Agile manufacturing, Lean production, Just in Time systems and products quality improvement

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Abstract: Agile manufacturing (AM) is a new concept in manufacturing intended to improve the competitiveness of firms. Manufacturing processes based on AM are characterized by customer-supplier integrated process for product design, manufacturing, marketing, and support services. Agile manufacturing, a recently popularised concept, has been advocated as the 21st century manufacturing paradigm. Lean production not only successfully challenged the accepted mass production practices in the automotive industry, significantly shifting the trade-off between productivity and quality, but it also led to a rethinking of a wide range of manufacturing and service operations beyond the high-volume repetitive manufacturing environment. The implementation of Lean Production Systems is more than redesigning some production processes. Quality improvement (QI) of industrial products and processes requires collection and analyses of data to solve quality related manufacturing problems

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1. Introduction

In today's competitive environment businesses are undergoing profound changes. There is a world-wide spread of education and technology, leading to intense and increasingly global competition and accelerating rate of marketplace change. There is a continuing fragmentation of mass markets into niche markets as customers are becoming more demanding with increasing expectations. The just-in-time (JIT) production system has been applied widely in many manufacturing enterprise around the world, mainly due to the success of Toyota Motor Company. The use of JIT system can result in minimizing the inventory level and manufacturing lead time, and simultaneously achieving high quality level and customer satisfaction. The underlying principle of JIT philosophy is to produce the right quantity of product at the right time with the right quality level. Kanban, which means a card in Japanese, is a tool used to achieve JIT production. In a JIT system, production is triggered by a kanban signal, which usually comes from the customer order.

The overall objective of a JIT system is to continuously improve the organization's productivity, quality, and ex- ibility. Each element of a JIT system provides some benefit for a manufacturer, but the application of each element potentially involves only certain areas in the organization, and unless a systems perspective is employed, the areas optimize locally, rather than at the organization level. Consequently, the potential synergic benefits are not fully realized until all elements of a JIT system are in- tegrated (Harber et al. 1990). Agile manufacturing is an emerging concept in industry that aims at achieving flexibility and responsiveness to the changing market needs. Critical to the success of an agile manufacturing system is to reconfigure the manufacturing cell and to integrate many disparate elements contained in cells. Manufacturing cells in general and flexible manufacturing cells specifically, are not especially new concepts, though their use and deployment are still in an early stage. The depiction of the agile manufacturing cell includes a synopsis of some of the change proficiencies obtained by the configuration. The agile configuration here brings additional values such as rapid new product introduction, accommodation to unpredictable demand, longer equipment applicability, etc.

In past two decades, the Japanese successful experience of using just-in-time (JIT) production has received a great deal of attention. The underlying goal of JIT is to eliminate waste, which can be achieved through various efforts, such as shortening lead time, reducing setup cost, and improving quality. To cite a typical introductory text to JIT, these systems ‘‘call for flexible schedules that pull material on demand and on short notice. This concept is, often mistakenly taken by suppliers as a request for buffer inventories. JIT considers buffer inventories a waste. It would not be healthy for a customer/supplier relationship to shift the

need for a buffer inventory from the customer to the supplier. In the long run, the supplier is going to resent it and will make the customer pay for it. Buffer inventories will also suffer the quality problems associated with keeping material built ahead of time... For a supplier, the best approach is to reduce lead times. This will make the supplier lean and responsivey'' (Hernandez, 1993).

Lean production techniques have contributed to a spectacular improvement in efficiency, speed of response and flexibility in production at many industrial enterprises, through process-based management, elimination of waste and the highly flexible implementation of these processes. Lean management has allowed these enterprises to offer a highly diversified range of products, at the lowest cost, withh ighlevel s of productivity, speed of delivery, minimum stock levels and optimum quality.

2. Just in Time system

JIT is a misused term that is less than adequate to describe this broad production system, but it is still the best term available be- cause it is a more universally accepted term than any of the alternatives. Therefore, JIT is used throughout this pa- per to describe a broad-based production system that strives to achieve excellence. Unfortunately, some confusion about JIT still exists and unanswered questions remain about im- plementation issues associated with JIT systems (Safayeni et al. 1991). JIT production is a concept for producing a required volume of a required item at a required point in time. Research on JIT production from various viewpoints is carried out all over the world, and, in recent years, the application of JIT concept to supplychain management is attempted (Zimmer, 2002). Some researchers, e.g. Price et al. (1994), provide reviews of the literature, and recently, Takahashi (2002) and Machuca (2002) edit special issues on JIT systems. In JIT production, the order release for each process is determined on the basis of the actual demand, that is, without demand forecasts. As JIT ordering systems, the Kanban system (Kimura and Terada, 1981) and the concurrent ordering system (Izumi and Takahashi, 1993) have been proposed.

In manufacturing, JIT has been credited with many holistic benefits. These benefits include reduced inventory levels; reduced investment in inventory; improved quality of incoming materials; and consistent high-quality products. Some additional benefits of JIT that have been achieved in manufacturing firms are: improved operational efficiency, uniform workstation loads; standardized components; standardized work methods; cooperative relationships with suppliers; closer collaboration with customers, and improved customer satisfaction. Despite the delayed start in service applications of JIT, there have already been some success stories which indicate that many of these JIT benefits that have been achieved in manufacturing can be replicated in services, although sometimes in a slightly different form. Chan (2001) indicated that kanban size did have effects on JIT manufacturing system performance. For multiple product production, as the kanban size increased, the fill rate increased with a decreasein manufacture lead time. JIT philosophy, which we refer to as theoretical or as conventional JIT seeks zero defective, setup time, inventory, breakdown, transportation cost, and lead-time (Schonberger, 2002). Most experts believe that the preceding goals are very idealistic and a practical, JIT should try to get close to them as far as possible. Several companies in the last 20 years have been restructuring their manufacturing systems to become a JIT or world-class company (Fohurley, 1999). JIT is used in Toyota plants in Japan and US, Mercedes Benz in Germany and US and in several auto industries in US and around the world. However, these systems were built to operate in a JIT fashion.

3. Agile manufacturing

The concept of agile manufacturing was originally introduced in the report entitled ''21st Century Manufacturing Enterprise Strategy'' and published by the Iacocca Institute of Lehigh University (Goldman and Nagel, 1991) as an option for managing firms in a dynamic world. Since then, it has been adopted by researchers, managers and consultants as the last stage in the evolution of manufacturing models or systems. However, perhaps because the concept of agile manufacturing is at the developmental phase, it has been surrounded by considerable confusion. The term agile manufacturing is sometimes incorrectly used to refer to concepts such as flexible manufacturing, lean production or mass customisation. Additionally, while the interest of agile manufacturing for firms has been widely disseminated, its relation with performance has not been empirically validated. Agile supply chain management system crossing each node has the internal organic coordination function, integrate information flow in tactical level to achieve synchronous supply chain planning and control. Dynamic changes of supply chain nodes and business rules increase the implementation complexity of supply chain system. The cooperation of more autonomy, adaptable, cooperative agency is needed to achieve the agility and reconfigurability of supply chain management system.

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. Agile manufacturing is not about small-scale continuous improvements, but an entirely different

way of doing business (Kidd, 1996). Agile manufacturing is a new expression that is used to represent the ability of a producer of goods and services to thrive in the face of continuous change.

The main points of the definition of various authors may be summarised as follow:

-High quality and highly customised products
- Products and services with high information and value-adding content
- Mobilisation of core competencies
- Responsiveness to social and environmental issues
- Synthesis of diverse technologies
- Response to change and uncertainty
- Intra-enterprise and inter-enterprise integration (Goldman, 1993).

4. JIT and agile manufacturing

Specific to our research is the relationship between agile manufacturing and the Just-in-Time (JIT) manufacturing strategy. Countless research regarding JIT and its individual elements has been generated in the last three decades. Claycomb et al. (1999) state that "in its ideal form, JIT integrates the entire supply chain's marketing, distribution, customer service, purchasing, and production functions into one controlled process." In an early work regarding JIT implementation, Mehra and Inman (1992) identified four elements of JIT: JIT-production strategy, JIT vendor strategy (purchasing), JIT education strategy and management commitment. Only JIT-production and JIT vendor strategies were found to have a significant impact on JIT implementation success. Since that time a number of published articles have at least partially supported these findings. Agile manufacturing has been defined as the capability of surviving and prospering in the competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets, driven by customer-designed products and services.

5. Lean production

The lean management makes it possible to obtain a product that is adapted to actual demand using the minimum amount of resources and therefore minimising the cost, with the appropriate quality and very high speed of response. Since the production system must produce in accordance withdemand, it cannot resort to economies of scale by dealing in large batches, as in the case of conventional management systems. In order to attune production to demand and obtain high performance without recourse to economies of scale, lean management is based on two main inherent characteristics:

(1) Firstly, it operates withth e least possible number of activities, thereby obtaining economies that are not economies of scale but rather of resources; for this purpose, all activities that do not add value, called wasteful, must be eliminated, including inappropriate processes, unnecessary carriage, unnecessary movement, stocks of all kinds which would result in increased costs, as well as quality defects and all manner of delays and times, which would be detrimental as regards the quality and response. Furthermore, production that is not attuned to demand is also wasteful (excess production), and avoiding this waste will result in a product or service that is faster, more appropriate and less costly.

(2) This last aspect is covered by the second main characteristic of lean management, i.e., flexibility, which means that the system must be attuned at all times to the type and volume of production required by demand.

Lean production is based on the principles and working processes of the Toyota Production System (TPS), and has been defined as doing more with less. In its simplest terms, lean production can be described as the elimination of waste. It has been most prominent in discrete, repetitive assembly-type operations. Liker suggests that the goals of lean production are highest quality, lowest cost, and shortest lead time. Lean production can be considered as a philosophy and as a set of tools and practices for the continuous improvement of operations.

Although there is agreement on the positive impacts of lean production (LP) on quality and productivity, the same is not true for the impacts of LP on working conditions (Delbridge et al., 2000). On the one hand, several authors have identified detrimental effects of LP. According to Niepce and Molleman (1998), typical principles of LP, such as continuous flow and the definition of work-in-process caps, couple processes tightly and, as a result, increase stress in workers and reduce their autonomy. Berggren (1992) and Klein (1989) point out other drawbacks of LP, such as: (a) the standardization of cycle time, which prevents workers from managing the pace at which they work; (b) multi-skilling, which often implies job enlargement and work intensification rather than job enrichment; (c) unlimited demands on performance; (d) willingness to work overtime very frequently and at very short notice; (e) close surveillance of the individual; (f) excessive regimentation of the workplace; and (g) little emphasis on preventing cumulative trauma injuries, which contrasts with a strong emphasis on accident prevention.

Lean production is a manufacturing system whose objective is to streamline the flow of production while continually seeking to reduce the resources (e.g., direct and indirect labor, equipment, materials, space, etc.) required to produce a given set of items; any slack in the system is referred to as ''waste'' (e.g., Womack et al., 1990). Rather than setting a goal of a

specific level of leanness, lean production is focused on a continuous improvement process. Each improvement in flow or reduction in waste leads to new goals (Womack et al., 1990).

6. Agile manufacturing and Lean production

Lean production is regarded by many as simply an enhancement of mass production methods, whereas agility implies breaking out of the mass-production mould and producing much more highly customised products - where the customer wants them in any quantity.

- In a product line context, it amounts to striving for economies of scope, rather than economies of scale-ideally serving ever-smaller niche markets, even quantities of one, without the high cost traditionally associated with customisation.
- Agile manufacturing further requires an all encompassing view, whereas lean production is typically associated only with the factory floor.
- Agility further embodies such concepts as rapid formation of multi-company alliances or virtual companies to introduce new products to the market.
- A lean company may be thought of as a very productive and cost e$cient producer of goods or services.
- An agile company is primarily characterised as a very fast and efficient learning organisation if it was not first productive and cost efficient (Booth and Hammer, 1995).

7. Conclusion

A key principle of JIT is reducing inventories to the bare minimum, and the effort to do so turns out to be powerful in finding waste and inefficiencies throughout a production process. Quality improvement of industrial products and processes requires collection and analyses of data to solve quality related manufacturing problems. Quality problems may involve several input and output variables that are not easy to model and/or optimise. As Yang and Trewn (2004) point out, data mining (DM) and knowledge discovery in databases (KDD) have been successfully used for solving Quality improvement and control problems involving multivariate data in various stages of product/process life cycles. Yet, a review of such problem solving approaches is needed to guide practitioners. Quality assessment and continuous quality improvement has long been recognized as a vital process in all societal systems and organizations. Lean production is often regarded as the gold standard of modern operations and supply chain management (e.g., Goldsby et al., 2006). Numerous studies have investigated the relationship between lean production and financial performance (e.g., Jayaram et al., 2008). Yet, the exact mechanism(s) through which lean production affects financial performance remain underresearched. Conventional wisdom holds that, as a manufacturing strategy, lean production strives to mini- mize waste and thereby increases efficiency (Womack et al., 1990), and by extension, financial performance. Although interest in Just-in-time (JIT) practices has been increasing for over two decades, empirical studies that examine the relationship between JIT adoption and firm performance are mixed (Fullerton & McWatters, 1999; Mia, 2000). The business environment, as a source of change and generator of uncertainty, has been considered the main motivator or agility driver. In fact, agile manufacturing describes ‘‘a comprehensive response to a new competitive environment shaped by forces that have undermined the dominance of the mass-production system’’ (Gunasekaran et al., 2001). Thus, new forces and changes in the market’s competitive landscape (changing customer expectations and escalating requirements to satisfy individual needs, globalisation, intensification of competition from a national scale to a global arena, social pressures, fragmentation of mass markets into niche markets, technology and management innovations, shorter product life cycles, increasing product variety, strong need for rapid and dynamic product innovation cycle, etc).

Lean production is a strategy or philosophy that promotes the use of practices, such as kanban, total quality management (TQM) and just-in-time (JIT), to minimize waste and enhance firm performance. Thus, the implementation of lean production practices is expected to result in improved operational outcomes, such as lower inventories, higher quality, and shorter throughput times, which, in turn, should improve financial performance. This description of lean production clearly indicates a number of mediating factors between lean production and financial performance. This notion is consistent with the ‘‘new inventory paradigm’’ (Chika´ n, 2011) which empha- sizes the connectedness to other processes and functions within firms and to firm profitability.

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