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Study & Investigation of Lean Manufacturing using modern hierarchy techniques

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ABSTRACT

This paper is a systemic literature review that examines how lean manufacturing is better than traditional manufacturing. The author justify the lean manufacturing vs. traditional manufacturing with the help of analytic hierarchy process (AHP) and find out the major benefits of lean manufacturing. By using AHP, global desirability index of lean manufacturing and traditional manufacturing are calculated and compared. In this research, the author finds out the critical success factors of lean manufacturing from various research papers. Then give the rank to these critical success factors with the help of technique for order preference by similarity to ideal solution (TOPSIS). We found that TOPSIS method has relatively high rationality and applicability when it is used to ranking the critical success factors of lean manufacturing in organization. In this research, the author identifies and prioritizes the solutions of lean manufacturing adopted in lean manufacturing to overcome its barriers. It helps organizations to concentrate on high rank solutions and develop strategies to implement them on priority. The author proposed a framework based on fuzzy AHP and fuzzy TOPSIS to identify and rank the solutions of lean manufacturing in organization and overcome to its barriers. This proposed framework provides more accurate, effective and systematic decision support tool for stepwise implementation of solutions of lean manufacturing in organization to increase its success rate.

INTRODUCTION

Top Japanese manufacturing industries have achieved excellent international competitiveness in a number of industries such as auto, electronics, and machinery in the past two decades. So due to intensive competition from the world, increasing manufacturing cost, and increasing operational problems, many manufacturing firms around the world, have made tremendous efforts to understand Japanese manufacturing practices. According to Hall (1983) and Schonberger (1982), Japanese had actually developed a new approach, because to increase the production rate and decrease overall cost in manufacturing firms.

So Japanese develop Lean manufacturing which is previously known as the Toyota Production System (TPS) or the Just-in-Time (JIT) system (Toyota, 1988; Womack et al., 1990). Lean manufacturing attracted a lot of attention in the United States from both academia and industry. In recent time many automobiles and other manufacturers are actively adopting the lean manufacturing concepts. Most auto manufacturers have now adopted at least some aspects of this system. Maccoby's did a study and according to his study one-fourth of United States plants have tried to adopt the lean manufacturing system in their industries. However, to transfer the lean production system in a foreign country is a very long journey and a very challenging work because so many different aspects of plant operation are involved to manufacture a component. The transfer of Just in time central to Toyota Production System, need a large amount of effort.

Lean manufacturing, developed by Toyota, involves quality and inventory control, industrial relations, labor management, and supplier-manufacturer practices. Some researchers (Cusumano and Takeishi, 1991; Liker, 1997; Womack and Jones, 1996b) suggest that transfer of traditional manufacturing system to lean manufacturing had a significant positive impact on the performance of manufacturing firms.

JIT works on the principle of small-lot production and JIT delivery (Purchasing, 1992).

According to Nakamura et al. (1998), just in time has improved the performance of manufacturing firms. The results of a study of 200 US manufacturers by Germain and Droge (1997) states that improved inventory, financial, and market performance correlates with increased adoption of Just in time purchasing methods.

Helper (1991) states that if United States automakers wish to continue to compete in the global industry, which is characterized by technology, time, and quality-based competition, they will need to establish long-term, mutual trust relationships between the suppliers and customers. According to Keller et al. (1991), for industries, supplier support was a very critical factor for the successful implementation of lean manufacturing system in industries. Helper's (1991) surveyed in industries and he states that to survive in long-term competition, it is important to encourage suppliers and customers to develop capabilities of JIT production as well as JIT delivery. Customers can obtain improvements in quality and delivery by motivating suppliers to adopt JIT production and JIT delivery. Similarly, suppliers have to learn to respond to the increasingly demanding needs of its customers in this competitive market, which is driven by ever-increasing requirements for cost reduction, responsiveness to customer needs, and JIT supply (Owen and Kruse, 1997).

Jones et al. (1997) states that the "value stream" is a new and more useful term to analysis the supply chain or the individual firm. They reinforce the importance of the value stream concept that extends both upstream from the product assembler into the "supply chain" and downstream into the "distribution chain". However, large manufacturers have a better chance in achieving such "lean logistics" than their suppliers do, because large firms to have more resources and bargaining powers than their suppliers. For suppliers, though it may not be possible for them to optimize their supply chain effectively, it is still critical for suppliers to have a responsive logistics system in place to meet the customer's demand.

According to Udoka (1993), in lean manufacturing, due to a large number of parts in small quantities coming into the assembly plant, efficient, effective containerization is important. According to Nicholas (1998), use of containers of a standardized size can help reduce inventories and facilitate the distribution process in plant. According to Schniederjans (1993), use of bar-coding can result in reduction in wasteful activities of inspection, classification, and storage of inventory and use of reusable containers can lead to improvement in materials handling methods.

According to Florida (1996), he examines the relationship between advanced production practices and innovative approaches to environmentally conscious lean manufacturing. He states that industries that are innovative in terms of their manufacturing process are likely to be more active in addressing environmental costs. According to Maxwell et al. (1993), we maintain a good relationship between lean manufacturing and innovative environmental manufacturing practices in industries.

LITERATURE REVIEW

The term "lean manufacturing" or "lean production" was first used by Womack et al. (1990) in their historical book "The Machine That Changed the World". The lean manufacturing describes the profound revolution that was initiated by the Toyota Production System against mass production system. Womack and Jones continued their research in lean production and studied the transfer of other companies into lean crusade in their second book, "Lean Thinking" (Womack and Jones, 1996). They explained that lean manufacturing is much more than a technique, it is a way of thinking, and the whole system approach that creates a culture in which everyone in the organization continuously improve operations. Liker (1997) wrote the third book in this series with the title of "Becoming Lean – Inside Stories of U.S. Manufacturers". The most recent book about the Toyota system is also by Liker (2004) where he describes the management principles of Toyota that he claims to be the world's greatest manufacturer.

Interestingly, every company has to find its own way to implement the lean method: there is no universal way that will apply to all. Despite the wide knowledge and available resources, many companies are struggling to stay "lean". The decade of 1990s was witness to many transformation of traditional manufacturing into lean approach. Many companies either transformed or created new cellular production system. There are also examples of how a complete factory could be designed in lean principles.

Taj and Ghorashyzadeh (2003) address the strategic issues for planning lean manufacturing plants and Taj et al. (2000) show a real example of designing a factory with a future in mind. In order to improve manufacturing operations, we need to assess the state of operations at the manufacturing facilities. Assessment is a valuable tool that must be used to study the current state. Goodson (2002) has developed a tool kit which helps experts to understand the plant within 30 minutes and tells that plant is truly lean or not. He describes his approach as rapid plant assessment (RPA). To do this assessment you would need a team of experts to tour the plant. During the tour, the team observes all aspects of plant's environment and looks for the evidence that the plant adheres to best practices. Lee (2004) an international renowned expert in lean manufacturing has also developed a lean assessment tool.

Monden (1993) suggested a new scheme of classifying operations into three generic categories as non-VA, necessary but non-VA and VA. This scheme proved to be more generic and was extended to different areas. Over the years, many lean manufacturing tools to support value stream have been developed and many more are being proposed every day (Womack et al., 1990; Barker, 1994; Cusumano and Nobeoka, 1998; Childerhouse et al., 2000).

Value stream mapping are used primarily for two requirements: one to understand the interdependence of one function, department or even whole unit over another, and second to capture a holistic view about a situation where the conventional industrial engineering recording tools do not help much. As the complexity of manufacturing and business is growing newer, value stream tools are emerging. Recently, there exists a plethora of different tools and techniques developed for different purposes and waste reduction or elimination. The classification scheme suggested by Hines and Rich (1997) about seven new mapping tools (namely, process activity mapping, supply-chain response matrix, production variety funnel, quality. Filter mapping, demand amplification mapping, decision point analysis and physical structure mapping) regarding their major application areas is very useful. Chitturi et al. (2007) explored practical issues in job shop using a standard VSM and also explained how improved VSM can eliminate some limitations of old VSM.

Singh et al. (2010a), developed an index for measuring leanness of any manufacturing firm based on the scores awarded by leanness measurement team members. Various types of manufacturing wastes addressed by lean manufacturing are taken as one parameter for measuring leanness index. This assessment tool helps to investigate, evaluate, and measure key areas of manufacturing. The tool is very user-friendly and the result is a deeper understanding of key issues, problem areas, and potential solutions.

Sanchez and Perez (2001) focused on six Lean Manufacturing indicators:

- Elimination of zero-value adding activities
- Continuous improvement
- Multifunctional teams
- Just-in-time production and delivery
- Integration of suppliers
- Flexible information system

JUSTIFICATION OF LEAN MANUFACTURING USING AHP

In this section, we compare the lean manufacturing and traditional manufacturing and justify that lean manufacturing is better than traditional manufacturing with the help of AHP. With the help of literature review, we find out the benefits of lean manufacturing which is shown in table 1. According to Sohal and Eggleston (1994), lean manufacturing increases the net profit because it reduced the wastages in the production system. Lean manufacturing increases productivity of the plant so that production rate increases (Philips, 2002). Shingo (1989) states that lean manufacturing decrease waste in the plant. Lean manufacturing eliminates the non value adding process so that wastage decreased. Gilson et al. (2005) states that Lean manufacturing improves the quality of product because it uses the standard process to make a product. According to Monden (1983), Lean manufacturing improves the flexibility in production system. According to Suzuki (1995), the amount of inventory reduced in industry when we use Lean manufacturing. With the help of Lean manufacturing, lead time reduced because it decreases the set up time of machine (Al-Najjar and Alsyouf, 2000).

Research Methodology

Saaty (1980) gives analytic hierarchy process (AHP) which is used to solve complex problems. Basically, decision makers have to decompose the goal of the decision process into its constituent parts, progressing, from the general to the specific perspective. It organises the basic rationality by breaking down a problem into its smaller and smaller constituent parts and then guides decision makers through a series of pair wise comparison judgements to express relative strength or intensity of impact of the elements in the hierarchy. Once the hierarchy has been structured, decision makers judge the importance of each criterion in pair-wise comparisons, structured in matrices. According to Satty (1980) the final scoring has been on relative basis after that compare the importance of one decision alternative to another. In analytic hierarchy process, we take both objective and subjective evaluations. In subjective evaluation, we directly question.

Measuring and collecting data

After building the AHP hierarchy, then our next step is to measurement and data collection. It was done by a team of experts and assigning pair-wise comparison to the main factors used in the AHP hierarchy. We use nine-point scale (Table 1) to assign relative scores to pair wise comparisons amongst the main factors. With the help of scale, experts assign a score to each comparison. Experts continue this process until all levels of the hierarchy and eventually a series of judgment matrices for the major factors were obtained. Team consisted of twelve experts, Out of these twelve experts; six were from industry, mainly from manufacturing sector such as automobile and electronics equipment sectors and six from academic sector. Each one of them has more than eleven year of experience in lean manufacturing area. A questionnaire consisting of all main factors of the two levels of AHP model is designed and is used to assemble the pair wise comparison judgment from all the experts. We do this process continue until we make a consensus otherwise decision of majority gives more importance. In past, some researchers adopted a team of decision makers which have less than ten experts. Bayazit (2005) used AHP approach in decision making for flexible manufacturing system by having a team of six experts from various departments. Zaim et al. (2012) also used a team of five decision experts while selecting maintenance strategy.

Table 1: Benefits of LM

S.NO.	Abbreviation	Benefits of LM	References
1	INP	Improve Net Profit	Sohal and Eggleston, (1994) Standard and Davis (2000)
2	IP	Improve Productivity	Lathin (2001) Philips (2002)
3	WR	Waste Reduction	Shingo, S. (1989) Ferch (1998) Claudius Consulting (2004)
4	IQ	Improve Quality	Gilson, L.L., Mathieu, J.E., Shalley, C.E. and Ruddy, T. (2005) Molleman, E. (2000)
5	IF	Improve Flexibility	Womack, J. et al. (1990) Allwood, J.M. and Lee, W.L. (2004) Monden, Y. (1983)
6	IR	Inventory Reduction	Shingo, S. (1990) Suzuki, T. (1995) Shen, C.H. and Wacker, J. (1997)
7	LTR	Lead Time Reduction	Al-Najjar and Alsyouf (2000) Schonberger (1986) Tajiri and Gotoh (1992) Teresko (1992)

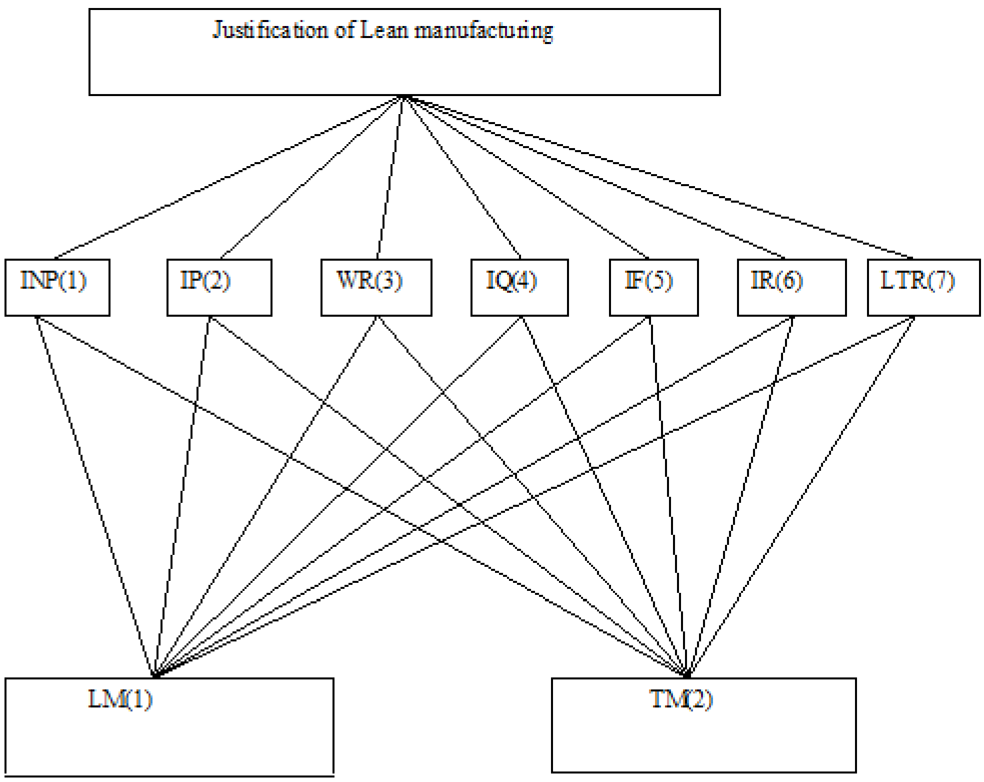

Fig. 1: Schematic of AHP model

RESULTS AND DISCUSSION

When we make AHP hierarchy model, table 1 shows seven main factors which are considered for analysis. AHP model developed as shown in Figure 1 is used for justification of Lean manufacturing in SMEs. Then we make pair-wise comparison judgment matrices to find out the normalized weight. Pair wise criteria comparison matrix shown in table 3.4, this table shows all the seven major benefits of lean manufacturing. After that we calculate the CR value to check the degree of consistency of the pair wise comparison matrix and CR for level 1. Then we follow same procedure to find the PV and CR for other levels. Then table 3.6 shows the results. We observed from that all seven factors of lean manufacturing have more PV in comparison to traditional manufacturing. We also examined that CR value is less than 0.1 for all decision factors. Local weight of attributes for alternatives. Global weight of major benefits for lean manufacturing.

Global weights have been calculated by following method:

Individual weight of the main factor = P.V. value from the respective normalized table

Individual weight of the sub factor = P.V. value from the respective normalized table

Global weight of main factor = individual weight of that main factor

Similarly, global weights for other strategic factors and sub factors can be calculated:

Global Wt. of lean manufacturing (LM) = Level 2 Wt. × LM Wt.

Global Wt. of traditional manufacturing (TM) = Level 2 Wt. × TM Wt.

Total global Wt. = sum of the global wt. of respective column.

Out of seven major benefits of lean manufacturing, lead time reduction has highest global weight

(0.33832). minimum lead time is required to obtain maximum profit because lead time decrease production increase.

Second highest global weight is to increase productivity (0.22258). If productivity increased then net profit increase. So we increase the productivity in such a manner that overall cost of operation decrease. Improve flexibility has third highest global weight whose global weight is (0.15218). If flexibility increases in production system then our profit increased. Fourth highest global weight is improves quality (0.07793). With the help of lean manufacturing, quality of product increased because we use standard process to make a product. Waste reduction is the fifth benefit of lean manufacturing whose global weight is 0.04861. With the help of lean manufacturing we eliminate non value added process so that our wastage is reduced. Six benefit of lean manufacturing is inventory reduction and its global weight is 0.03804. With the help of lean manufacturing, raw material and work in process inventory decreased because of standard process and JIT. Next benefit of lean manufacturing is increased net profit. When lean manufacturing used then production increased, inventory decreased, waste decrease, lead time decrease, increase flexibility and improve quality. So that effect of these factors our net profit increased. Global desirability index of lean manufacturing and traditional manufacturing shown in table 3.9.Global desirability index of lean manufacturing is 0.89568 and traditional manufacturing is 0.10431. So this analysis shows that application of lean manufacturing is better than traditional manufacturing.

The term Lean first defined by Womack, Jones and Roos (Womack et al., 1990, Womack and Jones 1996) which is another name of Toyota production system (TPM). Womack at al. (1990) wrote a book whose name is "The Machine That Changed the World". In this book first time "Lean manufacturing" or "Lean Production" was used. Womack and Jones (1996) write second book whose name is "Lean Thinking". In this book they described that lean manufacturing is not only a technique but it is a way of thinking and we improve the organization culture in such a way that everyone in the organization take participate to continuously improve operations. Karlsson and Ahlstrom (1996), states that lean production spread throughout the organization. It consists of lean procurement, lean development, lean manufacturing and lean distribution.

They states that lean manufacturing contain following items i.e. continuous improvement, elimination of waste, zero defects/JIT, multifunctional teams, decentralized responsibilities/integrated functions, vertical information system and pull versus push. The main aim of lean is to continuous improve in effectiveness and efficiency of organization by reducing waste. According to Womack and Jones (1996), an organization must find out the customer need and what a customer think as a value. Then an organization eliminates the non-value added process or waste and use only value added process. According to Nicholas (1998) waste can be found in any place and in any time in a production system and waste are found in various forms.

These wastes cannot add any value to the product but consume resources. Azharul and Kazi (2013) have observed that organization should identify the various manufacturing wastes and should improve the manufacturing processes to make them more effective. According to Russell and Taylor (1999), if we use more than minimum required resources to make a product then wastage occurs in the production system. The main aim to introduce lean production in any organization is to reduce waste, lead time and cost by increasing productivity and improving quality (Shriparavastu and Gupta, 1997). According to Roberto et al. (2013), there is positive and significant relationship between lean practices, quality, delivery, cost and flexibility. According to Melles (1997), lean production is not a new principle of management technique but it is combination of existing principles. Khokela (1992) observed that there are different methods to reduce cycle time like we use Just in Time principle to decrease stock of inventory and we decentralized the organization hierarchy.

Khokela also suggest that if we decrease the number of component in a product and reducing the material flow helps to simplify the production processes. Boyer and Sovilla (2003), states that successful implementation of lean manufacturing in an organization depends upon the top management support. Top management courage their employees and respect their efforts. If top management does not respect their efforts and discourage them then lean manufacturing cannot achieve their goal and ultimately lean manufacturing fail. Hayes (2000) states that first we proper plan the lean manufacturing after that we implement the lean manufacturing. Holland and Light (1999) states that any productivity improvement technique implemented in an organization then top management have clear vision and strategy about the cost and duration of project. Storch and Lim (1999) states that a clear communication required between shifts as well as all value stream to successfully implement the lean manufacturing in an organization. Robert and Rapinder (2013) make a lean system reliability model which determines the reliability of whole lean system. According to Manimay (2013) implementation of lean in Indian industry decrease manufacturing lead time, increased productivity and improve first pass correct output.

Top Management commitment (TMC)

Top Management Commitment is very important to implement the lean manufacturing. Top Management creates interest in organization to implement the lean manufacturing and also communicate to everyone for implement the lean manufacturing (Boyer and Sovilla, 2003). For implementing lean manufacturing, clear communication required between shifts as well as all value streams (Storch and Lim, 1999). If workers feel that Top Management does not respect their work, then discouragement occurs in workers and implementation of lean manufacturing fail. So all the staff members including top management involves an active engagement for implementing lean manufacturing. McLachlin (1997) describe the visible demonstration of commitment by managers is one of the usual management initiatives to support lean manufacturing. Management should manage the LP adoption process with proper planning and within time limit so that LP gives its outcome (Pedro et al. 2013).

CONCLUSIONS

In this paper, the critical success factors of lean manufacturing have been studied. There are total twelve critical success factors of lean manufacturing. Top management commitment got highest rank means it is most critical factor to successfully implement the lean manufacturing in organization. Top management commitment followed by process management, organization culture, employee training and team building, Just in time and lean practices, application of advanced tech. and tools, product design and development, value stream mapping, total productive, inventory management, supplier development, and customer involvement.

The success rate of lean manufacturing in organizations is low due to its barriers. So the author finds out the barriers of lean manufacturing. After that the author finds out the solutions to overcome the barriers of lean manufacturing. In this paper, the author presents a scientific framework to rank the solutions of lean manufacturing in organization to overcome its barriers by using a multi criteria technique which combines fuzzy AHP and fuzzy TOPSIS.

Fuzzy AHP is used to get weights of the barriers of lean manufacturing. Fuzzy TOPSIS is utilized to rank the solutions. Use of lean manufacturing process got highest rank and improved communication system got last rank.

These finding motivate the organizations to implement the lean manufacturing.

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