A Review on Lean Manufacturing Techniques

Vatan Misra

Department of Production Engineering, Naraina College
Of Engineering and Technology, Kanpur, Uttar Pradesh, India

Abstract

Lean Manufacturing, since its inception in 1950s-60s by Toyota Company, is among the favorite of the techniques used by the companies to reduce wastes and increasing the productivity. The concept was developed to reduce the production times as well as the response times from the suppliers to the customers. But with time, it was used as a response to competitive and fluctuating business environments. The ability to survive in these competitive times depends on a company's ability to continuously respond to the changes and enhancing the product value. The value addition plays a vital role to achieve customer satisfaction and thus the perfection; hence an implementation of Lean is becoming the core subject of companies to sustain. Lean considers everything that doesn't add a monetary value to the product as a waste. This is the waste that the customers are not willing to pay for. Aspects of Lean such as Value Stream Mapping (VSM), Kanban, 5S, Just in Time (JIT), Kaizen, Total Productive Maintenance, Visual Management, Poka-Yoke, and Single Minute Exchange of Die (SMED) etc. are implemented to eliminate these wastes and results in increasing the profit margin of the company and also the customer satisfaction. An attempt has been made for the developing the lean route map for implementing the lean manufacturing system.

Keywords: **Cellular Manufacturing, VSM, SMED, Pull System**

Introduction

The Lean Manufacturing System of simply lean developed as a post war response to boost the Japanese industries in 1950s-60s by the Toyota and was initially called the "Toyota Production System" or the "Toyota Way" [1] [2]. Many authors symbolize lean as a waste reduction technique, but in practice lean manufacturing aims at maximizing the product's value by minimizing the wastes [3]. Lean defines the value of a product as realized by the customer/consumer and then makes the flow in line with the pull system and strives for perfection through continuous improvisation to eliminate the wastes by sorting out the Non Value Added (NVA) and Value Added Activities (VA) [3]. These NVAs are the activities which do not add any value for the customer and hence they are unwilling to pay for them [4]. These NVA or wastes are Overproduction, Defects, Waiting, Transportation, Excess Inventory, Excess Motion, Extra processing, Unused Talents [5]. Successful implementation of Lean Manufacturing elements can eliminate these eight wastes.

Overview of Lean Element

The elements of Lean that were considered by earlier researchers include Push and Pull System, Value Stream Mapping (VSM), Cellular Manufacturing, Kanban, Single Minute Exchange of Dies (SMED) etc. *Push system* relies on schedules which are often pre-determined. This type of system does not consider much about the waiting time or defects in the various levels of production system. The *Pull System* relies on the requisites of the customer/consumer thereby, checking over production and wastes at each level in the production system and thereby eliminating waiting at each junction in the production line [6]. Each activity whether it is Value Added of Non Value Added is to be streamed in order to identify the wastes that are flowing with the information and production process. This mapping is termed as *Value Stream Mapping* [7]. The grouping done in order to minimize the production time, transportation time and waiting time by smoothen the process flow is called *Cellular Manufacturing*. Line balancing and U –line concept improves the fluctuation line flow. *Kanban* delivers the right number of parts at the required time [8]. *Just in Time* ensures production without backflow, interruption and scraps or backflow thereby, decreasing the holding cost, easing the Takt-Time, and decreasing the chances of operator errors and machine failures [9]. Reducing the changeover time by converting internal setting time (carried out when machine is at halt) to external time (when machine is in operation) simplifying and streamlining the remaining activity is called Single Minute Exchange of Die (SMED) [10]. Improve the production volume, productivity and quality by reducing waste, overburden of equipment and operators, and unevenness [11].

Lean Implementation Review

All the features of a production system like productivity, quality, availability, production volume, and hence, the Overall Equipment Efficiency (OEE) can be increased by successfully implementing the Lean principles. A lot of surveys focus on a single or two elements or a combination of two-three elements. Lean can be implemented successfully in an organization by implementing all its elements and sequencing the implementation task. This literature review tries to incorporate and sequence the lean elements.

1. Scheduling

An organization can start initialization of manufacturing system implementation by defining a clear production plan. In Indian context, some industries use point solutions or customize in order to get their work schedule smooth. Others rely on rigorous production schedule and adopt a "launch and hope" approach. They rely on the firefighting skills of their senior workers in order to get the production complete. But when the volume of the products is high, automation through software like ERP or Microsoft Dynamics AX can help. The ERP system creates production orders (work orders) pointing out what should be manufactured in order to meet customers' demand. While scheduling, the capacity and material must be present. Releasing work without these will increase the Work in Progress (WIP) and will result in lowering the profitability.

2. Employee Perception

For successful implementation of lean, identifying the influencing factors on employees' perception is necessary. Surveying can help in identifying these perceptions. As per Losonci et al. [12], an organization should analyze and understand the cultural changes of workers in daily life as well as understand the shop floor environment (work environment). The surveys can help us to identify the factors which make the workers feel about the success of Lean transformation to reveal the building blocks of successful lean transformation. As per Armenakis et al. [13], the belief is a conviction or an opinion that may be subjected to systematic verification. As suggested by David et al. beliefs, work methods, communication and commitments influence the perception of an employee. The workers involvement and identification can be strengthened by the work methods. Training and awareness can help building the employee perception [14].

3. Value Stream Mapping or VSM

Value Stream Mapping or VSM is also referred to as the material and information flow mapping [15]. It is a lean method to analyze the current state in a manufacturing process and design a future state that makes a product to pass through various stages until reaching the customer. A VSM is a visual tool which displays all the critical steps in a manufacturing process and quantifies time and volume at each level. It depicts the flow of information and materials as they pass through each step. As per Rother et al. [16], Visual representation helps in identifying value addition activities in a Value Stream and eliminates NVAs. Drawing a future state map based on the improvement plan is the second step in Value Stream Mapping. Value Stream Map indicates waiting time, lead time, process time, inventory etc. from which we can identify the critical spots or the bottlenecks against the Takt Time. Fawaz et al. [17] illustrates that to evaluate the basic performance measures before implementing lean simulation can be used. The continuous improvement initiates with the bottleneck analysis. Simulation tool is necessary for prediction of inventory level during demand uncertainty [18].

4. Takt Time

It refers to the frequency of a component or a part that must be produced in order to meet the customers' demand. In case the demand increases, the Takt time increases and vice versa. It depends on the monthly production demand. AS per the suggestions of Rahani et al. [19], takt time helps in estimating the costs that is to be incurred in production, ahead of the storage and retrieval of finished goods, before time purchasing of raw materials, premature costs incurred on wages, the cost of missed opportunities and costs for excess capacity and holding.

5. Bottleneck analysis

Bottleneck analysis refers to the hindrances that exist in a production system which restricts the capability of a production line to produce at its full potential. It can be determined by determining the maximum cycle time (CT). It helps in determining the exact plant/line capacity.

Line Capacity= Bottleneck Cycle time X Total Available time (1)

If Bottleneck Cycle Time< Takt Time, the customers' demand can be met (2)

If Bottleneck Cycle Time> Takt Time, Customers' demand is not met (3)

In a manufacturing system, the takt time is identified by past projection or from expected future demand. The VSM then helps in bottleneck analysis through the known takt time and the gap between the demands/ requirements and the capacity is calculated [19].

6. Group Technology

As per the suggestions of Das et al. [20], grouping of the parts with similarities (in design and manufacturing) can make the production planning and manufacturing easy and flexible. This will in turn, help in the implementation of flexible manufacturing system. Dissimilar machines can be grouped together to form a cell concept.

7. Cellular Manufacturing

The grouping of miscellaneous equipments in order to manufacture a family of parts is called the Cellular Manufacturing [17]. The route map for every part family is provided by the Value Stream Mapping based on which, dissimilar machines are grouped together to form a cell. As per Wemmerlov et al. [22], these dissimilar machines can be grouped in a sequential manner to meet the process requirements of the family of similar types of products. Metternich et al. [21] suggested that the efficient and effective clustering of machines can be improved by moving workstations, workers or both into a U shaped line that improves employees' interaction. The success of cellular manufacturing depends upon the successful implementation of Line Balancing, U line manufacturing and flow manufacturing.

8. U- Line Manufacturing

It is a special type of CM that improves flexibility in a manufacturing system [20]. As per Monden et al. [23], the exit and entrance of the U line are placed on the same position. U shaped lines helps in reducing the number of workstations, improving the line balance, communication, visibility, flexibility, quality and material handling. Guerriero et al. [22] defines line flexibility for stochastic line system and suggests that U line gives a greater flexibility in increasing/decreasing the number of workers when demand uncertainty arises. The performance of the U line was evaluated by minimum work relatedness, minimum number of workstations and minimum workload smoothness. U line flexibility gets interrupted in mixed model production line by line misbalancing and can be overcome by clearly investigating sequencing and balancing tasks carried out at the same time.

9. Line Balancing

Monden et al. [23] in his work suggested that human factors or disruptions lead to the necessity of considering task-time variability which leads to the U line balancing problem. The instability of humans with respect to skill, motivation and work rate as well as the failure sensitivity causes variability in task time. As per Becker et al. [24] and Chiang et al. [25], task is itself a source of variability and explains the environment where the task is performed and the workers who perform the task. This variability can be minimized by reducing the cost of movement of machines and men. The time consumed by operator while walking and the variations in the cycle time of man and machine leads to the line imbalance.. The changeover times also adds on to this invariability. This line imbalance can be overcome by increasing/decreasing the men and machines within the workstation. The free flow of information and material in the process of manufacturing leads to the man-machine flexibility [23].

10. Flow Manufacturing

Producing a component or an item at a rate equal to the cycle time is termed as Flow Manufacturing. For successfully implementing the flow manufacturing, the need of U line layout, standardized cycle time, multi skilled operator etc. can't be ignored. Moreover, the machines and equipments should be standardized, user friendly and less expensive. The tedious process flow, as per Miltenburg et al. [26], can be balanced by customizing the machines in order to balance the workstation cycle time. This mixed model flow can be smoothened by designing workstations with small lot size and quick changeovers.

11. Single Minute Exchange of Die (SMED)

This concept was developed by Shingo [2]. Based on the time study and video study, he separated the changeover time from internal and external set up time. Internal set up time refers to the time consumed by the activities when the machine is stopped and on the other hand, the time consumed by the activities when the machine is in operation is called external set up time. The internal set up time or the on line activities and external set up time or the offline activities can be analyzed by the Yamazumi chart. Based on the analysis, the possible internal set up can be converted to external set up and the remaining internal set ups are streamlined through the introduction of multi operator working panel during on line activities and one touch set up arrangements to convert the changeover time to single minute. The sustainability can be attained by standardization. Shingo [2] proposed visualization and Standardization as a rule to overcome the adjustment and trial run and machine with multiple production tooling. The initial good parameter for the initial trail run can be achieved by Taguchi experiment design. This experimental design helps in reducing the wastages in time, material and money by eliminating the trials required before the start of mass production. Maintenance, quality, life, safety, plant layout, energy and cost are the deciding factors that affect the decision making process in Single Minute Exchange of Die (SMED). Almomani et al. [28], in his research on Multiple Criteria Decision making Techniques (MCDM), provided a systematic procedure to select the best set-up techniques. These techniques are Technique for Order Preference by Similarity to Ideal Solution or TOPSIS, Analytical Hierarchal Process (AHP) and Preference Selection Index (PSI). Greater system flexibility and productivity can be achieved through the integration of MCDM and SMED. As per Cheg et al. [29], the set up time influences the make span of the part family I cellular manufacturing. [30]

12. Batches

A set of similar types of products is called a batch. Conventional manufacturing systems run on buffer production system. This built in buffer system was introduced to overcome the material flow interruptions in case of machine/ equipment breakdown, changeover time, absenteeism etc. Lean focuses on zero inventories in order to increase the visibility of product flows and capacity utilization. [31]

13. Inventory

As per the studies, more than 60 percent of wastes in the industries are due to inventories. Inventories can be classified into Raw Material (RM), Work in progress (WIP) and Finished Goods (FG). If there is an increase in the inventory of either of the three, then there is less inventory turnover. Inventory plays a decisive role in a company's turnover. Inventory refers to the material that is stored in house in a firm. The sale of finished goods brings revenue to a company whereas, the material that stays in the factory adds to costs like the holding cost, space cost, etc. Literatures from over 1000 world class manufacturing units reveal that 34% companies try increasing the inventory turnover for at least ten years [32]. As per Sakakibara et al. [33], poor planning results in more WIP. The excess RM ordered takes up the space (space is calculated as a cost in Lean) and adds on the cost for holding (refers to the holding cost), defective parts can also lead to the increase in WIP. Unnecessary transportation between the workstations increases WIP inventory, overproduction leads to increase in FG inventories which are stored in the warehouses and add on to the holding cost. Some of this may even not sell at all. Inventories can be reduced by proper planning, Just in time methodology, improving the quality, productivity, availability, lead time, and delivery. As per the suggestions by Demete et al. [34], cellular manufacturing or dedicated line assembly or even manufacturing parts as per customer orders reduces the FG. Kanban, JIT and Pull System control the WIP.

14. Pull System

It is a production based on customers' demands. Smalley et al. classified pull into sequential, replenished, and mixed pull system. The success of pull system depends upon the size of batches flowing in a manufacturing system. Small batches (one piece at a time wherever possible) is advisable. One piece concept refers to the movement of a single part at a specific time in a production system and considers factors such as setup time, sequencing, make to order policy. In a operator walk cycle designed by Stockton et al. [44] for an existing single piece flow flexible manpower line, a repetitive sequence was allocated to the operators to load and unload machine tools. The machines in this manpower line were arranged in U line. In one piece production system, the operator starts producing when shown a signal card or a Kanban card. Li et al [42] suggested that a multi objective evaluation is needed for the design of uncertainty based on one piece flow. He also developed the fuzzy ant colony optimization model to evaluate the multi objective task in order to minimize the cycle time, cell load variation, number of cells and changeover count [43]. The study in this area is limited.

15. Kanban

Kanban refers to the scheduling system and is also called Justin Time (JIT). Its developer Taiichi Ohno developed it in order to improve manufacturing efficiency [45]. Lead time and cycle time of the process steps and full process is measured and problematic areas are highlighted [46]. It is basically a subsystem of Lean Manufacturing that was created to control the level of inventories and the production and supplies. As per the suggestions of Junior et al. [47], an implementer can easily classify and analyze the variations in Kanban with the knowledge of creation and accumulation of Kanban systems. Sipper et al. [48] classifies Kanban system into transportation Kanban system (for signaling) and dual card Kanban system for signaling both transportation and production.

16. Heijunka

Business environments now days, are volatile which can lead to fluctuations in customer demands and invariability in the production systems. Leveling of customer requirements/ demands is necessary to overcome these fluctuations as these fluctuations can result in unutilized machines, man, quality issues, breakdowns, machine idle times and defects (in overburdened capacities) [11]. Bohnen et al. [49] suggested leveling the low volumes and high mix production based on the principle of Group Technology (GT). Every Part Every Interval Concept (EPEI) helps in achieving balanced work load in the production system. As per EPEI, the products are grouped based on product families and every product type is manufactured in a periodic interval. Heijunka controls the variability of the product arrival sequence to permit a higher utilization of capacity, also it avoids crests and troughs in the production schedule [49][50].

17. Quality at Source

The quality in a production system depends upon the time in which a defective item is identified in a production process. Usually, First Part Inspection (FPI) and First Part Approval (FPA) are performed to check the quality at the source. If the quality matches the required standard then the production is continued otherwise, it needs to stop. Error Proofing or Poka Yoke is incorporated within the production systems to prevent as well as identify the error occurrences. In manual systems, this quality defect can arise due to human causes as well as due to machines. But in automated processes, it is caused due to human errors in loading, unloading and set ups. Among the three types of errors, setup errors are prioritized as it creates problems for more products. Implementing False proofing helps improving the quality standards and reduces the operator inspection time [25][41].

18. Kaizen

Kaizen is a Japanese word which refers to continuous improvement. It is a concept that requires an involvement of all the members in an organization from the CEO to the assembly line workers. It is also applicable to logistics and purchasing, which can cross organizational borders into supply chain [51]. The aim of Kaizen is to eliminate wastes and redundancies by improving the processes and standardization. Peoples' inherent desire for cost and quality is the basis of continuous improvement as per Berger et al. [37]. The success of Continuous Improvement or Kaizen depends upon the employee belief, teamwork, adaptation, leader engagement, initiative, motivation and training. It includes problem solving, training on Kaizen tools and techniques, developing ideas and recognition and awards [35] [38] [39] [40]. No one knows a machine and working environment better than those who are engaged in it. Kaizen tries to incorporate a feeling of getting rewards and recognition as a part of solving the problem or improving the process. It depends upon the bottom up approach. The suggestions are taken from the employees in a Kaizen suggestion form and checked for the veracity. If it is implementable then it is used and the cost saved by the implementation is calculated.

19. Work Standardization

Development of technical standards based on the consensus of companies, users, interests, standard organizations, users and government is termed as Work Standardization [52]. Interoperability, safety, compatibility, repeatability and quality can be maximized by Standardization. In the opinion of Berger et al. [37], standardized work is the basic tool for continuous improvement. It refers to a set of analysis tools that helps in the development of standard operating procedures (SOP). SOP contains all the information pictorially as well as written instructions about the processes that the employees have to perform, its cycle time, sequence, WIP and process controls etc. and represents the best thinking to perform a specified job within the stipulated time. Takt time fluctuations can be very well managed by the Standardized work. With the increase in work, more workers can be added and vice versa [36] [37]. It was introduced by Monden in 1983 as Standardized Work Chart (SWC), Standard Operating Sheet and Standardized Work Combination Table (SWCT). These were helpful in improving, analyzing and standardizing the work. The Standard Work Charts takes into consideration the operator movement and location of material with respect to machines and layout. Standard Operating Sheet describes the work instructions and standards while Standardized Work Combination Table combined manual work time, movements, and time taken by machines to process each operation in a sequence. The purpose of SWCT is identifying the wastes such as waiting, overburden, WIP etc. [25]

Incorporating and sequencing lean elements are the important factors for successfully implementing the lean manufacturing system. In this paper, the roadmap for implementing lean is proposed for implementing lean elements with other independent ones. Make a Value Stream Map (VSM) and try analyzing the slacks in the production system. Based on these gaps, decide a goal for the implementation. Secondly, incorporate the Group Technology and group the parts in families and form cells of machines based on the part groups. Then implement cellular manufacturing along with implementation of U line system and flow manufacturing. Try streamlining it with Line balancing and flow manufacturing. This depends on Single Minute Exchange of Die (SMED) and lot size reduction to streamline Raw Materials, Work in Progress Materials and Finished Goods. The fourth step is to implement Pull System. Fifth step is controlling the quality at source which depends on implementing Poka Yoke or Error Proofing. Sixth step involves Kanban to start production. Seventh step Production leveling. The eighth step is is simultaneous implementation of continuous improvement (CI) and Standardization. The last step involves EPEI to satisfy customers.

Summary

Organizations focus only on a few aspects of lean such as the pull system, cellular manufacturing, and production leveling etc. in order to drive their manufacturing systems. The elimination of lack of planning, sequencing, and interdependent factors of lean can result in long term success of manufacturing firms. To overcome this issue, lean elements are implemented in sequence with corresponding independent factors. The findings of the paper suggest the lean roadmap to implement Lean Manufacturing.

Conclusion

The conclusion of this review paper suggests that the successful implementation of Lean needs integration of various lean elements along with proper sequencing. The paper also suggests a detailed road map which gives a theory for implementing Lean. The proposed structure decreases the implementation time and reduces manufacturing system divergence. Lean Manufacturing system can be sustained successfully in a competitive working/business environment. Future research should try for an integration of Lean principles with automation in order to develop Lean automation. This concept can help us reaping the benefits of Lean along with automation to sustain industries with the changing times.

References

[1] *Ohno, Taiichi- Toyota Production System: Beyond Large-Scale Production, CRC Press, 1988.ISBN 978-0-915299-14-0.*

[2] *Shingo, Shingeo- A Revolution in Manufacturing: The SMED System, 1985.Stamfor, Ct.:Productivity Press.*

[3] *R. Sundar, A.N. Balaji, R.M. Satheesh Kumar- A Review on Lean Manufacturing Implementation Techniques, 2014..*

[4] *Kamarudin Abu Bakar, Md. Fazli Md. Sam, M.I. Qureshi- Lean Manufacturing Design of a Two-Sided Assembly Line Balancing Problem Work Cell, 2022 in Md. Najib Alii Mokhtar, Zamberi Jamaludin, Md. Sanusi Abdul Aziz, Md.*

Nazmin Naslan, Jeeferie Abd Razak- Intelligent Manufacturing and Mechatronics: Proceedings of SympoSIMM 2021, Springer Nature, p.250.

[5] *Jonathan Law- A Dictionary of Business and Management, Oxford University Press, 2009*

[6] *Berna Dengiz, Kunter S. Akbay- Computer Simulation of a PCB production line: Metamodeling Approach, Int. J. Production Economics 63 (2000) 195-205.*

[7] *Rother M., Shook, J- Learning to See: Value Stream Mapping to Add Value and Eliminate Muda, The Lean Enterprise Institute, Inc., Brookline, MA. 1999*

[8] *Graves, R., Konopka, J.M., Milne, R.J.-Literature Review of Material Flow Control Mechanism (1995). Production Planning and Control 6 (5), 395-403*

[9] *S.G. Li, Y.L. Rong, The reliable design of one-piece flow production system using fuzzy ant colony optimization, Computers & Operations Research 36 (2009) 1656 – 1663.*

[10] *Shingo, A Revolution in Manufacturing: The SMED System, Productivity Press, Portland, 1985.*

[11] *Liker, J.K, the Toyota Way, McGraw-Hill, New York, 2004.*

[12] *David Losonci, Krisztina, Demeter,Istvan Jenei, Factors influencing employee perceptions in lean transformations, Int. J. Production Economics 131 (2011) 30–43.*

[13] *Armenakis, A.A, Bernerth J.B, Pitts J.P, Walker H.J, Organizational change recipients' beliefs scale. Development of an assessment instrument. The Journal of Applied Behavioral Science 43 (4) (2007) 481–505.*

[14] *Rajesh Kumar Mehta, Dharmendra Mehta, Naveen K Mehta, An Exploratory study n employee's perception towards lean manufacturing systems, Management & marketing, Volume X (2012) issue 1/2012*

[15] *Manos, Tony (June 2006). Value Stream Mapping- An Introduction. Quality Progress. American Society for Quality. P 64*

[16] *Rother, Mike, Shook, John (1999). Learning to See: Value-Stream Mapping to create value and eliminate muda. Brookline, Massachusetts: Lean Enterprise Institute.*

[17] *Fawaz A. Abdulmalek, Jayant Rajgopal, Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study, Int. J. Production Economics 107 (2007) 223–236.*

[18] *McDonald T, Van Aken E.M, Rentes A.F, Utilizing simulation to enhance value stream mapping: a manufacturing, case application. International Journal of Logistics, Research and Applications 5 (2) 2002 213–232.*

[19] *Rahani AR, Muhammad al-Ashraf, Production Flow Analysis through Value Stream Mapping: A Lean Manufacturing Process Case Study, Procedia Engineering 41 (2012) 1727 – 1734.*

[20] *K. Das, R.S. Lashkari, S. Sengupta, Reliability consideration in the design and analysis of cellular manufacturing systems, Int. J. Production Economics 105 (2007) 243–262.*

[21] *Joachim Metternich, Sven Bechtloff, Stefan Seifermann, Efficiency and Economic Evaluation of Cellular Manufacturing to enable Lean Machining, Procedia CIRP 7 (2013) 592 – 597.*

[22] *Urban Wemmerlov, Danny J. Johnson, Cellular Manufacturing at 46 user plants: Implementation experiences and performance improvements, IJPR (2010)*

[23] *Guerriero F, Miltenburg J, The stochastic U-line balancing problem, Naval Research Logistics 50 (1) (2003) 31–57.*

[24] *Monden Y, Toyota Production System. Industrial Engineering and Management Press, Norcross, GA 1983.*

[25] *Christian Becker, Armin Scholl, A survey on problems and methods in generalized assembly line balancing, European Journal of Operational Research 168 (2006) 694–715*

[26] *Wen-Chyuan Chiang, Timothy L. Urban, The stochastic U-line balancing problem: A heuristic procedure, European Journal of Operational Research 175 (2006) 1767–1781.*

[27] *John Miltenburg, U-shaped production lines: A review of theory and practice Int. J. Production Economics 70 (2001) 201–204.*

[28] *Mohammed Ali Almomani, Mohammed Aladeemy, Abdelhakim Abdelhadi, Ahmad Mumani, A proposed approach for setup time reduction through integrating conventional SMED method with multiple criteria decision-making techniques, computer and industrial engineering 66 (2013) 461-469*

[29] *Hui-Miao Cheng, Kuo-Ching Ying, Minimizing make span in a flow-line manufacturing cell with sequence dependent family setup times, Expert Systems with Applications 38 (2011) 15517–15522.*

[30] *Ali Allahverdi a C.T. Ng b, T.C.E. Cheng b, Mikhail Y. Kovalyov, A survey of scheduling problems with setup times or costs, European Journal of Operational Research 187 (2008) 985–1032.*

[31] *de Haan J, Yamamoto M, Lovink, G, Production planning in Japan: rediscovering lost experiences or new insights, International Journal of Production Economics 71, 101–109*

[32] *Krisztina Demete, Zsolt Matyusz, The impact of lean practices on inventory turnover, International Journal of Production Economics 133(1) (2011) 154-163.*

[33] *Sakakibara, S., Flynn, B.B., Schroeder, R.G., Morris, W.T., 1997. The impact of just- in-time manufacturing and its infrastructure on manufacturing performance. Management Science 43 (9), 1246–1257*

[34] *Krisztina Demete, Zsolt Matyusz, the impact of lean practices on inventory turnover, International Journal of Production Economics 133(1) (2011) 154-163.*

[35] *Halvor Holtskog, Continuous Improvement beyond the Lean understanding , Procedia CIRP 00 (2013) 000–000.*

[36] *Jamie W. Flinchbaugh, Implementing Lean Manufacturing Through Factory Design, Massachusetts Institute of Technology, 1998*

[37] *Anders Berger, Continuous improvement and kaizen: standardization and organizational designs, Integrated Manufacturing Systems, 89 (2) (1997) 110-117.*

[38] *John Bessant, David Francis, Developing strategic continuous improvement capability, International Journal of Operations & Production Management, 9(11) (1999) 1106 – 1119*

[39] *Nadia Bhuiyan, Amit Baghel, An overview of continuous improvement: from the past to the present, Management Decision, 43 (5) (2005) 761 – 77.*

[40] *Mike Kaye, Rosalyn Anderson, Continuous improvement: the ten essential criteria International Journal of Quality & Reliability Management, 16 (5) (1999), pp.485 – 50935*

[41] *Clifford Martin Hinckley, Combining mistake-proofing and Jidoka to achieve world class quality in clinical chemistry, 12 (2007) 223-230*

[42] *S.G. Li, Y.L. Rong, The reliable design of one-piece flow production system using fuzzy ant colony Optimization, Computers & Operations Research 36 (2009) 1656 – 1663*

[43] *Miltenburg J, One-piece flow manufacturing on U-shaped production lines: a tutorial source. IIE Transactions 33 (2001) 303--21. 2001*

[44] *Stockton DJ, Ardon-Finch J, Khalil R. Walk cycle design for flexible manpower lines using genetic algorithms, International Journal of Computer Integrated Manufacturing 18 (2005) 15-26.*

[45] *Ohno, Taiichi (June 1988). Toyota Production System: Beyond Large- Scale Production. Cambridge, MA: Productivity Press. P 29.*

[46] *Shingo, Shingeo (1989). A Study of the Toyota Production System from an Industrial Point of View. Productivity Press p. 228*

[47] *Muris Lage Junior, Moacir Godinho Filho, Variations of the Kanban system : Literature review and classification, Int. J. Production Economics 125 (2010)13–21*

[48] *Sipper, D, Bulfin Jr, R.L. Production: Planning, Control, and Integration, Mcgraw-Hill, New York, 1997.*

[49] *Fabian Bohnen, Thomas Maschek, Jochen Deuse, Leveling of low volume and high mix production based on a Group Technology approach, CIRP Journal of Manufacturing Science and Technology 4 (2011) 247–25.*

[50] *Andreas Huttmeir, Suzanne de Treville, Annvan Ackere, Leonard Monnier, Johann Prenninger, Trading off between heijunka and just-in-sequence, Int. J. Production Economics 118 (2009) 501–507.*

[51] *Imai, Masaaki (1986). Kaizen: The Key to Japan's Competitive Success.*

[52] *Xie, Zongjie; Hall, Jeremy; McCarthy, Ian P; Skitmore, Martin; Shen, Liyin (2016). Standardization efforts: The relationship between knowledge dimensions, search processes and innovation outcomes. Technovation. Innovation and Standardization. 48-49:69-78.*

[53] *Sipper, D, Bulfin Jr, R.L. Production: Planning, Control, and Integration, Mcgraw-Hill, New York, 1997.*

[54] *Colin Herron, Christian Hicks, The transfer of selected lean manufacturing techniques from Japanese automotive manufacturing into general manufacturing (UK) through change agents, Robotics and Computer-Integrated Manufacturing 24 (2008) 524–53.*