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A Review Paper on Lean Manufacturing Implementation Techniques

Sandeep Ahirwar[1,*], Prakash Ahirwar[2], Akash Tomar[3]

Abstract

Lean manufacturing was initially designed to reduce waste and maximize resource usage. Later, lean manufacturing was developed in response to the competitive and ever-changing business environment. Organizations are compelled to deal with difficulties and complications because of the business environment's rapid change. The ability of any business, whether manufacturing- or service-focused, to consistently and methodically adapt to these changes in order to increase the value of its products may ultimately determine whether it will survive. But in order to effectively apply lean principles, organizations need to focus on all the components, such as value stream mapping, cellular manufacturing, U-line structure, line balancing, management of inventory, single minute exchange of dies, pull the framework Kanban, manufacturing process leveling, etc. In this article, an effort has been made to create a lean implementation road map for an organization's lean manufacturing system. In order to highlight the implementation sequence of lean elements in a dynamic business environment, analyses of the results of the exploratory survey are reported in this paper. The review's findings were also combined to create a coherent theory for the application of lean elements.

Keywords: value stream mapping (VSM), single minute exchange of dies (SMED), cellular manufacturing (CM), U-line structure, Kanban, material flow control (MFC)

INTRODUCTION

The majority of lean concepts originated in Japanese businesses, particularly with Toyota. Although many authors believe that lean manufacturing is a waste reduction approach, in reality, lean manufacturing facilities maximize the economic worth of the product by minimizing waste. The value of the product or service is defined by the customer according to lean principles, which also call for aligning the flow to the customer's pull and pursuing perfection through continuous improvement to cut waste by separating value-added (VA) and non-value-added (NVA) activities. Transportation, inventory, motion waiting, overproduction, overprocessing, and defects are the main causes of NVA activity wastes. One major obstacle to VA activity is the trash from NVA activities. The successful application of lean principles results in the elimination of these wastes. Numerous surveys show that the majority of researchers concentrate on one or two factors when determining if waste exists and offer their opinions on how to put these factors into practice.

***Author for Correspondence**
Sandeep Ahirwar
E-mail: sk2392028@gmail.com

[1-2]Assistant Professor, Department of Mechanical Engineering, Infinity Management & Engineering College, Patheriya Jat, Madhya Pradesh, India
[3]Associate Professor, Department of Mechanical Engineering, Infinity Management & Engineering College, Patheriya Jat, Madhya Pradesh, India

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Overview of Lean Elements

Lean concepts primarily emerged from Toyota and Japanese companies. Although many authors have stated that lean manufacturing is a technique for reducing waste, it maximizes the value of the product by reducing waste. Lean principles establish the value of the product or service as perceived by the customer, align the flow with the consumer pull, and pursue perfection via continuous improvement to remove waste by differentiating between VA and NVA work [1, 2]. By enhancing the process flow, one may reduce waiting times, travel times, and process times. Kanban is a material flow control (MFC) mechanism that provides the proper quantity of parts at the right time, and it further improves erratic line flow [3]. The production stage and the withdrawal stage are the stages of this Kanban implementation. A just-in-time production system is ensured by one piece flow, which lowers the chance of equipment failures and human mistakes as well as Takt time and allows for the adoption of a simple timetable without disruption, backflow, or scrap [4]. By converting potentially internal setting time—performed during machine stoppage—to external time—performed while the equipment is operating—Single minute exchange of dies (SMED)/one-touch exchange of dies (OTED) is a method of methodically reducing changeover time while also streamlining and simplifying the process.

Lean Implementation

Through the effective use of lean principles, the manufacturing system can reach its ideal state. The majority of lean elements research focuses on just one, two, or combinations of two or three aspects. Practically speaking, the incorporation of all lean parts and task sequencing for implementation are necessary for success. The integration and sequencing of lean aspects throughout the implementation phase, as well as any implementation-related problems, are explained in this literature study.

Scheduling

Any organization can begin the deployment of a manufacturing system by creating a defined production strategy. The production plan created by scheduling determines service order, resource allocation, and queue management. Due to the accessibility of scheduling software, this evaluation does not specifically address scheduling.

Employee Perceptions

Employee perception surveys serve to pinpoint the variables that affect how employees perceive successful lean transitions. According to Losonci et al. [5], the organization needs to comprehend the new shop floor work environment and assess how workers' daily lives are changing due to culture. To identify the fundamental elements of effective lean transformations, a thorough study and survey are conducted to learn what aspects influence employees' perceptions of successful lean conversions. The results of the poll classify the perception aspect into crucial internal variables (belief, commitment) and external variables (interactions, lean work method) that impact the lean implementation's accomplishment from the perspective of the workers. These findings imply that employee commitment levels, along with communication and working techniques, play a critical role in determining the success of the lean transformation.

According to Armenakis et al. [6], a belief could be an opinion or a conviction about the reality of something that isn't always clear or can't be scientifically verified. Mehta others recommend that belief, commitment, work style, and communication all have an impact on employee views [7].

Value Stream Mapping

"The collection of all the particular steps required for communicating a particular item through the three essential management responsibilities of every company operation: problem solving, management of information, and physical change," is how a value stream is defined. Value stream mapping (VSM) is a method for mapping the information and material flows necessary to coordinate the tasks carried out by producers, suppliers, and distributors to deliver goods to customers. A current state map was initially created, from which the cause of waste was found and the opportunity for applying various lean strategies was discovered.

According to Abdulmalek and Rajgopal [8], the visual depiction of VSM makes it easier to identify value-adding activities in a value stream and get rid of those that don't bring any value. Drawing is the second phase of VSM. an improvement plan-based map of the future state. The information in the VSM is accessible, which supports and confirms the decision to deploy a lean tool. It can also inspire the business to continue with the implementation after it has begun to achieve the intended goals. We can determine the bottleneck cycle time versus Takt time using VSM's clear indication of inventory, process time, lead time, waiting time, etc. Using simulation, Abdulmalek and Rajgopal's case study [8] compares the "before" and "after" situations to highlight potential advantages including shortened lead times for production and decreased work-in-process inventory.

Before implementing lean, Abdulmalek and Rajgopal [8] determined that a simulation model can be utilized to assess fundamental performance measures. The bottleneck is when the systematic continuous improvement process begins area. A static model makes it impossible to see how inventory levels would change under different situations, making it difficult to anticipate levels throughout the manufacturing process [9]. Thus, a simulation tool is required to predict the inventory level under unpredictable demand.

Takt Time

Takt time describes how frequently a part or component needs to be produced to keep up with demand from customers. Takt time changes depending on the monthly production demand; if the demand rises, Takt time drops; if the demand falls, Takt time increases, affecting the output interval. Rahani and co. [10]. It was suggested that the significance of measuring Takt time was due to the expenses and inefficiencies associated with producing ahead of demand, including the costs of finished goods storage and retrieval, the early purchase of raw materials, the early payment of wages, the cost of lost opportunities to produce other goods, and the capital costs associated with excess capacity.

Bottleneck Process

By ascertaining the line's maximum cycle time, the bottleneck process or constraint is located. The bottleneck cycle time determines the line/plant capacity. Line performance must be determined as a combination of bottleneck cycle time (C/T) and overall available time for the purpose to meet the needs of customers. The manufacturing system's takt time is determined either from the anticipated future demand or from the prior estimated production delivery. Utilizing VSM, bottleneck operations with known Takt times are located. Based on this information, the gap between capacity and demand is estimated, and a lean implementation plan is then carried out [10].

Group Technology

Das et al. [11] claim that for a flexible manufacturing system to be successfully implemented, items must be grouped based on common design and manufacturing qualities. This allows for flexibility in the procedure of manufacture along with the production plan. As suggested by the lean approach, different machines are placed together to form cells based on the grouping of parts through similar processes. The nature of the process, which changes from firm to firm, is the only factor that influences cell creation.

Cellular Manufacturing

The collection of several pieces of equipment used in cellular manufacturing (CM) is used to create a family of parts [8]. Every part family is given a route map by VSM, and the dissimilar machines are then put together to form cells based on the route map. Different machines are clustered sequentially to satisfy the processing requirements of a family of products. Moving workers, workstations, or both into a U-shaped line that enhances employee engagement may improve the effectiveness and efficiency of clustering machines or cells according to Metternich et al. [12]. Several studies and literature reviews indicate that the U-line manufacturing is a particular sort of cellular manufacturing system which induces multi-skill process knowledge through the implementation of CM. The collection of several pieces of equipment used in CM is used to create a family of parts [8]. Every part family is given a route map by VSM, and the dissimilar machines are then put together to form cells based on the route map. The successive clustering of these heterogeneous machines enhances the capacity for adaptation of the operating system [13]. Line weighing, flow manufacturing, and the proper usage of the U-line production system are all necessary for the CM system to function well.

U-Line Manufacturing System

The U-entrance line and exit are situated in the same location in Monden's [14] overview. Due to the line's two ends being so closely spaced from one another, a relatively thin U-shape typically results. U-shaped lines reduce the number of workstations while improving material handling, visibility, communication, and quality. Guerriero and Miltenburg [13] detailed the stochastic U-line system's line flexibility and proposed that, in the event of demand uncertainty, U-line structure offers more flexibility to increase or decrease the required workforce. A minimum number of workstations, a minimum degree of work-relatedness, and a minimum degree of workload smoothness were used to measure U-line's performance. With a mixed model production line, line imbalance virtually prevents U-line flexibility. To redress this imbalance, make sure examination of the simultaneous execution of balance and sequencing tasks. Using line balancing and production flow, the line imbalance is resolved [15].

Line Balancing

According to Monden [14], the U-line balance problem is caused by human factors or numerous disturbances when job time variability is taken into account. The task time variability is mostly caused by human instability in terms of labor rate, skill, and motivation as well as by how sensitive complex processes are to failure. According to Becker and Scholl [15] and Chiang and Urban [16], the task itself can be a source of variability and can be explained by the person performing the activity as well as the surroundings. By keeping the cost of transferring people and equipment to a minimum, these sources of unpredictability may be managed. Line imbalance is caused by machine cycle time. Moreover, change over time leads to an imbalance in the mixed model line that is required for lean. To address the line imbalance, the number of employees and machines at the workstation are adjusted based on demand. Through the free flow of information and materials during the manufacturing process, human-machine flexibility is achieved [16, 17].

Flow Manufacturing

A U-line layout, multi-skilled operators, uniform cycle times, designing operator work as standing and walking styles, and standard, reasonably priced, user-friendly equipment/machinery are all necessary for the effective adoption of flow manufacturing. Flow manufacturing works on the basis of creating a single item at a rate that matches the cycle time [17]. It has been proposed that by adjusting the machine to the workstation's cycle time, the addition of a tailored machine can balance the breakthrough or laborious process flow [18, 19]. The mixed model flow is accelerated by designing the workstation with a fast changeover and a small lot size.

Quick Changeover/Single Minute Exchange of Dies

Standardization is the last step in ensuring the durability of these reductions to setup time. Shingo [20] presented two principles for standardizing setup time: machine with different production tooling systems and visualizations and standardization rules for overcoming adjustment and trial runs. Setting parameters for the first successful product during the first trial run after changeover is one of the most important tasks in changeover. Using Taguchi experimental design, the first effective product setting parameter for the first trial run may be accomplished. The Taguchi experimental design decreases the number of tests required to begin mass production as well as material waste during the first production phase. Cost, energy use, facility layout, safety, life, and quality are all elements that influence SMED's decision-making process. along with upkeep.

Almomani et al.'s [18] research on multiple criteria decision-making techniques (MCDM) provides a systematic approach to selecting the optimal setup techniques, including analytical hierarchical process (AHP), preference selection index (PSI), and technique for order preference by similarity to ideal solution (TOPSIS), by taking into consideration the aforementioned factors. The combination of MCDM with SMED results in increased productivity and system adaptability. In the manufacture of cells, changeover time is crucial for batch sequencing. Cheng and Ying [19] state that in cellular manufacturing, the manufacture span of the part family is influenced by startup time.

Small Lot Size/Small Batch

Many components from the same part family make up a batch. Although it is expected that part families be provided in advance, lot sizing is a factor in the decision-making process. Buffer production systems provide the foundation for conventional manufacturing systems. Buffer quantity needs to be optimum in order to improve material flow, resolve difficulties with lead time and quality, and reduce waste [21, 22]. In order to improve capacity used and boost product flow visibility, lean manufacturing is commonly connected with zero inventories.

Inventory

According to surveys from multiple papers, inventory is to blame for 60% of waste in the industrial chain. These inventories are divided into three categories: finished goods (FG), work-in-progress (WIP), and raw materials (RM). Less inventory turnover results from an increase in RM, WIP, or FG inventory. Inventory has a significant impact on a company's turnover. According to extensive research on 1000 top-tier manufacturing companies, 34% of those companies have attempted to boost their inventory turnover for at least 10 years.

Sakakibara et al. [23] state that the supply of raw materials, defective parts, waiting to be processed to result in increased WIP, and needless travel between working stations or facilities to raise WIP inventory are the main causes of the extra RM. Additionally, excess production of parts beyond the plan results in FG inventories that wait. might never be sold or spend a lengthy period in the warehouse. By increasing quality standards, rejection rates, delivery rates, lead times, and customer satisfaction, inventories may be decreased. To regulate RM, material is either bought in response to demand or, in the case of new products, only after the client has approved the design.

Cellular production and dedicated line deployment, according to Demete and Matyusz [24], can regulate WIP. When parts are assembled or produced in response to a client order, FG is reduced, and FG is delivered to the customer more quickly than normal. WIP requirements are brought about by imperfections brought about by a manufacturing system without process control. Decoupling buffers are inserted between processes to correct the flaw and lessen the influence on the surrounding process.

Every team must decide whether to halt the line to address issues. Buffer goes against the lean philosophy, yet in real life, a safety buffer is required in the event of system fluctuations. Individual workstations may run longer hours to replenish the inventory if some operate slower than others and the buffers are depleted. Manufacturing lead times lengthen as a result, which raises WIP. The lean components that regulate the WIP are the Kanban and pull systems.

Pull System with One-Piece Flow

The pull rules allow for production to be based on client demand; the customer or downstream process "pulls" the good or service from the producer. The draw is separated into replenishing pull, consecutive pull, and mixed pull schemes. The key components of a successful pull system include product flow in tiny batches (striving for one piece flow wherever feasible), process pace to talk time (to prevent overproduction), signaling restocking through a Kanban signal, and gradual leveling of product mix and amount [25].

The idea of transferring one part at a time between procedures inside a cell is known as one-piece flow. One-piece flow manufacturing systems consider factors including sequencing, setup time, and make-to-order policies; as a result, such factors should be considered whenever scheduling production. Holtskog [25] developed the operator walk cycles utilizing a previous one-piece flow adaptable human line, where workers received a repeated pattern to load and unload machine tools.

Their flexible labor line essentially functioned as a flow process line with a U-lined arrangement of the equipment. The key elements to take into account while developing the one-piece flow are the choice of work models, the assignment of operations to U-lines, and the production order. When a task change or other task occurs in a U-line, the entire production line is disturbed. In this situation, a buffer is allowed in a one-piece flow depending on necessity to address these problems. When a user displays the Kanban card or other part-related signal, manufacturing in a one-piece pull system starts.

Li and Rong [26] proposed that to decrease cycle latency, changeover count, cell load variability, and the number of cells, the design of an uncertainty-based one-piece flow requires multi-objective assessment. They also recommended using an imprecise ant colony optimization model for this purpose. Studies and surveys in the field of one-piece flow are scarce.

Kanban

The Kanban component of the lean manufacturing system was developed to regulate component production, supply, and inventory levels. The implementer can categorize and assess the many Kanban variations if they have knowledge about the development and accumulation of the Kanban system [27].

The Kanban system can be put into two categories: the dual card Kanban system for signaling production and the transportation Kanban system for signaling. When there is a lack of predictability in demand, buffer maintenance is required to smooth production flow and reconfigure the Kanban system to reduce inventory. Hence, the Kanban system offers mixed model production coupled with the ideal amount of inventory, resulting in a shorter lead time for product delivery and efficient use of resources like humans and machines.

Production Leveling/Heijunka

The current business climate is volatile, which causes changes in client demand, which causes fluctuations in output. Initial client demand levelling is required to overcome this variation. Without leveled, this fluctuation results in underused capacity, such as idle hours for people and equipment or quality issues, malfunctions, and defects (in the event of overloaded capacities) [28]. Leveling low-volume, high-mix manufacturing based on group technology principles is required to meet shifting client demand. Researchers created a cluster approach that uses a family- oriented leveling pattern and part family creation to build a low volume, high mix manufacturing system. Every aspect every interval (EPEO) is how the production achieves a balanced workload [29]. According to the EPEI concept leveling pattern, which is based on product families, each type of product is produced on a regular basis. The idea behind Heijunka is to reduce the unpredictability in the order in which jobs arrive to maximize capacity utilization and to prevent peaks and troughs in the production schedule.

Quality at Source

In a system of lean production, the lot size is reduced to one piece. By delivering, processing, and evaluating each individual object, one-piece flow eliminates the need for lot-based statistical processes for quality control or random examination of lot samples. The production line is immediately halted when a fault occurs until the reason is found and fixed. To stop/detect mistake occurrences, the production line incorporates false proofing/Poka Yoke. The connection must be halted in the event of detection until the reason is removed.

In this situation, the line is equipped with automation that can be stopped by a human touch if a procedure goes awry. The loading, unloading, and setup faults caused by humans are to blame for the quality issues with automated equipment. Setup issues are given priority among these issues since they affect the quality of a significant number of items. False-proofing the setup, loading, and unloading is necessary to meet the strictest quality standards. False-proofing implementation raises the benchmark and simplifies operator inspection times [30].

Continuous Improvement/Kaizen

Deming defined the idea of continuous improvement (CI) as "improvement initiatives that enhance successes and decrease failures." The management-driven component of continuous improvement works to modify the workplace's culture. After the process is stable, it is necessary to employ CI element tools to identify the root causes of inefficiencies and execute efficient solutions to decrease such inefficiencies. Defining and designing a process with no inventories reveals waste, including idle time, average wait time, commodity issues, and resource troubles. Management must train stable employees with a basis in the business in order to reduce this waste.

According to Berger [29], management must have faith in CI since it is built on a trust in people's innate desire for quality and worth is going to finally "pay." CI is crucial for prospering in this cutthroat market. The elements of CI include training in problem-solving operations, CI strategies and tools idea management, and reward and recognition systems [26, 30–32].

Standardized Work

The standard work is the fundamental instrument for continual improvement, according to Berger [29]. The term "standard work" relates to the safest and most efficient way to do a task in the smallest reproducible amount of time, leading in efficient use of resources including people, machinery, and materials. Work standardized may be regarded as a collection of instruments for analysis that produce a set of standard operating procedures (SOPs). SOPs include operator work processes including process stages, work sequences, cycle time, work-in-progress, and process control, among other things. SOPs offer the greatest ideas for completing a task in the allotted amount of time. After parametric tests has been created, it is feasible to manage and enhance work design in conformity with demand through slowdowns or accelerated work. Standardized work aids in rearranging the workload in light of Takt time variation, allowing us to gradually add staff as demand rises. We can gradually withdraw people from the production line as demand declines [33, 34]. In 1983, Monden [14] created the Standardized Work Chart (SWC), Standardized Work Combination Table (SWCT), and Standard Operation Sheet (SOS). These tools are helpful for reviewing and enhancing the standardized work [14]. The SWC visualizes how materials are placed in relation to machines and the overall process flow. SOS identifies the user.

According to the majority of the poll, integrating and sequencing lean elements with dependent aspects is essential for the effective deployment of a lean manufacturing system. This study suggests a lean strategy for the implementation of lean components along with additional interdependent factors. Here are the steps to putting the lean components into practice: VSM for capacity and performance analysis. Take the time to determine the production gap, and then build your implementation goals on it. The second phase is the use of group technology, in which machines are grouped based on the part families that the parts are organized into. CM implementation is the third phase. Cell development is influenced by group technology.

Together with the successful deployment of the U-line system and flow manufacturing, the family VSM further streamlines the U-line system through line balancing and material/information flow through flow manufacturing. SMED and lot size reduction are crucial for the successful use of flow manufacturing because they simplify FG, WIP, and RM. The fourth phase, which depends on the aforementioned components, is the installation of the one-piece flow pull system. Combining consistency and continuous improvement is the ninth phase.

SUMMARY AND DISCUSSION

A case study from many literature reviews illustrates the discussion and implementation process of the lean element. To shift their manufacturing system towards success, the firm concentrates on a select few lean elements, such as GSM manufacturing, pull system, production leveling, etc. Eliminating tedious problems like a lack of direction, a lack of planning, a lack of sequencing, and interdependencies across lean aspects is what will ensure a manufacturing system's long-term performance in a competitive business climate. The dull problem is resolved by implementing the lean elements in accordance with the appropriate interdependent aspects according to a good strategy. The survey's findings suggest a lean road map that provides a clear roadmap for putting the lean manufacturing system into effect. In addition to an in-depth analysis of the lean concept, it describes some additional crucial elements such buffer stacking for difficult or time-consuming tasks, design of the pull system with one-piece flow, and one set flow to apply the EPEI concept.

CONCLUSION

The results of this study show that integration and simultaneous deployment of lean elements, as well as the right order, are required for a successful lean manufacturing system implementation. The study also suggests a thorough implementation road map that provides a cohesive theory for implementing the lean manufacturing system. The length of the implementation process is therefore shortened, as is the divergence in the production system, thanks to the suggested implementation structure. It is suggested that the lean manufacturing system may survive in a cutthroat corporate climate as a result. Future studies should look for scheduling structures that are in accordance with the EPEI pull system while considering all the lean components.

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