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FROM LEAN TO AGILE MANUFACTURING- A JOURNEY TO ACHIEVE WORLD CLASS MANUFACTURING GOALS

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I. Introduction

During the past three decades, majority of the countries have witnessed the globalisation of their markets. As a result of globalisation, the companies restricting their operations within the national markets have been forced to compete with the products and services offered by multinational companies. The other development is that, numerous companies operating in different countries have begun to enter into the markets operating in various countries. These developments have resulted in the removal of trade barriers which were existing earlier along the borders of the countries. This phenomenon has been forcing the organisations to orient their strategies towards reaching world class manufacturing goals. However, this task is found to be challenging as world class manufacturing requirements demand high degree of quality of products and services at low prices. In order to face these challenges, the manufacturing frontiers have been advocating the adoption of lean manufacturing paradigm. According to lean manufacturing, the wastes encountered during manufacturing are required to be eliminated for achieving world class manufacturing goals.

Even as the world is about to settle on lean manufacturing paradigm, a new kind of challenge has emerged in the modern globalised markets. According to this challenge, the customers demand variety of products and services in different volumes. Due to the severe competition prevailing in modern markets, an organisation declining to offer any variety and any volume of product and service to a customer or to a group of customers is tending to loose its major market share in the customer domain. On the other hand, organisations successful in facing this kind of customers' dynamic demands are able to emerge as winners in world markets. Today, researchers address the capabilities of organisations that would enable them to meet this kind of dynamic demands of customers under the term called 'Agile Manufacturing' (AM). In fact, modern organisations are required at this moment of time to explore the way of acquiring AM characteristics as a means to achieve world class manufacturing goals. In this context, first lean manufacturing principles are discussed. After that, the AM characteristics are explored.

II. Lean Manufacturing

The origin of élan manufacturing can be traced to the Toyota Production System. TPS is also called as Just In Time manufacturing. According to TPS, a component is required to be produced only at the required quantity and at right time using pull system. While TPS under the name JIT was becoming popular, three authors by names James P.Womack, Daniel T.Jones and Daniel Roos brought out their book in the year 1990, under the title "The Machine that changed the World". In this book, these authors introduced JIT concepts with certain refinements under the terminology 'lean manufacturing'. Few definitions of lean manufacturing are available in literature. Two of them are presented below. According to the definition given by National Institute of Standards and Technology, lean manufacturing is defined as a systematic approach to identifying and eliminating wastes through continuous improvement, flowing the product at the pull of the customer in pursuit of perfection (Anderson et al. 2006). Likewise, Worley and Doolen (2006) have defined lean manufacturing as the systematic removal of waste by all members of the organisation from all areas of the value stream. As can be seen in these definitions, the heart of lean manufacturing lies on the elimination of wastes in production environment. Those wastes are enumerated below:

A. Overproduction

As the name implies, this waste refers to producing more volume of the components and products in a manufacturing environment.

B. Processing

This waste refers to the additional processes which may be avoided through prior planning.

C. Delay

This waste refers to the delay in getting raw material, semi-finished goods and finished goods at appropriate locations. This waste also refers to any other delays like arrival of transport and employees at the appropriate locations.

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D. Transportation

This waste refers to the movement of the resources of the organisation which are not adding value to the production of components and products.

E. Inventory

This waste refers to the accumulation for raw materials, work-in-progress materials and finished products which result in higher holding cost and blocking of the money which otherwise could be used for investing on value adding activities.

F. Wasted motion

As the name implies, this waste refers to the motion of the resource which has not resulted in any value addition. For example, a component may be transported to particular location, and returned back to its place of departure due to the non-availability of the operator to process it.

G. Defective parts

This waste refers to the production of defective parts which result due to errors caused due to man, material, machine and method.

In Japanese language, the above wastes are termed as "Muda". Lean manufacturing paradigm makes use of several tools, techniques, models and approaches which are available in various fields for eliminating the above seven wastes.

III. Lean manufacturing tools, techniques, models and approaches

Some of the tools, techniques, models and approaches which are encapsulated under lean manufacturing paradigm to eliminate the seven wastes described in the previous section are discussed in this section:

A. Total Quality Management (TQM)

TQM envisages the quality planning and installation of quality system to prevent the production of defective products and providing inefficient service.

B. Total Productive Maintenance (TPM)

TPM emphasises the involvement of operators for improving maintenance quality of equipments. TPM enlarges the scope of maintenance engineering by including even administration under one of its pillar named as office TPM. TPM philosophy recommends to consider the operators as the owners of the equipment and achieve high degree of maintenance quality by making use of a parameter called Overall Equipment Effectiveness (OEE). This model helps to prevent the process waste by ensuring trouble free and continuous operation of equipments.

C. Kaizen

Kaizen refers to achieving continuous improvement by forming a team. This team will have to participate in brainstorming sessions to evolve solutions and implement them to avoid all the seven wastes of production.

D. Kanban

Kanban refers to a "card" that mentions the quantity required by the next operator for subsequent processing. On seeing the kanban, the respective operator is required to produce only the required quantity of the parts. Kanban is a technique of pull system which avoids the waste titled as "overproduction".

E. 5S

This technique refers to housekeeping for ensuring that the necessary materials and tools are made available at right places. The expansion of 5S are Seiko (proper arrangement), Seiton (orderliness), Seiketso (personal cleanliness), Seiso (clarity), and Shitsuke (discipline). This technique will lead to the elimination of delay. This is ensured by avoiding the time of searching and transporting any material or tool.

F. One piece flow

According to this principle, at any one point of time, only one piece should be processed in a manufacturing cell. The manufacturing cell should be designed in such a way that all the machines required for processing a family of components/products are grouped together. When one piece enters, all the required processes are carried out in that cell. Moreover, all the manufacturing cells are designed to have processes that would match with Takt (required flow rate of pieces). This leads to line balancing of manufacturing cells. One piece flow helps in eliminating the wastes namely transportation, processing and wasted motion.

G. Single Minute Exchange Die

This approach emphasises the reduction of setting time during the processing of parts. For this purpose, the setting of the parts has to be carried out separately from the machine so that setting time does not result in delay of the processing of the parts.

H. Visual control

Lean manufacturing philosophy suggests the usage of signs and signalling facilities so that the progress of the work is visually seen and controlled. This helps to avoid the delay in tracing the process stage at which a part gets struck.

I. Poka Yoke

This refers to a set of principles which are aimed to exercise mistake proofing in production environment.

These principles were evolved by Shigeo Shingo. As the name implies, it calls for designing systems which may either be automated or manual driven to avoid mistakes. This set of principles are useful for eliminating the production of defective parts and wasted motions.

J. Value stream mapping

This technique makes use for pictorial symbols to trace the processes required for adding value during production. This technique also helps in identifying the non-value adding activities which could be eliminated by redesigning the system and layout.

The success of applying lean manufacturing depends upon the right and effective usage of the above tools, techniques, approaches and models.

IV. Lean manufacturing versus Modern market demands

The effective implementation of lean manufacturing principles will result in the production of products and services with high degree of quality, decrease in the processing lead time and reduction of inventory. These achievements are laudable as long as an organisation is required to produce products with relatively constant number of models. However, in the modern marketing scenario, customers demand variety of products within a short period of time at low price but with high quality. The capabilities required to meet these kinds of demands are not addressed in lean manufacturing. Hence, at this juncture, it is clearly discernable that the modern organisations shall not stop with implementing lean manufacturing principles and rather have to move towards creating infrastructures required for implementing AM paradigm.

V. Agility in Manufacturing Scenario

Modern manufacturing organisations are facing challenges from two directions. In one direction, newer manufacturing philosophies and technologies emerge to make the existing ones obsolete. In the other direction, today's customers are becoming more and more aggressive in demanding new products and services within a short period of time. (Maskell,2001; Tersine and Wacker, 2000). In order to meet these two major challenges, today's manufacturing organisations are required to act quickly in accordance with the surrounding competitive situations. On realising this trend, during the recent years, the manufacturing arena has been inclining towards the relatively new type of paradigm. The researchers have named this paradigm as "Agile Manufacturing"(AM)(Power et.al. 2001,Jin-Hai et.al. 2003). A considerable number of academicians and manufacturers view AM as a new approach (Rigby et.al, 2000). However, an overall view on manufacturing arena would indicate that, invisibly agility had been positioning its root during the past two decades. As a matter of fact, agility in manufacturing arena has been occurring as the spontaneous responsiveness to high degree of competition (Parkinson, 1999). As an evidence to this statement, the performance of today's mobile phones manufacturing companies can be cited. It is a common observation that these companies have been introducing several models very frequently and quickly. During the recent years, many automobile manufacturing companies have also been evolving new models relatively at a quicker speed. In fact, this agile trend has been dominating various types of manufacturing organisations with different levels of its adoption. Therefore, it is a fact that, practitioners have been imbibing AM concepts without explicit advocation. Whereas researchers had been examining AM issues explicitly for more than a decade. The study of literature in this direction reveals that the birth of AM principles is marked by the constitution of 'Agility Forum' by a group of researchers, at Iacocca Institute, Lehigh University in the year 1991(Ren., et.al, 2003, Jin-Hai et.al 2003). Thereafter a handful of researchers have contributed very valuable AM principles. The major contribution of researchers is the spelling out of meaning and definition of AM. Jin-Hai.et.al (2003) have enumerated the definitions of AM given by various authors. Some of the meanings and definitions enlisted by them are presented below:

"Agility means a manufacturing system with extraordinary capabilities (internal capabilities: hard and soft technologies, human resources, educated management, information) to meet the rapidly changing needs of the marketplace (speed, flexibility, customers, competitors, suppliers, infrastructure, responsiveness). A system that shifts quickly (speed, and responsiveness) among product models or between product lines (flexibility), ideally in real-time response to customer demand (customer needs and wants)" (As given by Iacocca Institute)

"Agile manufacturing is a vision of manufacturing that is a natural development from the original concept of ``lean manufacturing''. In lean manufacturing, the emphasis is on cost-cutting. The requirement for organisations and facilities to become more flexible and responsive to customers led to the concept of ``agile'' manufacturing as a differentiation

from the ``lean'' organization" (As given by the author Booth)

"Agile manufacturing can be defined as the capability of surviving and prospering in a

Competitive environment of continuous and unpredictable change by reacting quickly and

effectively to changing markets, driven by customer-designed products and services." (As given by Cho et al.)

"Agility is the successful exploration of competitive bases (speed, flexibility, innovation,

pro-activity, quality and profitability) through the integration of reconfigurable resources

and best practices in a knowledge-rich environment to provide customer-driven products

and services in a fast-changing market environment." (As given by Yusuf et al.)

For a better insight into the history and development of AM, a copy of Li Jin-Hai et.al. (2003) is supplied to the reader along with this article.

The most noticeable contribution of AM researchers is the development of the following

equation:

Agile Manufacturing = Flexible Manufacturing System + Lean Manufacturing

Although various definitions of AM are available in literature world, these definitions do not contrast much with each other. The commonality among most of them is the enunciation that AM is the capability of the manufacturing enterprise to quickly respond to the market requirements. Thus AM calls for radical changes in the system, culture and management styles that are being currently followed in traditional manufacturing environment. Meanwhile, the adoption of AM has been established as the need of the hour to face the high competitive market (Vokurka and Fliedner 1998; Meredith and Francis,2000). On the other hand the gradual and spontaneous adoption of AM principles have consumed long time to enable organisations to attain agility. This situation persists because majority of the manufacturers are devoid of the knowledge on AM criteria. Rather they progress towards agility by attempting to implement various criteria using unfocussed and crude methods. This approach results in retarded growth of agility in organisations. On realising this deficiency, during the recent years, researchers have been evolving researchers have been evolving the criteria that are required to attain agility in organisations. These criteria have been evolved particularly with the intention of enabling traditional manufacturing organisations to imbibe agility principles at a faster rate. However these criteria have been scattered in different directions. Moreover, the researchers who have contributed these criteria have not evolved programmes for their successful implementation. In this context, this article is presented in which a model called twenty agile manufacturing criteria and realistic programme for successfully implementing it in manufacturing organisations are brought out. The details of these contributions are described in the following sections.

VI. Twenty Agile Manufacturing Criteria Model

As mentioned in the previous section, soon after the principles of AM were formalized, few authors have identified the criteria that would establish AM environment. Most of these authors have oriented towards management criteria for attaining agility in organisation. Some authors have oriented towards both management and technology for effecting AM. Keeping these contributions as the basis, the simplest conceptual characteristic of AM is depicted in Figure 1.

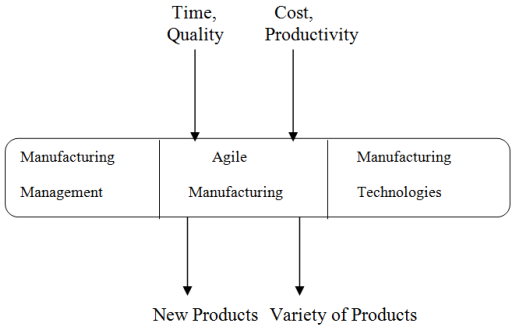

Figure1. Conceptual features of agile manufacturing paradigm

As shown, agility is driven through both technology and management. Albeit the valuable enumerations, the criteria enlisted by these papers had to be knitted for ensuring holistic implementation of AM. For this purpose, the twenty agile manufacturing criteria model is presented in this paper. Its conceptual features are depicted in Table 1. This table also distinguishes between the activities carried out in traditional and AM companies. The identification of twenty criteria necessitates to look for techniques and approaches that are required to attain them. Some of the approaches and techniques to attain twenty AM criteria are presented in Table 2.

VII. Realistic Implementation Programme

Although the twenty AM criteria model presented in this article would guide an organisation towards attaining agility, it would not ensure its successful implementation. In fact, a focused implementation programme procedure infused with success ingredients is vital to successfully implement twenty AM criteria model in an organisation (Maskell, 2001). For this purpose the implementation programme shown in Figure 2 is being proposed in this article. Its characteristics are briefly described in the following subsections.

A. Study the management's perspective on imparting agility in manufacturing

Though the benefit of agility is sensed in manufacturing arena, its scope and importance are seldom realised by today's captains of industries. In this context, this step which envisages the study of management's perspectives on agility assumes special significance. During this step, all the management personnel are appraised of the essential features of AM (Meredith, 2000). Followed by this, the impact of agility from various points of view are explained

to the management. Particularly, the anticipated increase in market domain after creating agility is narrated to the management. This effort increases the degree of acceptability of AM in the minds of management personnel. As the management will be sensitive to the profit, the impact of agility is be appraised from profitability point of view also.

B. Appraise the management over the requirements of AM

The management is informed of the requirements in case the company wishes to move towards agility. Particularly, the initial investment required is clearly specified. Although the whole AM programme might lead to heavy investment, it is advisable to suggest for very little initial investment (around two to five percent of total investment) so that

SL No	Criteria	Traditional Manufacturing Company	Agile Manufacturing enterprise
1	Organisational structure	Vertical, traditional and line (Maskell,2001; Vokurka and Fliedner, 1998;Assen,et.al,2000)	Flattened, and team managed, (Maskell,2001; Vokurka and Fliedner,1998; Meredith and Francis,2000; Hormozi,2001;Bustamante,1999; Assen,et.al,2000;Assen,2000; Sohal, 1999; Hooper, et.al, 2001).
2	Devolution of authority	Lack of empowerment, centralized and informal authority	Self autonomous and empowered (Maskell,2001;Vernadat,1999; Owusu,1999; Crocitto and Youssef,2003; Zhang and Sharifi, 2000)
3	Manufacturing set-ups	Rigid, long lasting; intolerable to changes	Flexible, easily collapsible, quick response to change. (Maskell,2001; Meredith and Francis,2000; Vernadat,1999; Hormozi,2001; Ramasesh,et.al,2001;DeVor,et.al,1997; Quintana,1998;Sohal,1999;Malek,et.al,2000; Kirk and Tebaldi,1999;Yusuf,et.al,2003)
4	Status of quality	Customers' satisfaction Meredith and Francis,(2000)	Customers' delight (Maskell,2001; Hormozi,2001; Rigby,et.al,2000; DeVor,,et.al,1997; McGaughey, 1999).
5	Status of productivity	Stagnant productivity with no reasonable evaluation and improvement	Rapid increase in productivity with practically feasible evaluation; productivity and quality are integrated.
6	Employees' status	Existence of specialists. No exposure to other functions and skills. Inflexible and ignorant to changes	Learning employees; multiskilled and multi-functional; and self committed. (Parkinson,1999;2.Brain Maskell,2001; Vokurka and Fliedner, 1998; Meredith and Francis,2000; Hormozi,2001;Owusu,1999; Bustamante,1999; Zhang and Sharifi, 2000; DeVor,et'al,1997;Sohal,1999; Duguay,et.al,1997;

SL No	Criteria	Traditional Manufacturing Company	Agile Manufacturing enterprise
			Yusuf,et.al,2003)
7	Employee involvement	Very little involvement of employees in decision making , ideas and knowledge are seldom shared or utilized	Fully empowered employees; ideas and knowledge of employees are fully utilised (Meredith and Francis,2000;Vernadat.B,1999; Hormozi,2001;Owusu,1999;Bustamante,1999; Crocitto and Youssef,2003)
8	Nature of management	Autocratic and stagnant	Participation based management and susceptible to changes and improvements (Owusu,1999; Crocitto and Youssef,2003; Hooper,et.al,2001; Bustamante,1999)
9	Customer response adoption	Very slowly takes place due to beaurocracy	Very fast and 100% response envisaged (Parkinson,1999; Maskell,2001; Meredith and Francis2000;Bustamante,1999; Assen, 2000; McGaughey,1999)
10	Product life cycle	Long and ineffective	Short and effective (Maskell,2001; Meredith and Francis,2000; Crocitto and Youssef,2003; Christopher and Towill2000;Kirk)
11	Product service life	Long and inflexible; Long mean down time	Short and flexible; Least or nil mean down time
12	Design-improvement	Very rarely practiced; generally only modifications are done	Very frequently and systematically practiced by conducting experiments (Parkinson,1999; Maskell,2001;Meredith and Francis,2000;Vernadat,1999; Bustamante,1999; Crocitto and Youssef,2003; Zhang and Sharifi, 2000;Onuh and Hon,2001; Ashley,1997; Yusuf.Y,et.al,2003)
13	Production methodology	Dominated by internal manufacturing	Dominated by main assembly of components external manufacturing and outsourcing.
14	Manufacturing planning	Long and cost-ineffectiveness Tersine .J,et.al,2000	Short, Just In Time (JIT) purchase and least dead investment (Takahashi,et.al,2000,Tersine,et.al,2000)
15	Cost management	Traditional type (with classifications namely prime and overhead costs)	Management of costs using activity, strategy, quality and productivity based costing systems. Hooper,et.al,(2001)
16	Automation type	Direct and rigid automation Dove,1999	Flexible, smart and adaptable automation

SL No	Criteria	Traditional Manufacturing Company	Agile Manufacturing enterprise
17	Information Technology (IT)integration	Direct integration of IT into the existing system	Reengineered IT integration (Parkinson,1999; Maskell,2001; Hormozi,2001; Paixao and Marlow,2003; Crocitto and Youssef,2003; Zhang and Sharifi,2000; .Burgess,1994; McGaughey,1999)
18	Change in BPR	Very difficult to incorporate; almost impossible	The flexible set up enables to effect economical changes in processes. (Hormozi,2001;Dove,1999)
19	Time management	Very inefficient	Very Efficient (Assen,2000; Quintana,1998)
20	Outsourcing	Only subcontracting is adopted	Supply chain management principles are adopted. (Parkinson,1999; Maskell,2001; Vokurka and Fliedner,1998;Malek,et.al,2000; Christopher and Towill2000;Hoek,et.al,2001 Jones, et.al,2000)

Table 1. Twenty agile manufacturing criteria model

Criteria	Approaches / Techniques recommended
Organisational structure	Cutting down of organisational layers, building of cross functional teams and their management (Vokurka and Fliedner, 1998; Meredith and Francis,2000; Hormozi,2001;Bustamante,1999;Assen, et.al,2000;Sohal,1999; Hooper,et.al,2001)
Devolution of authority	Education and training to enable the teams to become self-managed gradually and imbibe empowerment with no compromise on agility; clear definitions on authority. (Crocitto and Youssef,2003; Zhang and Sharifi, 2000;Maskell,2001; Meredith and Francis,2000;Vernadat,1999;Owusu,1999)
Manufacturing set-ups	Least expensive and collapsible, throw away, reconfigurable and scalable fixtures, patterns, jigs, dies and other production facilities (Meredith and Francis,2000;Vernadat,1999; Ramasesh,et.al,2001; Assen,2000; Malek,et.al, 2000; Kirk,et.al,1997)
Employees' status	Providing more and more importance to on-line training; limit off line training methods ; create rewarding environment to induce interest to learn more; bring about rotation based job allotment (Maskell,2001;Vernadat,1999;Hormozi,2001;Bustamante,1999; Assen,2001;Duguay,et.al,1997)

Criteria	Approaches / Techniques recommended
Employee involvement	Promote suggestion schemes; quality circle programmes etc, to tap ideas and knowledge of employees. Create provisions to enable the employees to participate in decision making processes (Meredith and Francis,2000;Vernadat,1999; Hormozi,2001; Owusu,1999; Crocitto and Youssef,2003;Duguay,et.al,1997)
Nature of management	Educate the managerial personnel about the importance of responsiveness towards the employees and values of life rather than mere profit. Bring about transparency in operations by sharing information; conduct frequent management employees meeting. (Maskell,2001; Owusu,1999; Crocitto and Youssef,2003; Hooper,et.al,2001)
Customer response adoption	Promote a rewarding scheme to invite customers' reactions over the products and services offered; Use tools like cause and effect diagram to record the customers' reactions; Develop an information system to communicate the right information on customer response adoption at right time at right person to execute the necessary changes. (Maskell,2001; Meredith and Francis,2000; Hoek,2000; Hormozi,2001; Lee and Lau1999;Bustamante,1999; Crocitto and Youssef,2003;Dove,1999; Christopher and Towill2000; McGaughey,1999)
Product life cycle	Design the product which would be least priced, brought to the market within the least time, lasts for comparatively less period with high maintainability and reliability.(Meredith and Francis,2000; Zhang and Sharifi, 2000;Kirk and Maskell,2001)
Product service duration	Provide modular design so that modules can be replaced within no time and the performance is restored. (Maskell,2001;Vernadat,1999)
Design improvement	Consider design as the continuous activity; undertake improvements by adopting Rapid Prototyping Technology, Concurrent Engineering, CAD, Design for Manufacturing and Design of Experiments. (Parkinson,1999;Maskell,2001;Vernadat,1999; Crocitto and Youssef,2003; Zhang and Sharifi,2000;Onuh,et.al,2001; Ashley,1997)
Production methodology	Production system shall enable the adoption of innovative processes and current technologies; Apply the concepts of FMS; Install information integrated facilities; support automatic and hundred percent inspection. (Bustamante,1999; Crocitto and Youssef,2003; Zhang and Sharifi, 2000;Sohal,1999)
Manufacturing planning	Execute short range planning with provision for quick decision making (Takahashi and Nakamura,2000;Quintana,1998; Tersine and Wacker,2000)
Cost/ Accounting systems	Adopt activity based costing approach without affecting the legal requirements. (Hooper,et.al,2001)
Automation type	Flexibility is given highest priority. Adopt electronically programmable production facilities
Information Technology integration	The tasks that are not to be supported by paper work are removed and then integrated by IT; Use of multimedia is highly recommended. (Hormozi,2001; Crocitto and Youssef,2003; Zhang and Sharifi, 2000; Bajgoric,2000; Paixao and Marlow,2003,Burgess,1994; McGaughey,1999)
Change in	Apply the concepts of Business Process Reengineering (BPR); Design the set-ups such as that they are

Criteria	Approaches / Techniques recommended
business and technical processes	tolerant to modifications and changes within the quick span of time. (Dove,1999;Burgess,1994)
Time management	Effect enterprise management such that information on time schedule is communicated to teams so as to enhance quality of timely delivery; Use design reuse concepts to cut down design, production and marketing lead times.(Assen ,2000)
Status of quality	Design the products, processes and service in such a way that innovation is infused while attaining higher degrees of quality and customers feel delighted. (Vokurka and Fliedner,1998;Meredith and Francis,2000;Vernadat,1999;Rigby,et.al,2000: DeVor,et.al,1997)
Status of productivity	Care should be taken to see that quality is not infused at the cost of productivity; Apply totality concepts in achieving productivity.
Outsourcing	Do not go for subcontracting only; where technologies and processes are not available, select suppliers and design the supply chain so that new product/brands are conceived quickly. (Parkinson,1999; Meredith and Francis,2000; Hoek,2000; Christopher and Towill,2000; Lau,et.al,2003; Duguay,et.al,1997; Jones,et.al,2000)

Table 2. Approaches/ Techniques for attaining twenty AM criteria

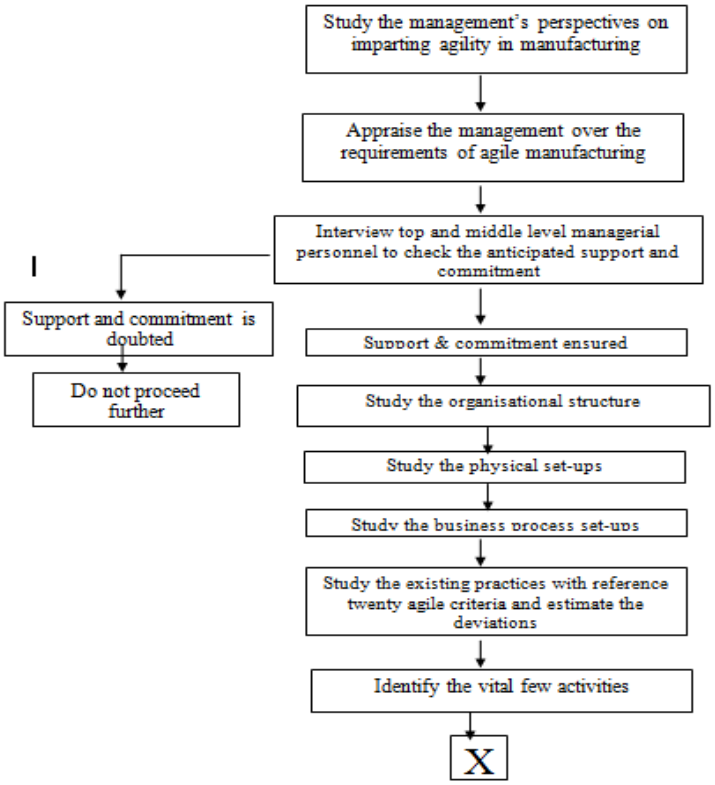

Figure 2.1. Implementation Programme

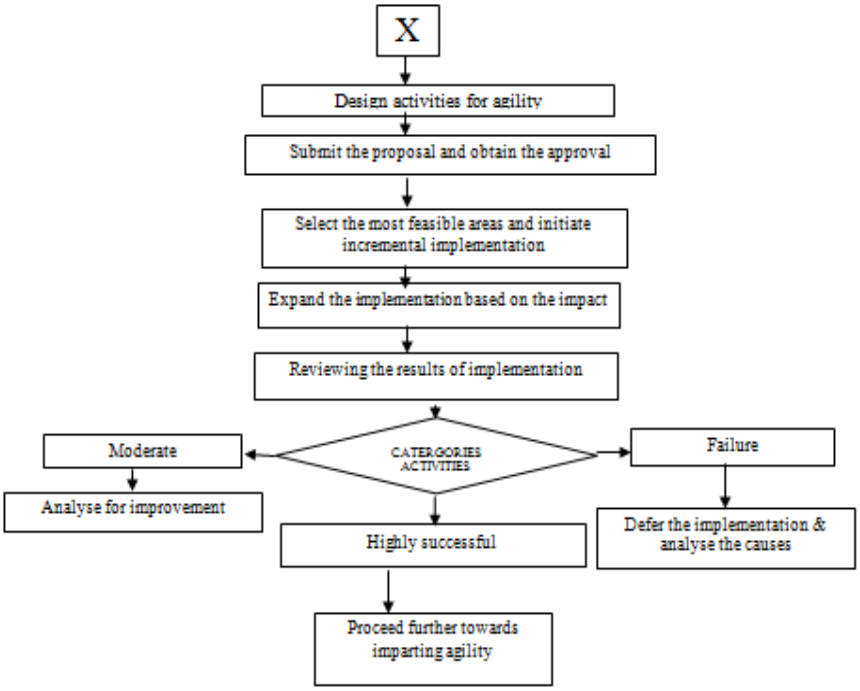

Figure 2.2. Implementation Programme

management may not hesitate to implement the AM programme. Also, the change in physical requirements like, replacement of existing machine tools and machines with automated and compact machines, rearrangement of working place etc. are specified to the management. Likewise, any serious change required with regard to management policy is also deliberated. This step is vital since it prevents the management from partially attempting on agility and discontinuing the efforts at a later stage.

C. Interview top and middle level managerial personnel to check the anticipated support and commitment

During the previous two steps, the management's overall view of implementing AM is realised. Also the requirements of AM are also particularly appraised. However in order to ensure systematic and sustainable AM, several levels of managerial personnel are to be interviewed to gauge their willingness to adopt agility. For this purpose, interview questionnaires are to be developed to evaluate the response of top and middle level managerial personnel. Essentially the questionnaires shall cover the nature of changes anticipated, and benefits expected. The efficient interview process will provide the result whether the manufacturing environment is matured enough to accept changes for initiating AM. In this stage, the decision regarding the further progress of AM effort is made. In case the support and commitment from any levels of managerial personnel irrespective of top management's commitment are found to be doubtful, then the effort should be dropped at present. In case the majority of managerial personnel agree and show interest, then the efforts may be continued further.

D. Study the organisational structure

The most important change that is required to be effected for creating AM environment is the organisational structure. The manufacturing world had been following hierarchical organisational structure for more than four decades. These structures were formulated by Taylor which was found to be working well till 1970's. After mass production reached a peek during the beginning part of twentieth century, this kind of vertical organisational structures were adopted. However, during the past one decade, there has been a realisation over the need of redesigning the traditional organisational structure. Presumably, this was sensed when Hammer and Champy (1993) brought out Business Process Reengineering (BPR) concepts to the world. According to the requirements of AM, activities are formulated into modules and teams consisting of cross-functional members are built to accomplish each module. An appropriate organisational structure designed to manage teams is an imperative for creating agility in manufacturing environment. There are many situations which exemplify the need of teams for bringing out AM environment. Consider a situation in which the company has received customers' reaction about one of its product. In case, the conventional organisational structure is adopted, this information will pass through many non-value adding channels and steps. These channels and steps would act as hurdles of imparting agility in the company. This deficiency can be easily

avoided with no extra investment of any resources if team based organisational structures are formulated. Hence, it evokes little meaning in case a manufacturing company with traditional organisational structure attempts to create AM environment. An overall survey would hint that, most of the software developing companies have nourished the benefit of team based organisational structures. Hence, in manufacturing environment too, the management should be consulted and appraised of the team based organisational structures which are essential for implementing AM concepts. In case the management hesitates to effect change in organisational structure, then few areas (particularly newly developed sections) are be selected for this purpose and teams are created and their worthiness are explored. This task enables the management to think favourably towards bringing out the change in organisational structure for creating AM environment.

E. Study the physical set-ups

The BPR concepts proclaimed by Hammer and Champy (1993) envisage the restructuring of only the business processes. This task requires only the change of mind in managerial personnel. However, AM will be effective only if the physical set-ups like machineries, buildings, storage facilities etc, are re-established and made flexible to the best possible extent. In comparison to the software developing companies, manufacturing companies struggle to impart agility in them. Because, when the manufacturing companies were established several decades ago, their physical structures were installed in such a way that they would exist for a prolonged period. Hence unearthing the rigid establishments to suit AM environment is not only seen as a very difficult task but also an expensive attempt. A agility cannot be expected in case the physical structures are rigid and unsuitable for integration through automation. This may highly be reflected in the form of inefficient information management. Hence, this phase assumes special significance in case the agility in manufacturing is attempted. An overall observation on the manufacturing scenario indicated that, the re-establishment of physical structures is acceptable to the manufacturing community in case gradual change in this direction is promulgated. Accordingly, it is suggested that the manufacturing company's physical set-ups are studied. During this study, physical set-ups are classified and enlisted under three main categories namely rigid, semi- rigid and flexible. In the beginning, the easily flexible physical structures like portable machineries, tools, cabins etc., can be used to incorporate agility. Later on, semi-rigid and rigid structures may be subjected to agility by adopting tactical methods (Montgomery and Levine, 1996). One of the methods adopted for this purpose is presented here. A traditional manufacturing company shall group the conventional machines into a manufacturing cell and test for its effectiveness. If found feasible, this group of machines shall be replaced by a CNC machining centre. This practice will result in technology driven AM.

F. Study the business process set-ups

Next to rigid physical set-ups, the most vividly observed obstacle in converting traditional manufacturing firm into AM enterprise is the existence of long, complicated, non-value-adding and inflexible business procedures. In traditional manufacturing firms, the activities which would consume financial sources such as training and skill development programmes, new product introduction etc. are carried out after obtaining approval of management. This task is carried out after a number of documents are processed through business process set ups with substantial time delays. This cannot be tolerated in AM environment. An overview on literature hints that, gradual implementation of organisational re-structuring enables the companies to move towards attaining agility. Besides empowering people, simplification of the business procedures and automation of the routine activities are found to be the foundation of AM environment. The most frequent objection raised in this direction by managerial personnel is the loss of control when business processes are redesigned to suit agility. Hence, agility in manufacturing should be incorporated by redesigning, reengineering and restructuring the business process setups but without compromising the controls.

G. Study the existing practices with reference to twenty agile criteria

The two stages of the implementation programme described in the previous two subsections would have resulted in the identification of the existing set-ups. This identification would even indicate either the feasibility or infeasibility of imparting agility in the company. Followed by this, the existing practices are studied with reference to the twenty AM criteria. Followed by this deviations of practices from the requirements of twenty AM criteria are assessed. In order to carryout this exercise, it is recommended that the comparative table shown in Table 3 is used. Then, the gap existing between AM requirement and the existing setups are identified and remarked in the comparative study table. In the remark column of Table 3, the major issues such as change in policy decision, financial implications, prevailing culture etc., may be entered. At the end of this phase, the requirements for effecting changes in the current practices for attaining agility can be assessed.

H. Identification of vital few activities

It is difficult to expect the management to accept all changes envisaged for the installation of AM. It is a common observation that many managerial programmes proposed by academicians and consultants fail to evoke expected gains because some of the changes proposed are

not acceptable to the management. While installing AM also, there exists every chance that the management might withdraw its support in case unacceptable, crucial and sensitive changes are proposed. For example, changes in organisational set-ups and wider distribution of authority may not be acceptable to the management of the traditional firms.

Category No.	Serial number	Requirements of AM	Existing Set-up	Deviation	Remark
			Physical set-ups		
			Business process set-ups		

Table 3. Comparative Study Table

Even those suggestions would have the potential of making the AM implementation programme fail. In order to effect such changes, Vokurkka and Fliendner (1998) have suggested agility improvement model. However, such a generalised model may not be acceptable to the management and subsequently the AM programme will fail. Hence, the deviations identified are subjected to a modified Pareto analysis. In this analysis, the deviations are graded by referring to various tangible and intangible factors. Based on this grading, the vital few activities which would not provoke any dissatisfaction or hesitation in the mind of management should be identified. Other complicated issues may be deferred until the success is phenomenal due to the implementation of the vital few activities.

I. Design activities identified for AM

Soon after the identification of the vital few change requirements, efforts should be exerted to design activities for accomplishing them. Normally about 10 to 20 activities need to be identified as vital activities and their design activities are carried out. Among them, vital few activities which can be implemented within six months are selected. The results of implementation are to be visibly made available to the management. This is due to the reason that, generally management expects quick results. Also, the usual tendency is to lose faith on any new approach which fails to yield result in a span of about six to nine months.

J. Submission of proposal

The proposed design details of activities to be undertaken to install AM with time schedule is prepared and compiled in the form of the proposal. The proposal should be submitted to the top management and the contents should be briefed through casual discussions and formal presentations. Besides clarifying the important points, steps should be taken to correct and modify the proposal according to the suggestions of top managerial personnel. The end of this phase will be marked by obtaining endorsement of top managerial personnal, which will mark the approval of the proposal.

K. Incremental implementation in feasible areas

As pointed out in the earlier sections, careful efforts should be exerted to see that the management does not lose confidence while implementing AM criteria. In order to ensure this requirement, it is suggested that, very few feasible areas are identified for the implementation of vital few activities. The feasible areas shall be identified based on the expected level of reception by the employees, expected favourable outcome, and the guaranteed performance improvement through increased profit. Even in the feasible areas, full-fledged and sudden implementation are not recommended for this approach would sometimes create negative impact. Instead, incremental implementation by releasing assignments gradually for the concerned personnel is recommended for increasing the success rate considerably. As a matter of fact, the change should be so progressive that, the receivers (both employees and management) should not so easily sense that the change process is getting positioned in the company.

L. Expansion of implementation

On sensing the impact of incremental implementation, the decision regarding further expansion should be made. The activities in which the results are significant and instantaneous, further expansion of activities shall be effected. The activities in which the results are moderate, subsequent expansion should be avoided and the existing level may be continued. In case the results are not satisfactory or have shown failure trend, those activities should be stopped for the time being.

M. Reviewing the results

After a period of about six to twelve months, the consolidated results of AM implementation are prepared. While it is required to understand the overall performance, it is also required to classify the activities into moderate, highly successful and failure. The activities and areas which have shown moderate results should be subjected to analysis for the purpose of identifying the feasibilities for improvements. In case highly successful results are obtained, the efforts should be continued in the present manner. The functions in which failure results are observed, the implementation should be deferred and should be subjected to analysis for identifying the effect of latest advanced technologies in AM. This phase is a very important since majority of the advanced technologies aid in imparting agility in manufacturing environment. Thus the journey towards AM continues and its sustenance is ensured.

VIII. Conclusion

Researchers have pointed out that during the beginning of twentieth century, Ford showed to the world that inventory could be eliminated. This can be interpreted that this is the beginning stages of lean manufacturing. Therefore, lean manufacturing is one century old. However, the effective implementation of lean manufacturing began only during 1990s, when James Womack's book titled "The Machine that changed the world" sensitised the managers towards waste elimination through the achievement of perfection in production environment. During the recent years, several researchers have also contributed papers examining the implementation of lean manufacturing principles. However, even before many organisations in the world began to implement lean manufacturing, the modern organisations are required to be agile to face the dynamic demands of the customers. Almost in parallel to the researchers on lean manufacturing, the researches on AM are also being pursued by considerably many number of researchers. The emergence of a considerable numbers of papers reporting AM research in literature world leads to an impression that agility has come to stay in manufacturing environment (Vokurka and Fliedner,1998). As mentioned in one of the previous sections, agility has started to invade in various forms in manufacturing enterprises. However, even today there exists some hesitations among the manufacturing community to adopt AM principles due to various reasons. The following common doubtful views persist in the minds of today's manufacturers:

"This will not work out in our country"

"This would not be suitable to our company"

"The business is currently at a low key. How can we adopt it now? "

"We have been investing a lot on various manufacturing management programmes. We have not got much in return. How can we trust Agile Manufacturing Programme?"

"During the past five years, the management and employee relationships are spoiled due to strikes and lay-offs. How can we expect enthusiastic participation to create Agile manufacturing environment?"

"Most of our employees are school-drop-outs. How can we expect them to learn continuously?"

It is suggested that the manufacturers with the above ideas and perceptions can refer to the software developing companies. This is due to the reason that these companies incorporate agility in their operations in spite of the emergence of new technologies and competitors at a rapid pace. At this juncture, it is realised that the valuable contributions on AM are scattered in literature world. The need of the hour is to knit them and following this exercise, this article has contribute Twenty AM criteria model and its implementation programme The contributions of this article are timely because in spite of the emergence of considerable number of research articles in literature, the practitioners, particularly from the manufacturing arena are devoid of the knowledge on AM criteria and their systematic and result oriented implementation. Finally it is pointed out that, the growing competition and dynamic demands of customers strain the companies and compel them to be agile. Hence, AM is going to be an imperative for manufacturing enterprises of the future (Hormozi, (2001).

References

[1] Anderson, R., Eriksson, H. and Torstensson, H. (2006), "Similarities and deifferences between TQM ,Six Sigma and Lean", The TQM Magazine, Vol.18, No.3, pp.282-296.

[2] Ashley,S., (1997), "Rapid – response design", *Mechanical Engineering- CIME*, Vol .119, No.12,p. 72(3).

[3] Assen,M.F., Hans,E.W and Velde,S.L., (2000), "An agile planning and control framework for customer-order driven discrete parts manufacturing environments", *International Journal of Agile Management Systems*, Vol.2, No.1, pp. 16-23.

[4] Assen,M.F., (2000), "Agile-based competence management: the relation between agile manufacturing and time based competence management", *International Journal of Agile Management Systems*, Vol 2, No.2, pp 142- 155.

[5] Bajgoric,N., (2000), "Web based information access for agile management" *International Journal of Agile Management Systems* ,Vol 2, No.2 , pp. 121- 129

[6] Burgess,T.F., (1994), "Making a leap to Agility: Defining and achieving Agile manufacturing Through Business Process Redesign and Business network Redesign", *International Journal of Operations & Production Management*,Vol, 14, No.11,pp.23-34.

[7] Bustamante,G,P., (1999), "Knowledge management in agile innovative organisations", *Journal of Knowledge Management*, Vol. 3, No.1, pp. 6 – 17.

[8] Christopher,M and Towill.D.R., (2000), "Supply chain migration from lean and functional to agile and customised", *Supply Chain Management: An International Journal*, Vol.5, No.4, pp. 206-213.

[9] Crocitto,M and Youssef,M., (2003), "The human side of organizational agility", *Industrial Management and Data Systems*, Vol. 103, No.6, pp.388 – 397

[10] DeVor,R, Graves,R and Mills.J.J., (1997),"Agile manufacturing research: accomplishments and

opportunities.*(special issue of design & manufacturing on Agile manufacturing), IIE Transactions,* Vol 29,No.10,pp 813(11)

[11] Dove, R., (1999) "Knowledge management, response ability, and the agile enterprise", *Journal of Knowledge Management*, Vol. 3, No.1, pp. 18 – 35.

[12] Duguay,C.R., Landry.S and Pasin,F., (1997), " From mass production to flexible/ agile production " , *International Journal of Operations & Production Management*, Vol.17,No.12, pp.1183 -1195

[13] Hammer,M and Champy.J., (1993), Reengineering the corporation - a manifesto for Business Revolution, *Nicholas Brealey Publishing Ltd.,* London.

[14] Hoek,R.I, Harrison,A and Christopher,M., (2001), " Measuring agile capabilities in the supply chain", *International Journal of Operations and Production Management,* Vol 21, No.1/2, pp. 126-147.

[15] Hoek,R.I., (2000), "The thesis of leagility visited", *International Journal of Agile Management Systems*, Vol.2, No.3, pp.196-201.

[16] Hooper,M.J, Steeple,D and Winters,C.N., (2001), "Costing customer value: an approach for the agile enterprise ", *International Journal of Operations & Production Management*, Vol. 21, No 56, pp. 633-644.

[17] Hormozi,A.M., (2001), "Agile manufacturing: the next logical step", *Benchmarking, An International Journal*, Vol.8, No.2, pp.132-143.

[18] Jin-Hai, Anderson,A.R and Harrison,R.T., (2003), " The evolution of agile manufacturing" *Business Process Management Journal*, Vol 9, No.2, pp .170-189.

[19] Jones,R.M, Naylor,B and Towill,D.R., "Engineering the leagile supply chain", *International Journal of Agile Management Systems*, Vol 2, No.1, pp. 54-61.

[20] Kirk,S and Tebaldi,E., (1999), "Design of robotic facilities for agile automobile manufacturing" *Industrial Robot*, Vol.24, No.1, pp .72 -77.

[21] Lau,H.C.W, Wong,C.W.Y, Pun,K.F and Chin,K.S., (2003), "Virtual agent modeling of an agile supply chain infrastructure" *Management Decision* , Vol 41, No. 7 , pp.625 -634.

[22] Lee,W.B and Lau,H.C.W., (1999), "Factory on demand: the shaping of an agile production network". *International Journal of Agile Management Systems*, Vol 1,No.2 ,pp 83-87

[23] Malek,L.A, Das,S.K and Wolf,C., (2000), "Design and implementation of flexible manufacturing solutions in agile enterprises", *International Journal of Agile Management Systems,* Vol.2, No.3, pp187-195.

[24] Maskell,B., (2001), "The age of agile manufacturing", *Supply Chain Management: An International Journal*, Vol.6, No.1, pp. 5-11.

[25] McGaughey,R.E., (1999), "Internet technology: contributing to agility in the twenty-first century", *International Journal of Agile Management Systems*, Vol 1, No.1,pp.7-13.

[26] Meredith,S and Francis,D., (2000), "Journey towards agility: the agile wheel explored", The TQM Magazine, Vol.12, No.2, pp.137-143.

[27] Monker,P.M., Search for Agile Manufacturing, *Manufacturing Engineering*, Volume 113, No. 5, pp.40-43, Nov. 1994.

[28] Montgomery,J.C and Levine,L.O (ed.)., (1995), The Transition to Agile Manufacturing - Staying Flexible for Competitive Advantage, *ASQC Quality Press*, Wisconsin, U.S.A.,

[29] Onuh,S.O and Hon, K.K.B., (2001)," Integration of rapid prototyping technology into FMS for agile manufacturing" *Integrated Manufacturing Systems*, Vol 12, No3 , pp. 179 – 186.

[30] Owusu,Y.A, (1999), "Importance of employee involvement in world class agile management systems", *International Journal of Agile Management Systems*, Vol.1, No.2, pp.107-115.

[31] Paixao,A.C and Marlow,P.B., (2003) " Fourth generation ports – a question of agility", *International Journal of Physical Distribution and Logistics Management*,Vol.33, No.4, pp 355-376.

[32] Parkinson,S., (1999), "Agile Manufacturing", Work Study, Vol.48, No.4, pp.134-137.

[33] Power,D.J., Sohal,A.S and Rahman,S.U., (2001), "Critical success factors in agile supply chain management. An empirical study", *International Journal of Physical Distribution and Logistics Management*,Vol.31, No.4, pp 247-265.

[34] Quintana,R., (1998)," A production methodology for agile manufacturing in a high turnover environment ", *International Journal of Operations & Production Management*, Vol. 18, No. 5, pp. 452-470.

[35] Ramasesh,R, Kulkarni,S and Jayakumar,M., (2001) "Agility in manufacturing systems: an exploratory modeling framework and simulation" *Integrated Manufacturing Systems*, Vol 12, No.7, pp.534 – 548.

[36] Ren,J, Yusuf,Y.Y and Burns,N.D., (2003) "The effects of agile attributes on competitive priorities: a

neural network approach" *Integrated Manufacturing Systems*, Vol 14, No.6, pp. 489-497

[37] Rigby,C, Day,M, Forrester,P and Burnett,J., (2000) "Agile supply: rethinking systems thinking, systems practice ", *International Journal of Agile Management Systems*, Vol.2, No.3, pp. 178-186.

[38] Sharifi,H, and Zhang.Z., (2001), "Agile manufacturing in practice: Application of a methodology", *International Journal of Production & Operations Management*, Volume 21, Number 5, pp. 772-794.

[39] Sohal,A.S., (1999), "Developing agile manufacturing in Australia", *International Journal of Agile Management Systems*, Vol 1, No.1 ,pp. 60 -63.

[40] Takahashi,K and Nakamura,N., (2000), "Agile control in JIT ordering systems", *International Journal of Agile Management Systems*, Vol.2, No.3, pp. 242-252.

[41] Tersine,R.J and Wacker,J.G., (2000), "Customer-aligned inventory strategies: agility maxims", *International Journal of Agile Management Systems*, Vol 2, No.2,pp.114-120.

[42] Vernadat,F.B., (1999), "Research agenda for agile manufacturing", *International Journal of Agile Management Systems*, Vol.1, No.1, pp.37-40.

[43] Vokurka,R.J and Fliedner,G., (1998), "The journey toward agility", *Industrial Management and Data Systems*, Vol. 98, No.4, pp.165-171.

[44] Worley, J.M. and Doolen, T.L. (2006), "The role of communication and management support in a lean manufacturing implementation", Management Decision, Vol. 44, No.2., pp.165-172.

[45] Yusuf,Y.Y., Adeleye,E.O and Sivayoganathan.K., (2003), "Volume flexibility: the agile manufacturing conundrum", *Management Decision*, Vol 41, No.7, pp. 613-624.

[46] Zhang,Z and Sharifi.H., (2000), "A methodology for achieving agility in manufacturing organisations", *International Journal of Production & Operations Management*, Vol. 20, No.4, pp.496-513.

Books for Reading

1. Feld, W.M. (2001), "Lean Manufacturing: Tools, Techniques and How to use them", APICS Publications.
2. Hobbs, D.P.(2004), "Lean Manufacturing Implementation", Narosa Publisher.
3. Linker, J.K. and Womack, J.P. (1997), "Becoming lean", Productivity Press.
4. Joseph C. Montigomery & Lawrence O. Levine(ed)., "The Transition to Agile Manufacturing Staying flexible for Competitive Advantage", ASQC Quality Press, Milwaukee, Wisconsin, USA, 1996.
5. David M., Anderson & Joseph Pine B.H, "Agile Product Development for Mass Customization", Irwin Professional Publishing, Chicago, USA., 1997.
6. S.R.Devadasan, V.Mohan Sivakumar, R.Murugesh and P.R.Shalij (2012), *Lean and agile manufacturing: Theoretical, Practical and Research Futurities,* Prentice Hall of India Learning Private Limited, India