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A Review on Lean Manufacturing Implementation Techniques: A Conceptual Model of Lean Manufacturing Dimensions

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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. Lean manufacturing or also known as lean production has been one of the most popular paradigms in waste elimination in the manufacturing and service industry. 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. This paper describes a preliminary study in developing a conceptual model to measure leanness in manufacturing industry. Thorough literature survey, books and report analysis contribute to the main preliminary analysis of this study. The most common tools or techniques and their usefulness have been investigated. In this research, a conceptual model for leanness measurement in the manufacturing industry has been developed and designed in two main levels, namely the dimensions and the factors. There are seven main dimensions in measuring leanness in lean manufacturing practices such as manufacturing process and equipment, manufacturing planning and scheduling, visual information system, Supplier relationship, customer relationship, workforce and product development & technology. In addition, the model also shows how lean dimensions in the manufacturing system relate to eight types of wastes. 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 organization 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 Leveling etc. In this paper, an attempt has been made to develop a lean route map via collection of technical papers for the organization to implement the lean manufacturing system.

Keywords: VSM, Cellular manufacturing, SMED, Pull system, Lean manufacturing, Lean production, Lean indicators, Lean assessment, Model

I. Introduction

Manufacturing has been recognized as the main engine for growth of the economy. Ever changing globalized environment has been posing challenges of competitiveness and survival to all the constituents of the economy. Manufacturers in the World industry have always faced heightened challenges such as rising customer's demand for better and improved products, erratic demand, and competition in markets. There is no disbelief that the manufacturers are always embracing changes and improvements in their key activities or processes to cope with the ever growing challenges. To be more efficient is the only way to stay and earn profit in a global market. Industries are giving lot of attention to Lean manufacturing. Several industries in India are struggling to be world class. Principal adoption of lean manufacturing is still found to be complex. Lean Manufacturing is a set of techniques, which have developed gradually over a long period and are based on various minor to major breakthroughs that help in reducing cost and hence increase productivity. The word "lean" refers to lean manufacturing or lean production as it uses less of everything, compared to mass production. It only uses half of the human effort in the factory, half of the manufacturing space, half of the investment in tools and half of the engineering hours to develop a new product in half the time. 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. In another review of lean manufacturing, Narasimhan et al have concluded that the efficient use of resources through the minimization of waste is the essential aspect of leanness as the aim of lean manufacturing is to reduce waste and non-value added activities. Essentially, the core idea of lean manufacturing is to maximize customer value while minimizing waste. The ultimate goal of implementing lean production in an operation is to increase productivity, enhance quality, shorten lead times, reduce cost and so on [Singo et al]. These factors indicate the performance of a lean production system. Some claim that lean manufacturing techniques were first identified as a cause of Japanese success. The supported idea is based on the fact that the lean management model was first developed at Toyota Motor Company by the Japanese after the Second World War in their effort to reduce cost. Therefore, the introduction of lean has significantly changed the market and the strategy during its first emergence in the development of the car industry that was pioneered by Toyota Production System (TPS). The success of TPS shows and proves that lean techniques are powerful and significant. 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) andNon-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" [Rother et al], Push and Pull System which describes, the Pull system rely on customer requirement whereas push system rely on predetermined schedule. [Benin Dergiz et al], 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, Kanbanis Material. Flow Control Mechanism (MFC) which delivers the right quantity of parts at right time [Graves R, Konopka]. Stages of this Kanban implementation are production stage and withdrawal stage. One piece flow ensure just-in-time production system in order toadopt straightforward schedule without interruption, backflow or scrap, relaxing the Takt time and decreasing the risk ofmachine failures and operator mistakes [Li et al].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 [Singo et al].Production Levelling enhances production volume as well as production mix and production efficiency by means of reducing waste, unevenness, and overburden of people or equipment [Liker et al].Leveling 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.

II. Research Objective and Methodology

The primary aim of this study is to find out the needs and examine the degree to which the concepts of lean management are put into practice within various manufacturing Industry.

(i) This is an overview for finding the current situation of lean management practices in manufacturing industries.

(ii) It is a measure to identify the constrains that retains lean manufacturing in the infant stage in manufacturing firms and helps to identify the muda (waste) that evolves in an processing unit and gives out supporting measures to remove the same. The constraint that predict the implementation and sustainability of lean manufacturing tools and techniques are also discussed.

III. Literature review

The aim of this paper is to structure the research field on lean manufacturing in the context of relationship, benefit and its effect on performance and point out the most important gaps. Therefore, this review covers academic papers in the period between 2000 and 2014. This review includes the following major research databases: Elsevier Sciencedirect.com. The database search yielded ten articles. Each of the articles was examined to ensure that its content was relevant from the perspective of the aims of our research. The examination and selection of the articles is based on the criteria that only those of which main contribution revolves around the interrelationships among Lean manufacturing on performance will be selected. The result of this process was that seven articles were eventually selected for in-depth evaluation. In order to the descriptive analysis we selected categories: year, author's country, journal, methodology and sustainable dimensions. The results are structured in two parts: firstly, we provide a quantitative descriptive analysis to get an overview on the research agenda on Lean manufacturing. Secondly, this paper presents a qualitative thematic analysis to provide analysis of relationship lean and developing integrated model and its impact on performance. All manufacturing industry has put in continuous efforts for its survival in the current impulsive and competitive economy. In order to handle the critical situation, manufacturers are trying to implement new and innovative techniques in their manufacturing process by making it more effective and efficient. A detailed literature survey has been conducted to identify the lean practices in various manufacturing industry. The results revealed that the status of Lean Manufacturing (LM) implementation in still in thriving stage. This paper will further assist the organizations to improve its process, align it to the requirements of its customers and relentless contribution to manufacturing sector to enhance productivity, quality and competitiveness is immense. In the current era of globalization, industries are adopting new tools and techniques to produce goods to compete and survive in the market. The most daunting issue faced by manufacturers today is how to deliver their products or materials quickly at low cost and good quality. One promising method for addressing this issue is the application of lean management principles and techniques. Lean management simply known as lean is production practice, which regards the use of resources for any work other than the creation of value for the end customer, is waste, and thus a target for elimination. Though there had been numerous claims on the real origin of Lean Manufacturing principles, it was generally accepted that the concept with this niches. There is no doubt that the manufacturing industry are confronted with challenges and looking to implement improvements in their key activities or processes to cope with the market fluctuations and increasing customer demands. Applying lean management philosophy is one of the most important concepts that help businesses to complete. In this paper, the literature survey findings such as existing level of lean practices, types of lean tools employed, and perceived level of different encountered by the various manufacturing industries are discussed. A detailed review of research in current trend of lean management in various manufacturing industry like automotive industry, machine tool industry, semi-process industry, electronics manufacturing industry, steel industry, pump industry and furnishing industry has been discussed. Lean manufacturing is a multi-dimensional management practice including just in time-quality systems, work teams, cellular manufacturing, supplier management etc. the popular definition of Lean Manufacturing and the Toyota Production System usually consists of the following [Wilson, L. et al].

• It is a comprehensive set of techniques which when combined allows you to reduce and eliminate the wastes. This will make the company leaner, more flexible and more responsive by reducing waste.

• Lean is the systematic approach to identifying and eliminating waste through continuous improvement by flowing the product or service at the pull of your customer in pursuit of perfection.

Lean Production System

Liker J. (2007) discussed the performance benefits of lean systems are often remarkable, greatly improving quality, cost, and delivery and studied the fundamental misunderstanding of TPS, viewing it as a specific tool kit technically implemented in a formulaic way to achieve pre-specified results. According to Shah, R et al, lean production is a multi-dimensional approach that encompasses a wide variety of management practices, including just in time, quality system, work teams, cellular manufacturing and supplier management in an integrated system. According to Petersen, J., in his article made the analysis of the lean literature and concluded that among the authors dominates a view that lean is more than a set of tools, since it is a philosophical approach to lean. Therefore, lean production is also considered as a philosophy of continuous improvements and respect to people.

House of Lean

Liker (2003) illustrated the most common lean tools in the form of house as shown in Figure 1. The goal of lean production is set in the roof and consists of reaching for the best quality, lowest costs, shortest lead-time, highest safety and high morale. The left pillar encloses Just-in-Time principle that consists of production planning and leveling tools like takt time, continuous flow, pull system, quick changeover and integrated logistics. The right pillar deals with Jidoka, which prevents a defective part from proceeding into the next workstation as well as insists on separating people from machines. People are in the center of the lean house concept since people see waste and solve problems that lead to continuously improvement of the processes. In addition, it is important to consider the characteristic of a lean work organization since the responsibilities are decentralized to multifunctional teams. The foundation of the house has to be stable for the pillars to stand steadily and consists of the tools like 5S, standardized work and leveled production.

Fig. 1 Lean House (J. Liker -2003)

Lean Manufacturing Techniques

Lean manufacturing as discussed above is not easy to achieve. It requires all round improvements in almost every aspect of function of an organization. There are the number of techniques and parameters which help to maintain the lean manufacturing system for an organization. Few are listed below:

· Value Mapping
· Single Minute Exchange of Dies
· Single Piece Flow
· Inventory Control via Card System
· Concept (Separate, Self-discipline, Simplify, Standardize, Sustain)
· Total Productive Maintenance
· Visual Management
· Production Line Optimization

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Types of Waste Targeted by Lean Method

According to shabeena et al article, different kinds of wastes in a process are categorized in following categories. It is interesting to note that the "wastes" typically targeted by environmental management agencies, such as non-product geo-output and raw material wastes, are not explicitly included in the list of manufacturing wastes that lean Practitioners routinely target.

Defects	Production of Products not as per Specification, Components or Services which Consequence in scrap, Rework, Replacement Production, going over, and/or Defective Materials
Waiting	Delays associated out of stock, delay in processing, equipment downtime, competence bottlenecks
Unnecessary Processing	Process steps that are not required to produce the product
Overproduction	Manufacturing of extra items for which no orders are there.
Movement	Human motions that are unnecessary or straining, and work-in-process (WIP) transporting long distances
Inventory	raw material in excess, or finished goods
Unused Employee Creativity	Failure to tap employees for process improvement suggestions
Complexity	More parts, complicated process steps, or requirement of time more than necessary to meet customer needs

Lean core methods

Described below are eight core lean methods

- Cellular Manufacturing / One-piece Flow Production Systems
- 5S
- Just-in-time Production
- Total Productive Maintenance (TPM)
- Kaizen
- Kanban
- Six Sigma
- Pre-Production Planning (3P)

Tools for Lean Manufacturing

Vorne et al Discussed the most important lean management tools such as 5S, Andon, Bottleneck Analysis, Continuous Flow, Gemba, Heijunka, HoshinKanri, Jidoka, Just-In-Time, Kaizen, Kanban, KPI, Overall Equipment Effectiveness, PDCA, Poka-Yoke, Root Cause Analysis, Single Minute Exchange of Die (SMED), Six Big Losses, SMART Goals, Standardized Work, TaktTime, Total Productive Maintenance, Value Stream Mapping and Visual Factory used for productivity improvement in manufacturing industries.

Cellular Manufacturing (CM): Cellular manufacturing is a concept that increases the mix of products with the minimum wastage possible. A cell is made up of equipment and workstations and is arranged in an order, to maintain a smooth flow of resources and components through the process.

Continuous Improvements (5S): One of the most effective tools of continuous improvement is 5S, which is the starting point for an effective lean company. 5S is a first, modular step towards serious waste diminution. 5S is made up of five Japanese words Seiri (Sort), Seiton (Straighten), Seiso (Sweep and Clean), Seiketsu (Systemize), and Shitsuke (Standardize).

Seiri: Deals with moving those items that are not currently being used on a continuous basis (e.g., items which won't be used for the next month or so) away from those that are.

Seiton: Has to do with having the right items in the right area. Items that do not belong to a given area must not be in that area.

Seiso: Deals with cleaning and sweeping the work place methodically. The workplace should look neat and clean and ready to use for the next shift.

Seiketsu: Is to maintain a high standard of housekeeping and workplace arrangement.

Shitsuke: Is accountability of management to train people to follow housekeeping rules.And at times the sixth S for Safety is added though 5 S purists say that an effective implementation of 5 S will eventually result in safety.

Just - in-Time: Closely associated with lean manufacturing is the principle of just-in-time, since it is a management idea that attempts to eliminate sources of manufacturing waste by producing the right part in the right place at the right time. It broadly consists of three elements: (i) JIT production, (ii) JIT distribution, and (iii) JIT purchasing.

Kaizen: Kaizen, a Japanese term that basically translates to 'continuous improvement' or 'change to grow to be good', this is a management concept originated by the Japanese in order to continuously effect incremental changes for the better, involving each and every one within the organization from managers to workers. The aim of Kaizen is to give more and more production value with less and less wastes (superior efficiency), to attain better working environment, and develop a stable processes by standardization.

Issues and Challenges in Manufacturing Process

It is well known fact that by application of LMS any organization can reap the benefits of the existing resources. Many companies who put into practice Lean do not adequately take advantage of the improvements. Extremely successful companies will discover how to market these new benefits and turn them into increased market share. In this age of modern technology & globalization some employees are not aware about a system that can be handy for their professional growth and betterment of working environment. With the application of LMS there is unseen danger of rejecting or overruling of certain existing technique & tools in an organization. The success of LMS highly depends upon various factors but the key factor is perception of employees and working of the management. Despite the fact that LMS is not a very old technique to strengthen the quality & production in any organization, nevertheless it requires an in-depth understanding, knowledge and skills to apply it successfully in a given frame work. Training generally provides employees with a golden opportunity to hone their latent skills and enable them to become aware about the latest trends & technologies. Since LMS is a new phenomenon so employees require undergoing training seriously. But sometimes organization thinks that training is an extra financial burden that may reduce their share of profit & of no use for their employees. LMS is considered as a very useful technique in the modern day setting of organization. It is very beneficial in reducing the cost and waste management. The success of LMS a great deal depends upon planning and implementation of plans & policies. Total quality management has been termed as the need of the hour organization like to have total quality in their management system. 6 Sigma also meant to improve the quality & production without increasing the cost of production. LMS can be very beneficial in implementing TQM & Six Sigma. Employees like to see their career graph moving. They always seek and like to be in constant touch with the latest technologies. They can contribute to a great deal to their working organization, if they get proper training & guidance along with healthy working environment. Many organizations consider training as a very important aspect for employee's growth. By providing regular and rigorous training to the employees organization can easily meet the objectives of LMS. Training programmes need be planed as per the requirement of employees and the organization.

Approaches adopted for implementation of lean manufacturing

A successful implementation of any particular management practice frequently depends upon organizational characteristics, and not all organization can or should implement the same set of practice.

Unionization: It is generally supposed that because implementation of manufacturing practices requires negotiating changes in work organization, unionized facilities will resist adopting lean practices and lag behind non-unionized facilities.

Age of Plant: Plant age may imply either a tendency toward resistance to change or a liability of newness. The "resistance to change" view is supported by the organizational sociology literature which suggests that the age of an establishment should inversely influence the rate of adoption of innovations, because organizational forms tends to be "Frozen" at birth.

Size of Plant: Large manufacturers are more likely to implement lean practices than small manufacturers [Shah Rachna et al].

Review of Lean Implementation

Eswaramoorthi et al discussed the current status of lean implementation in Indian machine tool industries as well as tinted some allied issues. The survey has attempted to formulate simple questionnaire based tool to identify the existing level of lean practices, reasons for inadequate priority to lean concepts, type of lean tools employed, perceived level of different wastes, and the common difficulties encountered by the Indian Machine tool Manufacturers. The survey results revealed that 31.6% of the companies have implemented different lean tools and techniques in selected areas. The remaining 68.4% of the companies have not yet taken up the lean initiatives. Nitin Upadhay et al described major actions taken by the company to implement lean philosophy to improve its efficiency and effectiveness. This study attempted to point out various wastages and issues to implement the lean manufacturing systems in MSME. It is observed that Lean Manufacturing Systems (LMS) helps to identify and minimize waste. Lean tools like kaizen, JIT, VSM, 5S, SQC, preventive maintenance, total employee involvement, and SMED were used to find and eliminate the wastages in a MSME. The implementation of lean tools and techniques will be successful only if these are used wisely. Pool et al studied the principal of flow and pull production suggesting a regular demand driven product flow in semi-process industry by introducing cyclic schedules for improving production quality and supply-chain coordination. Demete et al found a significant relationship between lean management practices and inventory turnover and found the different 19types of inventories are sensitive to different contingency factors. WIPs affected strongly by the production system, while the type of order affects raw material and finished goods and further emphasis the important of the proper decoupling point placement in the supply chain. Rubio et al has implemented a reverse logistics system for remanufacturing end-of-life products in a lean production environment. Rachna Shah et al mapped the operational space corresponding to the conceptual space surrounding lean production also identified the critical factor of lean production, how are the various factors of lean production related to each other and why they are related. Fawaz et al described a case where lean principles were adapted for the process sector for application at a large integrated steel mill. They have used value steam mapping as a lean tools to identify the opportunities for various lean techniques and described a simulation model to contract before and after scenarios in detail to reduce production lead-time and to lower work in process inventory. Doolean et al found that while electronic manufacturers have implemented a broad range of lean practices, the level of implementation thus vary and may be related to economic, operational or organizational factors. The numerous literature researches works shows the effectiveness of lean practices that have been published in various journals. This will further assist all manufacturing sector to gauge their level of leanness, continuously improve their productivity, better customer satisfaction and will serve as a foundation for future research work. 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.

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.

Employee Perceptions

Survey on Employee Perception helps to identify the influencing factors on employees' perceptions for successful lean transitions. Losonci et al. 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 [David Losonci et al]. Armenakis et al. 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 Losonci et alsuggest 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 [Mehta et al].

Value Stream Mapping

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 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 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 [Mcdenolad T et al].

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. suggested that the importance of measuringTakt 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.

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 [Rahani et al].

Group Technology

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.

Cellular Manufacturing

Cellular Manufacturing is the grouping of miscellaneous equipment to manufacture the family of parts [Rother, M et al]. VSM provide route map for every part family, based on the route map the dissimilar machine are grouped together to form a

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cell. Metternich et al 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 [K.Das et al]. The Cellular Manufacturing system success depends on the successful implementation of U-Line manufacturing system, Line balancing, and Flow manufacturing.

U-Line Manufacturing System

Monden et al in his overview the entrance and the exit of the U-line, are placed on the same position. A rathernarrow 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 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.

Line Balancing

Monden et al. 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. and Chiang et al. 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 [Mondenet al].

Flow Manufacturing

The principle of flow 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. 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 [John Miltenburg et al].The mixed model flow is smoothened by designing the workstation with Quick changeover and Small lot size.

Quick changeover / single minute exchange of die

The quick change over time was introduced and developed by Shingo et al, 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 upset 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 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.

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 [de Hann J et al].

Inventory

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 [Demete et al]. Sakakibara et al 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.

Pull 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 as replenishment 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 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. 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 [Miltenburg J et al]. The study and survey in the area of one-piece flow is limited.

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 suggest that with the knowledge in the creation and accumulation of Kanbansystem, the implementer can classify, and analyze the variations of the Kanban. Shipper et al. Classify the Kanban system into the dual card Kanban system for signaling production and transportation Kanban system for signaling. 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.

Production Levelling

Current business 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) [Liker, J.K et al]. Bohnen et al suggested that the levelling low volume and high mix production based on the principles of Group Technology is necessary for fluctuating customer demand. Bohnenet al. develop the cluster technique for part family formation and family oriented levelling pattern for implementing low volume, and high mix production system.

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 [Christian Becker et al], [Clifford Martin Hincley et al].

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 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 [NitinUpadhay et al], [John Bessent et al], [Nadia Bhuyian et al], and [Mike Kaye et al].

Standardized work

Berger at al 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 [Janie W. et al], [Berger at al]. 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 fourth step 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 market eighth step should be repeated.

IV. Challenges in Lean Implementation and Sustainability

The challenges faced in the process of implementing and sustain lean is a tedious job as the concept relates to time, cost, interest, and involvement, the concepts that together support the new change for development in an firm. The study tells that new firms introduce and accept lean manufacturing and other innovative concepts than the old and existing firms. The forces opposing and driving a change to lean is shown in Figure 2.The following important factor of resistance to change in manufacturing sectors is

• Fear to change the legacy system with the new successful trends and methodologies
• Not utilizing the opportunities and advantages of the new policies
• Market destabilization will lead to force the change, which will be in a non-standard format

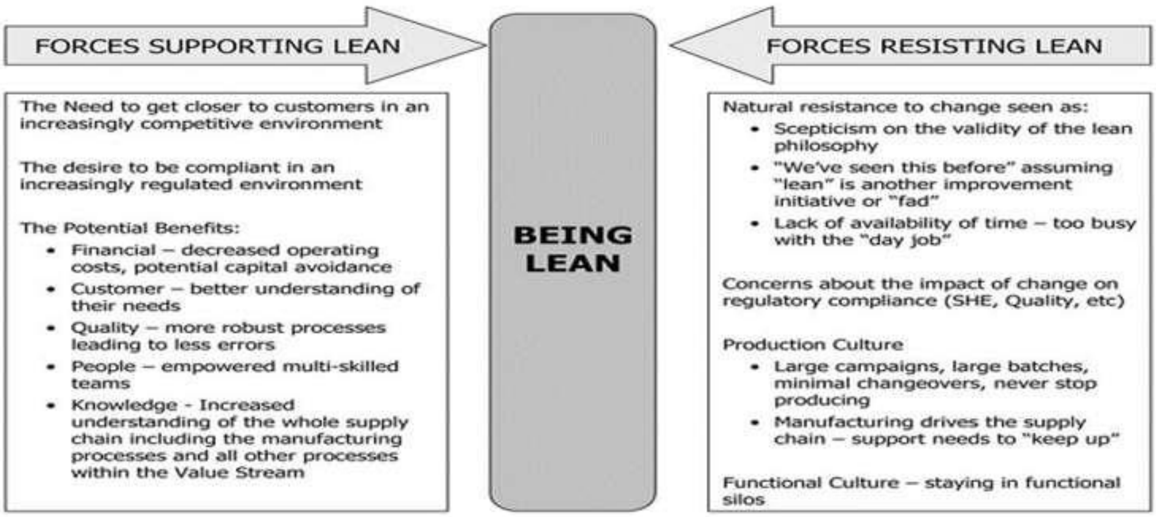

Fig. 2. The forces opposing and driving a change to 'lean' (**T. Melton 2005**)

V. 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.

VI. Conclusion

Manufacturers are under intense, remorseless pressure to find a new ways to reduce production cost, elimination of waste, enhance high quality of product, increase the productivity, and better customer satisfaction. These parameters are usually achieved through the implementation of lean management practices in their industries. The traditional manufacturing practices are indicated inadequate representation in lean management. This paper presented an important imminent into the status of lean manufacturing implementation in manufacturing industries. The progress in lean implementation is snail-paced and needs to be augmented. It has a further scope to develop focused lean concepts, which could be implemented in other kind of manufacturing environment like low volume, high variety and high volume and low variety. The major reasons for the low level of lean management were anxiety in changing the attitude of workers, lack of awareness, and training about the lean management concepts, cost and time involved in lean implementation. Therefore, it can be concluded that the manufacturing industry needs to give more attention to implement lean management in all the key areas. Hence, appropriate lean education, training, and research setup in association with manufacturing industries are to stimulate the lean awareness and technological development in all type of manufacturing industries. This helps to industries and researchers create awareness about Lean Managements Tools, and techniques, so as it could be supportive to opt suitable lean practices for implementation, continuous development and for sustaining leanness in the competitive environment of current scenarios. 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.

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