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A Review on Lean Manufacturing Implementation Techniques

R.Sundar[a], A.N.Balaji[b,*], R.M.SatheeshKumar[c]

[a]*Assistant professor, Department of Automobile K.L.N. college of Engg,pottaplayam-630611,Tamilnadu*
[b]*Professor, Department of Mechanical Engg,K.L.N. college of Engg,pottaplayam-630611,Tamilnadu*
[c]*Professor, Department of AutomobileEngg,K.L.N. college of Engg,pottaplayam-630611,Tamilnadu*

Abstract

The concept of lean manufacturing was developed for maximizing the resource utilization through minimization of waste, later on lean was formulated in response to the fluctuating and competitive business environment. Due to rapidly changing business environment the organizations are forced to face challenges and complexities. Any organization whether manufacturing or service oriented to survive may ultimately depend on its ability to systematically and continuously respond to these changes for enhancing the product value. Therefore value adding process is necessary to achieve this perfection; hence implementing a lean manufacturing system is becoming a core competency for any type of organizations to sustain. The majority of the study focuses on single aspect of lean element, only very few focuses on more than one aspect of lean elements, but for the successful implementation of lean the organisation had to focuses on all the aspects such as Value Stream Mapping (VSM),Cellular Manufacturing (CM), U-line system, Line Balancing, Inventory control, Single Minute Exchange of Dies (SMED), Pull System, Kanban, Production Levelling etc., In this paper, an attempt has been made to develop a lean route map for the organization to implement the lean manufacturing system. Analyses of the exploratory survey results are summarized in this paper to illustrate the implementation sequence of lean elements in volatile business environment and the finding of this review was synthesized to develop a unified theory for implementation of lean elements.

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Keywords: VSM, Cellular manufacturing, SMED, Pull system

* Corresponding author. Tel.: +0-452-209-0971; fax: +0-452-209-0070.
*E-mail address:*balajime@yahoo.com

1. Introduction

Lean concepts are mostly evolved from Japanese industries especially from Toyota. Lean Manufacturing is considered to be a waste reduction technique as suggested by many authors, but in practice lean manufacturing maximize the value of the product through minimization of waste. Lean principles defines the value of the product/service as perceived by the customer and then making the flow in-line with the customer pull and striving for perfection through continuous improvement to eliminate waste by sorting out Value Added activity(VA) and Non- Value Added activity(NVA). The sources for the NVA activity wastes are Transportation, Inventory, Motion Waiting, Overproduction, Over processing and Defects. The NVA activity waste is vital hurdle for VA activity. Elimination of these wastes is achieved through the successful implementation of lean elements. Various Survey demonstrate that most of the researcher focus on one or two elements for finding out the existence of wastes and suggest their views on implementing these elements.

2. Overview of Lean Elements

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The major elements considered by the earlier researchers for the implementation of the lean manufacturing system are *Value stream Mapping (VSM)*which defines value stream as “Each and every activity including Value-Added activity (VA) and Non-Value-Added activity (NVA) required to convert the raw material into finished product through the mapping of process and information flows essential to every product” [2], *Push and Pull System* which describes, the Pull system rely on customer requirement whereas push system rely on predetermined schedule. [1],*Cellular Manufacturing*defines the facility grouping in order to produce the product with minimum process time, waiting time, and transportation by smoothen the process flow. Further fluctuating line flow is improved by U-line concept and line balancing concept,*Kanban* is Material Flow Control mechanism (MFC) which delivers the right quantity of parts at right time [3]. Stages of this Kanban implementation are production stage and withdrawal stage. *One piece flow*ensure just-in-time production system in order to adopt straightforward schedule without interruption, backflow or scrap, relaxing the Takt time and decreasing the risk of machine failures and operator mistakes [4]. *Single Minute Exchange of Dies (SMED)/One-Touch exchange of Die (OTED)* is systematic reduction of changeover time by converting possible internal setting time (Carry out during machine stoppage) to external time (performed while the equipment is running) and to simplify and streamline the remaining activity [5]. *Production Levelling*enhancesproduction volume as well as production mix and production efficiency by means of reducing waste, unevenness, and overburden of people or equipment [6]. Levelling of parts leads to successful implementation of *Every Part Every Interval (EPEI)* concept,*Employee perceptions* include Belief, commitment, work method and communication, for lean transition the motivation for cultural change is needed to improve employee perception. The other supporting elements such as TPM, TQM are not considered in this review article.

3. Review of Lean Implementation

The perfect strive of the manufacturing system can be achieved through successful implementation of lean elements. Majority of the survey on lean elements focuses on only one or two element or combination of two or three elements. For successful implementation of lean, practically need incorporation of all lean elements and sequencing of implementation task. This literature review explains the incorporation and sequencing of lean elements during implementation period along with implementation issues.

3.1 Scheduling

By defining a clear production plan any organization can start initializing the manufacturing system implementation. The production plan generated by scheduling decides service order, allocation of resources and manages queue of service request. This review does not focus the scheduling due to readily available scheduling software’s.

3.2 Employee perceptions

Survey on Employee Perception helps to identify the influencing factors on employees’ perceptions for successful lean transitions. Losonci et al. [7] suggest that the organization must understand the new shop floor work environment and analyze the cultural change of workers’ in everyday lives. The detailed study and survey helps to determine which factors make workers feel that lean transformation was successful in order to reveal the building blocks of successful lean transformations. The conclusion of this surveys stratify the perception factor into critical intrinsic factors (commitment, belief) and external factors (lean work method, communication) which affect the success of the lean implementation from workers’ point of view and suggest that the possibility of the lean transformation success, is on the hands of employees’ commitment levels, beliefs, communication and work methods. [7] Armenakis et al. [8] suggested that the belief is an opinion or a conviction about the truth of something that may not be readily obvious or subject to systematic verification. David et al. suggest that employee perceptions can be influenced by Belief, Commitment, Work method and Communication. Work methods can strengthen worker identification and involvement, particularly commitment. The employee perception can be achieved through training and awareness by defining road map, metrics and measurement [9].

3.3 Value stream mapping (VSM)

Value Stream is defined as “the set of all the specific actions required to bring a specific product through the three critical management tasks of any business: Problem Solving, Information Management and Physical Transformation”. Value Stream Mapping (VSM) is the process of mapping the material and information flows required to coordinate the activities performed by manufacturers, suppliers and distributors to deliver products to customers. Initially a current state map was drawn from which the source of waste identified and its finds the opportunity for implementing various lean techniques. Rother et al [10] suggest that the Visual representation of VSM facilitates the identification of the value-adding activities in a Value Stream and elimination of the non-value adding activities. A second step in VSM is to draw a future state map based on improvement plan. The availability of the information in the VSM facilitates and validates the decision to implement lean tool and can also motivate the organization during the actual implementation in order to obtain the desired results. VSM clearly indicate the inventory, process time, Lead time, waiting time, etc and process flow from which we can sort out bottleneck cycle time against Takt time. Fawaz et al. case study investigate the ‘‘before’’ and ‘‘after’’ scenarios, through simulation which helps to illustrate the potential benefits such as reduced production lead-time and lower work-in-process inventory. Fawaz et al. [10] concluded that simulation model can be used to evaluate basic performance measures before lean implementation. The systematic continuous improvement starts with the bottleneck area. The prediction of levels throughout the production process is usually impossible with only a future state map, because with a static model one cannot observe how inventory levels will vary for different scenarios, so simulation tool is necessary for predicting the inventory level during demand uncertainty [11].

3.4 Takt time

Takt time refers to the frequency of a part or component must be produced to meet customers' demand. Takt time depends on monthly production demand, if the demand increases the Takt time decreases, if the demand decreases the Takt time increases which mean the output interval increases or decreases. Rahani et al.[12]Suggested that the importance of measuring Takt time due to the costs and inefficiency factors in producing ahead of demand, which includes Storage and retrieval of finished goods, Premature purchasing of raw materials, Premature spending on wages, the cost of missed opportunities to produce other goods, Capital costs for excess capacity.

3.5 Bottleneck process

Bottleneck process/constrain in the line is identified by determining the maximum cycle time in the line. The line/ plant capacity is decided by this bottleneck cycle time. Line Capacity is the product of Bottleneck Cycle time(C/T) and Total Available time, If Bottleneck C/T <Takt time, then Customer demand met, If Bottleneck C/T >Takt time, and then Customer demand is not met. With the past projected production delivery or from the expected future demand, the takt time is identified for the manufacturing system. With the known Takt time the bottleneck process are identified from the Value stream mapping (VSM), the gap between the capacity and demand is calculated and based on this gap the lean implementation plan is executed [12].

3.6 Group Technology

Shunk et al. [13] suggested that the successful implementation of flexible manufacturing system need grouping of parts using similarity among the design and manufacturing attribute which make the production plan and manufacturing process flexible. Based on the grouping of parts through similar process, dissimilar machines are grouped together to form a cell concept as suggest by lean concept. Cell formation is purely based on the nature of the process which varies from organization to organization.

3.7 Cellular manufacturing (CM)

Cellular Manufacturing is the grouping of miscellaneous equipment to manufacture the family of parts [10]. VSM provide route map for every part family, based on the route map the dissimilar machine are grouped together to form a cell. Wemmerlov et al. [14] suggest those dissimilar machines are clustered in sequential manner in order to meet process need of a family of product. Metternich et al. [16] suggested that the effective and efficient clustering of machine or cell is improved by moving employees, Workstations, or both into a U-shaped line which improve the employees' interaction. CM inducing multi skill process knowledge through implementing U-shape manufacturing line, many of the research and literature survey suggest that the U-line manufacturing is special type of Cellular Manufacturing system which improves flexibility in manufacturing system [15]. The Cellular Manufacturing system success depends on the successful implementation of U-Line manufacturing system, Line balancing, and Flow manufacturing.

3.8 U-line manufacturing system

Monden et al. [18] In his overview the entrance and the exit of the U-line, are placed on the same position. A rather narrow U-shape is normally formed since both ends of the line are located narrowly together. U-shaped lines line reduces number of work station, improve line balancing, visibility, communication, quality, flexibility, material handling. Guerriero et al. [17]clearly define the line flexibility for stochastic U line system and suggested that when demand uncertainty occurs, U-line layout provides greater flexibility to increase or decrease the necessary number of workers. The performance of U-Line was evaluated by minimum number of workstations, minimum work relatedness, and minimum workload smoothness.Virtually U-line flexibility is interrupted by line imbalance in mixed model production line. In order to overcome this imbalance clear investigation of both balancing and sequencing task to be carry out simultaneously. The line imbalance is overcome by implementing line balancing and production flow.

3.9 Line balancing

Monden et al. [18] suggested that the consideration of task time variability is due to human factors or various disruptions which leads to U-line balancing problem. The task time variability is mainly due to the instability of humans with respect to work rate, skill and motivation as well as the failure sensitivity of complex processes. Becker et al. [19] and Chiang et al. [20] suggested task itself a sources of variability and explains the worker performing the task, and the environment where the task is performed. These sources of variability are controlled by minimizing the moving cost of men and machine. The operator walking time and fluctuation of man and machine cycle time leads to line imbalance. Also the change over time creates imbalance in the line for mixed model line which is necessary for lean. Based on demand, the number of worker and machine within the workstation are increased or decreased in order to overcome the line imbalance. Man-machine flexibility is achieved through free flow of material and information in the manufacturing process [18].

3.10Flow Manufacturing

The principle offlow manufacturing is producing an item at a time at a rate equal to the cycle time, the successful implementation of flow manufacturing needs U-line layout, multi-skill operator, standardized cycle time, designing operator work as standing and walking manner and the equipment/machine should be standard and less expensive user friendly . Miltenburg et al. [21] Suggested that the break-through or tedious process flow can be balanced by introducing the customized machine in the workstation in order to balance the machine with the workstation cycle time [21].The mixed model flow is smoothened by designing the workstation with Quick changeover and Small lot size.

3.11Quick Changeover/Single Minute Exchange of Die

The quick change over time was introduced and developed by Shingo [5] which is popularly called as Single Minute Exchange of Dies (SMED).Based on time/video study Shingo separated the changeover (C/O) time into internal and external-up set time. The activities performed by stopping the machine are called internal set-up time and the other hand the activity are performed without stopping the machine, these activity are called external set-up time. Yamazumi chart is used to analyze the internal (on-line activity) and external (off-line) set-up time. Based on these analysis possible internal set-up time are converted to external set-up and internal set-up time are streamlined by introducing multi operator working parallel during On-line activity and one touch set-up adjustments to convert the C/O time to single minute. Finally the sustainability of these set-up time improvements is achieved by standardization. Shingo [5] proposed rules for standardization of set-up time and they are Visualizations and standardization rule for overcoming adjustment and trial run and Machine with multiple productions tooling system. One of the critical task in C/O is setting parameter for first good product during initial trial run after C/O. The first good product setting parameter for initial trial run can be achieved using Taguchi experimental design .As a result of the Taguchi experimental design the trials needed to start mass production is reduced and also it reduces the wastage of material during initial production phase. The factors that affect the decision-making process of SMED are cost, energy, facility layout, safety, life, quality and maintenance. Almomani et al. [22] research on Multiple Criteria Decision-Making Techniques (MCDM) and provide a systematic procedure for selecting the best setup techniques such as Analytical Hierarchal Process (AHP), Preference Selection Index (PSI) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) by considering the above factors. The integration of MCDM with SMED leads to greater system flexibility and increase the productivity. C/O time play vital role in sequencing the batch in cellular manufacturing. Cheng et al. [23] suggest that the makespan of the part family in cellular manufacturing depends on set up time [24].

3.12 Small Lot size/Small Batch

A batch is a set of parts of the same part family. While part families are supposed to be given in advance, lot sizing is a part of the decision making process. Conventional manufacturing systems are run based on buffer production system. The built-in buffer system was introduced to overcome the material flow interruption in case of for equipment break down, machine C/O, absenteeism which lead to high quality problem and lead time. In order to smoothen the material flow and to overcome the quality and lead time issues, buffer quantity should be optimized. In practice, Lean is associated with zero inventories to increase the visibility of product flows and optimize the utilization of capacity [25].

3.13Inventory

Survey from various articles indicates that 60% of wastes in manufacturing system are due to inventory. These Inventories are classified into Raw material (RM), Work-in-process (WIP),Finished goods (FG). Increase in inventory of RM, WIP or FG leads to less inventory turnover. Inventory plays a vital role in firm's turnover, detailed literature from 1000 world class manufacturing firms revealed that 34% firms try to increase inventory turnover for at least 10 years [26]. Sakakibara et al. [27] suggested that the excess RM is due to poor projection of product plan, availability of raw material, defective parts, waiting for processing leads to more WIP, and unnecessary transportation between working stations or plants increases WIP inventory, overproduction of parts beyond the plan leads to FG inventories which wait long time in the warehouse or might never be sold. Inventories are reduced by improving the quality levels, rejection rates, delivery rate, lead time and customer satisfaction. RM is controlled by ordering material against the demand or ordered only after the design is accepted by the customer in case of new product. Demete et al. [28] suggested that WIP is controlled by implementing cellular manufacturing/dedicated line Assemble or manufacture the parts against the customer order reduces FG which means FG goes to customer without unusual delay. Imperfection due to lack of process control in the manufacturing system creates the WIP requirement in workstation. In order to reduce the impact adjacent process, the decoupling buffers is placed between processes to overcome the imperfection. The buffers allow each of the teams to make decisions regarding stopping the line to fix problems. Buffer violates the lean system but in practice safety buffer is necessary in case of system fluctuation. If certain workstation run worse than others and the buffers are stripped, individual workstation can run overtime in order to build back up the inventory. As a result manufacturing lead time increase which in turn increase the WIP. Kanban and Pull systemare the lean elements that control the WIP.

3.14Pull System with One-Piece Flow

The Pull system enables the production based on customer demand; the downstream process/customer takes the product/service they need and 'pulls' it from the producer. Smalley et al. classify the pull asreplenishment pull, sequential pull, and mixed pull system. The successful pull system depends on flowing product in small batches (approaching one piece flow where possible), pacing the processes to takt time (to stop overproduction), and Signaling replenishment via a Kanban signal and leveling of product mix and quantity over time .One-Piece Flow refers to the concept of moving one part at a time between operations within a cell. One- Piece Flow production system consider factor such as sequencing, setup time and make-to-order policy, therefore consideration to be given to those factor during scheduling of production. Stockton et al. [38] Designed the operator walk cycles for an existing one-piece flow flexible manpower line, in which operators were allocated a repetitive sequence to load and unload machine tools. Their flexible manpower line was essentially flow process line where the machines were arranged in U-line. Work model selections, operation assignment to U-line and production sequence are the important factor to be considered while designing the one-piece flow. In U-line when Change over task or other task takes place, the whole production line is disrupted in such a case buffer is permitted in One-Piece Flow based on requirement in order to overcome these issues. In one-piece pull production system, the producer begins the production when a user shows the Kanban card/signal for parts. Li et al. [36]suggested that the design of uncertainty based one-piece flow need multi-objective evaluation; also develop the fuzzy ant colony Optimization model for evaluating the multi-objective task to minimize cycle time, changeover count, cell load variation and the number of cells [37]. The study and survey in the area of one-piece flow is limited.

3.16 Kanban

Kanban is a subsystem of the Lean manufacturing system which was created to control inventory levels, the production and supply of components. Junior et al. [41] suggest that with the knowledge in the creation and accumulation of Kanban system, the implementer can classify, andanalyze the variations of the Kanban. Sipper et al. [42]. Classify the Kanban system into the dual card Kanban system for signalling production and transportation Kanban system for signalling. During demand uncertainty the buffer maintenance is necessary for smoothening production flow and reconfigures the Kanban System in order to lower the inventory. Thus Kanban system provide mixed model production along with optimal inventory level which results in less lead time in product delivery and effective utilization of resources such as man, machine etc.

3.15 Production Levelling/ Heijunka

Currentbusiness environment are volatile which leads to fluctuation in customer demand, this fluctuation leads to variability in the production. In order to overcome this fluctuation initially levelling of customer demand is necessary, Without levelling, this fluctuation leads to underutilized capacities such as man and machine idle times or quality problems, breakdowns, and defects (in case of overburdened capacities) [6]. Bohnen et al. [39] suggested that the levelling low volume and high mix production based on the principles of Group Technology is necessary for fluctuating customer demand. Bohnen et al. develop the cluster technique for part family formation and family oriented levelling pattern for implementing low volume, and high mix production system. The Balanced work load in production is achieved through Every Part Every Interval Concept (EPEI) levelling pattern which is formed based on product families, According to EPEI every product type is manufactured within a periodic interval. The concept of Heijunka is to control the variability of the job arrival sequence to permit higher capacity utilization, also it avoid peaks and valleys in the production schedule [39] [40].

3.17 Quality at source

In lean manufacturing system the lot size is reduced to one piece. In one-piece flow the part are conveyed, processed and inspected one at time, as a result the random inspection of lot samples or lot-based statistical quality control methods is eliminated. When a defect occurs, immediately the production line is stopped until the cause is eliminated. False-proofing/ Poka Yoke is incorporated with production line to prevent/detect the error occurrences. In case of detection the line must be stopped until the cause is eliminated. In such case the line is equipped with Autonomation/Jidoka (automation with human touch) which has the ability to stop line when process goes wrong. The quality problems in the operation of automated equipment are due to human errors in loading, unloading and setup. Among these error priority is given to setup errors because it create quality problems for the more number of products. To achieve the highest levels of quality, the setup, loading, and unloading must be False-Proofed. Implementation of False-Proofing improves the quality standard and reduces the operator inspection time. [19][35]

3.18 Continuous Improvement (CI)/Kaizen

Continuous Improvement (CI) is a philosophy that Deming described simply as “Improvement initiatives that increase successes and reduce failures” Continuous Improvement is the management driven element which effort the cultural change in the workplace. Once process stability is established, CI element tools are required to determine the root cause of inefficiencies and apply effective countermeasures to reduce those inefficiencies. Establish and design a process with zero inventories exposes waste such as the idle time, waiting time, inventory and resource problem. In order to eliminate this waste, management need to develop the stable personnel with organization knowledge base. Berger et al. [31] overviews that Continuous Improvement is based on a belief in people’s inherent desire for quality and worth, and management has to believe that it is going to “pay” in the long run. In this competitive environment CI is necessary for sustaining in the market, but the success of the Continuous improvement depends on employee perception, adaptation, team work, leader engagement, motivation, initiative, and training. CI mechanism include training problem, process problem solving, training CI tools and technique, development of idea management and development of reward and recognition system. [29][32] [33][34]

3.19 Standardized Work

Berger at al. [31] suggested that the Standard Work is the basic tool for continuous improvement. . Standard Work refers to the safest and most effective method to carry out a job in the shortest repeatable time as a result the utilization of resources such as people, machines, and material is effective. Work Standardization can be described as a set of analysis tools that result in a set of Standard Operating Procedures (SOPs). SOP contain operator work process such as process steps, work sequences, cycle time, work-in-process, process control etc., SOPs represent the best thinking on how to do a particular job within the target time.Once Standardized work is established, it is possible to control and improve work design with respect to demand with slow-downs or speed-ups in work. Standardized Work helps in reorganizing the work with respect to Takt time fluctuation; with demand increases we can incrementally add workers. If demand decreases, we can incrementally remove workers from the assembly line [30][31].Monden in 1983 introduced Standardized Work Chart (SWC), Standardized Work Combination Table (SWCT) and Standard Operation Sheet (SOS) are useful for analyzing and improving the standardized work. The SWC Visualizes operator movement and material location in relation to the machine and overall process layout.SOS describes the operator The SWCT Visualizes the combination of manual work time, walk time, and machine processing time for each operation in a production sequence. The purpose of SWCT is to identify the waste such as WIP, waiting and overburden of work. Finally, the work instruction of the operation is described by SOS [1 9].

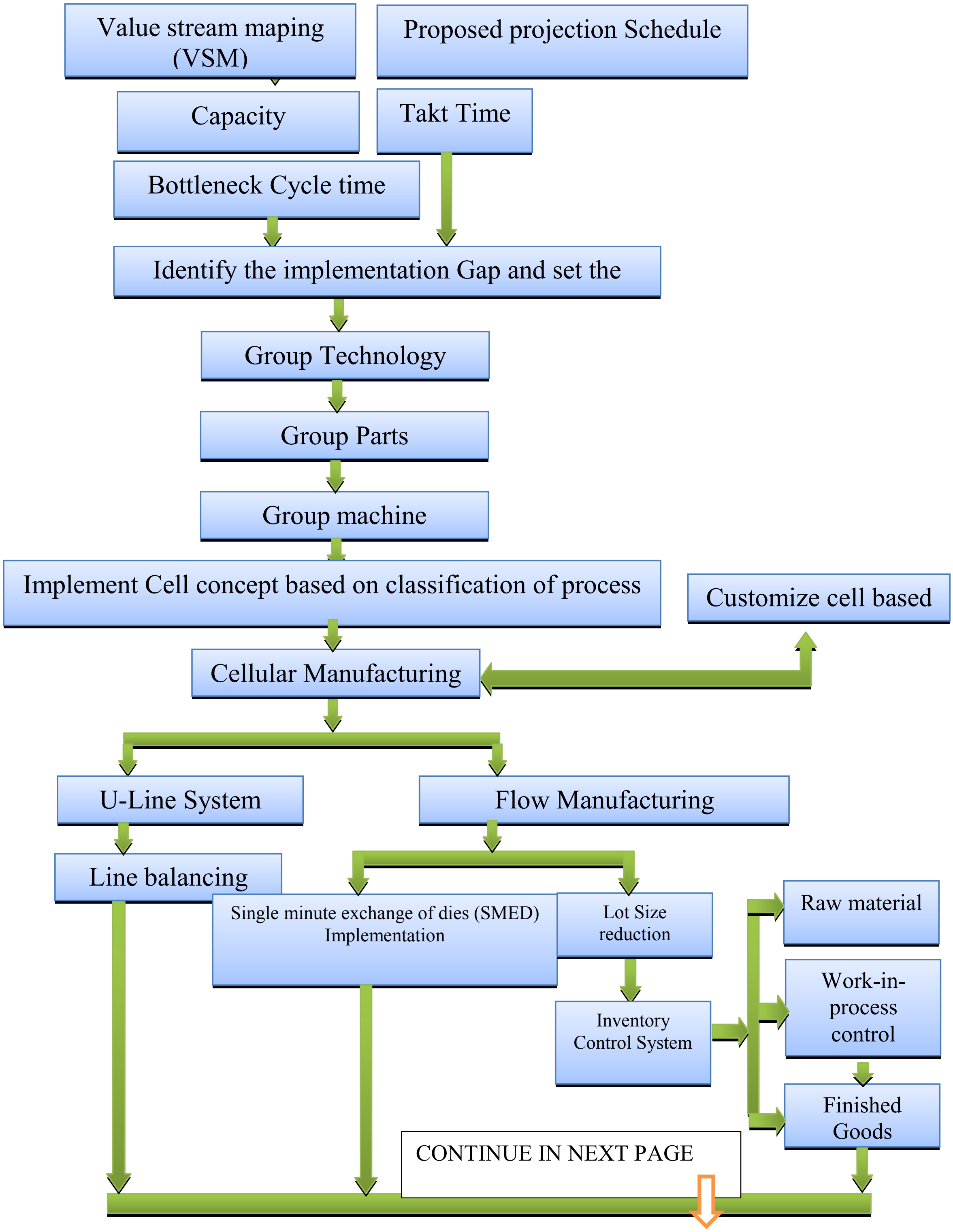
Incorporation and sequencing of lean elements with dependent elements are the vital factor for the successful implementation of lean manufacturing system as suggested by most of the survey. In this survey, a lean road map is proposed for implementation of lean elements along with other interdependent elements. Steps in implementing the Lean elements are as follows VSM for analyzing the capacity and Takt time to identify the production gap, based on this gap, implementation goal is proposed. Second step is implementation of Group Technology; here parts are grouped into part family and machines are grouped based on these part family. The third step is implementation of Cellular Manufacturing. Cell formation depends on group technology and part family VSM along with successful implementation of U-line system and Flow Manufacturing, further U-line system is streamline through Line Balancing and material/information flow is streamline through Flow manufacturing. The successful implementation of Flow Manufacturing depends on SMED and Lot size reduction which stream line RM, FG and WIP. The fourthstep is implementation of One-Piece Flow Pull System which depends on all the above elements. The fifth step is quality control at source, which depends on implementation of False-Proofing and Autonomation. The sixth step is implementation of Kanban system for triggering the production. The seventh step is Production Levelling; implementation of this element depends on successful implementation of all the above said elements. The eighth step is simultaneous Standardization and Continuous Improvement. Finally EPEI concept should be implemented to satisfy Every Customer in Every Interval. In order to sustain in the competitive marketeighth stepshould be repeated.

4. Summary and Discussion

Case study from various literature surveys demonstrates the lean element deliberation and the implementation process. In practice, the organization focuses on only few aspects of lean elements such as Cellular Manufacturing, Pull System, Production Levelling etc., for driving their manufacturing system towards the success. In reality, long term success of manufacturing system in the competitive business environment depends on elimination of dreary issue such as lack of direction, lack of planning, lack of sequencing and interdependency factors of lean elements. To overcome this dreary issue, the lean elements are implemented in sequence in-line with corresponding interdependent factors with proper plan. The finding of survey proposes the Lean Road Map which gives the detailed guide line for Lean Manufacturing System implementation. Detailed survey of Lean concept also summarizes some of the other important aspect such as buffer stacking in case of imbalance / tedious process/ C/O, design the Pull System with One-Piece flow / One Set Flow to implement Every Part Every Interval Concept.

6. Conclusion

Conclusion of this survey reveals that the successful Lean Manufacturing System implementation needs integration and simultaneous implementation of Lean elements along with proper sequence. The survey also proposes the detailed implementation Road Map which gives a unified theory for Lean Manufacturing System implementation. Thus the proposed implementation structure reduces the implementation duration and reduces manufacturing system divergence. As a result it is proposed that the Lean Manufacturing System can be sustained in competitive business environment. Future research should try to find Scheduling structures in-line with EPEI pull system by considering the whole lean elements.


Value stream maping (VSM)
Proposed projection Schedule
Capacity
Takt Time
Bottleneck Cycle time
Identify the implementation Gap and set the
Group Technology
Group Parts
Group machine
Implement Cell concept based on classification of process
Customize cell based
Cellular Manufacturing
U-Line System
Flow Manufacturing
Line balancing
Single minute exchange of dies (SMED) Implementation
Lot Size reduction
Inventory Control System
Raw material
Work-in-process control
Finished Goods
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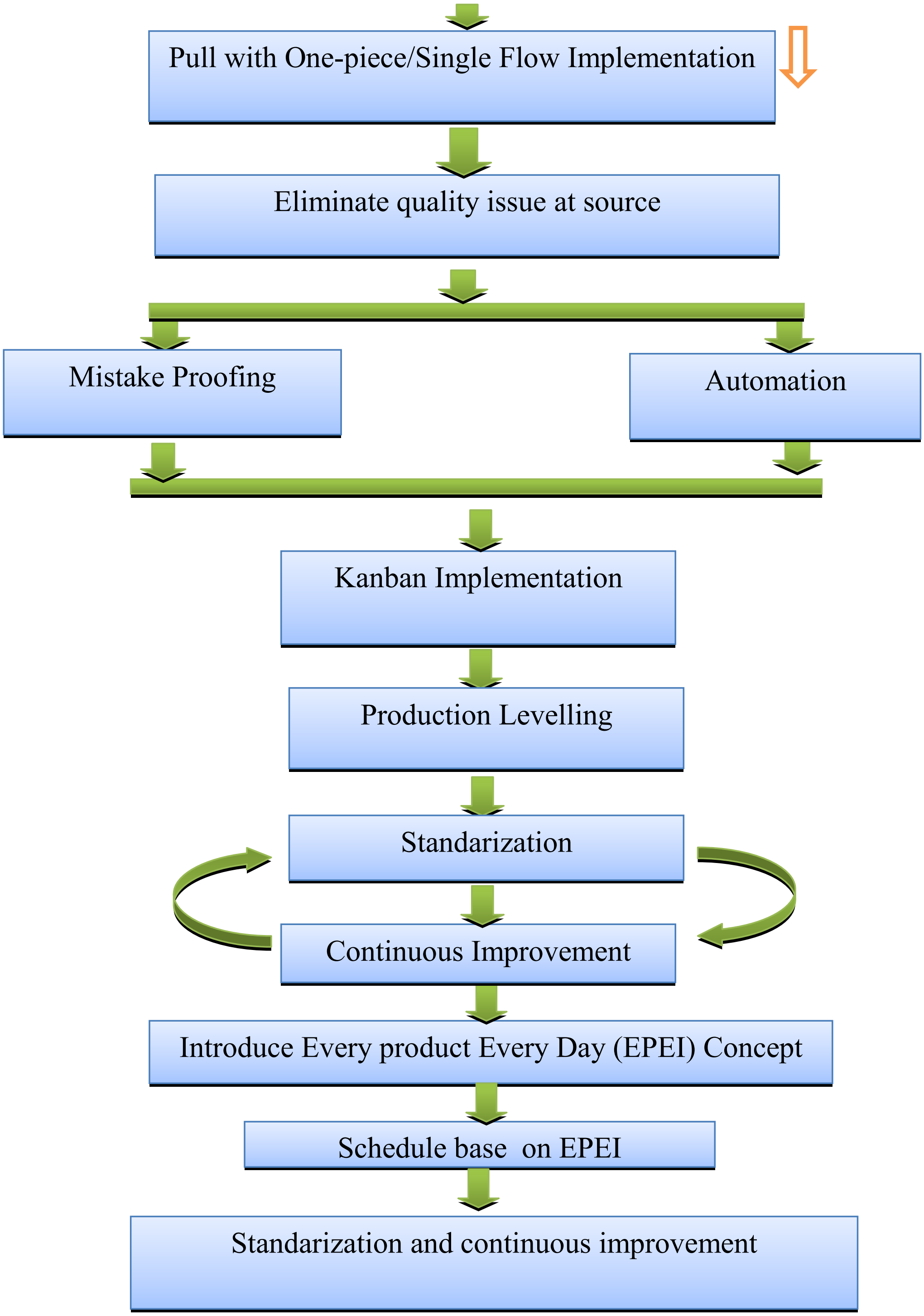

Fig 1 Proposed Road Map for the Implementation of Lean Manufacturing System

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