Agile Manufacturing: Literature Review

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Key Words:

1. Agile Manufacturing
2. Lean Production.

Abstract

This paper reviews the literature on agile manufacturing and classifies it into ten themes namely concept of agility, concept of agile manufacturing (AM), drivers of AM, enablers of AM, measurement of agility, benefits of AM, applications of AM, combinative studies, caution of AM and criticism of AM. The paper concludes that implementation of agile manufacturing has resulted in the enhancement of marketing, operational and financial performance of the firms. However, there is an increasing trend in combining agile with lean manufacturing to secure even better performance by securing efficiencies resulting from lean and flexibility resulting from agile production.

INTRODUCTION

The practice of agile manufacturing (AM) is on the rise in India; in other words, there exists ample scope for the adoption of the concept by the Indian industry. Research on AM in the Indian context is also limited. It is in this context that a literature review of agile manufacturing becomes important. The literature reviewed were classified into ten themes namely concept of agility, concept of agile manufacturing (AM), drivers of AM, enablers of AM, measurement of agility, benefits of AM, applications of AM, combinative studies, caution of AM and criticism of AM. The paper is organized as follows: part one briefly discusses the method, part two discusses the review of literature and part three consists of conclusion.

METHOD

Papers published in journals and conferences as well as books were referred for review of literature. Published and presented papers were accessed on the electronic databases with agile manufacturing as key words. Some databases had only abstracts and not full papers. A list was prepared of such abstracts that included the names of authors, titles of papers, name of the journal, volume number, issue number and year of publication or presentation. This list was submitted to a reputed library with a request to provide full text papers. This library provided the same to the author. On review of literature, the same was categorized into ten themes namely concept of agility,concept ofAM, drivers of AM, enablers of AM, measurement of agility, benefits of AM, applications of AM, combinative studies, cautionof AM and criticism of AM. The extant literature is reviewed in the order of its publication.

CONCEPT OF AGILITY

(Goldman et.al., 1995 and DeVor et. al., 1997) consider agility as comprehensive response to the business challenges of profiting from rapidly changing, continually fragmenting markets for high performance, high quality, customer configured goods and services. (Goldman et. al., 1995) as cited by (Hooper et. al., 2001) has four tenants namely total solution products, virtual organizations, knowledge enhancement and entrepreneurial organization. As reviewed by (Sharifi and Zhang, 2001) agility is looked at from two perspectives namely, total integration of business components; and flexibility of manufacturing, people and organisation. (Kidd, 1995; Dove, 1996; Sharifi and Zhang, 2001) state that the concept of agility has two components: responding to changes in appropriately and exploiting changes and taking advantages of opportunities. (Gunasekaran et. al., 2002) consider agility as changing the patterns of traditional operation and casting off old ways of doing things that are no longer appropriate. (Sarkis, 2001) as cited by (Dowlatshahi and Cao, 2006)considers agility as the ability to thrive in an environment of continuous and often unanticipated change.

CONCEPT OF AGILE MANUFACTURING

(Burgess, 1994) claims that the content of AM was not clearly defined for a period of three years of its introduction

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and was considered as a synthesis of existing technologies and methods of organizing production functions. (Cho et.al., 1996) define AM as 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-defined products and services. (Quinn et. al., 1997) consider AM as the ability to accomplish rapid changeover from the assembly of one product to the assembly of a different product. (Gunasekaran et. al., 2002) consider AM as an entirely different way of doing business with a primary emphasis on flexibility and quick response to the changing markets and customer needs. (Buyukozkan et.al., 2004) state that the concept of AM was introduced in the year 1991 out of the government-sponsored effort at Lehigh University.(Dowlatshahi and Cao, 2006) consider AM as smaller scale with modular production facilities and cooperation between firms will define the competitiveness in future.Thus a common thread that can be seen in various definitions of AM is the quick and appropriate response to the changing business environment.

DRIVERS OF AGILITY MANUFACTURING

(Zhang and Sharifi, 2000) developed a conceptual model of agility consisting of agility drivers, agility capabilities and agility providers. Agility drivers are the changes in the business environment that directs a firm to search for new ways of managing business to ensure competitive advantage. Agility capabilities are the capabilities a firm needs to respond appropriately to the changes. Agility providers are the means by which the requisite capabilities are obtained. (Vijayasarathy and Turk, 2012) identify training and subjective norms as significant drivers of adoption of agile processes and methods. Thy also claim that subjective norm, training and the interplay between perceived benefits and perceived hindrances are the major influencers of adoption of agile methods.

ENABLERS OF AGILE MANUFACTURING

(Sharp et. al.. 1999) identify agile manufacturing enablers as core competencies, virtual enterprise, rapid prototyping, concurrent engineering, multi-skilled and flexible people, continuous improvement, team working, change and risk management, information technology and empowering. (Wang et. al., 2004) developed two kinds of assembly models namely Assembly Variants Model and Assembly Mating Graph as new product development methods under the setting of agile manufacturing. In their second study, (Wang et. al., 2004) developed assembly variant design methodology to facilitate the variant design of complex assembly products in the agile manufacturing setting. (Dowlatshahi and Cao, 2006) in their study on the impact of alignment between virtual enterprise (VE) and information technology (IT) claim that alignment between VE and IT on business performance was more significant that the impact of VE and IT on business performance individually. They further generalize these findings and claim that synergy and interaction effect among enablers of AM could be more of a determining factor for success of AM than are the individual enablers. They further claim that achieving AM is a multi-disciplinary endeavour. (Vinodh and Kuttalingam, 2011) identify technical enablers such as computer-aided design, computer-aided manufacturing, computer numerical control, computer-integrated manufacturing, rapid prototyping, rapid tooling, reverse engineering, virtual enterprise and information technology. (Wang et. al., 2006) as cited by (Vinodh, 2011) identify managerial enablers as total quality management, total productive maintenance, supply chain management, enterprise resource planning, Kanban, Kaisen and 5S. (Vinodh and Kuttalingam, 2011) in their study of enablers of agile manufacturing, claim that application of computer aided design and computer aided engineering augment the firm's ability to design customized products in shorter time period and also increases its flexibility in designing new products.

MEASUREMENT OF AGILITY

(Kumar and Motwani, 1995) identified 23 factors that influence agility and developed agility index for a firm. This index constitutes a framework that facilitates systematic evaluation of agility of a firm.(Sharifi and Zhang, 2001) developed a methodology to provide a basis for assessing the business situations and guideline for identifying required capabilities to develop strategic policies and pursue agile manufacturing. They also conclude that agility may be achieved by use of manufacturing best practices and tools. (Arteta and Giachetti, 2004) measured agility using a proxy measure of complexity. (Lin et. al., 2006) developed a fuzzy supply chain agility index to address agility measurement using the concept of multi-criteria decision-making. They argue that the fuzzy agility index is more informative and reliable. They also claim that it can help identify supply chain weaknesses and also provides ideas for overcoming them. (Lu and Tseng, 2010), present a systematic methodology for developing an object-oriented agile manufacturing control system in the software context. (Vinodh and Aravindraj, 2011) used the IF – THEN approach to assess the agility of a modular switch manufacturer in India. Using this approach, they studied the gaps that obstructed the agility and suggested solutions to improve the agility of the firm. (Vinodh, 2011) in his study of an electronic switch manufacturing unit in India, developed an axiomatic design model that served as a framework to

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clarify the interrelationships, concepts, principles and methodologies to improve the agility of the firm. He claims that the model will also serve as a guideline for the formulation of transformation process for agile manufacturing (Vinodh et. al., 2012) designed an agility assessment model consisting of three levels. The first level consisted of five agility enables such as management responsibility agility, manufacturing management agility, workforce agility, technology agility and manufacturing strategy agility. The second level includes agility criteria and the third level includes agile attributes. This model was used to assess the agility of a firm using scorer model; validation was done using multi-grade fuzzy approach.

BENEFITS OF AGILE MANUFACTURING

(Kirk and Tebaldi, 1997) in their study on design of robotic facilities for agile manufacturing in the automobile sector, claim that AM can offer benefits not only in industries where product life cycles are shorter but also to niche firms in traditional industries. (Hooper et. al., 2001) argue that use of Activity Based Costing (ABC) is most adaptable for agile enterprises. They also claimed in their case-study based study in the UK context that ABC adoption helped the firm in becoming customer-centric and also helped it in identifying long-term resource implications of adopting agile manufacturing. (Srinivasan, 2007) in his study on agile manufacturing in the context of refineries, argues that artificial intelligence methodologies may be effectively used in managing business changes, process changes and design life cycle changes. (Inman et. al., 2011) in their study on relationship between JIT, operational performance and firm performance concluded that higher levels of manufacturing agility has positive impact on firm's marketing, operational and financial performance.They further explain that JIT- purchasing and JIT-production when practiced together enhance a firm's manufacturing agility. Improved manufacturing agility leads to improved operating performance which again leads to improved marketing and financial performance of the firm. (Concas et. al., 2012), claim that the use of agile practices like pair programming, test based development and refactoring improves the quality of the software.

Applications of Agile Manufacturing: One school of thought argues that a la carte application of agile methods is not possible and that must be applied in totality to achieve the benefit of agile manufacturing (McBreen, 2003 and Swhwaber and Beedle, 2002). (Buyukozkan et.al., 2004) reviewed the concurrent new product development tools like networking and management tools, modelling and analysis tools, predictive tools and intelligent tools and claim that these tools can result in significant gains in CNPD. (Fitzgerald et.al., 2006) however, dispute the school of thought endorsed by (McBreen, 2003 and Swhwaber and Beedle, 2002). In their study on tailoring of agile methods argue that even if lean methods may be individually incomplete in facilitating software development process, they may be useful when used in combination. They used extreme programming (XP) and scrum together for developing software at Intel's Shannon facility. They picked up six out of twelve XP practices namely pair programming, testing, refactoring, simple design, collective ownership and coding standards. The Scrum practices used included planning and architecture in the pre-game phase, sprints in the main game phase and closure in the post game phase. They concluded that the combination of SP and Scrum resulted into reducing the code defect density and delivery of projects ahead of scheduled time. Agile manufacturing finds application in Information Technology, supply chain management, new product development, telecommunication, and healthcare apart from manufacturing.. (Li et. al., 2006) in their study on effective method to quantify effect of disruption at a Haier company in China, claim that by timely sharing of supply information, firms at downstream stages can warn the firm at upstream stage of disruption, and buy some time and make suitable decisions to counter the impact of the disruption. Based on this they argue that information sharing enhances the agility of firms while improving the stability and performance of the whole supply chain. (Jain et. al., 2008) proposed fuzzy intelligent agents approach to model dynamic agility and introduced dynamic agility level index. (Conforto and Amaral, 2008) applied agile manufacturing to new product development projects and claimed that the same improved the project performance. (Karlsson and Agerfalk, 2009) demonstrate with the help of three cases that method for method configuration can be used in software development projects to achieve agile goals. (Sutharshan, 2011) identified culture specific agile attributes like trusting people more than process, transparency, authority, quick decision-making, empowerment, pro-activeness, management support, collective ownership, blame-sharing, negotiation and conflict-resolution claims that an understanding of these attributes will help implement agile values and improve team management. (Soni and Kodali, 2012) developed and validated constructs for lean, agile and leagile supply chain in the context of the manufacturing sector in India. The constructs for agile supply chain included strategic management, manufacturing management, information technology, collaboration management, demand management, logistics management, marketing management and supplier management.

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COMBINATIVE STUDIES

(Naylor et. al., 1999) argue that lean and agile paradigms should not be seen in progression or isolation. They further argue that choosing of the lean or agile capability development depends upon the location of the supply chain members and that it would be advisable to develop a combination of lean and agile paradigms. (Robertson and Jones, 1999) applied lean and agile manufacturing to telecommunications business. They observe that the telecommunications product has two parts namely physical network connection and service over the connection. They recommend that lean approach would be suitable for network connection, while for services agile approach would be better as services have to be customized for individual customer and thus needs flexibility. (Gunasekaran et. al., 2002) in their study on application of agile manufacturing in an aerospace company conclude that lean manufacturing is more suitable for well established products while agile manufacturing is more suitable for new products. . (Prince and Kay, 2003) used the enhanced production flow analysis methodology to identified two virtual groups (VG)process-oriented virtual groups and product-oriented virtual groups in two firms under study. They claim that in process-oriented groups, lean manufacturing ensures maximum utilization at minimal costs since the processes were standardized. If products fail to pass through this VG with predictability and 100% quality, later stages of agile manufacturing will not function optimally. In other words the claim suggests that lean is a precursor to agile manufacturing. In case of product-oriented VG, application of agile manufacturing resulted in value-addition and satisfying customer demands. (Krishnamurthy and Yauch, 2007) classify the extant literature on lean and agile manufacturing into three different groups. One classification considers that lean and agile concepts cannot co-exist, the second one consider that lean and agile manufacturing are supportive of each other and the last group considers lean as a precursor to agile. (Aronsson et. al., 2011) in their study on healthcare supply chains suggest that 'supply chain for one patient group passing through different departments can be designed by combining an agile strategy in department 1, followed by a lean strategy in department 2 and so on'. They observe that hospitals do use lean manufacturing for planning and reduction of waste. However, argue that the use of agile manufacturing will improve the flexibility of a hospital and thereby reflect that both lean and agile manufacturing must be adopted in healthcare. (Lu et. al., 2011) in their study on application of lean and agile model to housing construction, claim with the help of a simulation model that application of lean – agile model avoids inventory accumulation and facilitates customization opportunities and also provides a stable process with shorter cycle time. (Carvalho et. al., 2011) developed a combined lean, agile, resilient and green approaches and claimed that some supply chains are positively associated with all the paradigms and that their implementation will create synergies among them. They further concluded that all the paradigms lead to increasing information frequency, integration level, and decreasing production lead time and transportation lead time. Differences between the paradigms are noted on attributes like capacity surplus, inventory level and replenishment frequency. The authors argue that the capacity surplus and inventory level increases provide the supply chain with agility and resilience characteristics thus enabling a firm to address to customer needs and unexpected events. (Flumerfelt et. al., 2012) argue that lean manufacturing is a precursor to agile manufacturing. They drew an interesting comparison between lean and agile manufacturing and conclude that these are related systems and can be applied together in firms. They also claim that both the systems excel at sustainability, complexity management and learning. (Soni and Kodali, 2012) identified leagile SCM constructs as strategic management, marketing management, logistics management and collaboration management.

CAUTION OF AGILE MANUFACTURING

A few issues need to be paid attention to in order to implement AM and reap its benefits.(Hormozi, 2001) argues that successful implementation of agile manufacturing is contingent on government regulation, business cooperation, IT, reengineering and employee flexibility. He insists that government must create an environment of cooperation in the industry, firms must become flexible and more creative, they must adopt the latest IT and re-evaluate and reconstruct business processes. He further suggests that the employees should also become creative and more open to accept challenges while performing their jobs. (Sharifi and Zang, 2001) concluded that different organizations need different combinations of practices for securing the benefits of agile manufacturing. (Buyukozkan et.al., 2004 caution that right resource allocation and personnel training are necessary to make the tools more efficient and effective. (Lu and Tseng, 2010) point out in the software context that reconfiguration and integration of disparate equipment resources in the manufacturing system is critical to the success of agile manufacturing system. (Amir, 2011) argues that adoption of agile manufacturing not only needs technical tools but also needs a change in the culture of the organization. (Zhang, 2011) identified three agility strategies namely

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quick, responsive and proactive and concluded that choice of agility strategies is contingent on the nature of markets and competition, characteristics of products in terms of life cycles and degrees of maturity and market positions of individual firms.

CRITICISM OF AGILE MANUFACTURING

(Poesche, 2002) in his study on agile manufacturing and business ethics claims that there is very little that agile manufacturing strategy will do to ensure that it shall not result into death or long-term illness of human beings. He also argues that while agile manufacturing will result into a firm being more customer-centric, its emphasis on creativity and innovation may result in an unfavourable impact for people not possessing the same. This will result into dividing the society into 'haves' and 'have nots'. He further claims agile manufacturing adds the risk of outflow and obsolescence of intellectual capital. (Carlson and Yao, 2008) argue that small batches better accommodate changes in schedules, methods, material handling and product configuration and reduce delivery time. (Vinodh, 2011) identify failures of agile implementation practice as the lack of scientific formulation for agile manufacturing and its associated transformation process, lack of precisely identified needs and reason for change.

CONCLUSION

The current paper observes that eight papers under the concept of agility theme, six papers under the concept of agile manufacturing theme, two papers under the drivers of agility theme, six papers under the enablers of AM theme, eight papers under the measurement of agility theme,five papers under the benefits of agile manufacturing theme,ten papers under the application of AM theme, ten papers under the combinative theme, six papers under the cautions for AM theme and three papers under the criticism of AM theme are included. The total works out to 64 papers. This number exceeds the total number of references because a few papers have multiple themes and hence they have been counted repeatedly. Implementation of agile manufacturing has resulted in the enhancement of marketing, operational and financial performance of the firms. However, there is an increasing trend in combining agile with lean manufacturing to secure even better performance by securing efficiencies resulting from lean and flexibility resulting from agile production.

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