core concept of this integration to find the relationship among BIM, Lean and Sustainable Construction that will help identify positive interactions of technology and management leading to attain the goal of sustainability. More, so BIM, Lean and Sustainable construction are commonly helpful and cooperative. This study will explore in an integrated approach at theoretical level that links BIM, Lean construction principles to promote sustainable construction using BIM.

BIM is considered as a tool or platform for lean philosophy implementation in construction; hence its uptake can trigger less wasteful and more efficient processes with significant implications workflow, time and cost. Hence a diagnostic approach of lean philosophy implementation can identify common area of problem with BIM application. Accordingly addressing these common issues or problems of lean a BIM can be more effective and ultimately a more sustainable solution to productivity and performance complications in construction. Hence at this stage the common barriers to BIM and Lean implementation are discussed.

Common Barriers to BIM and lean construction solutions

According to Sarhan *et.al*. (2018) study revealed 22 barriers to Lean construction to the Kingdom of Saudi Arabia construction industry. However, principal factors that constitute these barriers were found to be traditional practices, client related, technological, performance and knowledge. Therefore, the study provides a global overview in the barriers affecting implementation of Lean construction.

An extensive literature review on the implementation of BIM world-wide and within the Middle East was performed by Matarneh R. & Hamed S. (2017), which was utilized to identify the benefits and challenges of BIM in construction industry. However, the study reveals that the adoption of BIM in Jordan is still in a very its rudimentary stages and it faces a number of critical barriers such as, thou not limited to, the absence of government incentives, lack of BIM standard, lack of BIM awareness, lack of BIM need, cost and resistance to change. Therefore, the study showed that it can help AEC practitioners in Jordan to recognize potential areas in which BIM can be useful in AEC practice, and as well can be applicable to every construction industry world-wide for positive outcome. Most of the barriers recognized in this study associated with organizational and industry level issues within the construction sector.

Tran *et al*. (2012) made a case for establishing a BIM research framework in New Zealand, and in the process he identified three reasons why BIM has not been widely used such as: slow acceptance by companies; lack of New Zealand-focused creativities; and a lack of BIM-based building life cycle considerations. Out of the three reasons the first looks to be a circular argument while the second reason was well made, and despite interest in BIM from policy makers, it would look as if there is no real taste by political leaders to initiate BIM implementation at a policy level and the third reason would appear to have some strength, but is are mainly industry related issues which are not unique to New Zealand.

One of the significant challenges to BIM implementation encountered by some participants were strong cultural resistance, and lack of support from senior staff in New Zealand organizations; however, BIM use by main contractors on large commercial projects is well established in New Zealand although at a fairly elementary level to date Smith P. (2014). There was high disapproval to change towards new ideas or inventions such as lean construction among the contracting organizations, while there was an unfavorable procurement system which pushed the risks involved in implementing new ideas to only the contractors. According to Krygiel. (2008) BIM is an information system put together using a universal common structure. It inspires good collaboration and co-ordination also allow related information to be connected, more significantly in construction industry Jackson B. A. *et. al*. (2019).

BIM is a process of creating, gathering and managing design, construction and operational information. It allows for the integration of data and information from multiple sources such as design, cost, programmed and marketing. BIM is also a database that can be interrogated in many ways with different outputs, so good decisions can be made at all stages of a project, from concept through to construction and operations. According to Jelodar *et.al*. (2016) for such schemes to succeed a joint relationship in order and relationship quality is of extreme importance. A working relationship starts from early stages of any project execution and it was generally agreed on that quality relationship is a make or breaker in order to achieve the desired goals of that project for client satisfaction. The study further states quality relationship in any project execution is credited to acceptance and sharing ideas which makes a great difference towards achieving a desired aims and goals in construction industry. The essence of BIM platform is based on information shearing, a standard of trust and relationship quality; hence lack of these elements can be a significant barrier to its implementation and success.

However, other specific documented issues relating to the New Zealand context were the structure of New Zealand industry, New Zealand regulatory issues relating for acceptance, though it is believed AEC in New Zealand is at the early development stage of BIM life-cycle analysis. The barriers to wider implementation of BIM, particularly could be training structure of New Zealand industry and lack of BIM educational provision Miller *et. a*l. (2013). In a study performed by Eliwa H. *et.al*. (2018) the strategic alignment of business and IT strategy was a determining success factor for technology platform implementation, which basically is performed with the aim of lean construction process. It is also mentioned that organizational and IT infrastructure should be in functional integration with each other. Base on figure 2 common barriers to BIM and Lean construction solutions; at industry level is lack of technology awareness; organization level is lack of infrastructure, and at project level are; project size, lack of employee.

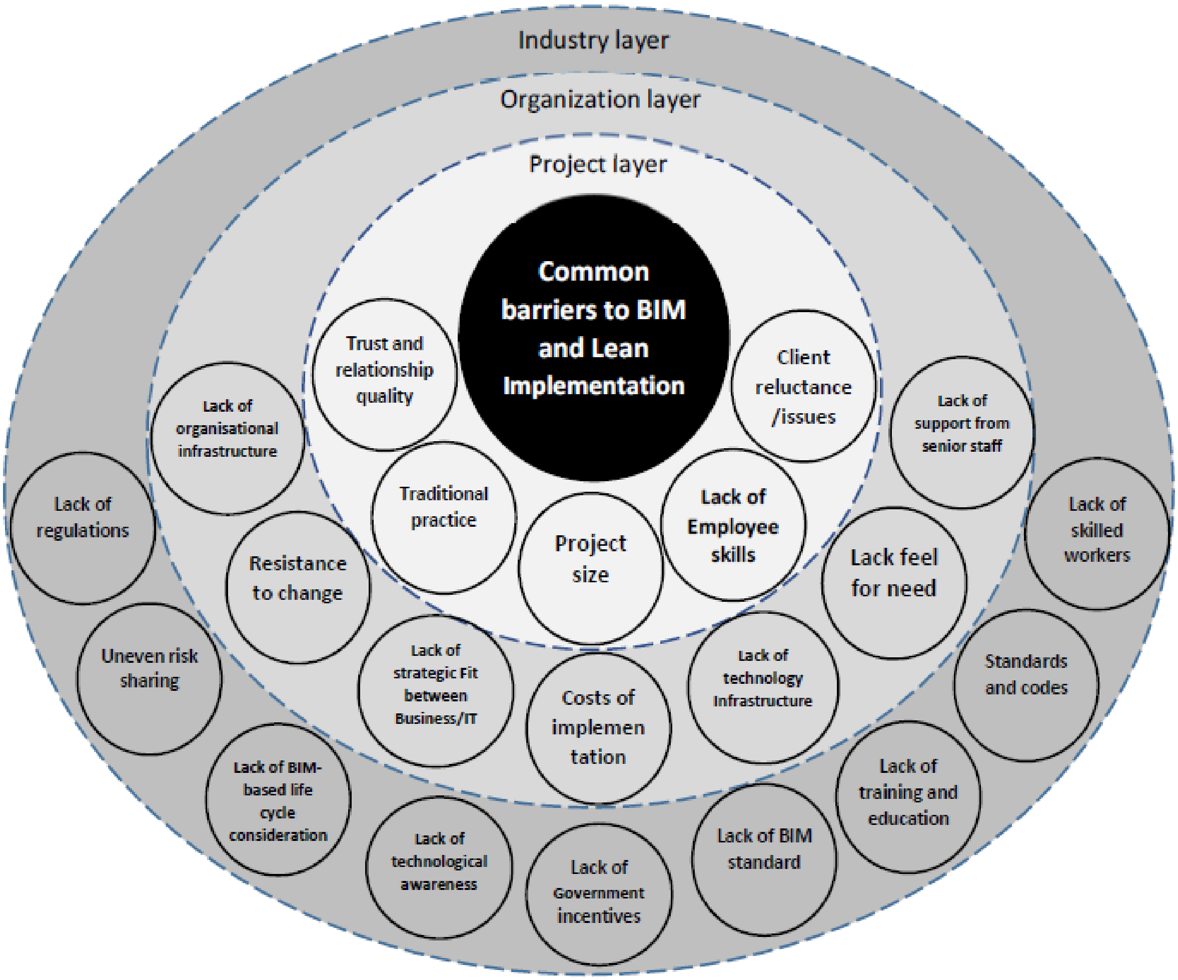


Figure 2: Common Barriers to BIM and lean construction solutions

According to Tran V. *et.al*. (2012) though there has been considerable work on benefits of BIM for construction processes and the expectation for BIM in the construction industry is huge, there is lack of BIM-focused research specifically to the construction market in New Zealand. However, accept the fact that all major construction management research organizations in New Zealand currently have development plans in the pipelines, including potential re-developments of the Christchurch City, which seems the perfect opportunity required to take BIM-based research initiative in collaboration to construction industry in New Zealand. A cooperative BIM research programmed is hence needed in New Zealand in order to move forward Ghaffarian *et. al. (*2017).

Figure 2 is the classification of the reviewed literature which distinctly indicates that BIM and lean implementation barriers occur in three layer of project, organization and industry. Some of them contribute to their outer layers and some have a systematic effect on inner layers, which could trigger cause and effects cycles.

In addition, in a study by Soetanto *et.al.* (2014) a method for BIM execution planning to define sustainable building design process was adopted and the study findings indicated that project delivery method have a significant effect on the sustainable outcome of buildings. The development of a building process can as well assist sustainable design practice among building professionals based on the study conducted.

Results and Discussion

BIM and Lean Construction involve different methods which have significant impacts in the AEC industry especially on productivity. Therefore, the collaboration and potential for the AEC industry on these issues has been acknowledged. Consequently, Sacks *et al*. (2010) stated that an integrated approach of BIM and lean can increase the potential of their implementation in projects via an integrated project delivery approach. According to Ahmad Latiffi *et al. (*2013) BIM deals with design, and the government can gives more encouragement to the industry players to implement BIM in construction projects, which helps to overcome construction problems such as delay, clash of design and construction cost overrun. Ahmad Latiffi. *et.al.* (2013) study shows that construction players need awareness and knowledge of literature findings on implementation of BIM in other aspects such as safety management.

On the other hand BIM, Lean construction and sustainable principles is achieved through training, good communication flow and client satisfaction and trust in their perforce. Performance, excellence philosophy, competences and skill gaps amongst construction players also play a huge role in successful implementation strategies. Major studies in construction revealed the key challenges encountered in the implementation of BIM, Lean construction to construction projects are; (1) knowledge and skill gaps among faculty, limited time for development (2) lacking to adopt integrated approach at conceptual level to link BIM and Lean construction to uphold sustainable principles over the entire lifecycle of a project and (3) determinant factors and implementation gaps such as infrastructure and skills. A lot of the barriers were identified at the industry and organization level, including incentives and support from the government. On the other hand some of the barriers such as trust issues, traditional practices and client reluctance exist at project level.

The study also identifies the relationship between BIM, Lean construction and sustainable principles with readiness amongst construction players in Singapore, Canada, Japan, Hong Kong, Saudi Arabia and Australia to go through rigorous training schemes for better flow of communication. This shows serious readiness and willingness at different layers of project, organization and industry to accept the root to enhanced productivity and better construction processes through BIM as an integrated part of lean philosophy. This is also in accordance with studies conducted by Succar. (2009), Wong *et.al.* (2011), and Aryani *et.al*. (2013) which demonstrate that design technologies are key to project affordability; hence, integration and collaboration should commence at the earliest possible stage. Successful BIM implementation can be the trigger for transformation of technology, people, and process utilization and application.

Conclusion

In conclusion, the outcome of the reviewed literature revealed some key challenges in BIM and Lean construction implementation towards a more sustainable and productive construction sector. Barriers such as traditional practices, client related issues, technological performance, knowledge and awareness, lack of lifecycle consideration, readiness, resistance to change, cost of implementation, lack of infrastructure, alignment issue, standard and regulation problems, uneven risk sharing, lack of government incentives and etc. were identified. However with studying these barriers at a macro level it was clear that the barriers can occur at different layers of project, organization and industry. Figure 2 represents the outcomes and is the conceptualization of these barriers at different layers of the construction sector.

Therefore, adequate attention is needed for BIM, Lean construction and sustainable principles implementation, through appropriate strategies observed accordingly at each layer. According to the temporary nature of work and projects the timeframe of these strategies will be much more restricted in the project layer and should be achievable in shorter period of time. However to overcome barriers at organizational and industry level much more planning and time is require to make some more structural and permanent effects.

References

Bolpagni, M., Burdi, L., & Ciribini, A. L. C. (2017). Integration of lean construction and building information modeling in a large client organization in Massachusetts. *LC3*, *2*, 9-12.

Construction, M. H. (2010). Smart Market Report. *Green BIM: How Building Information Modeling is Contributing to Green Design and Construction", Bedford*

Eastman, C. M., Teicholz, P., Sacks, R., and Liston, K. (2008). *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Architects, Engineers, Contractors, and Fabricators*, John Wiley and Sons, Hoboken, NJ.

Eliwa, H., Jelodar, M. B., & Poshdar, M. (2018). *Information technology and New Zealand construction industry: an empirical study towards strategic alignment of project and organization.* Paper presented at the 18th International Conference on Construction Applications of Virtual Reality (CONVR2018), Auckland. New Zealand.

GhaffarianHoseini, A., Tien Doan, D., Naismith, N., Tookey, J. 2017. Amplifying the practicality of contemporary building information modelling (BIM) implementations for New Zealand green building certification (Green Star). *Engineering, Construction and Architectural Management*, *24*(4), pp.696-714.

Ghaffarianhoseini, A., Tookey, J., Naismith, N., Azhar, S., Efimova, O. and Raahemifar, K., 2017. Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges. *Renewable and Sustainable Energy Reviews*, *75*, pp.1046-1053.

Hosseini, M.R., Azari, E., Tivendale, L., Banihashemi, S. and Chileshe, N., 2016. Building Information Modelling (BIM) in Iran: an exploratory study. *Journal of engineering, project, and production management*, *6*(2), pp.78-89.

Hardin, B. and McCool, D., 2015. *BIM and construction management: proven tools, methods, and workflows*. John Wiley & Sons.

Jelodar, M.B., Yiu, T.W. and Wilkinson, S., 2016. A conceptualisation of relationship quality in construction procurement. *International Journal of Project Management*, *34*(6), pp.997-1011.

Jelodar, M.B., Yiu, T.W. and Wilkinson, S., 2015. Dispute manifestation and relationship quality in practice. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *8*(1), p.C4515003.

Kiviniemi, A., Karlshøj, J., Tarandi, V., Bell, H. and Karud, O.J., 2008. Review of the development and implementation of IFC compatible BIM.

Krygiel, E. and Nies, B., 2008. *Green BIM: successful sustainable design with building information modeling*. John Wiley & Sons.

Latiffi, A. A., Mohd, S., Kasim, N., & Fathi, M. S. (2013). Building information modeling (BIM) application in Malaysian construction industry. *International Journal of Construction Engineering and Management*, *2*(4A), 1-6.

Matarneh, R. and Hamed, S., 2017. Barriers to the adoption of building information modelling in the Jordanian building industry. *Open Journal of Civil Engineering*, *7*(03), p.325.

Meyer, K.D. and Thurnell, D., 2016.New Zealand Main Contractors'use of Bim during the Pre-Construction Stage**.**

Miller, G., Sharma, S., Donald, C. and Amor, R., 2013, July. Developing a building information modelling educational framework for the tertiary sector in New Zealand. In *IFIP International Conference on Product Lifecycle Management* (pp. 606-618). Springer, Berlin, Heidelberg.

McGrath, R.G., 2010. Business models: A discovery driven approach. *Long range planning*, *43*(2-3), pp.247-261.

Porwal, A., & Hewage, K. N. (2013). Building Information Modeling (BIM) partnering framework for public construction projects. *Automation in construction*, *31*, 204-214.

Rahman, A., Gonzalez, V. A., & Amor, R. (2013). Exploring the synergies between BIM and lean construction to deliver highly integrated sustainable projects. In *21st Annual Conference of the International Group for Lean Construction, July31-August* (Vol. 2, pp. 1-12).

Rogers, J., Chong, H.Y. & Preece, C., 2015. Adoption of building information modelling technology (BIM) perspectives from Malaysian engineering consulting services firms. *Engineering, Construction and Architectural Management*, *22*(4), pp.424-445.

Sarhan, J., Xia, B., Fawzia, S., Karim, A., & Olanipekun, A. (2018). Barriers to implementing lean construction practices in the Kingdom of Saudi Arabia (KSA) construction industry. *Construction Innovation*, *18*(2), 246-272.

Sacks, R., Koskela, L., Dave, B. A., & Owen, R. L. (2010). The Interaction of lean and building information modeling in construction. *Journal of Construction Engineering and Management*, *136*(9), 968-980.

Smith, P. (2014). BIM & the 5D project cost manager. *Procedia-Social and Behavioral Sciences*, *119*, 475-484.

Stanley, R. and Thurnell, D., 2014. The benefits of, and barriers to, implementation of 5D BIM for quantity surveying in New Zealand.

Soetanto, R., Zanni, M.A. and Ruikar, K., 2014. Defining the sustainable building design process: methods for BIM execution planning in the UK. *International Journal of Energy Sector Management*.

Tran, V., Tookey, J. E. and Roberti, J. (2012). Shaving BIM: Establishing a framework for future BIM research in New Zealand. *International Journal of Construction Supply Chain Management,* Vol. 2, No. 2 (pp. 66-79)

Wong, J., Wang, X., Li, H., & Chan, G. (2014). A review of cloud-based BIM technology in the construction sector. *Journal of information technology in construction*, *19*, 281-291.

Wang, E., Shen, Z. and Barryman, C., 2011. A building LCA case study using Autodesk Ecotect and BIM model.

Yaakob, M., Mohd Nawi, M. N., Ibrahim, A., & Hanafi, M. H. (2014). A propose study of developing Building Information Modelling (BIM) framework in the Malaysian construction industry. Knowledge Management International Conference 2014 (KMICe2014).

ACHIEVING INTEGRATED SUSTAINABILITY THROUGH WORK STRESS REDUCTION WITH BIOPHILIC OFFICE DESIGN

Abdul-Manan Sadick[1], Imriyas Kamardeen[1]

[1]School of Architecture and Built Environment, Deakin University, Geelong, Australia

Abstract

The thesis that incorporating nature elements like plants and green walls within workplaces is likely to enhance employees' wellbeing and performance has resulted in a plethora of studies. However, most of these studies have focused on direct or indirect nature exposure and either its social or economic impacts. There is therefore limited understanding of how different types of nature exposure collectively contributes to social and economic sustainability through workplace design. The aim of this paper is to present an integrated framework for achieving sustainability through employees' exposure to nature within office work environments. A systematic review process was employed in this study, which retrieved relevant peer-reviewed journal articles from the multidisciplinary scientific research database, Scopus, using several keyword combinations. Findings of the review suggest that the impact of different types of nature exposure are complementary and can be leveraged to optimise employees' wellbeing and work performance. The proposed integrated sustainability framework has three levels including environment (direct and indirect nature exposure), social (indoor air quality, thermal comfort and enhanced relaxation) and economic (employee performance and productivity). This conceptual framework should be of interest to workplace researchers, designers and employers looking to leverage nature exposure to optimise employees' wellbeing and performance.

Keywords

Integrated sustainability; work stress; wellbeing; job performance; biophilic office design; greenspaces.

Introduction

The concept sustainable development argues for a balance among environmental, social and economic performance of any project or business endeavour. However, as it has been applied over the last three decades, the essence of achieving a balance has been lost and little trade-off between the three pillars of sustainability has been achieved. The understanding of this concept has been slightly skewed so much so that environmental sustainability alone has become the synonym for sustainability. Since recently social and economic sustainability considerations have gained momentum, particularly in relationship to employment and work health and safety domains. However, efforts that strive to achieve social and economic sustainability work independently. It is critical that a balanced approach is taken in all aspects of development or operations of businesses.

Once critical social sustainability aspect is employment and work health, safety and wellbeing of the workforce that is the lifeblood of any organisation. This is also related to the economic sustainability of employees and employers. Safe Work Australia has estimated that Australian businesses lose over $10 billion yearly due to lost productivity resulting from work-related mental stress that significantly impacts on workers' health and performance (Work Safe Australia, 2018). The work-related mental stress profile produced by Safe Work Australia ascertained that about 7,800 Australians receive compensation for work-related mental stress annually (Work Safe Australia, 2015). An Australian study conducted in 2016 estimated that nearly 75% of employees experienced stress at work in 2015 (Phillip, 2019). Furthermore, a steep rise in suicide, substance abuse and serious illnesses such as cardiovascular diseases, tumour, cancer, diabetes and obesity have been identified as the most prevalent consequences of work stress in Australia (Roche et al., 2012; Waters, 2017). Therefore, the Australian Work Health and Safety Strategy 2012-2022 identifies work-related mental stress as a key national priority to address.

The current body of knowledge on workplace environments suggests that exposing office workers to greenery and other nature elements (e.g. views of water bodies) will have a positive impact (Bjornstad, Patil, & Raanaas, 2016; Largo-Wight, Chen, Dodd, & Weiler, 2011). Consequently, greenspaces have been incorporated into several office buildings in various forms including green roofs, green courtyards, green walls and indoor plants (Xue, Gou & Lau, 2017). Research has associated indoor green courtyards with positive psychological feelings among employees, while green walls have been found to enhance performance in creative tasks besides significantly decreasing concentrations of indoor air pollutants like carbon dioxide and volatile organic compound (Gunawardena & Steemers, 2019; Loh, 2008; Sheweka & Magdy, 2011). Studies that investigated green roofs have focused on its ability to reduce urban heat islands (Jayasooriya, Ng, Muthukumaran, & Perera, 2017; Takebayashi & Moriyama, 2007).

Despite work stress having long been associated with poor performance, staff turn-over and many health issues of employees and the potential that building greenspaces can offer to address the challenge, the topic has received very limited attention (Work Safe Victoria, 2019). Moreover, Australia is lagging behind most developed countries in implementing green roofs, walls, courtyards and plants in workplaces (Irga et al., 2017). Hence, it is essential to demonstrate how the incorporation of greenspaces in office buildings might help organisations achieve balanced sustainability goals via reduced work stress, improved employees' well-being and high performance. Hence, this study aims to demonstrate the dynamic relationship among office greenspace exposure, work stress control and performance enhancement.

Work stress undermines sustainability

Work stress is caused by the failure of an individual to cope with the mental strain/pressure exerted by stressors at work (Kamardeen 2019) and is reflected by changes/symptoms in their emotions, behaviour, cognition and body. Figure 1 summarises the symptoms of work stress under these four categories.

Emotions • Anger/irritability/frustration • Anxiety • Defensiveness • Mood swings • Excessive worry	**Behaviour** • Mistakes • Accidents • Eating/sleeping disorders • Problematic social behaviour (withdrawal, aggression) • Smoking, alcohol/drug use
Cognition • Poor concentration • Poor organisation & decision making • Less creative in problem solving • Hypersensitive to comments	**Body** • Low energy/fatigue • Aches, pains & tense muscles • Loss of libido • Frequent infections • Sweating, dizziness, nausea, short breath

Figure 1: Symptoms of work stress (Source: modified from (Michie, 2002))

Enduring work stress for an extended period can result in more serious outcomes for employees and organisations. Work stress effects on employees undermine the social sustainability whereby employees are adversely affected in three dimensions such as mental wellbeing, physical heath and job performance. Lupien, McEwen, Gunnar, and Heim (2009) argued that chronic stress triggers the presence of high levels of glucocorticoids, which affects the frontal cortex and hippocampus of the brain, increasing the risk of depressive disorders. Work stress has also been found to cause anxiety disorders

(Melchior et al., 2007). Dollard (2001) suggested that long-term psychological effects of work stress may result in permanent mental illness or even suicide.

Public health literature claims that enduring long-term excessive stress can cause chronic and serious diseases, such as: obesity, hyperlipidaemia, type 2 diabetes, high cholesterol levels, coronary heart disease, cardiovascular disorders, musculoskeletal pain, gastrointestinal problems, headache and migraine, prolonged fatigue, respiratory infections, reproductive system disorders, immune system weakening and early mortality (Salvagioni et al., 2017). Further evidence from the public health domain revealed a bi-directional relationship that suffering chronic diseases such as lung disease, arthritis, cardiac disease and cancer were positively associated with increased depressive symptoms over time (Bisschop, Kriegsman, Beekman, & Deeg, 2004). This suggests that stressed out employees are at a high risk of suffering a vicious cycle between chronic diseases and depression, slowly resulting in the worse form of disability that could cripples not only individuals but also their families. The combination of mental and physical illnesses can adversely impact on an employee's work performance and potential. When a large number of employees suffer the above consequences, it will significantly impact on organisational operations via increased absenteeism, presenteeism, low productivity, poor work safety records, high insurance and compensation costs, high employee turnover, continual recruitment and training costs, low job satisfaction, industrial actions and reputation damage. All these collectively affect the economic sustainability of businesses/organisations (Kamardeen 2019).

These can collectively cause enormous socio-economic losses for affected employees and their families. Examples of possible economic losses are: loss of salary, reduction of professional capacity and medical cost. Social costs include: pain and suffering, strain on relationships, lifestyle changes, lowered self-esteem and burden on family (European Union 2011). When the socio-economic costs suffered by each affected employee is aggregated, it can constitute a huge loss to the society in the form of production loss, increase in welfare and medical costs, decrease of standard of living and reduction in human labour potential (European Union 2011).

In conclusion, it is evident that chronic work stress adversely affects the social and economic sustainability of individuals, organisations and society. Suitable stress management measures should be adopted by both individuals and organisations to prevent the negative consequences of work stress.

Biophilic office design for integrated sustainability

Conventionally, work stress studies tend to focus on psychosocial stressors predominantly. Consequently, stress intervention/prevention strategies proposed also place a heavy emphasis on altering the psychosocial conditions at workplace to reduce work stress. Vischer (2007) argued that physical features of the workplace impact on work stress experiences, job satisfaction and job performance. Accordingly, Everett (2019) claimed that biophilic office design, which incorporates elements from nature into the workplace, improves employees' mental wellbeing, physical health, productivity and loyalty to workplace. The biophilic design framework posits that offices should mimic natural environment in three aspects (Kellert & Calabrese, 2015):

- Direct experience of nature in workspace - experiencing natural light, wind, water, plants, natural landscape, and/or ecosystems)
- Indirect experience of nature - use of natural materials for furniture/space design, images of nature, naturalistic shapes and forms, natural colours or symbolic representation of nature
- Experience of space and place - workspace in which one can observe/view nature or provision of space for refuge in nature

Hui and Aye (2018) suggested that the combination of various biophilic design features would have a varying effects on mental wellbeing at workplaces. Hence, how different biophilic office design features impact on employee wellbeing thereby integrated sustainability of employees and organisations needs to be modelled to promote its uptake in workplace design.

Method and material

This study used a systematic review method to identify published scientific studies relevant its aim. The preferred database for this review was Scopus given that it is one of the largest multidisciplinary databases covering life sciences, social sciences, physical sciences and health sciences and indexes 34,346 are peer-reviewed journals. Different combinations of keywords and the "AND" Boolean function was used. Table 1 presents examples of keywords used for the search.

Table 1: Keywords

Exposure-related words/design	Impact related words
Nature exposure	Well-being
Exposure to nature	Work performance
Connection to nature	Work-related stress
Nature connection	Workplace stress
Green space	Work stress
Greenspace	Psychological well-being
Green roof	Physical well-being
Green wall	Mental stress
Indoor plant	Employee satisfaction
Window view	Work satisfaction
Greenery	Job stress
Workspace	Occupational stress
Workspace design	Employee performance
Office design	Work productivity
Office green	Job satisfaction
Workplace green	Occupational health

The "search within results" function in Scopus was used to limit search results to nature exposure of office works. Only peer-reviewed journal articles were retrieved totalling 369. Following detailed review of article titles and abstract, the included sources reduced to 123 and 44 respectively. Only 18 of the 44 sources were included in this paper. The articles included in this paper were reviewed in detail to identify the types of nature exposure investigated and their associated social and economic impacts. Findings extracted from the 18 sources were synthesised to develop the proposed integrated sustainability framework.

Framework of integrated sustainability through workplace design

Researchers aiming to improve workplace environment and enhance socio-economic development have explored the three types of nature exposure advanced by the biophilic design framework. Palanica, Lyons, Cooper, Lee, and Fossat (2019) found that nature stimuli within workspaces had a positive impact on the creativity of office workers. Additionally, Raanaas, Evensen, Rich, Sjøstrøm, and Patil (2011) reported that the presence of nature elements like plants in an office environment improved workers cognitive performance. However, Shibata and Suzuki (2002) found that a single plant within a workspace had a positive effect on performing creative task and not simple tasks. The findings of Shibata and Suzuki (2002) suggest that the presence of nature within workspaces is most beneficial for high order tasks. Other studies have highlighted the location of nature elements within workspaces as an essential consideration. Shibata and Suzuki (2002) reported that placing plants in front of office workers had the greatest effect on creative tasks relative to plants placed on the side. The link between office workers perceived thermal comfort and productivity is widely reported in literature with temperatures above or below comfort zones having negative impact on productivity. Several studies (Hoelscher, Nehls, Jänicke, & Wessolek, 2016; Vox, Blanco, & Schettini, 2018) have demonstrated how the thermal insulation properties of green walls can be leveraged to effectively avert overheating and thermal loses in summer and winter respectively. Using green walls to regulate indoor thermal environment will enhance workers thermal comfort in addition to the reported positive psychological benefits. The direct organisational benefits of using green walls in office work environments to improve thermal comfort will include reducing energy consumption (i.e. through mechanical heating and cooling) and carbon footprint (Jayasooriya et al., 2017; Takebayashi & Moriyama, 2007).

The impact of nature or greenspace on workplace stress has received limited attention and the few studies (e.g. T. Bringslimark, T. Hartig, & G. G. J. H. Patil, 2007; Largo-Wight et al., 2011) that have investigated this relationship have used global measures of stress. Tina Bringslimark et al. (2007) found no association between plants within workspaces and a global measure of perceived stress. In contrast, Largo-Wight et al. (2011) reported a decrease in perceived stress due to increased exposure to nature at work. These contradictory findings highlights the downside of using global measures given that they are likely to underestimate essential contextual factors. However, the majority of studies that have investigated associations between employees' exposure to nature within workspace have reported positive impact on workplace stress (Bjornstad et al., 2016; Colley, Brown, & Montarzino, 2016; Genjo, Matsumoto, Ogata, & Nakano, 2018). The negative impacts of workplace stress include tiredness, difficulty in making decisions, absenteeism, staff turnover and subsequently productivity and organisational performance (Work Safe Victoria, 2019), thus making workplace stress an essential consideration in workplace design.

Research has shown that indoor nature including plants and green walls can significantly reduce concentration of indoor air pollutants like carbon dioxide and volatile organic compound through filtration and sequestration (Gunawardena & Steemers, 2019; Loh, 2008; Torpy, Zavattaro, & Irga, 2017). Reducing concentration of indoor air pollutants in office environments will have positive impact on employees' health. Bjornstad et al. (2016) found a negative association between employees' exposure to indoor plants and the number of sick leave days on one hand, and a positive association with subjective health on the other. T. Bringslimark, T. Hartig, and G. G. Patil (2007) in an earlier study reported similar positive associations between employees' exposure to indoor plants and number of sick leave days. High concentrations of carbon dioxide within office indoor environments have been associated with headaches and mucosal irritations (Smith, Fsadni, & Holt, 2017). The evidence supports the health benefits of incorporating active indoor plants and green walls to improve indoor air quality in offices.

Jahncke, Hygge, Halin, Green, and Dimberg (2011) explored office workers exposure to nature during breaks between office task and found that it resulted in an energising feeling. This study highlights the restorative effective of nature exposure and agrees with Shibata and Suzuki (2001) who in an earlier study found that indoor plants reduced fatigue during a break between very demanding tasks. Therefore, office workers' exposure to nature away from their primary workspace will likely enhance their wellbeing and indirectly improve their productivity. F. Xue, Z. Gou, and S. S. Y. Lau (2017) fond that integrating green spaces into office building through indoor courtyard increased workers' visit frequency and had a positive psychological impact. The majority of studies that have investigated green roofs have focused on its ability to reduce urban heat islands, improve buildings' thermal insulation, and reduce operating cost due to energy consumption (Jayasooriya et al., 2017; Takebayashi & Moriyama, 2007). Yaghoobian and Srebric (2015) found that green roofs reduced roof surface temperature by 34% relative to bare roofs and resulted in decreasing indoor cooling demand by 5%. Two important consideration about green roofs in urban environments are physical access and visual access. Together, these types of access can maximise the number of workers exposed to nature especially in central business districts (Loder, 2014). Loder (2014) reported positive psychological impacts of green roofs on offices workers who accessed it either visually or physically. The evidence suggest that the benefits of green roofs in urban environments is multifaceted including societal benefits (e.g. mitigating heat island effect) and business benefits (e.g. productivity improvement by enhancing workers psychological well-being). Tina Bringslimark et al. (2007) found that plants in office workers view through a window had a positive impact on self-reported productivity, sick leave and perceived stress, thus, further supporting the relevance of indirect nature exposure through visual assess.

The evidence presented above support the thesis that office workers exposure to nature is likely have a positive on their wellbeing and work performance. However, the different types of nature exposure and their impact have generally been investigated in isolation, thus, limiting our understanding of the intricate interaction between the exposure types and their benefits. Figure 2 presents a proposed framework that integrates the different types of nature exposure, mechanism and impact on employees. The dynamic integrated framework is divided into three sections as environment, social and economic in line three intersecting spheres of sustainability. The environment level consist of all direct and indirect nature in workplaces. The literatures shows both direct and indirect nature exposure have complementary benefits that can be leveraged to optimize impact on employees. The social level represents the first stage impact of nature exposure on employees. The social impact of either wellness or wellbeing is based on either improved indoor air quality, thermal comfort or enhanced relaxation that result from introducing nature elements. The economic level is the final impact of nature exposure on employees' primary function at the work. Improved employee performance will lead to organisational performance and sustain employees' earnings. Consequently, the proposed dynamic framework highlights integration of nature exposure within workplace design a strategic tool for achieving sustainability. The framework suggest that workplace design researchers and practitioners have to consider multiple exposure strategies (environment level) to leverage complementary direct impact (social level) to sustain impact on employee performance (economic level).

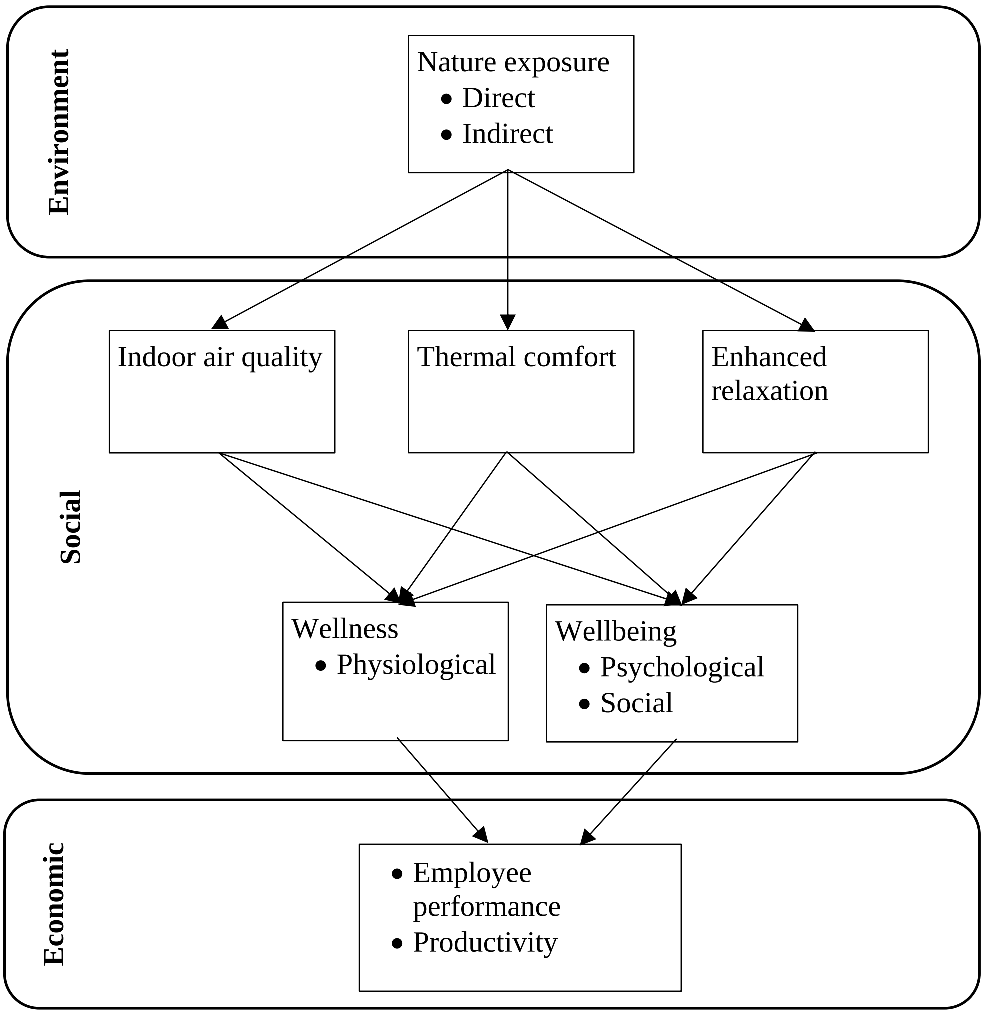


Figure 2: Proposed integrated sustainability framework

Conclusion

This review sought to present a conceptual framework of integrated sustainability through workplace design. The evidence showed how researchers that incorporating nature elements within workplaces is likely have a positive effect on employees' wellbeing and work performance. However, most studies have focused one a particular type of nature exposure (direct or indirect) and either social or economic impact, thus, limiting our understanding of how nature exposure contributes to sustainable development. The proposed dynamic sustainability framework in this paper is an initial attempt to integrate the environmental, social and economic aspects of office employees' exposure to nature. The framework show that the complementary benefits of the types of nature exposure can be leveraged to optimise the impact on employees' wellbeing and work performance. This conceptual framework will contribute to comprehensive assessment of employees' exposure to nature at work to aid strategic decision making on workplace design. However, the dynamic framework proposed in this paper need empirical testing to ascertain its practical utility and required refinements.

References

Bisschop, M. I., Kriegsman, D. M., Beekman, A. T., & Deeg, D. J. (2004). Chronic diseases and depression: the modifying role of psychosocial resources. *Social science & medicine, 59*(4), 721-733.

Bjornstad, S., Patil, G. G., & Raanaas, R. K. (2016). Nature contact and organizational support during office working hours: Benefits relating to stress reduction, subjective health complaints, and sick leave. *Work, 53*(1), 9-20. doi: 10.3233/WOR-152211

Bringslimark, T., Hartig, T., & Patil, G. G. (2007). Psychological benefits of indoor plants in workplaces: Putting experimental results into context. *HortScience, 42*(3), 581-587.

Bringslimark, T., Hartig, T., & Patil, G. G. J. H. (2007). Psychological benefits of indoor plants in workplaces: Putting experimental results into context. *42*(3), 581-587.

Colley, K., Brown, C., & Montarzino, A. (2016). Restorative wildscapes at work: an investigation of the wellbeing benefits of greenspace at urban fringe business sites using 'go-along' interviews. *Landscape Research, 41*(6), 598-615. doi: 10.1080/01426397.2016.1197191

Dollard, M (2001) Work stress theory and intervention: From evidence to policy a case study. *In, The NOHSC Symposium on the OHS Implications of Stress*.

European Union (2011) Socio-economic costs of accidents at work and work-related ill health. http://www.ilo.org/public/libdoc/igo/2011/468757.pdf. URL (13 April 2016)

Everett, C. (2019). Five benefits of biophilic office design. Retrieved 25 September, 2019, from https://www.raconteur.net/business-innovation/biophilic-design-office

Genjo, K., Matsumoto, H., Ogata, N., & Nakano, T. (2018). Feasibility study on mental healthcare effect using plants installation in office space. *Journal of Environmental Engineering (Japan), 83*(743), 1-10. doi: 10.3130/aije.83.1

Gunawardena, K., & Steemers, K. (2019). Living walls in indoor environments. *Building and Environment, 148*, 478-487. doi: 10.1016/j.buildenv.2018.11.014

Hoelscher, M.-T., Nehls, T., Jänicke, B., & Wessolek, G. (2016). Quantifying cooling effects of facade greening: Shading, transpiration and insulation. *Energy and Buildings, 114*, 283-290. doi: https://doi.org/10.1016/j.enbuild.2015.06.047

Hui, F., & Aye, L. (2018). Occupational stress and workplace design. *Buildings, 8*(10), 133.

Irga, P., Braun, J., Douglas, A., Pettit, T., Fujiwara, S., Burchett, M., . . . Greening, U. (2017). The distribution of green walls and green roofs throughout Australia: Do policy instruments influence the frequency of projects? *, 24*, 164-174.

Jahncke, H., Hygge, S., Halin, N., Green, A. M., & Dimberg, K. J. J. o. E. P. (2011). Open-plan office noise: Cognitive performance and restoration. *31*(4), 373-382.

Jayasooriya, V. M., Ng, A. W. M., Muthukumaran, S., & Perera, B. J. C. (2017). Green infrastructure practices for improvement of urban air quality. *Urban Forestry & Urban Greening, 21*, 34-47. doi: https://doi.org/10.1016/j.ufug.2016.11.007

Kamardeen (2019). Preventing workplace incidents in construction: data mining and analytics applications. London: Routledge.

Kellert, S., & Calabrese, E. (2015). The Practice of Biophilic Design. Retrieved 25 September, 2019, from https://www.biophilic-design.com

Largo-Wight, E., Chen, W. W., Dodd, V., & Weiler, R. J. P. H. R. (2011). Healthy workplaces: The effects of nature contact at work on employee stress and health. *126*(1_suppl), 124-130.

Loder, A. (2014). ‘There's a meadow outside my workplace’: A phenomenological exploration of aesthetics and green roofs in Chicago and Toronto. *Landscape and Urban Planning, 126*, 94-106. doi: https://doi.org/10.1016/j.landurbplan.2014.01.008

Loh, S. (2008). Living walls–A way to Green the Built Environment. *Environment Design Guide*, 1-7.

Lupien, S. J., McEwen, B. S., Gunnar, M. R., & Heim, C. (2009). Effects of stress throughout the lifespan on the brain, behaviour and cognition. *Nature reviews neuroscience, 10*(6), 434.

Melchior, M., Caspi, A., Milne, B. J., Danese, A., Poulton, R., & Moffitt, T. E. (2007). Work stress precipitates depression and anxiety in young, working women and men. *Psychological medicine, 37*(8), 1119-1129.

Michie, S. (2002). Causes and management of stress at work. *Occupational and environmental medicine, 59*(1), 67-72.

Palanica, A., Lyons, A., Cooper, M., Lee, A., & Fossat, Y. (2019). A comparison of nature and urban environments on creative thinking across different levels of reality. *Journal of Environmental Psychology, 63*, 44-51. doi: 10.1016/j.jenvp.2019.04.006

Phillip, K. (2019). Six ways your office can reduce stress. Retrieved 20 July, 2019, from https://www.morganlovell.co.uk/knowledge/opinion-pieces/six-ways-your-office-can-reduce-stress/

Raanaas, R. K., Evensen, K. H., Rich, D., Sjøstrøm, G., & Patil, G. (2011). Benefits of indoor plants on attention capacity in an office setting. *Journal of Environmental Psychology, 31*(1), 99-105. doi: 10.1016/j.jenvp.2010.11.005

Roche, A. M., Fischer, J., Pidd, K., Lee, N., Battams, S., & Nicholas, R. (2012). Workplace mental illness and substance use disorders in male-dominated industries: A Systematic Literature Review. Retrieved 20 July 2019, from https://s3.amazonaws.com/academia.edu.documents/32492221/bw0203.pdf?response-content-disposition=inline%3B%20filename%3DWorkplace_mental_illness_and_substance_u.pdf&X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIAIWOWYYGZ2Y53UL3A%2F20190806%2Fus-east-1%2Fs3%2Faws4_request&X-Amz-Date=20190806T014029Z&X-Amz-Expires=3600&X-Amz-SignedHeaders=host&X-Amz-Signature=61f4bad08ea07dc658c9e20d3f5f51ff6b4f109c157b33f1c984b8b9da7bd13b

Salvagioni, D. A. J., Melanda, F. N., Mesas, A. E., González, A. D., Gabani, F. L., & de Andrade, S. M. (2017). Physical, psychological and occupational consequences of job burnout: A systematic review of prospective studies. *PLoS ONE, 12*(10), e0185781.

Sheweka, S., & Magdy, A. N. (2011). The living walls as an approach for a healthy urban environment. *Energy Procedia, 6*, 592-599.

Shibata, S., & Suzuki, N. J. J. o. e. p. (2002). Effects of the foliage plant on task performance and mood. *22*(3), 265-272.

Shibata, S., & Suzuki, N. J. N. A. J. o. P. (2001). Effects of indoor foliage plants on subjects’ recovery from mental fatigue. *3*(3), 385-396.

Smith, A. J., Fsadni, A., & Holt, G. (2017). Indoor living plants’ effects on an office environment. *Facilities, 35*(9-10), 525-542. doi: 10.1108/F-09-2016-0088

Takebayashi, H., & Moriyama, M. (2007). Surface heat budget on green roof and high reflection roof for mitigation of urban heat island. *Building and Environment, 42*(8), 2971-2979.

Torpy, F. R., Zavattaro, M., & Irga, P. J. (2017). Green wall technology for the phytoremediation of indoor air: a system for the reduction of high CO2 concentrations. *Air Quality, Atmosphere & Health, 10*(5), 575-585. doi: 10.1007/s11869-016-0452-x

Vischer, J. C. (2007). The effects of the physical environment on job performance: towards a theoretical model of workspace stress. *Stress and health: Journal of the International Society for the Investigation of Stress, 23*(3), 175-184.

Vox, G., Blanco, I., & Schettini, E. (2018). Green façades to control wall surface temperature in buildings. *Building and Environment, 129*, 154-166. doi: https://doi.org/10.1016/j.buildenv.2017.12.002

Waters, S. (2017). Suicide voices: testimonies of trauma in the French workplace. *Medical humanities, 43*(1), 24-29.

Work Safe Australia. (2015). Work-related mental stress disorders profile 2015.

Work Safe Australia. (2018). Supporting business to provide a mentally healthy workplace. Retrieved 20 July, 2019, from https://www.safeworkaustralia.gov.au/book/supporting-business-provide-mentally-healthy-workplace

Work Safe Victoria. (2019). Work-related stress: Safety basics. Retrieved 11 July 2019, from https://www.worksafe.vic.gov.au/work-related-stress-safety-basics

Xue, F., Gou, Z., & Lau, S. (2017). The green open space development model and associated use behaviors in dense urban settings: Lessons from Hong Kong and Singapore. *URBAN DESIGN International, 22*(4), 287-302.

Xue, F., Gou, Z., & Lau, S. S. Y. (2017). Green open space in high-dense Asian cities: Site configurations, microclimates and users' perceptions. *Sustainable Cities and Society, 34*, 114-125. doi: https://doi.org/10.1016/j.scs.2017.06.014

Yaghoobian, N., & Srebric, J. (2015). Influence of plant coverage on the total green roof energy balance and building energy consumption. *Energy and Buildings, 103*, 1-13. doi: https://doi.org/10.1016/j.enbuild.2015.05.052

THE HOUSING AFFORDABILITY PROBLEM AMONG YOUNG HOUSEHOLDS IN JOHANNESBURG, SOUTH AFRICA

Kolawole Ijasan[1], Kudzai Mawoyo[1], Ese Ijasan[2]

[1]School of Construction Economics and Management, Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, South Africa

[3]Reception House, Waterloo Canada

Abstract

Housing affordability is of major concern and it is a very broad topic that does not have a uniform definition; instead, it entails the use of indexes to measure the affordability of households. These parameters used to measure affordability range from household disposable incomes, housing prices and the choice of housing just to mention a few. The imbalance between increasing housing prices and household's disposable incomes; more especially for low-income earners makes it increasingly unaffordable for them and they end up suffering the most. Furthermore, young households who have graduated and secure employment, are considered to be first time home buyers in most cases and are subjected to more problems in housing affordability; i.e. choice of housing, household disposable income and the housing price identified as key elements. Surveys were conducted and the result showed that there is the peculiar challenge of housing affordability among young households which is further exacerbated by house price, household income and housing choice in the housing market. The key findings of this study suggest that there is a gap in affordable housing for young households in the housing market.

Keywords

First time home buyer, House Prices, Housing, Johannesburg SA, Young Professionals

Introduction

In recent years the affordability problem has become more and more important in large number of housing markets in South Africa especially in the City of Johannesburg where the cost of living is considered in comparison to other cities in Africa. Housing has several functions for humankind (the society and amongst individuals). Not only does housing provides shelter for the users, it serves as a consumption, a good investment and it also provides a social space for the households and a platform where social interaction as well as relations with the society are continuously reproduced. In addition, Tekeli (1998) noted that apart from these vital functions, the housing aspect has a specific feature which makes it a subject of government policy.

The issue of housing affordability has been a crucial topic of interest for both researchers and policy makers in different countries across the globe and it is not a new crucial topic. The imbalance between increasing housing prices and household's disposable incomes; more especially for low income earners makes it increasingly unaffordable for them and they end up suffering the most (Aksoy, 2017). Additionally, young households who have graduated and secure employment, are considered to be first time home buyers in most cases and are unfortunately subjected to more problems in housing

Corresponding author: Kolawole Ijasan

Tel: Mob: Email: kola.ijasan@wits.ac.za

affordability; i.e. choice of housing, household disposable income and the housing price identified as key elements Zyed et.al. (2016).

In Johannesburg, an average household's income can afford a home worth R280,000 (roughly USD20,000), yet the average sale price is about R825 000, with fewer properties below R500 00. The income -housing gap created by the municipal reveals that it takes 3 times the average household income to afford an average house. Inadequate income to purchase house relates to the issue of increasing house prices which makes it unaffordable for the young households and the limited housing choice/supply of affordable housing in the housing market which is most likely to affect low income earner (Zyed et. al,2016).

The recent trends in Johannesburg reveals high rate of urbanization more especially the young households who are seeking for greener pastures, some who have just completed their studies. Getting ready to enter the working space. On the hand property prices are increasing by a greater margin of income received by this low income-earners.

Hence the main objective of the research is to identify, classify and evaluate the critical issues contributing to the housing affordability problems faced by young households in the City of Johannesburg, South Africa; with a view to suggesting recommendations.

This research asks three crucial questions: What are the key elements affecting housing affordability amongst the young households in the City of Johannesburg, South Africa? What are the criteria in measuring household affordability for young households/households in the City of Johannesburg South Africa? How is the housing affordability issue influencing the housing choice and behaviours of households?

Literature review

Housing Affordability HA- The issue of housing affordability HA has risen to the top of national housing agendas especially in the most emerging markets across the globe. Housing is termed as housing that is built specifically for residential purposes in order to provide basic privacy and security for the people to live in.

The idea of HA, can be explained in numerous ways and the precise definition is at best ambiguous (Linneman & Megbolugbe 1992). HA is mainly influenced by the levels and distributions of home prices, household's income as well as the financial structure. In addition, researchers have developed mathematical expressions /models in attempt to details the relationship between these variables According to (Linnenman & Megbolugbe 1992). However, these definitions all reveal that the concept of HA has two elements; the people and what they want to buy (Cai, 2017).

The two elements also represent the demand – supply side of the problem and it is a high priority that affordability of any given item be correlated with the buying power of its potential end users. The prices in the real estate market have become more unstable due to economic performance in many countries across the globe more especially after the second world war (Lin& Lind 2011). In this regard, there has been a wide gap between the high-income and low-income earners, which makes it unaffordable for the low-income earners to own a comfortable house of their choice (Lin & Lind 2011).

Housing not only serves as an investment only but also for social protection.; which is provided by the state to the customers who are mostly low-income earners or has lower competition in the social market. Furthermore, HA recognizes the needs of households whose incomes are not adequate enough for them to access appropriate housing in the market (Milligan et al. 2004).

The complexity evolving around the definition of HA reveals that there is no one measure for assessing the nature and degree of HA problems. Milligan et al. (2004) noted that practical definitions explaining HA are usually specific to the policy and program context in which they are used, and they typically have common features such as the notion of what comprises of affordability and the specific targeted group. The term HA in this paper targets the young households residing in Johannesburg South Africa and this will be discussed further in the next section.

Housing Affordability HA Among Young Households

HA problem is most common in middle-class and affluent young adults with ever-growing expectations of owning a house. Young households are facing problems in the housing market because they are considered as new entrants in the employment sector and first-time buyers which becomes risk for many funding entities (Zyed et.al. 2016). Furthermore, the perceived affordable housing in the market is open to all income groups which reveals that young households are faced with competition from all other income groups in the market for home-ownership. According to Wilcox, 2003; 2006; 2008), the age of young households is considered as first-time buyers and their age ranges from 20-39 years old.

In contrast to HA being a problem faced by the young households, Ortalo-Magne and Rady (1999) observed co-movements of housing prices, owner occupancy rates and explained the increasing rate in home-ownership among young households because of the deregulation of the mortgage market which entails easement of accessibility to mortgage credit for the young households.

Zyed et.al (2016) stated that the increase in terms of owner occupancy rate among households is not only because of less interest rates but also savings rate.

What is the Problem?

Typical young households are considered to be first -time buyers who have relatively low income and savings (Fisher & Gervais 2007). Furthermore, increasing housing price booms have been known for centuries, since the late 1990s and it is evident in first world and some emerging markets such as Australia, Canada, China, France, India, Ireland, Italy, Korea, Russia, Spain, the United Kingdom and the United States of America, to mention a few (Shiller 2017). Hence, one of the common problems identified by previous researchers is the issue of down payment which is one of the constraints for both the younger and middle-income earners, so they end up postponing home-ownership. Zyed et. al. (2016) stated that one of the key contributing elements to the HA among households is the limited supply of affordable housing in the market. In addition, this is the attributed to key problems of house price, household's income and the housing choice in the market faced by the young households.

Embong (2013) noted that the supply of these affordable housing is yet to be fulfilled in the market, yet the affordable housing is on open to all income groups which suggest that households will end up competing with other income groups in the open market for home ownership.

There is a gap for state intervention across the globe in the market to introduce effective ways that will combat the HA problems face by young households (Zyed et.al 2016). One of the ways is the National Housing Partnership are organisations that dedicate resources in making investment that betters and allow accessibility to home-ownership by low- middle income earners. With state intervention comes with the implementation of policy options which are perceived to be a solving instrument and improving the affordability problems not only for the young households but for all age groups that are financially disadvantaged households (Aksoy 2017). The next section discussed the HA problems among young households residing in Johannesburg South Africa.

Housing Affordability HA Problems Among Young Households in South Africa

According to the demographic analysis of demand in South Africa by Gardener (2004), the country's population is divided into eight sub groups based on differences in income. Approximately 79% of the population is eligible for housing assistance in terms of the R3500 per month income limit of the national housing subsidy scheme and 90% of the country's population earns less than R7,500 monthly income (Rust 2006).

In order to fulfil the aim of this paper, more focus is put on the targeted young households residing in Johannesburg who are currently facing employment problems as well as distribution of income that is insufficient enough for them to afford housing. In the South African context, the term HA among young households refers to as a specific type of housing that comprises of the following attributes;

- Target group (restricted to moderate and /or low income earners aged 18-35)
- Considered as new entrants to the market financed through a mix of public subsidies, planning benefits, private equity and/or debt financed
- First time home buyers
- Initiated and owned by non-government not for profit providers

One of the major factors not to be overlooked in the South African context apart from income difficulties, economic fluctuation is the racial indifferences and the legacy of the apartheid system where housing was supplied and used as an instrument to pave way for social segregation among the black community and mixed race (Burgoyne 2008). This is evident in Western Cape, other parts in Johannesburg such as Soweto; where by the black community was subdued to class separation making great resistance to low-income housing projects by the neighboring communities , as new housing projects are perceived as dysfunctional ghettos (Department of Local Government and Housing, 2005).This is further discussed in the next section that deals with the South African housing policy and implementation that reversed the older policies that suppressed the black community to better the young generation of today.

In summary, literature findings reveal that one of the main problems experienced by young households is the limited supply of affordable housing in the market. This attributed to crucial problems of housing choice, house price, household's income and housing preference which is discussed in the next section.

***Housing Choice*:** Housing choice explains the action taken by households in deciding their choice of house and this include tenure, type of house, location, neighbourhood (Zyed et.al 2016). The rationale that is HA index should consider factors such as location because the aim of HA policies is not only dedicated to providing shelter but also to supply units that are accessible to jobs, education and other related amenities. (Cai, 2017). Problems evolving around HA in housing choice are viewed in the perspective of purchasing due to the notation that every citizen is entitled a right to housing and it is the state's duty to ensure households enjoy this right. In summary, housing policies are there to better barriers and constraints faced by the households in the housing market. According to Zyed et al (2016), younger households are likely to live with other such as family and a large group of friends if their housing choice is not met. Tenure choice plays a huge role in understanding the trend among the young households in the housing market; be able to identify the growing trend (buy/rent). Theoretically, one of most efficient way to solve the HA problems among the young households is increasing supply at the bottom rung of housing stock and ensuring these housing units are made available as well as affordable to most low-income earning households (Cai, 2017).

Housing Price: Since the early 1980s, price has been regarded as an important instrument and most reliable index of housing market (Stutz and Kartman, 1982). Rapid urbanization, growing population, economic growth like the South African market and the liberalization of housing market and inadequate supply of affordable housing are influencing factors towards the rising housing price level (Mak et.al 2007). Furthermore, supply and demand for housing explanations are not mutually exclusive and does not have any significance in price changes more especially if housing demand is stable or declining (Matlack & Vigdor, 2008). In contrast, Mak et al.. (2007) research reveals that demand and supply are closely related and while there is an increase in housing demand, the supply lags behind housing demand. In the South African market, there has a decline in terms of sub R200 000 housing category from 70% of delivery in 2000 to comprising less than 40% of delivery in 2005. Furthermore, housing prices are continuously increasing while inflation has rising since 2000 (Rust 2006). According to the Banking Association , it reported that South Africa's housing backlog is continuously expanding and there was a shortage in supply of affordable housing in the sub R200 000 price with the greatest log experienced in Gauteng (191 000 houses lacking for the demand created by FSC target housing loans).With the growing economy in South Africa, it is highly unlikely for someone in to improve their income by a margin that will enable them to get funding institutions in order to purchase a home. This entails that even households accessing or trying to access affordable housing with Financial Sector Charter loans are unlikely to ever succeed and better their housing situation further. Due to political instability and ever-growing economy that is unpredictable, has led to other developers opting to leave the low-cost housing affordable to low income-earners; younger households will continue to face such difficulties. The idea of inadequate income to afford housing may present an issue for young leaseholds in terms of housing prices.

Household Income: Matlack and Vigdor (2008) noted that increases at the high end of distribution can raise house price levels paid by the low income-earning households (young households). The increase in income inequality gap leads to a growth in residual income of households, decreases and crowding occurs. Young households are mostly affected by this parameter because there are relatively young in the working environment and earn a smaller amount of income before acquiring more experience and as result this limits the young household's asset accumulation and their reliance on the private sector (Rappaport, 2008).

In summary, the issue of HA faced by the young households in the housing market is an inter-related problem between, housing choice, housing price levels and household income.

It can be summarized that the problem of inadequate income to purchase a home translates to house price levels that are not affordable for the households and limits their housing choice (Zyed et. al., 2016). Moreover, the gap between the average housing price and the average income by low-income earners is so huge that it takes three times the average income to afford the average housing in Johannesburg, South Africa. Young households in South Africa also face problems in accessing support from banking institutions. Furthermore, young households and young professionals are limited in terms of asset accumulation.

Research design and sampling

Research design essentially focuses on developing a research question and objectives into a research project and it considers research strategies, the choice and time horizons. A research design gives a detailed outline of how an investigation is to be carried out.

This study uses a survey research method. In this research, probability sampling approach would be used because it allows unbiased inferences about the population to be made. A combination of stratified and simple random sampling would be used in this study. The target population will be divided into strata and a simple random sampling technique would be applied in each stratum. Simple random sampling allows the sample to be chosen by a simple random selection where every subject of the population has an equal chance of being selected. Stratified random sampling occurs in population that consist of different or heterogeneous groups. The respondents were randomly selected based on their knowledge regarding housing affordability problems among young households. All young households in the two metropolitans with knowledge on housing affordability had equal chances of selection to be part of the sample.

Data analysis and findings

The responses from the questionnaire were coded, data cleaning was performed, and the selection of the appropriate data analysis technique was done. The data was captured in an excel sheet and exported to R Software due to its extensibility. In choosing the appropriate statistical analysis, the research questions together with the data collected were considered.

Data analysis and interpretation was done using both descriptive and inferential statistics. The descriptive statistics was done to describe the distribution of the data using mean, minimum, maximum and standard deviation for the continuous variable while frequencies and graphs were used to report categorical variables. Inferential statistics were used to make judgments based on the sample collected from the population. The study will use Pearson correlation test, independent sample T-test, ANOVA and Spear man correlation test.

Table 1: Results and Analysis

	Description	Frequency	Percentage
Age group	18-23	3	3.8
	24-29	48	61.5
	30-35	22	28.2
	36-39	5	6.4
Gender	Female	32	41
	Male	46	59
Ethnicity	Black	59	75.6
	Coloured	3	3.8
	Indian	10	12.8
	Others	1	1.3
	White	5	6.4
Marital status	Married	16	20.8
	Single	60	77.9
	Widow/widower	1	1.3
Education	Bachelor degree	17	21.8
	Honours	41	52.6
	Masters	16	20.5
	Other	3	3.8
	PhD	1	1.3
Home owner	No	43	58.8
	Yes	34	44.2
Occupation	Private sector	59	76.6
	Public sector	12	15.6
	Self employed	4	5.2
	other	2	2.6
Workplace location	Ekurhuleni	7	9.0
	Johannesburg	60	76.9
Gross monthly salary	Below R10000	4	5.4
	R10001-R20000	12	16.0
	R20001-R30000	25	33.3
	R30001-R40000	16	21.3

	R40001-R50000	10	13.3
	Above R50001	8	10.7
Years of work experience	Less than 1 year	2	2.6
	1-5 years	48	62.3
	6-10 years	21	27.3
	11-15 years	5	6.5
	16-20 years	1	1.3
Spouse working	No	11	30.6
	Yes	25	69.4
Spouse qualification	Bachelor	14	50.0
	Masters	6	21.4
	PhD	1	3.6
	Other	7	25
Spouse occupation	Private sector	16	57.1
	Public sector	5	17.9
	Self employed	3	10.7
	other	4	14.3
Spouse gross monthly salary	Below R10000	2	8.3
	R10001-R20000	9	37.5
	R20001-R30000	2	8.3
	R30001-R40000	6	25
	R40001-R50000	5	20.9
House location	Ekurhuleni	14	21.2
	Johannesburg	52	78.8
Years at current residence	Less than 1 year	21	27.6
	1-5 years	39	51.3
	6-10 years	7	9.3
	More than 10 years	9	11.8
Current residence	Family	14	18.7
	Own	30	40.0
	Rent	31	41.3
Price of house	Less than R400000	4	8.2
	R400001-R500000	7	14.3
	R500001-R600000	4	8.2
	R600001-R700000	5	10.2
	R700001-R800000	5	10.2

	Above R800001	24	48.9
How did you own house	Financial institution with family support	14	31.1
	Financial institution without family support	22	48.9
	Others	6	13.3
	cash	3	6.7
Total rental per month	Below R3000	2	5.5
	R3001-R5000	8	22.2
	R5001-R7000	14	38.9
	R7001-R9000	6	16.7
	More than R9001	6	16.7
Financial assistance to rent	No	29	85.3
	Yes	5	14.7

A total of 78 respondents were involved in this study. The respondents were identified based on their age group and location of work place in Ekurhuleni and Johannesburg metropolitan area. From the survey conducted between June 2017 and January 2018, 34 (44.2%) of the respondents are homeowners while 43(55.8%) are not home owners. Majority of the respondents in the study are not home owners. A total of 31(41.3%) rent apartments, 30(40.0%) own their homes, 14(18.7%) live with their family.

Age and qualification: The age category of the respondents is 18 to 23 years old, 24 to 29 years old, 30 to 35 years old and 35 to 39 years old. From the data available, majority (61.5%) of the respondents are in 24 to 29 group. Among the total number of respondents who participated in the study, there were 41 (52.6%) of the respondents who had honours degree, 17 (21.8%) had bachelor’s degree and 16 (20.5%) had Master’s degree. 1 respondent had doctoral degree and 3 had other types of educational qualifications. The results presented in Table 4.1 suggests that among the professionals who responded to the survey, 59(76.6%) of them work in the private sector, 12 (15.6%) work in the public sector while 4 (5.2%) are self-employed. There were 2 (2.6%) respondents who had a different occupation.

Professional Experience: The respondents were asked about the number of years they have worked in their different professions. Based on the results obtained, it suggests that 1(1.3%) of the total number of respondents have16 to 20 years of working experience, 2 (2.6%) have less than 1-year experience, 5 (6.5%) have 11 to 15 years of working experience, 21(27.3%) have 6 to 10 years’ work experience while majority (62.3%) have 1 to 5 years of working experience. From the statistics gathered, a higher percentage of those who participated in the study worked for a higher number of years in their fields.

Work Location: The location of work for the respondents was captured as well. From the available data, 60(76.9%) work in Johannesburg while 7 (9.0%) work in Ekurhuleni municipality. It is revealed from the study that most of the respondents work in Johannesburg municipality. Also, majority (52%) of the respondents live in Johannesburg municipality. The findings were cross-tabulated between location of work and location of residence and it shows that majority of the respondents working in Johannesburg municipality live in same municipality. However, the majority of the respondents working in Ekurhuleni municipality live in Johannesburg municipality.

Most respondents aged 24 to 29 in the study rent their own apartments, followed by owning their own apartments with a few respondents living with their family. Out of the two municipalities, majority of the respondents are currently renting in Ekurhuleni municipality while majority own their own apartments in Johannesburg.

In both Johannesburg and Ekurhuleni, majority of the respondents aged 24 to 29 are currently renting. Most of the respondents aged 30 to 35 in Ekurhuleni are also currently renting while most of the respondents aged 30 to 35 in Johannesburg own their places of abode. Furthermore, the rentals paid by the respondents who are currently renting were also analyzed. By age group, respondents aged 24 to 29 pay rentals between R5001 to R7000 followed by R3001 to R5000. Most of the respondents aged 35 to 39 pay rentals between R5001 to R7000. Majority of the respondents aged 24 to 29 years who are renting pay between R5001 to R7000. For respondents aged between 35 to 39 years, the rental paid is between R5001 and R7000. None of the respondents in the 18 to 23 age categories are currently renting.

Remuneration: There were 25 (33.3%) of the respondents who received between R20001 and R30000, followed by 16(21.3%) who receive between R30001 and R40000. From the data available, 4 (5.4%) of the total number of respondents received below R10000, 12 (16%) received between R10001 to R20000, 10 (13.3%) received between R40001 and R50000 while 8 (10.7%) had more than R50001. From the data gathered, it is evident that majority of the respondents are in the R20001 and R30000 monthly salary bracket.

The gross monthly salary of the respondents was also collected. From the available data, most of respondents aged 24 to 29 receive between R20001 to R30000 as their monthly salary. Most of the respondents have stayed between 1 to 5 years at their current residence. The rentals which are paid every month by participants who are renting was also analyzed. From the study, majority of the respondents pay a rental between R5001 and R7000.

Table 2: Perception on housing affordability problems

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Houses are not affordable if the housing costs excessively displace your other non-housing expenditures	3 (3.8)	6(7.7)	8 (10.3)	42(53.8)	19(24.4)
Inadequate Income is a major concern for aspiring home-buyers	1(1.3)	3(3.8)	3(3.8)	22(28.2)	49(62.8)
Housing preferences influence housing affordability	1 (1.3)	4(5.1)	12(15.4)	29(37.2)	32(41.0)
The perception that young Households with more working experience will have better housing choice in the housing market that they can afford.	8(10.3)	11(14.1)	15(19.2)	33(42.3)	11(14.1)
There are limited affordable housing choice in housing market	2(2.6)	13(16.7)	20(25.6)	18(23.1)	25(32.1)
The current house price in the housing market are expensive for you to purchase		10(12.8)	14(17.9)	31(39.7)	23(29.5)
You believe overvaluation is attributable to the rising house price	1(1.3)	16(20.5)	13(16.7)	30(38.5)	18(23.1)

The house prices in the current housing market are unpredictable.	2(2.6)	26(33.3)	16(20.5)	22(28.2)	12(15.4)
Increase of foreign investors in the housing market decreases the house price in the housing market	10(12.8)	29(37.2)	26(33.3)	10(12.8)	3(3.8)
Houses are not affordable if you pay more than 30% of your income to purchase (mortgage) a house	4(5.1)	10(12.8)	10(12.8)	33(42.3)	21(26.9)
Rentals are not affordable if you pay more than 25% of your income to rent a house	1(1.3)	12(15.4)	16(20.5)	34(43.6)	15(19.2)
You have difficulties in purchasing a house because your income is insufficient to secure a housing loan (deposit, mortgage, transfer fees, tax)	5(6.4)	12(15.4)	9(11.5)	30(38.5)	22(28.2)
Houses are not affordable because of your financial commitments	1(1.3)	10(12.8)	16(20.5)	29(37.2)	22(28.2)
Your tenure choice if you cannot afford to purchase a house is to rent	1(1.3)	5(6.4)	9(11.5)	50(64.1)	13(16.7)
You will opt to purchase low cost houses if you can afford it & eligible for it	3(3.8)	20(25.6)	25(32.1)	24(30.8)	6(7.7)
You would like to purchase & live in urban areas if you can afford it		1(1.3)	6(7.7)	45(57.7)	26(33.3)
You do not want to bear transportation costs & purchase a house outside of urban areas.		7(9.0)	11(14.1)	27(34.6)	33(42.3)
You are fully aware of National Housing Policy	10(12.8)	24(30.8)	20(25.6)	18(23.1)	6(7.7)
You agree that similar strategy to assists low income households should be applied to Young Households	2(2.6)	5(6.4)	12(15.4)	37(47.4)	22(28.2)
You agree that financial literacy programmes should be incorporated in housing policy & schemes		3(3.8)	5(6.4)	47(60.3)	23(29.5)
You agree that young households should be more involved in designing & creating affordable housing in housing policy & schemes		5(6.4)	5(6.4)	48(61.5)	20(25.6)
You agree that there should be a policy on controlling a segment of housing market by the state especially for affordable housing	2(2.6)	1(1.3)	9(11.5)	36(46.2)	30(38.5)

From the data available, more than 70% of the respondents agree that houses are not affordable if the housing cost excessively displace other non-housing expenditure. Also, more than 60% of the respondents believe that inadequate income, housing preferences, households with more working experience will have better housing choice and limited affordable housing choice are key elements which affect affordability of houses among young households.

Key Findings: from the study, it is established that the criteria for measuring household affordability for young households depend on a number of factors. It states that houses are not affordable if one pays more than 30% of income to purchase a house, rentals not affordable if one pays more than 25% to rent, when one has insufficient income to secure a housing loan and also due to financial commitments.

What are *the key elements affecting housing affordability amongst the young households (YH) in the City of Johannesburg, South Africa?*

This section sought to investigate the factors affecting housing affordability amongst young households in the two municipalities; Johannesburg and Ekurhuleni. Respondents were asked to ranked questions relating to factors affecting housing affordability. On the issue of houses not being affordable if the housing costs excessively displace your non-housing expenditures, 3 (3.8%) of those who participated strongly disagreed, 6 97.7%) disagreed, 8 (10.3%) are neutral, 42 (53.8%) agree while 19 (24.4%) strongly agree. Inadequate income is one of the reasons stipulated as a major concern for aspiring home buyers. From the results obtained, 1(1.3%) strongly disagree, 3 (3.8%0 disagree, 3 (3.8%) were neutral, 22(28.2%) agree while 49 (62.8%) strongly agree. It is therefore evident from the empirical studies that inadequate income is a major concern for respondent who aspire to buy homes. More than 90% of the total number of respondents in the study indicated that inadequate income is a major concern whenever young households decide to buy a house.

On the issue of housing preferences influencing housing affordability, 1 (1.3%) strongly disagree, 4(5.1%) disagree, 12 (15.4%) were neutral, 29 (37.2%) agree while 32 (41%) strongly agree. Generally, more than 50% of the respondents believe that limited affordable housing choice in the housing market is a major issue regarding affordability among young households. More than 40% of the respondents believe that young households with more working experience will have better housing choice in the housing market.

What is the criteria in measuring household affordability for young households/households in the City of Johannesburg South Africa?

This section dealt with the criteria for measuring household affordability for young households. From the results, 4(5.1%) strongly disagree, 10(12.8%) disagree, 10(12.8%) were neutral, 33 (42.3%) agree while 21(26.9%) strongly agree that houses are not affordable if one pays more than 30% of income to purchase (mortgage)a house. Regarding rentals, 1(1.3%) strongly disagree, 12(15.4%) disagree, 16(20.5%) were neutral, 34 (43.6) agree while 15(19.2%) strongly agree that rentals are not affordable if one pays more than 25% of income to rent a house. Sometimes, it is difficult to purchase a house because income is not sufficient to secure a housing loan. From the results, 5(6.4%) strongly disagree, 12 (15.4%) disagree, 9 (11.5%) were neutral, 30 (38.5%) agree while 22 (28.2%) strongly agree that it is indeed difficult to purchase a house because of challenges in securing a housing loan with insufficient income.

Some of the respondents believe that financial commitments can hinder housing affordability. From the data available, 1(1.3%) strongly disagree, 10 (12.8%) disagree, 16 (20.5%) were neutral, 29(37.2%) agree while 22(28.2%) strongly agree that houses are not affordable due to financial commitments. From the results, more than 65% of the total respondents agree that houses are not affordable due to financial commitments.

How is the housing affordability issue influencing the housing choice and behaviours of households?

In certain instances, there are low cost houses which are available for sale. Those who are not able to buy expensive houses due to financial constraints could opt for low cost houses provided they are able to pay. From the study, 3(3.8%) strongly disagree, 20(25.6%) disagree, 25(32.1%) were neutral, 24(30.8%) agree while 6(7.7%) strongly agree that they will opt for low cost houses if they are able to afford it and eligible for it. From the results, quite a number (29.4%) believe that low cost houses are not an option even if they can afford and are eligible for it. It is likely that these respondents may decide to rent for some time while saving for a house of their choice rather than opting for a low-cost house.

From the results, 1(1.3%) disagree, 6(7.7%) remained neutral, 45(57.7%) agree and 26(33.3%) strongly agree that they will purchase and live in urban areas if they can afford it. It is clearly evident that majority of the respondents agree that their preference is urban areas if only they can afford it. Costs of transportation is increasing on regular basis and has become a factor in housing choice and affordability. Results from the study indicate that 7(9.0%) of the total respondents disagree, 11(14.1%) are neutral, 27(34.6%) agree and 33(42.3%) strongly agree that they do not want to bear transportation cost and purchase a house outside of urban areas. Most of the respondents prefer to live in the urban areas in order to reduce their cost of transportation to work and other places of interest.

What changes in housing affordability can be identified?

This section sorted the opinions of the respondents on changes in housing affordability that are identified. About 3(3.8%) disagree, 5 (6.4%) were neutral, 47(60.3%) agree and 23(29.5%) strongly agree that financial literacy programmes should be incorporated in housing policy and schemes. From the results, it is established that more than 80% of the respondents believe that financial literacy programmes need to be part of housing policy and schemes.

There were 5 (6.4%) of the total respondents who disagree, 5(6.4%) remained neutral, 48 (61.5%) agree and 20 (25.6%) strongly agree that young households should be more involved in designing and creating affordable housing policy and schemes.

The state needs to play an active role in the housing market so as to make houses affordable for young households. From the study, 2 (2.6%) strongly agree, 1 (1.3%) disagree, 9 (11.5%) were neutral, 36 (46.2%) agree and 30 (38.5%) strongly agree that there should be a policy on controlling a segment of housing market by the state especially for affordable housing.

Construct	Cronbach alpha
Affordability	0.4
House price	0.7
Household income	0.6
Housing choice	0.6
Housing policy	0.6

The Cronbach alpha values for the different factors affecting housing affordability are shown in the table above. Apart from affordability which has a low Cronbach alpha, the rest of the factors have a high Cronbach alpha. The correlation between housing affordability and housing price and household income are statistically significant. The correlation coefficient between affordability and housing price is 0.5 and highly statistically significant, and the correlation coefficient between affordability and household income is 0.4 and also statistically significant. There was no statistically significant correlation between affordability and housing choice.

	Minimum	Median	Mean	Maximum	Std Dev
Affordability	1.8	4.0	3.9	5	0.6
House price	1.8	3.4	3.3	5	0.8
Household income	2.0	3.8	3.7	5	0.7
Housing choice	2.5	3.8	3.8	5	0.6
Housing policy	2.0	3.8	3.8	5	0.6

The average affordability perception for females and males is 4.1 and 3.7, respectively. There was a statistically significant difference in affordability perception between males and females. Females had a higher affordability perception rating than males. Also, there was a statistically significant difference in house price perception between males and females. There was no statistically significant difference in household income, housing choice and housing policy perception between males and females.

There was no statistically significant difference in affordability, housing price, household income, housing choice and housing policy for participants in the Johannesburg and Ekurhuleni municipalities and also between respondents who own a house and those who do not own a house. There was a statistically significant difference in affordability perception between married and single respondents. However, there was no statistically significant difference in housing price, household income, housing choice and housing policy between married and single respondents.

The average physical health for participants with high and normal FBS is 60.51587 and 56.58730, respectively. There was a statistically significant difference in physical health between high and normal FBS participants (t-value=2.2952, p-value=0.02394).

Since the p-value is less than 0.05, we can reject the null hypothesis and conclude that the mean physical health for high and normal FBS participants is significantly different. The result therefore suggests that participants with high FBS have significantly different amount of physical health from those with normal FBS. The average physical health for high FBS participants is 3.92857 more than the average physical health for normal FBS participants

There was no statistically significant difference in psychological effect between high and normal FBS participants (t-value=1.4316, p-value=0.1556). The result suggests that participants with high FBS do not have significantly different psychological effect from those with normal FBS. The average psychological effect of the participants with high FBS and normal FBS are 60.10802 and 57.03704, respectively.

The aim of this analysis is to determine the housing affordability problems as perceived by YWH and to examine the relationship of the housing affordability problems. The perceptions of housing affordability problems are considered as problems in terms of housing affordability, house price, household income, housing choice and housing policy.

There is no statistically significant difference in perceptions about affordability between respondents who own, rent and stay with family from a Mann-Whitney U test. Similarly, there are no statistically significant differences in perceptions regarding housing price, household income, housing choice and housing policy among the respondents who are renting, owning an apartment and those who live with their family.

There is no statistically significant difference in perceptions about affordability, housing choice and housing policy among the different age groups. However, there is a statistically significant difference in housing price between the different age groups. The results reveal that there is a significant difference in perception about housing price between respondents who are aged 24 to 29 and those aged 18 to 23, and also significant difference between respondents aged 18 to 23 and those aged 30 to 35. The average perception for housing price for respondents aged 18 to 23, 24 to 29, 30 to 35, 36 to 39 are 4.5, 3.3, 3.1 and 3.7, respectively. There is no statistically significant difference in perceptions regarding affordability, housing price, household income, housing choice and housing policy for the different occupations.

Conclusion

The housing affordability problems among young households are influenced by house price, household income and housing choice in the housing market. The key findings of this study suggest that there is a gap in affordable housing for young households in the housing market.

- The findings also showed that the supply of affordable housing for young households is limited and further decrease their opportunity to purchase a house.
- Furthermore, the justification of majority of the young household to live and work in the same municipality is due to the fact that they still live in their family houses. There is a positive relationship between housing affordability and housing price and household income. The analysis and discussions of findings indicated that housing affordability is affected by housing price and household income.
- The housing affordability problems being experienced by young households indicates that there is a need for initiatives by the government to implement and execute policies which are designed to solve housing issues especially for young households. Affordable housing for young households has not achieved much to encourage private sector participation which could help solve the issue. There is limited government involvement in policy implementation for affordable housing.

However, there were also views on the absence of financial literacy among young households which led to the housing affordability problems. In addition, the reluctance of young households to purchase low cost available affordable houses outside urban areas and their spending behaviour are among the housing affordability problems being encountered.

In addition, the perception of housing affordability among young households have statistically significant differences between gender, ethnic groups, different occupations and marital status.

Overall, the housing affordability problems among young households in this study are attributed to affordability, housing price, household income, housing choice and housing policy.

However, these four problems are interrelated. There is a positive relationship between affordability and housing price and household income while affordability is not related to housing choice and housing policy. The positive relationship between house price and household income relatively shows young households who have affordability problems in terms of house price will have problems in household income as well. Similarly, there is also no relationship between household income and housing choice and a positive relationship between household income and housing policy.

References

Aksoy, E.S.M.A., 2017. Housing affordability of different income groups in Turkey: Regional comparison. Unpublished Master Thesis) Middle East Technical University, Ankara.

Burgoyne, M.L., 2008. Factors affecting housing delivery in South Africa: A case study of the Fisantekraal housing development project, Western Cape (Doctoral dissertation, Stellenbosch: University of Stellenbosch).Cai, Z. (2017). Analyzing Measurements of Housing Affordability (Doctoral dissertation).

Department of Local Government and Housing, 2005).

Embong, A.R., 2013. Responding to globalization and the state: negotiations and contestations by the middle class in Malaysia. In Globalization and Social Transformation in the Asia-Pacific (pp. 63-77). Palgrave Macmillan, London.

Fisher, J.D. and Gervais, M., 2007. First-time home buyers and residential investment volatility (No. 148). Society for Economic Dynamics.

Gardner, D. 2004. Sharpening the focus. A new look at South Africa's housing strategy. Presentation prepared for the Housing Finance Resource Programme.

Lin, J. & Lind, H., 2011. The development of affordable housing: A case study in Guangzhou City, China. Masters thesis Department of Real Estate and Construction Management Division of Building and Real Estate Economics

Linneman, P.D. and Megbolugbe, I.F., 1992. Housing affordability: myth or reality?. Urban studies, 29(3-4), pp.369-392.

Mak, S.W., Choy, L.H. and Ho, W.K., 2007. Privatization, housing conditions and affordability in the People's Republic of China. Habitat International, 31(2), pp.177-192.

Matlack, J.L. and Vigdor, J.L., 2008. Do rising tides lift all prices? Income inequality and housing affordability. Journal of Housing Economics, 17(3), pp.212-224.

Milligan, V., Phibbs, P., Fagan, K. and Gurran, N., 2004. A practical framework for expanding affordable housing services in Australia: learning from experience.

Ortalo-Magne, F. and Rady, S., 1999. Boom in, bust out: young households and the housing price cycle. European Economic Review, 43(4-6), pp.755-766.

Rappaport, J., 2008. The Affordability of Homeownership to middle-income Americans. Economic Review, 4.

Rust, K., 2006. Analysis of South Africa’s housing sector performance. FinMark Trust.

Shiller, R.J., 2003. From efficient markets theory to behavioral finance. Journal of economic perspectives, 17(1), pp.83-104.

Stutz, F.P. and Kartman, A.E., 1982. Housing affordability and spatial price variations in the United States. Economic Geography, 58(3), pp.221-235.

Tekeli, I., 1992. Development of urban administration and planning in the formation of Istanbul metropolitan area. Development of Istanbul Metropolitan Area and Low Cost Housing, pp.1-111., Edited by: Tekeli, İ., Şenyapılı, T., Türel, A., Güvenç, M. and Acar, E. Istanbul: Turkish Social Science Association, Municipality of Greater Istanbul, IULA-EMME.

Zyed, Z.A.S., Aziz, W.N.A.W.A. and Hanif, N.R., 2016. Housing affordability problems among young households. Journal of Surveying, Construction and Property, 7(1), pp.1-18.