Lean Production applications: Examined and unexamined domains

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Abstract

During the past two decades, manufacturing companies are facing severe competition. One of the strategies followed by these companies to face the competition is the implementation of Lean Production (LP). The implementation of LP has been examined by the researchers in several domains. In order to explore such researches, the literature review reported in this paper was carried out in two phases. In the first phase, the LP researches on application in engineering products were examined. In the second phase, the LP application in industrial sectors was examined. The results of the examinations revealed that LP has been applied on the production of several products and in many industrial sectors. Yet several other industrial sectors are yet to taste the implementation of LP. These examined and unexamined domains of lean production applications have been signified in this paper.

Key words: Lean production, Manufacturing companies, Industrial sectors, Lean tools, Value stream Mapping, 5S.

1 Introduction

During the recent days, companies are forced to increase the efficiency of the manufacturing processes to meet the ever increasing competition (Dhiravidamani et al 2018; Ramos et al 2018; Goncalves & Salonitis 2017; Porter & Lee 2013). In line to this development, Lean Production (LP) principles are increasingly being implemented in manufacturing companies to reduce cycle time and to improve productivity and quality and to achieve customer satisfaction (Seth et al. 2017; Jasti & Kodali 2016). The efficiency of the manufacturing processes is improved through the implementation of LP principles by eliminating seven wastes namely motion, waiting time, over production, over-processing, defect, inventory, transportation and reducing the variability of the internal resources and processes (Nadeem et al. 2017; Anvari et al. 2011; Shah et al. 2008).

In 1950, Toyota Corporation faced high level of layoff and labour dispute. Japan's productivity was as low as one-eighth and was too poor to buy new machines at that time. As a result, new production system emerged to survive by increasing the productivity with less money. This system was later termed as Toyota Production System (TPS). Two Japanese engineers by names, Taiichi Ohno and Eiji Toyoda developed the

TPS between 1950 and 1975 (Ohno 1998). As the extension of TPS, LP emerged in the world.

Many researchers have claimed that implementation of LP system facilitates the companies to achieve performance enhancement. LP emphasizes on achieving performance enhancement through continuous improvement through systematic elimination of wastes (Ramesh & Ravi 2017; Yang et al. 2011; Pool et al. 2011; So & Sun 2010; Thomas et al. 2009; Naslund 2008; Taj and Berro 2006). The term lean was first coined by Krafcik (1988). Subsequently, LP began to be propagated widely after Womack et al. (1991) released the book titled "The Machine that changed the world". During its initial days of propagation, LP was customized to suit large size organizations. There were little reports on implementing this paradigm in small and medium sized organizations (Gurumurthy & Kodali (2010)). In the background of making this observation, the literature was surveyed to identify the examined and unexamined domains of LP implementation in the manufacturing engineering arena. The details of conducting this literature survey are reported in this paper.

This literature survey reported in this paper was begun by gathering research papers from the databases namely Google scholar, Science direct, Springer and Taylor and Francis by inputting the keywords namely, lean production, lean manufacturing and lean implementation. Under the first category, the papers reporting researches on application of LP in the production of engineering products were reviewed. Under the second category, the papers reporting researches on applying LP in industrial sectors were reviewed. The details of carrying out these activities are presented in the following sections of this paper.

2 Lean production on engineering products

Reviewing the papers reporting researches on lean manufacturing revealed that the application of LP and its tools on various engineering products are highly being examined by the contemporary researchers. In this direction, 17 papers dealing with such researches on 17 different products were identified. The researches reported in these papers are highlighted in Table 1.The researches reported in these papers are described in the following paragraphs.

Table 1 LP implementation and tools used on engineering products

Serial Number	Research paper	Products	Tools used
1	Cui et al. (2018)	Solar cell	Process optimization
2	Deshmukh et al. (2017)	Bottle molding machines, filter	*Kaizen*

		masks for pharmaceuticals, electrical component manufacturing and assembling, Customized gear manufacturing	
3	Nallusamy & Saravanan (2016)	Gear shaft	Value Stream Mapping (VSM)
4	Kumar et al. (2014)	Hydraulic cylinders	VSM, method study,
5	Paranitharan et al. (2014)	Modulator valve	VSM, line balancing, layout change, *Jidoka*
6	Eswaramoorthi et al. (2011)	Machine tools	JIT, pull system and kanban Visual management, Single piece flow, line balancing, Heijunka-leveling variety/volume, cell layout , VSM Jidoka, Single Minute Exchange of Die (SMED), Andon
7	Mohanraj et al. (2011)	Pump	VSM and Quality Function Deployment (QFD).
8	Vinodh et al. (2010)	Cam shafts	VSM
9	Grewal (2008)	Bicycle	VSM
10	Sahoo et al. (2008)	Forged components	VSM
11	Abdulmalek & Rajagopal (2007); Brunt (2000)	Steel	Cellular manufacturing, 5S, VSM, JIT, Heijunka, Total Productive Maintenance (TPM) and Visual systems.
12	Cumbo et al. (2006)	Steel components	Statistical process control
13	Kumar et al. (2006)	Die cast components	Current state map, 5S, Total Productive Maintenance (TPM).
14	Abduelmula et al. (2005)	Robotic assembly cell	Preventive maintenance, SMED, two bin system, layout change.
15	Mukhopadhyay & Shanker (2005)	Tyres	Kanban

16	Soriano et al. (2002)	Ceramics tableware	Pull system, zero defect, Just In Time (JIT), Cross Functional Team (CFT)
17	Mottershead (2001)	Capital equipment	Pull system, kaizen, visual factory

Cui et al. (2018) reported the application of LP in the Photovoltaic (PV) cell manufacturing production lines. Most of the PV manufacturing companies have negative returns. After introducing the production to a lean one by tuning the diffusion process, the negative impacts caused by the poor quality of the wafer are reduced. By the use of this better process design and control, the company could reduce the cost and improve the quality, and generate profit. Deshmukh et al. (2017) mentioned the application of LP principles for increasing the productivity in manufacturing of bottle molding machines, filter masks for pharmaceuticals, electrical components manufacturing and customized gears. The productivity improvement was achieved by improving the labour management, reducing the wastes and cost, increasing the profit ratio, enhanced quality and higher degree of customer support. They have also mentioned that lean is not extensively used in India.

Nallusamy (2016) reported the application of LP in a gear shaft manufacturing company using VSM technique. He stated that LP is yet to be applied in many manufacturing companies. Kumar et al. (2014) evaluated the LP application by minimizing the setup time and cycle time in manufacturing of hydraulic cylinders. The process was evaluated in detail and counter measures were proposed to improve the operations thus reducing the lead time by fifty percent. Paranitharan et al. (2014) implemented lean approach in modulator valve manufacturing through VSM by minimizing the non-value added activities, lead time and work in process inventory by balancing the takt time.

Eswaramoorthi et al. (2011) studied the implementation of LP in machine tool manufacturing industry by designing and supplying a questionnaire. The results of analysing the surveyed data indicated the reasons for low priority towards implementing lean practices and adopting suitable measures to overcome the same. Mohanraj et al. (2011) have examined the application of QFD technique in an Indian pump manufacturing organization. QFD technique was used for scientific prioritization of wastes and their elimination. Moreover, VSM technique was proposed to identify the wastes, for streamlining the processes. Vinodh et al. (2010) applied VSM technique in an Indian camshaft manufacturing company for enabling leanness. The improvement in leanness metrics was found by preparing current state map and proposing future state map. They have suggested that the same tool can be deployed in other manufacturing organizations. The results of this research indicated that lean parameters significantly improved on applying VSM.

Grewal (2008) implemented LP by using VSM in a small bicycle manufacturing company by mapping the current activities carried out by the company and identifying scope for improvement. Takt time of the production processes were calculated to set the pace of production. The benefits achieved by the company are reduction in lead time, cycle time and inventory levels. Sahoo et al. (2008) have applied LP techniques to achieve substantial reduction in set-up time and work-in-process (WIP) inventory level in a forging company. Abdulmalek & Rajagopal (2007) identified opportunities for improvement using VSM in a large integrated steel manufacturing company. While mapping the current state, reduced lead time in production and lower WIP inventory were achieved. Similar to this kind of research, Brunt (2000) has applied VSM in the steel manufacturing sector, steel service centre and first tier component suppliers and Cumbo et al. (2006) in a rough mill. The lean performance metrics measured in both rough mill and the overall business level were compared against the benchmark. It was found that the companies involved in implementing LP shortened their order-to-delivery lead time.

Mukhopadhyay & Shanker (2005) reported the implementation of kanban in a continuous product line of a tyre manufacturing company. They designed a practical approach to design the Kanban card, determine the number of kanbans and container size, enumerate the operating rules and carry out the day-to-day scheduling of machines. Besides the above papers, Soriano-Meier & Forrester (2002) reviewed the LP literature for identifying and measuring the lean variables and elements in the manufacturing industries. A quantitative analysis of LP was carried out in the ceramics tableware industry. Vital results and conclusions were arrived from the application and usefulness of the LP. The review papers presented in this section has led to an impression that LP has been applied to enhance productivity of various products. Its formal application on many other engineering domains is yet to begin. In total, the reviewing of the above research papers indicated that so far researchers have examined the application of LP on 18 products using 16 lean tools and techniques.

3 Lean Production in industrial sectors

An overview on literature arena indicated that rather than applying LP on specific products and components, some researchers have reported its application in certain industrial sectors. In this context, the literature review being reported in this paper was carried to identify various industrial sectors that got benefitted by applying LP concepts. The researches presented in these papers are highlighted in Table 2 These researches are briefly described in the following paragraphs.

Table 2 LP implementation in manufacturing organizations

Serial Number	Research paper	Industrial sector	Tools used
1	Dhiravidamani et al.(2018),Nallusamy (2017); Upadhye et al.	Auto components manufacturing sector	Cross Functional Team (CFT), Just In Time (JIT) , TPS, *5S*, U shaped layout,

	(2010a); Motwani (2003); Seth & Gupta (2005); Yadav et al. (2010); Lee & Jo (2007); Domingo et al. (2007); Gunasekaran et al. (2000), Paranitharan et al. (2011)		*kaizen* and VSM, line balancing and kanban, continuous improvement
2	Dudley (2005); Crute et al. (2003); Bamber & Dale (2000)	Aerospace components manufacturing sector	VSM, Kawasaki Production System (KPS)
3	Gurumurthy & Kodali (2009)	Consumer goods sector	JIT, Benchmarking.
4	Gurumurthy & Kodali (2011), Czabke (2007)	Wood manufacturing sector(Doors, Windows, drawer fronts)	VSM, JIT
5	Borges Lopes et al. (2015), Upadhye et al. (2010b)	Food and beverage sector	VSM, Single Minute Exchange of Die (SMED) and *5S*
6	Kumar et al. (2018), Saravanan et al. (2018), Upadhye et al. (2010a), Achanga et al. (2006)	Small and Medium Enterprises	*5S*, *kaizen*, Total Productive Maintenance (TPM) and total employee involvement, Delphi techniques.

Kumar et al. (2018) reported the implementation of Lean-Kaizen concept in a small- and medium-scale enterprise (SME). Current state map was prepared to describe the existing situation of the shop floor. Takt time was calculated, and bottlenecks were identified and future state map was developed. The "5-why" method was used for identifying root causes .The study reported benefits such as reduction in machine setting time by 65.85%, manpower by 40%, production lead time by 69.47%, and value added time by 75.25% which smooth production and ease working condition of the industry. Dhiravidamani et al (2018) presented a case study carried out in a foundry division of an auto parts manufacturing industry. Two lean tools namely value stream map and Kobetsu-Kaizen were implemented to improve along with computer-based lean audit system for measuring the lean characteristics and improving the production performances. The implementation of these tools resulted in the reduction of sand leakage, average core rejections, air lock problem, reduced set-up time, lead time, non-value-added time and number of operators.

The importance of adopting LP has been demonstrated by Nallusamy (2017) in an Indian midsized auto components manufacturing industry. The processes were improved by using situation specific set of tools and techniques like team based work. The improvement in the process met the requirements of achieving shorter product development, reduction in manufacturing lead-time and lowering the setup/changeover times. Paranitharan et al. (2011) proposed a five step approach for visually identifying the

wastes in the current practices of manufacturing brake actuators. The implementation was carried out through layout modification and balancing the *takt* time in the automotive assembly line. These tasks resulted in significant productivity improvement, lead time, and inventory reduction and also minimization of the rejection rate. Yadav et al. (2010) studied the application of lean principles and then investigated the level of its implementation in automotive industry. Similar, researches have been reported in Motwani (2003); Seth & Gupta (2005); Mohanty et al.(2007); Lee & Jo (2007); Domingo et al. (2007); Gunasekaran et al. (2000). Several LP tools, approaches and systems like TPS, *5S*, Hoshin exercise, U shaped layout, *kaizen* and VSM in auto component industry were applied while carrying out these researches.

Dudley (2005) studied the application of VSM and associated analytical tools in aerospace industry. This has been done with the focus on reducing the inventory and improving quality of the products. The impact of improved floor employee involvement was also evaluated. The results of this study indicated that the development of team skills and empowerment play crucial roles in LP implementation. Crute et al. (2003) also discussed the key drivers of LP in aerospace industry and examined the difficulties that arise while implementing LP. Bamber & Dale (2000) reported the application of LP in an aerospace manufacturing company and mentioned that a number of methods of LP implementation were not used as effectively as in the electrical motor manufacturing environment. Gurumurthy & Kodali (2009) utilized a structured benchmarking process to list out the elements and performance measures of LP. Further the gaps in terms of performance and practices of consumer goods segment were listed. It was believed that managers would be able to apply benchmarking to gauge the LP implementation in their companies. Only a preliminary benchmarking study was carried out and not all the steps of the benchmarking process proposed were validated.

The significance of implementing LP in wood products has been explained by Gurumurthy & Kodali (2011). They enabled practitioners to appreciate the role of simulation by making them understand the transformation of various departmental operations in the organization. Simulation studies were carried out to analyse current state VSM and future state VSM. Increased customer demand without any additional resources was achieved in the performance of the job shop production system in which doors and windows were manufactured. Czabke (2007) stated that in order to stay competitive in an increasingly global marketplace, wood products manufacturers are adopting new manufacturing approaches like LP. The adoption of LP principles resulted in the implementation of efficient and cost effective manufacturing practice by reducing defects, lead time and inventory. Communication issues were the major challenges faced during the implementation of LP.

LP was implemented in food products manufacturing sector also. The application of LP in the production system of food and beverage was investigated by Borges Lopes et al. (2015). They have used the tools namely VSM, SMED and *5S*, and the corresponding shift in philosophy in the production system. In addition to the application of LP tools, major implementation drawbacks were identified and analysed. The results of this analysis revealed that significant gains have been obtained by effecting continuous

improvement culture in both the companies. These authors found that production flexibility with reduced lead time was also achieved as a result of LP implementation. Upadhye et al. (2010b) studied LP implementation in a medium sized biscuit manufacturing plant. After the implementation, it was observed that *5S*, *kaizen*, quick changeover and TPM were some of the tools that effectively improved equipment availability, reduced wastage of material and improved quality. To survive the intense global competition, organizations were forced to find and adopt efficient and effective operations. Uncertainty and fluctuation in demand, necessity to provide wide variety of products to attract and hold the ever demanding customer were the major challenges faced by the companies.

Saravanan et al. (2018) reported that small and medium sized manufacturing company need to practice LP for facing rigorous competition and be profitable for the survival. They have proved this claim by introducing SMED in the manufacturing system of injection moulding facility. The change over time was reduced by about 67.72% from the current setup time of 39.94 minutes to less than 10 minutes. Thus reduction in change over time indirectly reduced production losses and increased the productivity. Upadhye et al. (2010a) have mentioned that LP has not been well adopted in SMEs. Achanga et al. (2006) have mentioned that critical success factors namely leadership, management, finance, organizational culture, skills and expertise were the most pertinent for LP implementation in SMEs manufacturing food products. Guidelines for the implementation of lean principles were also provided. SMEs were not willing to provide useful and timely information for carrying out further investigations.

It is found that LP has been adopted worldwide across numerous industrial sectors. Its prominence is significant in automobile, electronics and aerospace sectors. Quite interestingly, this inference corroborates with that of Panizzolo et al. (2012).

4 Unexamined domains

During the past three decades, researchers attempted to apply numerous techniques for implementing LP in several industrial sectors (Vinodh et al 2011). However, the result of literature review reported in the previous two sections indicates that this endeavour is yet to go a long way. Even if this domain is restricted to manufacturing arena, the list of uncovered industrial sectors is very long. These arenas unexamined by LP researches and practices are pinpointed in this section.

A reference to the Standard Industrial Classification (SIC) maintained by the USA Government revealed the existence of twenty manufacturing sectors. As mentioned in the previous sections, LP researches have been prominent in automobile, aerospace and electronic industrial sectors. However, LP research dealing with household products is scarcely reported in literature arena. In this context, the scope of this literature review was limited to household product industry under SIC (Code: SIC 3600). Subsequently, the products under this sector listed by SIC were identified and the LP implementation covering these products reported in literature arena was reviewed. These papers and the

candidate products of the LP research are presented in Table 3. The researches reported in these papers are briefly described in the following paragraphs.

Table 3 Papers reporting the researches on applying LP in household product industry

Serial Number	Household products dealt in the LP research	SIC Code	Papers reporting LP research and practices
1	Wet grinder	Not listed	Devi et al.(2018)
2	Refrigerators	3632	Chowdhury et al. (2014)
3	Sewing machines	Not listed	Obeidat et al. (2012)
4	Amplifiers	3650	Maneechote et al. (2010)
5	Washing machine	3633	Romano et al. (2009)
6	Water heaters	Not listed	Serrano et al. (2008)

Devi et al. (2018) used the lean tool VSM to understand the value added and non-value added activities in the wet grinder manufacturing system. VSM is employed to visualize the non-value added activities for improvement in the current process. The benefits achieved were reduction in the lead time of the assembly process by 23%. The researchers have used the FSM to meet the increased customer demand. Chowdhury et al. (2014) have reported a research on implementing LP by utilizing the Failure Mode and Effect Analysis (FMEA) and prioritizing the defects during the manufacturing of thermoformed refrigerator liners. The critical defects that lead to heavy losses are extra resources like man, money, material, time and machines. These defects soar up the investments. Analysing and effective management of these resources are of prime importance in preventing these defects, which eventually results in the implementation of cost effective solutions.

Obeidat et al. (2012) adopted LP by employing VSM technique to identify the wastes. Moreover, the application of lean techniques like line balancing, quality-at-the-source and layout redesign resulted in the reduction of 96% production wastes and 43% lead time in the sewing machine manufacturing line. Maneechote & Luangpaiboon (2010) reduced the mean and variance of the production time of amplifiers using LP principles in a first in first out control flow process layout. Romano et al. (2009) implemented LP concepts in the manufacturing line of washing machines by sizing the amount of "*Kanban* reintegration" codes by completely re-organizing the line. In the next stage, the progress of production flow was simulated using ARENA for studying the improvements of the business performances and achieving flexibility. Serrano et al. (2008) implemented LP in the water heaters manufacturing industry. Lean tools and techniques like

continuous flow and mixed levelling were implemented to optimize the design of the shop floor layout.

The results of the literature review presented above have indicated that some of the most commonly used household products like air-conditioners, compressors, generators and wet grinders have not been subjected to LP examination in research and practices. In India, the wet grinder manufacturing industry has been growing significantly since liberalization and is recognized as an important sector that contributes towards the development of the economy of the country. The successful implementation of LP in wet grinder manufacturing companies by exploiting the tools and techniques can enable the companies to cater to the customized demands and to meet the customer expectations for carrying out the day-to-day activities.

5 Conclusion

In lieu of global competition it is inevitable for the modern industries to excel in their business to sustain the market share. In order to cope up with the competitive environment, the industries need to adopt Lean manufacturing paradigm. Numerous research papers report the LP benefits obtained by many industries and through its application in various types of industries. After understanding the significant benefits that the companies imbibed, researchers recognized the potential of LP in implementation. Hence, during the recent times, researchers have been exploring the practicality of LP principles in different sectors. However, researches on applying LP in the manufacturing of household products like wet grinder and refrigerator are yet to be carried out. Such kind of research involving the application of LP in a wet grinder manufacturing companies is reported in Devi et al. (2018). The contemporary household products manufacturers practice conventional and non-scientific manufacturing practices. Hence it is essential to implement LP for and improving the performance level of the house hold products manufacturing companies.

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