TOWARDS THE ORGANIC FACTORY OF THE FUTURE

Hilal Hurriyet

School of Management, UNIVERSITY OF WESTERN SYDNEY, Sydney , Australia

h.hurriyet@uws.edu.au

TOWARDS THE ORGANIC FACTORY OF THE FUTURE

ABSTRACT Designing a manufacturing system that is competitive, flexible, adaptive and perhaps even sustainable in the future, has been challenging for the many researchers and practioners. In this paper and organic approach and self organising structures and processes are proposed as an alternative to design manufacturing organizations and the factory of the future (FOF). The paper analyses major patterns of the models that have been proposed for the FOF. It groups the model of FOF in relation to the major manufacturing management trends while discussing key issues that are centred on the FOF concept. It draws conclusions from similarities between the existing models of the FOF and proposed process of becoming organic and organic characteristics.
Keywords: *Factory of the Future, Organic Organisations, Integration, Flexibility, Agility*

BACKGROUND

Manufacturing organisations, named as factories are complex production systems which are collections of somewhat incompatible systems (Senker and Beesly,1985). They play important role in the economic development of the countries by adding value to the inputs of the factory systems (converting materials into products). The concept of the FOF had existed since the first discovery of the factory concept, even before industrial revolution. For this purpose new models and systems of factories are being designed, developed and implemented with success or no success. The current systems have also been updated with an aim of achieving a better fit of production factors. Today the declining trend within the manufacturing industry across the world is a major concern for the planners and practitioners of factories. New concepts and new approaches are emerging in manufacturing management to achieve continued survival. They all have short life span and limited applicability.

A. THE MODELS FOR THE FACTORY OF THE FUTURE

The literature on the history of FOF goes in parallel to the literature on management of manufacturing technology. The evolution of machinery is analysed as a technical fact under the engineering approach and as a social artefact under the social approach in which machine is linked to the social environment Braverman (1975). Common themes in order to group the models of FOF's are likely to take either technical or social perhaps a mix of them where is required.

1.Automation Model Of The FOF (Technological Aspect Is The Most Referred In The Literature)

For most people the concept of FOF pictures a scenario full of automated machines and robots doing the job on the factory floor with very few people around (Advanced Manufacturing Industry Study

Report, 1996). Gerold (2004) states that more than fifty years ago a vision called as “lights out factory of the future”emerged with the invention of robotic arm. Current literature would still draw similar pictures which are mainly at the high technology level.

Spheres of Automation*:* In Kaplinsky’s model for the FOF, automation has three spheres and each sphere has activities. Intra-activity automation takes place when a discrete operation is independently automated. The next step is intra-sphere automation refers to the linking of different activities within the same sphere, for instance the linking of machine tools through direct numerical control (DNC) or Flexible Manufacturing Systems (FMS). And finally inter-sphere integration in which three different spheres are linked and it is called as “Automated factory of the future” where the structure and organization of the firm is highly unitary. Kaplinsky (1984) predicted that the true “factory of the future” i.e. fully automated production in many sectors including those now characterized by small; batch production would emerge by the 1990s and be fairly widespread.

The literature on the FOF can be categorised into groups. Under the title of “*Towards the FOF”* prediction of the total picture in operational terms was done by Eloranta, 1992; Cross, 1990; Smith, 1983 and Automated factory report, 1994. ‘Automation’ and ‘robots’ are used interchangeably in this group of articles. Integration aspect of FOF has been tracked along with automation such as integration through automatic identification systems Narasimhan(1985); functional integration and CIM with open system view within the FOF Groover *et al.*,(1986). The readiness of organisations is tracked through Schlefer, 1985; Ryan, 1984; Langevin, 1984 and Page, 1993. Specific works such as production planning and control, best practice also were studied by Richardson, 1988; Zachary *et al.*, 1993 and Burton, 1993. Senker and Beesly(1985) argue that the justification for the automatic factory claim that perfect up-to-date data on what is going on everywhere in the factory is generated through computers and computer controlled machinery capable of processing and conveying materials, components and sub assemblies are taken in an orderly way through the automated factory. The various “Manufacturing Technology Shows”,(1996, Michigan and 2000, Hanover) encouraged factory automation in different areas of production; materials handling and logistics, vision technology, surface treatment and R&D through high speed mode technologies. Shaiken (1985) argues that

equipment never seemed to break down at trade shows, but some automated factories are down a third of the time. Currently, factories which were the FOF of past times seem to have problems that are not technological, but managerial and organizational.

Skills for the FOF*:* Involvement of the employees is reduced to a minimum level in highly automated plants and that is why the possible Tayloristic route is likely to disadvantage the organisations in the future. Piore and Sabel (1985) suggests that the wider applications of new flexibly specialized production systems depends on deployment of flexible but craft based work replacing narrow and routine jobs. **The de-skilling theses***:* Management uses mechanization and automation as occasions for increasing its leverage over the work force and skilled employees are replaced by the low skilled ones which results in erosion of craft work. Another disadvantage is shown as the design of technology and procedures to support it which lacks skills and direct workers suffers from loss of control (Blumberg and Gerwin, 1985). The managers should allow and encourage their workforces to retain and expand their knowledge in automated factories. **The upgrading thesis**: Technology is viewed as a tool to automate the lowest, most routine activities while creating new, different types of skill, as production technologies change. Weimer (1996) states automation meant enrichment of labour since w*hat an operator of a modern machining center must know today equals what a professional engineer knew in the 1950's*. Adler(1991) points out that in many firms today the managers are indifferent to the roles played by three way interaction among technology, people, and organization. In Braverman's (1975) model people's contribution is achieved by a relatively small corps of workers. The workers attain the level of mastery over the machinery offered by engineering knowledge. This is supported by the best practice methods MRP, CAPP, CAD etc. and all placed on identical or parallel pathways which will converge, into "a total system automated factory". Such integration will enable management to gain total control over the whole process of production.

2. Advanced Manufacturing Model (AMT) Model Of The FOF AMT adoption into a company will require " a total business approach" to design a manufacturing system which is capable of meeting corporate objectives over a period of time within a forecasted environment to be able to manage the transition from existing to proposed systems in an efficient way.

Integration- (The role of CIM in FOF) It is viewed as one aspect of automation which comes after mechanisation and regulation of processes or control. With integration an organisational dimension is incorporated into technology and its application. Bessant (1985) points out that integration in manufacturing started within the Kaplinsky's spheres even in the early factories by combining functions in the single machines and later, integration has been observed largely with the discovery of direct numerical control whereby a set of multi function machine tools can be controlled within a production cell by a master computer. With the advent of FMS which allow handling and transport to be automated, integration between spheres is accomplished and the coordination and production activities are brought together. The computer aided design and manufacturing (CAD/CAM) and computer based inventory control and purchasing systems inevitably leads to the idea of fully computer integrated manufacturing in which all spheres of manufacturing are linked. CIM is implemented in three major ways through integration 1.Inside to outside integration-data exchange between a manufacturer and its suppliers and/or customers 2.Beginning to end integration- creating a data continuum from earliest design and planning to the end of production to link functional parts on the factory floor 3.From top to bottom integration- disseminates information downward for better control of manufacturing operations and to feed information upward from the shop floor for use in business management and planning. Inter-sphere automation achieves technological links between spheres and refers to a degree of merging of activities. Buchanan and Boddy (1984) point out that the significance of this convergence includes the merging of occupational structures and the dissolving of departmental barriers which can not be achieved through technology only. The mismatch or misconnection between spheres in CIM implementation shows that there is significant lag between the rate of technology adoption and that of organisational adaptation. The trend towards highly integrated technology for the (FOF) will have to consider combining "best practice" in production engineering with new management techniques and integrated organisational forms (Bessants, 1985). Schonberger (1990) also supports the view of successful performance in terms of productivity and quality comes as a result of organisational changes (systematic process of problem identification and elimination) rather than technological changes. Similarly, flexibility also can be achieved by reducing the set up time for

new batches of products (Japanese small improvements of dies and press tools) as well as by new technology.

3. EUROKA Project A project of European Union which was established to develop sustainable factories in the future. Initially focus was on flexible assembly systems and hardware however it was shifted to new organisational concepts which better integrated a company's human resources with its technological system. The five strategic areas of the dynamic nature of the manufacturing environment were revealed. 1.A competitive portfolio of products and processes. 2.Being flexible enough in production to react to a turbulent environment 3.Managing in circulation to turn recycling to competitive advantage 4.Human Being, Values and Society aims (integrating the company into the social environment) 5. Innovation and the Creation of Knowledge (learning from experiences within the business). The study found that agility requires abilities such as technology management and continuous strategy evaluation, coupled with a competent and empowered workforce. The FACTORY project identified major market trends and find out type of industrial system to answer those trends in the future.

Table:1Euroka Models for FOF

Model	Market	Example	Manufacturing objectives
Elastic Enterprise	*Limited number products;* strong fluctuations in demand	Building and Construction	Adapt manufacturing to volume fluctuations while maintaining consistent efficiency, quality and cost
Flexible Enterprise	*Volatile;* requires new, more customer focused products	Electrical domestic equipment	Produce diverse products with same equipment in small quantities with short time-to-market
Total Service Enterprise	*Very complex products;* customer need manufacturer to manage product through its lifecycle	Aerospace, defence	Develop long-term relationships with customers and suppliers; offer complete service package with constant product upgrades, maintenance, recycling etc.
Technological Leader	*Very competitive mass market;*-set product apart through technological innovation	Automotive	Encourage innovative climate inside company and with partners: reduce lead times between concept and product
Virtual Enterprise	*Fast moving niche markets*	Investment goods	Identifying emerging market opportunities and quickly organising " ad hoc" networks to assemble resources to exploit them

The table above shows five different factory models for the FOF.

The study concluded the requirements of the FOF to be a blend of two or more models. The components of the Factory of the Future (in order of importance for achieving the FOF dreams) are listed as: 1. Implementing dynamic, flexible manufacturing structures; 2. EDI links to transfer

information to/ from customers and suppliers; 3. Introducing new technologies into the production system; 4. Knowledge transfer and sharing of experience; 5. Improvement of innovation; 6. Improvement of Product Development Process; 7. Computer Aided Design, Electronic Product Definition.

4. More Human Models Of FOF

In Vasilash (1996), Miko Milano's view in of the FOF is "Simpler Machines and More Humane Organisations". Socio Technical System Design (STSD) is one way of accomplishing this view (Dankabaar, 1997 ; Du Roy,1989). In STSD the socio-organizational system must be seen as being as important and decisive as the technical system therefore a joint design should be done . In the Human Centred Systems, which is next stage, the objective is to develop software which will enable the operator to program the computerized machine by making the first of a batch of parts, and in doing so, to develop a methodology for the simultaneous consideration of social and technical aspects during the development of new technology. If the machines are human-centred, it will provide good human-machine symbiosis, in which there will be pro-active creative human beings. The system will be transparent and people will be capable of acting in an informed way in the event of uncertainty. Human Intelligence Based Manufacturing (HBIM) is the new manufacturing system which seeks to combine the deep knowledge and experience of engineers and human factors with the manufacturing technology (Martensson *et al*, 1993). It takes account of the culture of the manufacturing. It suggests that there is a requirement for introducing flair, thought process, skill, experience, knowledge and so on to the computer environment in the production of highly value-added goods.

5. Approaches To The FOF

Patterns (common approaches) of the FOF (An empirical taxonomy). Boyer, *et al* (1996) investigated predominant patterns of technologies in use and uncovered approaches and strategies towards automation. Three general types of AMT are identified (in the areas of design, manufacturing and administrative). The outcome of the cluster analysis was four distinct groups of companies with respect to their approaches toward investing in AMTs .1. Traditionalist does not invest heavily in any of the 3 types of AMT's. 2. Generalist has moderate investments in each technology. 3. High investors

have the highest investment in each of the 3 technology types. 4.The most interesting group may be the designers, which have least investments for manufacturing and administrative AMTs, but have the second highest investment in design. Analysis reveals that more technology –intensive firms have more employees and a higher degree of integration. Excellent performance requires infrastructural issues such as worker empowerment, managerial support, and commitment to improvement programs such as JIT, TQM or concurrent engineering as well as AMT. When flexibility is an important element of the firm's manufacturing strategy, AMT is a must. **Virtual Factory Model:** It provides an intelligent control for entities in the virtual reality enabling the user to participate in real-time to the self organization simulation through the virtual reality interface (Vaario, *et al* 1997). It shows how static virtual models could be converted into living models with a novel idea of combining a virtual reality with an automated action control based on self-organization simulation principles. **Learning organisations model:** It is based on supportive information management, the hierarchy is deconstructed, alliances and new skills are created and everybody becomes a designer for the new systems to support the new context Senge (1990). The information systems should facilitate the learning process. **Thinking organisations:** Business firms are repositories of productive knowledge arranged as hierarchies of routines linked to the execution of tasks. The knowledge embedded in these routines is represented by the skills of the members executing those tasks. **Distributed autonomous/next generation manufacturing systems**: They are based on the model or working principles of self-organising properties of biological entities (Tharumarajah, 1995) Their evolution during a long time period is a continuos process and in the end they change into a new form even if they are not adaptive. *Bionic Manufacturing* uses the example of organs of a life form seemingly acting on their own while coordinating their actions and maintaining harmony. The lowest life form of cell corresponds to the core production unit, then organs to team of units. Each layer in the hierarchy supports and is supported by neighbour layers. A modelon structure is exploited to realise whole-part relations, self-decision, integration and harmony among the autonomous units. In *Holonic Manufacturing* Holon,-particle or part- describes the hybrid nature of sub-whole/ parts in real life systems. The concept of complex system will evolve from simple systems much more rapidly if there are stable intermediate forms than if there are not. A Holon has self -assertive tendencies (dynamic expression of a holon's

wholeness) and integrative tendencies (the dynamic tendency of its partness). Each production unit can be a holon and these units cooperate with each other to manufacture products. Koestler, who is the pioneer of these systems, describes holarcy as a hierarchy of self-regulating holons, which acts as autonomous wholes, dependent parts and in coordination with local environment. A holon can be purely informative, a physical object that is endowed with additional information processing capabilities. *Fractal Manufacturing* is based on the principles of Fractal Geometry (pattern -inside of pattern). Main characteristics are self-organizing, self-optimizing, and dynamics (Warnecke,1993). Fractal is living organisms having small number of self-imitating elements. By using these elements Fractals arrives at multiple solutions. Fractals navigate in the sense of constantly checking their target areas, reassessing their positions and progressing and correcting if necessary in a chaotic environment. It is the establishment of systems which are self-regulating. The basic aim of the fractal is the creation of self-regulating organizational working groups each within its own area of competence. It answers the FOF model of Total System Enterprise (EUROKA, 1995) and is consistent with the new organizational forms that require a deeper understanding of the fundamental inseparability of technology, practice and community (Ruhleder ,1996).

B. OTHER VIEWS ON FACTORY OF THE FUTURE

Forcing the Factory of The future: Jones(1997) studied whether the transformation of small-batch production by cybernetics into the “Factory of The Future” was taking place (the prospects for a fully cybernated batch production through computerisation) and the likelihood of a universal model transcending previous paradigms (intellectual problem of whether the emerging patterns deepens and continues, or breaks with previous lines). The findings suggested that the characteristic of organisation of batch production in metalworking continues. The constraint on the achievement of cybernation is the continuing importance of human skills. In order to build a manufacturing capability that is less susceptible to market forces, and more disposed to achieve manufacturing competitiveness the . solutions would be a combination of a stable and skilful employment, an imitation of Japanese Fordism and the process-specific, decentralised workshop pole of batch production. **Paperless Factories-Simplification Model** (Black,1991) suggests a simplified system which provides real time

features to support factory operations. Integrated Manufacturing Production System(IMPS) redesigns the existing system, creates cells and reduces the amount of subassembly work while paperwork simplification is achieved through electronic transfer between customer and supplier. **Reinventing the factory: from a technical perspective:** (Adapted from Harmon, 1992)The ultimate technology for the FOF is considered to be CIM consisting of several elements namely: product (CAD) and process (CAPP and CAM) engineering systems, manufacturing planning and control systems such as MRPII and JIT, factory support systems, direct/ distributed numerical control (DNC), factory execution systems. The reinvention comes through three linked areas of simplification, automation and integration which link all processes using computers, communication networks, and on the shop floor, material-handling devices and robots. A manufacturing company considers the next two stages- automation and integration even though significant benefits are achieved through simplifications alone due to the factors regarding product line flexibility, process precision and flexibility, safety, security and information requirements The higher the degree of required excellence in the above areas of factors, the higher the applicability of automation and integration. Simplified factory and office operations are a vital prerequisite to achieving superior computer integrated manufacturing.

C. ORGANIC FACTORY OF THE FUTURE

Manufacturing systems are modelled as open and dynamic operational systems that present complexity. Continuous changes of external environment and complexities of internal environments can only be simulated under the broad framework of open systems theory (Wysk, *et al*, 1994) and biological systems which have been used as a model/ metaphor to draw conclusion from. Biology has been used as model by McCarthy (1995) to classify manufacturing systems with an aim of enhancing knowledge and understanding as well as enabling predictions to be made about manufacturing system behaviour as well as Biological Manufacturing.

The research proposed that organic organisations would have characteristics similar to those in the 'natural systems'(Agrawal and Hurriyet, 2004). "Organisms" have proven capacity to survive, although organic products have limited life and have an inherent characteristic of self-decline. Organisms combine themselves producing outcomes, the range of which is limited only by the

capacity to comprehend and ability to recognise these outcomes. Organisms can have different shapes and different forms. They can mutate and combine without any set pattern. They can die and re-emerge. It is argued that 'organic process' is the answer to managing organizations within unpredictable environments. FOF would have to focus on the development of self-based characteristics for self- actualisation, a necessary condition for their survival in the environment.

A picture of the FOF was formed through historical evolution of manufacturing technology as the major aspect of the analysis of FOF (Hurriyet and Agrawal, 1999). An initial description of being organic reflected in a machine which is human like or a factory presenting all production factors interacting with each other and growing in a harmony acting same as an organ of the body.

At macro level manufacturing eras (paradigms) such as craft, mass, lean and agile are analysed. Evolution of different manufacturing technologies are also examined over the significant eras of production. The main characteristic, which can be transferred from craft production to the FOF is customisation. Flow production, low cost, and balanced assembly lines can be transferred from mass production. Flexibility, whole person, lean cells, smooth and synchronized production are the characteristics can be carried from lean production. And finally, flexible structures, autonomous entities and agility are the characteristics that can be transferred from agile production. Production factors of technology, human, organisational structure and information are main dimensions that were analysed in the pictures of the factories over historical time.

Different scenarios of the factories, (Waddell 1953; Warnecke,1993; Waurzyniak,2001; Teresko,2004) are drawn to highlight the importance of production factors over the development process. It then analyses the external working of factories in the context of the evolution of FOF and emerging trends (Arie de Gaus, 1997; Stock,1993; Santosus,1998; Smith et al.,2000) in the disciplines of Organisation Theory and Operations Management. These two approaches then, are cross analysed and linked together in order to identify contemporary characteristics of organic factories.

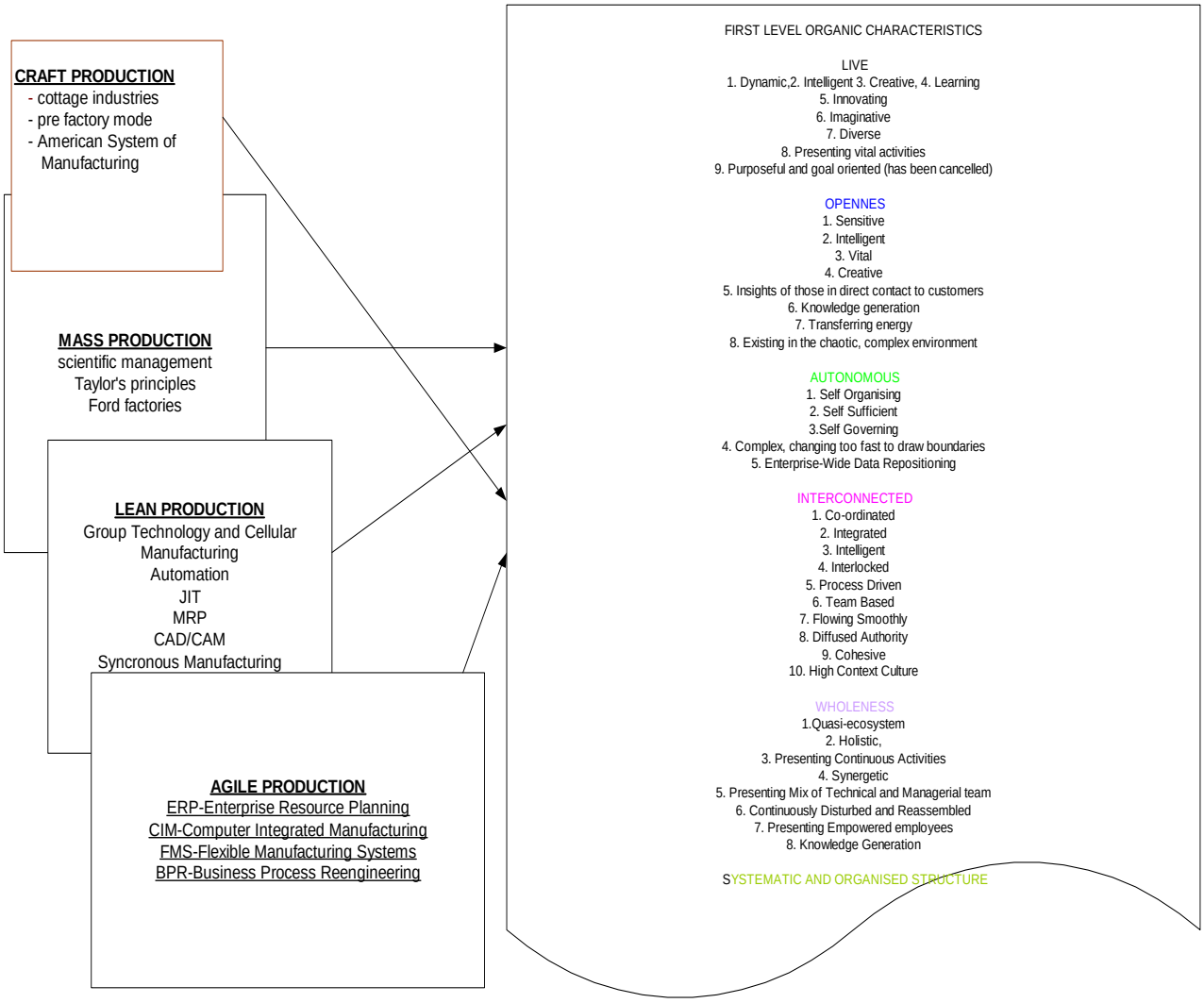
At the micro level analysis, the term organic means acting as a living whole. This has been described as the most comprehensive and novel way of surviving in continuously changing chaotic environments. Based on the definition of dictionary meaning of organic described by the sciences such

as biology, chemistry, and philosophy the main features of organic are drawn. Immediate dictionary meaning and chemistry meaning of organic is “characteristic of, relating to or derived from living organisms (animal or plant)” and from this meaning “being live” is carried to the features of being organic (The Macquarie Dictionary, 1997). The noun definition of organism in biology is defined as “an individual composed of mutually dependent parts constituted for subserving vital processes”. A philosophy linked to the definition is called “organicism” and supports the theory that vital activities arise not from any one part of an organism, but from its autonomous composition. Autonomous composition is added to others as the new feature of being organic. The characteristics that carried from philosophy are the interconnectedness that relates the interactions of the parts of the living organisms to the whole. As a result, organism is any structure that the parts of which function not only in terms of one another, but also in terms of the whole. Similar characteristics existed within the distributed manufacturing systems.

The main features of being organic are outlined in Hurriyet and Agrawal (2001). (shown in the figure no:1) 1. The existence of a whole consists of mutually dependent parts structured systematically. 2 The parts are interconnected and interlocked. The parts function not only in terms of one another, but also in terms of the whole. 3. The whole shows autonomous composition as a result of mutually dependent parts structured systematically. 4. The autonomous composition results in vital activities or processes and vital activities lead to being live. The characteristics of being organic have been identified through above features and new characteristics drawn from the literature review (Allee, 1997; Banner,1995; Cathcart,1995) of operations and technology management as well as organizations theory (Hannah 1998; Barnatt, 1997). These two groups have been integrated into one set of characteristics. When scaled, true natural systems show the highest level of being organic and then it gradually decreases towards control based systems (Hurriyet and Agrawal, 2001). These characteristics are used for the development of the proposed organic model. The organic features that have been drawn from meaning of organic are considered as the basis of the search for capturing the stages or perhaps the levels of being organic. Main characteristics are adjectives and reflections of being organic, can be placed into groups, existed in the past and carried over to the future. The natural systems are the ultimate

framework for the stages of becoming organic. Macro level phenomena have been a significant input to the process of realization of the stages of becoming organic. But the speed of changes at the micro (factory based) level is different than the speed of changes that happens at macro (era based) level.

F*igure:1Features and characteristics of being organic*



The process of becoming organic starts with reforming or deconstructing into smaller parts-cell structure. The parts are inherently dynamic. Parts are interconnected through AMT and lean production techniques. The interactions amongst parts are accelerated through advances in information technology and information management systems. Empowerment, autonomous entities, and 'culture'

would be used as tools to create the 'whole' which is a living organism that is self-adaptive, self-optimised and self-evolving. Through synergy and growth it reaches a stage where it transforms into more complex forms. **Linkages with the previous models and systems:** The organic model for the FOF relates to the three stages of reinventing the factory; simplification, automation and organisational integration/computer integration. This has been reflected in the stages of becoming organic and also historical development of manufacturing technology.

Table:2 Linkages between Organic Model and Euroka Models

Model	*Organic Characteristics* *(Output)*	*Organic Characteristics* *(Input)*	*Organic Features*	*Organic Stages*
Elastic Enterprise	Adaptable	Dynamic,Coordinated,Integrated, Process Driven, Team based, Intelligent, Responsive, Learning, Presenting ContinuousActivities, Cohesive, Presenting Empowered Employees, Flowing Smoothly	Live, Systematic Structure, Interconnected	**CELL** **DYNAMISM** **INTERCONNECTION**
Flexible Enterprise	Adaptable Flexible	Dynamic, Coordinated Integrated, Process Driven, Team Based, Intelligent, Responsive, Learning, Presenting Continuous Activities, Cohesive, Empowerd Employees, Diverse, Innovative	Live, Systematic Structure, Interconnected, Opennes	**CELL** **DYNAMISM** **INTERCONNECTION**
Total Service enterprise	Adaptable Flexible Growing, Agile	Dynamic, Coordinated Integrated, Process Driven, Team Based, Intelligent, Responsive,Learning, Presenting Continuous Activities, Cohesive, Empowered Employees Diverse, Innovative, Holistic Imaginative, Creative, Enterprise Wide Data Repositioning, High context Culture.	Live, Systematic Structure, Opennes Wholeness	**CELL** **DYNAMISM** **INTERCONNECTION** **WHOLE**
Technological Leader	Adaptable Flexible Growing, Agile	Dynamic, Coordinated Integrated, Process Driven, Team Based, Intelligent, Responsive,Learning, Presenting Continuous Activities, Cohesive, Empowered Employees Diverse, Innovative Holistic Imaginative, Creative, Enterprise Wide Data Repositioning Self Organising, Self sufficient, Self Governing, Changing too Fast to Draw Boundaries , Knowledge Generation	Live, Systematic Structure, Openness, Wholeness, Autonomous	**CELL** **DYNAMISM** **INTERCONNECTION** **WHOLE** **SYNERGY&GROWTH**
Virtual Enterprise	Adaptable Flexible Fast, Growing, Agile	Dynamic, Coordinated Integrated, Process Driven, Team Based, Intelligent, Responsive,Learning, Presenting Continuous Activities, Cohesive, Empowered Employees Diverse, Innovative Holistic Imaginative, Creative, Enterprise Wide Data Repositioning Self Organising, Self sufficient, Self Governing, Changing too Fast to Draw Boundaries Existing In a Chaotic Environment, Synergetic, Knowledge Generation, Learning, Existing in Quasi –Ecosystem Presenting Insights of Those in Direct Contact To	Live, Systematic Structure, Openness, Wholeness, Autonomous	**CELL** **DYNAMISM** **INTERCONNECTION** **WHOLE** **SYNERGY&GROWTH** **TRANS.COMLEX FORMS**

		Customers, Continuously Disturbed and Reassembled		

EUROKA models show similarities to the organic model. The dynamic nature of manufacturing environment which were reflected in five strategies are included within the organic model. The organic features of live interconnected, presenting a whole, autonomous, being open and presenting systematic and organised structure will provide organisations required adaptability, flexibility and agility to manage products and processes in a turbulent environment.

As they grow and transform into more complex forms the organisations can integrate better and interconnect with environment in which they exist. The environmental strategies can be turned into competitive advantage and encouraging human involvement in decision making, acquiring new techniques and technologies through creation of knowledge and experiences are involved in the last three stages of becoming organic. Five generic enterprise models are linked to the organic characteristic/ features, output variables and the stages of becoming organic (table 2).

When analysed under the framework of Organic model, The Elastic enterprise would present least amount of both organic characteristics and the level of extent it is organic. The first three stages which are cell structure, dynamism and the interconnection are to be accomplished to adapt to volume fluctuations while being consistent with efficiency, quality and cost. Flexible enterprise would have higher level of interconnection stage along with more emphasis on being open to the external environment. With the Total Service Enterprise existence of whole/ creating of whole take place resulting in the organisation having stronger connections and collaboration with external environment. Technological Leader Enterprise will acquire advanced technology and create knowledge through experience. Synergy and growth would accelerate these processes. Virtual Enterprise would be created as a result of transforming into complex forms which has more organic structure.

CONCLUSION

Trend towards the FOF presents a total systems picture and a holistic approach. As new technologies and the models are discovered, manufacturing technology will achieve a better level of integration with its social environment. Thus, it would be a step towards filling the gap resulted from imbalance

between the technical and social aspects of production systems. Serious consideration should be given to designing less complex manufacturing concepts which stress interaction between human and technical components. Organic model as an integrated and people oriented approach involves a combination of both advanced technology and human factors. It supports human involvement in the learning processes and knowledge production and its usage at large within the organisation. The factory of tomorrow will require greater levels of knowledge and more effective modes of information transfer about the quality and quantity of goods manufactured.

REFERENCES

Adler, P. S.(1992), *Technology and the Future of the work*, Oxford University Press, New York.

Advanced Manufacturing Industry Study Report, ICAF Publications, 1996.

Agrawal, R.K. and Hurriyet, H.(2004) " The Advent of Manufacturing Technology for the Value Chain Development:", *Internationa Journal Of Logistics and Physical Distribution*, June 2004.

Allee, V (1997), "Knowledge and self-organization", *Executive Excellence*, 14(1), January, pp.7,

Arie de G.. (1997), *Living Company* Harvard Business School Press, April.

Banner, D.K. (1995), *Designing Effective Organizations, Traditional and Transformational Views*, Thousands and Oakes, Sage Publications,

Barnatt, C. (1997), *Challenging Reality*, John Wiley & Sons.

Bessant, J. *Implementing New Technologies (innovation and Management of Technology* Editors, Eds Rhodes and David Wield, Oxford: Basil Blackwell.

Black, J.T. (1991), *The Design of the Factory with a Future*. McGraw _Hill Inc.

Blumberg, M and Gerwin, D. (1984), "Coping with Advanced Manufacturing Technology, " *Journal of Occup. Behaviour*, vol5, 113 -130, 1984.

Boddy, D. and Buchanan, D. A. (1984), "Information technology and productivity: Myths and realities", *Omega*, 12(3), 112-140.

Boyer, K and P. Ward and G. Keong Leong (1996) " Approaches to the Factory of the Future: An Empirical Taxonomy", *Journal of Operations Management*, Vol. 14, No. 4, 1996, pp. 297-313.

Braverman, H. (1975), *Labor and Monopoly Capital*, New York: Monthly Review Press.

Burton, P.. (1993), "TI supports "factory of the future" forging project" *Metallurgia*, v.60, sept, 1993 p318.

Cathcart, J.(1997),"Organic Organizations," *Executive Excellence*, Volume 14 No1, January, pp.6, 1997.

Cross, M. (1990), "West sceptical over Japan's factory of the future", *New Scientist*, v.127, July, p34.

Dankabaar, B. (1997), " Lean production: Denial, confirmation or extension of sociotechnical syst," *Human Relations*, 50(5):567-583, 1997 ,May.

Du Roy, O (1989) *The factory of the Future, Socio-Technical Investment Management*, Europian Foundation for the Improvement of working conditions.

Eloranta, E. (1992), " The Future Factory ", *International Journal of production Economics*, v.28, No2, November, 1992.

EUROKA Project *Factory of the Future , key Findings*

Gerold, J. (2004), "The Factory of the Future", *Automation World*, Editorial Director, accessed at, http://www.automationworld.com/articles/Departments/850.html?ppr_key=07.2004&sky_key=07.2004&term=07.2004 .

Groover, M.P. (1986), "CIM and the flexible automated factory of the future", *Industrial Engineering*, v.18, January, p74-85.

Hannah, D.(1998), *Designing Organizations for High Performance*, Addison Wesley Od Series, 1998.

Harmon, R and Peterson, L.D.(1992) *Reinventing the factory*. New York: Collier Macmillan .

Hurriyet, H and Agrawal, R.K. (2001), "Organic Organizations/ A Conceptual Framework". *Conference Proceedings, Portland International Conference for Management of Engineering and Technology(PICMET).*

Hurriyet, H and Agrawal, R.K. (1999) "An Organic Approach to the Evolution of Manufacturing Technology," *PICMET'99, Proceedings.*

Jones, B. (1997), *Forcing the Factory of the Future* Cybernation and societal Institutions, Cambridge University press.

Langevin, R.G..(1984), "Getting quality ready for the factory of the future", *Quality progress*, v.17, June 1984. p.54-55.

Martensson, N and L. Martensson, and J. Stahre, (1993) " Human Centred Flexible manuf. Systems,"in *Human Intelligence Based Manufacturing."* by Yoshimi Ito, Tokyo Institute of Technology, Springer Verlag, Japan.

McCarthy, I. (1995), " Manufacturing classification :Lessons from organizational systematics and a biological taxonomy", *Integrated Manufacturing Systems*, V6, No6, pp37-43

MTS 96, *Manufacturing Technology Show News*, Chicago, Sept 4-11 1996.

Narasimhan, S.L. and K. Russell, (1985), "Automatic identification systems serve as integrators in the factory of the future", *Industrial Engineering*, v17, February, p58-60.

Page, M. (1993), "Merging to survive" , *Modern Machine Shop*, v.66,September, p.44

Piore, J and Sabel, M. (1984) *Mass Production as Destiny and Blind Decision*

Richardson, J. (1988), " Scheduling the factory of the future for a quality product", *Wire Journal, International*, v21, February, 1988, p108.

Ruhleder, K and B. Jordan, and M.B. Elmmes, "Wiring the new organization, integrating collaborative technologies and team based Work,", *Annual Meeting of the Academy of Management*. 1996.

Ryan, J.(1984), "Whither X Statistics in the factory of the future", *Quality Progress*, v17, June, p56-57.

Santosus, M.(1998), "The organic root system", *CIO*, 12(6), December, p. 38-45, 1999, 1998/January

Schlefer, J. (1985), " Negotiating the factory of the future", *Technology Review*, v88, January, p24-27

Schonberger, R. (1990), *Japaneese Manufactuirng Techniques*, The Free press, New York.

Senge, P. (1990), *The Fifth Discipline: The Art and Practice of the Learning Organization*, Currency.

Senker and Beesly. (1985) *Implementing New Technologies (innovation and Management of Technology* Editors, Eds Rhodes and David Wield, Oxford: Basil Blackwell.

Senker, P.(1990) "Toward the Automatic Factory ?The Need for Training" *Factory Automation Handbook* Ed. D. I. Cleland and Bapaya Bidando.

Shaiken, H. (1985), "The Automated Factory: The view from the Shop Floor," *Technological Review*, January, 1985.

Smith, R.(1983),“ Robotic vehicles will perform tasks ranging from product retrieval to sub assembly work in factory of future”, *Industrial Engineering*, v.15, September, 1983, p62-63.

Smith,S and D. Transfiel,and J.Bessant, and P. Levy and C. Ley, “ Factory 2000: Organization design for the factory of the future ,”

Stock, G. (1993), *Metaman*, Bantam, London,1993.

Teresko, J (2004) “ Lean, Green, & Smart ” *Industry Week* 5(253),pp45, Cleveland May 2004.

Tharumarajah, A (1995), “Scheduling of Distributed Autonomous Manuf. Systems”, PhD Thesis, *Dept. of Mech. and Manufac. Eng. Univ. Melbourne*, 1995.

Tharumarajah, A (2003) “ A self-organizing view of manufacturing enterprises” , *Computers in industry*, 51(2) , pp185, Amsterdam , June 2003

The Macquarie Dictionary, Australia’s National Dictionary, Third Edition,1997.

Vaario, J. and N. Fujii and D. Scheffter and M. Mezger (1997), Factory Animation by Self-Organization principles, *International Conference on Virtual Systems* . Japan.

Vasilash, G.S.(1996), *The Future of Manufacturing: Mikio Kitano’s Dream of Simpler Machines & More Humane Organisations,* August.

Waddell, H.L. (1953) “ Factory of Future : Completely Automatic- Technological Dream Coming True,” *Advanced Management*, v 8 n9, 1953 .

Warnecke, H.J (1993),*The Fractal Company, A Revolution in Corporate Culture*, Springer Verlag.

Waurzyniak, P. (2001), “Moving toward the e-factory”, *Manufacturing Engineering*, Vol. 127 No. 5, pp. 42-60.

Weimer states (1996) George Weimer, “Manufacturing 2000: Rise of the organic factory”, *Material Handling Engineering*, 50(11), October, pp.27, 1995

Wysk, R. and R. Disney, and B. Peters, J. Smith (1994), “Model World- An open system for manufacturing systems analysis”, *Industrial Engineering*, 26(7): 49-54. Jul.

Zachary, W.B. and E. Richman, (1993), “Building an operations management foundation that will last:

TQM, JIT and CIM”, *Industrial Engineering* , v.25, August,1993.