CHAPTER

REVIEW OF LITERATURE SURVEY

STUDY, ANALYSIS AND APPLICATION OF LEAN METHODOLOGY TO A
CLASS OF IT ENABLED SERVICES
2.1 INTRODUCTION

Both Lean and TPS can be seen as a loosely connected set of potentially competing principles whose goal is cost reduction by the elimination of waste. These principles include Pull processing, perfect first-time quality, Waste minimization, Continuous improvement, Flexibility, Building and maintaining a long term relationship with suppliers, Autonomation, Load leveling and Production flow and Visual control. The disconnected nature of some of these principles perhaps springs from the fact that the
TPS has grown pragmatically since 1948 as it responded to the problems it saw within its own production facilities. Thus what one sees today is the result of a 'need' driven learning to improve where each step has built on previous ideas and not something based upon a theoretical framework.

Toyota's view is that the main method of Lean is not the tools, but the reduction of three types of waste muda ("non-value-adding work"), muri ("overburden"), and mura ("unevenness"), to expose problems systematically and to use the tools where the ideal cannot be achieved. From this perspective, the tools are workarounds adapted to different situations, which explains any apparent incoherence of the principles above.

It is at this juncture the author felt necessary to study and analyze the available scanty literature on different concepts and applications of lean manufacturing which through study let to the presentation of a comprehensive review of literature presented by different authors. This survey of literature will be of immense help for the general practitioners of lean and to the research community folk in particular for further study and analysis of lean manufacturing processes.

2.2. DEFINITION OF LEAN MANUFACTURING

"Lean Production" (a term coined by IMVP researcher John Krafcik [60] as "lean" because it uses less of everything when compared to mass production-half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also, it requires keeping far less than half the needed inventory on site, results in many fewer defects, and produces a greater and ever growing variety of productions."
Lean Manufacturing at the website of the Lean Aerospace Initiative, LAI discusses, 'Lean' is not a new concept. If you are reducing inventory, expanding jobs and responsibilities, participating on a multi-functional work team, benchmarking, or creating and maintaining relationships with customers, then you are practicing a part of lean production.

Ohno [68] indicated that Lean is a manufacturing phenomenon that seeks to "maximize the work effort of a company's number one resource, the People." Lean is therefore "a way of thinking" to adapt to change, eliminate waste, and continuously improve. There are a number of tools and techniques, to be used in concert, to achieve maximizing the effort of the workforce and to operate as a "lean" company.

Womack et al. [87], [88], [89] recognize the Toyota Production System (TPS) as the foundation of Lean Manufacturing and mention many of the tools and techniques used. The TPS is often represented as a house with strong foundations and solid pillars containing highly motivated people working to continuously improve.

Nightingale and Mize [67] discuss that, Lean manufacturing is a corporate activity of continuous improvement and requires effective strategies to successfully implement. Experience from lean implementation efforts shows that, these specific business strategies are significantly impacted by the stage of manufacturing. Daniel t jones [73] Nightingale and Mize [67] discuss that, a good strategy needs to be defined and redefined dynamically according to the current circumstances of manufacturing during the lean implementation.
Charles [72] has discussed on the Lean metrics to be implemented in the wood manufacturing industry, based on identifying the measurement schemes on leanness of the wood products company, comparing a non-lean producer with the conventional producer of wood products and the positive impacts one can gain through the implementation.

Hay, E.J. [40] has proposed a holistic approach to lean manufacturing, where he discusses the methods of removing waste from the system and consistent improvement in the efficiency. He discusses that, Waste is “anything other than the absolute minimum resources of material, machines, and manpower required to add value to product”.

2.3. LEAN ANALYSIS- DECISION MAKING

In lean manufacturing careful analysis and decision making plays a major role. Before any decision is taken the needs are to be analyzed and carefully evaluated. The traditional manufacturer will be applying a set of tools to analyze the system of manufacturing and the decisions are based on the results. Care should be taken to select suitable lean tools to solve the problem.

In lean methodology there is a fundamental difference to the traditional methodology of data collection, analysis and making decisions. In lean analysis, everyone will share the data in the same way and hence will have the same information to begin with. Further, these lean tools are very simple.
Oliver et al., [69] has proposed the basic principles of lean production. He suggested that, there is a relationship between the activities taking place inside the factory and the supply chain. He proposes that there is a need for the team based work organization to solve the problem and should tightly integrate material flows with active information exchange. He proposes that these Measures invariably reduce the cost. Hence, he proposes that all the employees should work as a team and strive towards cost reduction.

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The real problem, according to Womack [87], [88], [89], is that once a lean principle is applied, it is rarely written down as to the specific steps that they took to implement that principle. Then, when another application needs to be introduced, they will find the things difficult to handle.

Howardell [44] has opined that the premise behind Lean Manufacturing is to help a system work toward supplying customer demand. “Lean manufacturers, lean
enterprises, lean supply chains and lean extended value streams are in various stages of construction by companies looking for competitive advantages in tough markets". Lean is such a broad application that many organizations have had problems implementing Lean principles because of differing opinions between Lean experts.

Howardell [44] opined that, in order to have a lean enterprise, one need to have lean people and the people have to get lean before the company can get lean. Lean people make a lean enterprise!" The decision should be made whether or not the company just needs lean manufacturing, or if it needs a lean enterprise. A Lean enterprise encompasses the entire system, including all personnel and programs. In his opinion, Lean manufacturing refers to the information flow and production flow of the system.

2.4. LEAN THINKING AND VALUE STREAM MANAGEMENT

Lean thinking help managers clearly specify value, to line up all the value-creating activities for a specific product along a value stream, and to make value flow smoothly at the pull of the customer in pursuit of perfection.

Womack and Jones [88] discusses that the managers should identify the value of the customer and focus on their existing organizations to redefine the value and continuously strive for the elimination of wastes through value addition tools. As Lean Thinking clearly demonstrates, these simple ideas can breathe new life into any company in any industry, routinely doubling both productivity and sales while stabilizing employment.
Further, Womack and Jones state that, Value is defined “in terms of specific products with specific capabilities offered at specific prices through a dialogue with specific customers”.

Hines et al. [43] has proposed the following ten lean thinking scenarios which can help in the effective implementation of Lean Manufacturing, and he discusses the ten “Not Just” Lean thinking scenarios, which introduce the complex environments at which the lean needs to be applied.

2.5. LEAN MANUFACTURING TECHNIQUE AND ITS IMPLEMENTATION

Lean manufacturing technique consists of four steps. The first step is to realize that there are wastes in the system to be removed. The second step is to identify the different forms of the waste. In this step, tools like Ishikawa diagrams or cause and effect diagrams can be used to a large extent. In the third step, the solutions for the identified root causes are carried out. The final step is the implementation process and making sure things are going in the intended way.

Womack and Jones [88] have suggested that the companies should define a strategy to orient their growth while implementing Lean, and to assure a sustainable path of improvements through the years. According to them, companies that worry about immediate gains and fast growing profits achieved through the reduction of staff cannot sustain a supposedly lean company for several years. Womack [89] suggest that Lean should be first implemented in activities that are “important and visible”, e.g., production, so that all people in an organization can see the benefits achieved with Lean.
Feld [33] stresses that, it is imperative that all members understand their roles on the team and why they were selected for the assignment and they should be trained to play a key role in the successful implementation of lean. He proposes a model plan for the lean implementation.

Black and Hunter [15] have suggested the ten steps for the Lean production methodology and implementation and examined the points in the implementation of lean manufacturing.

Alarcon. [3] has discussed the implementation of tools and principles in the construction sites in specific areas of production. The principles and tools implemented have a low level of complexity and can be easily implemented with minor adaptations to construction settings.

Arbulu and Zabelle [8] suggest that there are two approaches for the effective implementation of Lean manufacturing. The first approach is Shallow and wide. In this case companies want to implement Lean quickly and through imposition of the top-level management (top-down). Actions are implemented in several projects at once what puts high levels of pressure in all workers. The second approach is Narrow and deep – initially, Lean is implemented in projects, later, the initial changes are extended. Company-wide people may impose barriers and resist the change. The second approach requires less effort in terms of tutoring and coordination as the change is carried out in a project-basis.

Cole [18] points out that the implementation of Quality in American companies initially went through the superficial use of its tools, principles, and concepts, before Quality
effectively became part of these companies businesses. He highlights that in the old Quality model, Quality was seen as another specialty inside companies’ organizational structures, and was promoted by a specific department not by the whole company; His implementation methodology can be linked with the lean implementation tools.

Dennis [25] stresses the importance of strategy deployment to guide actions necessary to achieve an organization’s goals. The author suggests that organizations should define a true north to guide their actions and align these actions to achieve the organization’s strategic goals in defined period of time. He also presents comprehensive procedural steps required to be performed for successful implementation of lean methods.

Featherston [32] has discussed the link between the implementation of Lean Construction and the companies' business strategies. He stresses that the implementation of Lean has to be preceded by a desire to change, which may be imposed by external forces that may jeopardize the organization survival or by the possibility of being rewarded with the change. Garnett [35] describes the initiative of the Construction Industry Task Force in UK to apply the principles of Lean thinking to construction at strategic levels.

Deming [24] has proposed 14 principles for the quality movement. This was identified as the milestone in the implementation of quality circle in the industries. Deming’s proposals can be effectively used in the TQM and Lean Manufacturing principles.

Lewis [61] present that focusing on apparently key attributes such as Kanban cards or and on boards etc. will help in reducing the waste and improve productivity. Also
opines that the Lean Methodology can be applied in the construction companies. The principles and tools implemented have a low level of complexity and can be easily implemented with minor adaptations to construction settings.

According to Kiyoshi. [58], it is important to never vary the pace of the work, where efficiency improvements are made. Labour should be removed to maintain the same intensity of work in order to maintain the challenge of continual improvement. Hence, the JIT eliminates batch processing allowing the product to flow to the next customer in the process; the system is usually supported by Kanban a visual scheduling system as stated by Ohno [68].

Suzaki [84] has identified the seven types of waste. He classifies the wastes as, waste from overproduction, waste of waiting time, transportation waste, processing waste, inventory waste, waste of motion, and waste from product defects. Later during the course of his further study has added an eighth waste namely, the waste of underutilized people’s skills and capabilities. He confesses that the implementation of lean manufacturing requires the identification and removal of these forms of waste and need for the continuous improvement techniques in the total elimination of wastes.

Murman et al [66] in his paper, opined that the implementation of lean manufacturing tools are not limited to only automobile industry, but it can be applied to aerospace industry and other allied industries.

Hunter [46] has proposed Lean production in the furniture manufacturing industry The double D assembly cell, which highlights the implementation methodologies carried
out on circular subassembly flow line and the Double D manufacturing cell implementation.

2.6 COMPLEXITIES AND CHALLENGES IN LEAN IMPLEMENTATION ROADMAPS

Today's complex industrial setup shows the research scholar realize the challenges and complexities of implementation of Lean Manufacturing concepts. But, Lean manufacturing is relatively easy to simplify, as it generally appears in most articles and books. In small plants, producing simple products, it may be easy to identify all the areas that must be changed to create a lean system.

One of the barriers is the behaviors of people accepting the change. According to Boyer and Sovilla [17], about 95% of the people within the organization would accept the need for change and would be willing to perform that change but would need strong leadership. About 3 to 5% of the employees would not only accept the change but could potentially be strong advocates for the change. The remaining group of about 5% would be completely opposed to the change. Finally, Boyer et.al [17] recommends that seven rules can bring in change in the behaviours of the people. He also identifies that the possible problems that can occur while trying to implement lean manufacturing are due to Executive issues, Cultural issues, Management issues, Implementation issues & Technical issues.

Mejabi [64] feels that the companies have an ad hoc approach to planning and then implementing their lean strategies. But he observed that the companies have experienced mixed results.
Hancock [91] has proposed that there are many factors that need to be anticipated for reducing the work in process inventory. Some of the issues like “pull flow”, demand, issues of Kanbans, batch production, maintenance etc have to be properly understood. For example, quality is achieved by having each operator check their work or having the preceding operator check the product before sending it to the next station etc.

2.7. LIMITATIONS OF LEAN MANUFACTURING

Ahlstrom [2] and Lewis [61] contends that the more successfully any firm applies lean production principles, the less it will engage in general innovative activity. They further contend that establishing causal linkages between inputs and outputs is notoriously difficult in any complex system.

Katayama and Bennett [53] have discussed that the changing competitive world from the Japanese perspective to other nation’s perspectives makes the implementation of lean manufacturing concepts more difficult. They have indicated several difficulties involved in different environments. They also argue that the lean production model may not be robust enough as an approach to cope with changing and volatile economic and market conditions.

Cusumano [21] has discussed traffic congestion due to frequent deliveries, supplier’s difficulties in producing smaller batches and getting suppliers willing to take on such work and the shortage of ‘blue-collar’ workers as the major hurdle in effective implementation of Lean Manufacturing.
Hence in summary the limitations of implementing lean manufacturing can be reduced to two primary elements namely, inability to deal with turbulent and consistent change and the pursuit of perfection to the extent that any scope for flexibility has been eliminated. It is observed that lean succeeds on a stable environment.

2.8. TOOLS OF LEAN MANUFACTURING

Drickhame [30] have stated that, lean tools play a key role in the implementation process. Lean principles function to orient the thinker in the right direction, such as the Just-in-time principle to reduce or eliminate the stagnation of material and information, or the Jidoka principle to build quality into the product by “stopping at the first defect.” The lean principles tell us which performance metrics are important and which will help us see problems that before hand might have been overlooked. Literature surveys on some of the lean manufacturing tools are discussed in the following sections.

Ohno [68] has put great emphasis on the use of Kanban to signal and pull orders through the Toyota plant. Considering the state of IT in 1978, it is no wonder that the chosen medium was hardcopy, printed cards. When the work cells are in “line of sight,” the cards are effective. But, as Kanban extends to a larger area, problems start to occur. Occasionally, cards are lost causing a lost signal, stock-outs and disruptions in production. When Kanban extends to multiple plants, printed cards become unworkable.

Monden [65] has defined, Kanban as an information system that is used to control the number of parts to be produced in every process. The most common types of Kanbans are the withdrawal Kanban, which specify the quantity that the succeeding process

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should pull from the preceding process, and the production ordering Kanban, which specifies the quantity to be produced by the preceding process.

Kanban in Japanese means "signal" or "card". Kanban authorizes the upstream process to produce only when there is a requirement for production. Kanban is an effective system to eliminate losses occurring due to overproduction.

Rajendran [80] has discussed the Kanban issue connected with the technological advancement. The conventional method of push production system is linked with Material Requirement Planning (MRP) was changed to pull type JIT production system to meet out the global competition, where the work-in-process (WIP) can be managed and controlled more accurately than the push-production system. He has integrated MRP II with the Kanban and has proposed a Kanban formula for the determination of number of Kanban. He proposes the link between manufacturing requirements planning (MRP II) with the Kanban.

Blair [16] has proposed a review of the Kanban production system and has discussed the different approaches of conventional push system with JIT pull system. The details of his proposals are as follows.

**Push system** It is a conventional system of production. When a job completes its process in a workstation, then it is pushed to the next workstation where it requires further processing or storing. In this system, the job has a job card and the job card is transferred stage by stage according to its sequence.
Pull system A pull type production system consists of a sequence of workstations involving value addition in each workstation (WS). In the pull system, from the current workstation (j), each job is withdrawn by its succeeding workstation (j+1). In other words, the job is pulled by the successive workstation instead of being pushed by its preceding workstation. The flow of parts throughout the product line is controlled by Kanban Cards as proposed by Berkley [12]. In practice, these Kanban cards can be either “single-card system” or “two-card system”.

Blair & J. Berkley [16], Sarathapreeyadarishini et al. [80] have described that, a Kanban system operates only with single card is called production order Kanban (POK). If the distance between the consecutive workstations is very short, a single buffer mode is made available between the workstations. This buffer mode acts as both outbound buffer for the current workstation j and inbound buffer for the succeeding workstation j+1, respectively.

Greg Gorbach and Ralph Rio [37] discuss that, when there is a small group of work-cells that are in close proximity with “line of sight”, physical Kanban cards work well. In normal operation, runners periodically gather manual signals (usually cards) from fixed collection points and physically move them to upstream supply centers.

Why is Kanban Necessary? It has been observed from standard books on JIT that, Kanban implementation provides the following benefits to the industry Viz., reduce inventory and product obsolescence, Reduce waste and scrap, Provides flexibility in production, Increase Output, Reduces Total Cost.
Richard [74] - have depicted another variation of Kanban. They have proposed that, a supermarket when introduced between processes to stock a predetermined quantity of parts/components, the process downstream pulls from the supermarket the required quantity of the parts/components, by issuing a withdrawal Kanban. At the supermarket, this automatically indicates that the parts/components withdrawn have to be replaced.

Kimura O. et al. [57], Hemamalini et al. [41], Jones [35], have discussed that, in the two-card system, where the distance between the two consecutive work stations are more, each work station will have separate inbound buffer and outbound buffer and the cards are called as Production Order Kanban (POK) and Withdrawal Kanban (WK) respectively.

2.9. RESEARCHES ON KANBAN

Strarton [83] has proposed in his literature review, the research work carried out during the period 1980 – 2005 on Kanban, are depicted in the following table.

Researches in different periods on Kanban [36]

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It is observed from the literature review on KANBAN, during the period of 2001-2005 in the flow shop there are a total of 6 Kanban implementation studies have been carried out. It is also observed that, Periodic Strategic Reviews are required for the fluctuating or exceptional demand.

2.10. VALUE STREAM MAPPING

The use of waste removal to drive competitive advantage inside organizations was pioneered in the 1980s by Toyota’s chief engineer, Taiichi Ohno [68] and is oriented fundamentally to productivity rather than to quality. The wastes in the Toyota production system proposed by Womack and Jones [88] as seven types of wastes categorized as overproduction (faster-than-necessary pace), Waiting, Transport (conveyance), Inappropriate processing, Unnecessary inventory (excess stock), Unnecessary motion and Defects (correction of mistakes).

Taiichi Ohno [68], Womack & Jones [87][88][89], Duggan. Peter Hines and Nick Rich [43] have studied the implementation of Value Stream mapping effectively. In essence, Value Stream Mapping (VSM) is a visualization tool oriented to the Toyota version of Lean Manufacturing (Toyota Production System). It helps to understand and streamline work processes using the tools and techniques of Lean Manufacturing. The goal of VSM is to identify, demonstrate and decrease waste in the process.

Toyota have been benefiting since 1940’s, from Material & Information Flow Mapping (Value stream mapping). Taiichi Ohno [68] could not see waste at a glance (especially across a geographical area). He developed Material and Information Flow Mapping (VSM) as a standard method for mapping the flows visually and it became the standard basis for
designing improvements at Toyota - as a common language. It became one of their business planning tools. VSM is now utilized throughout the world, in many businesses to strategically plan and it is the starting point to any lean transformation and implementation.

Womack [89] and James [50] have stated that, the organizations of many types are implementing lean manufacturing, or lean production, practices to respond to competitive challenges. They have mentioned that lean initiatives can be taken up in the fields of automotive sector, aerospace, and consumer goods industries around the world.

Doolen [27] has extended the applications of lean production techniques in other electronics manufacturing perspectives. Further, Hay [40] has implemented Lean manufacturing in the office - service and administrative processes. Rother Shook has discussed that Value Stream Mapping (VSM) is used to define and analyze the current state for a product value stream and design a future state focused on reducing waste, improving lead-time, and improving workflow. The use of VSM appears to be increasing, particularly since the publication of “learning to see” by Rother Shook. One of the unique characteristics of VSM in comparison with other process analysis techniques is that one map depicts both material and information flow that controls the material flow. The focus of VSM is on a product “value stream” (all actions required to transform raw materials into a finished product) for a given “product family” -- products that follow the same overall production steps.

Badrinarayana S et.al [10] discusses that the interdependent components form the value stream and Value Stream is the set of all specific actions required to bring out a specific product. A Value Stream Map captures the real time product flow as well as the information flow.

Taiichi Ohno [68], Rojo [3], and Shigeo Shingo [81], Peter Hines and Nick Rich [43], Featherston [32] have discussed that the industry should always produce in Takt time, and to develop continuous flow wherever possible. They should use supermarkets to control production where continuous flow does not extend upstream, should define a pacemaker process, should level production and should level production volume and should always control overproduction.

The challenges in controlling Takt time are to provide faster response to problems, to eliminate causes of unplanned downtimes and to achieve low changeover times. Doug [29] states that there should be continuous flow as far as possible in the line i.e. producing one unit at a time with each unit passed immediately from one process step to the next without stagnation.

Monden [65], Hines [43], Badrinarayana [10] have discussed that the manager's roles is to report lean implementation progress to the top person on site, should be an authority in the line function with the capability to make changes whenever required, lead in the creation of the current-state, future-state value-stream maps and take active role in the implementation of plan proposed.
The authors Greg [37], Douglass [44], Fung [45] et.al have suggested certain activities have to be addressed for eliminating "Non Value Added Activities".

It is suggested by Douglass [44], Hyer [47] that, the value stream is supported by systematic approach from problem definition to measurement systems (SEDAC), which is a team oriented problem solving tool and uses a rigorous application to target the problem area and collects the cause and effect side of the facts, analyses the problems and propose improvement measures to be taken up.

S. Badrinarayana et.al [10] discusses that, the 3 stages have to be studied in analyzing the VSM. The 3 stages are,

1. mapping using the Current State VSM,
2. analyzing the Current State VSM and
3. Propose the desired Future State VSM.

He has suggested that the standard steps like collecting the data in the shop floor as regards to cycle time, setup time etc and map the current VSM,

The future state map forms the basis for the implementation plan, including "kaizen bursts" for focused improvement initiatives (such as set-up reduction). It is observed that many guidance materials for applying VSM are available in several books in RIO [37], Hines [43], and Douglass [44] and examples have been documented by Cicmil [45]. Badrinarayana [10] has proposed certain questions to explore the value addition.
Mejabi [64] has discussed the strategies for improvement through FVSM. He discusses nine important parameters if used effectively, can bring in improvement in the Value added ratio. He proposes that, one can check at the possibilities of reducing the changeover time of equipment, reducing the cycle time of equipment, improving the uptime of the equipment, identifying the possibilities of producing the parts using an alternate process,

Shingo [81] has discussed the strategies for the effective implementation of Value Stream Mapping in a wood industry. He also opines that loops can be formed to identify the similar processes and these loops will be helpful in identifying the non value activities in a systematic manner. He has suggested the ways to eliminate non value added activity and proposed measures to increase the Value added ratio.

Garnett, [35], and Doolen [27] have discussed that 5S, Pull system/Kanban, Cellular/Flow Manufacturing, Single Minute Exchange of Dies (SMED), Total Productive Maintenance (TPM), Value Stream Mapping (VSM) techniques can be effectively applied to the manufacturing industry in order to reap the benefits of lean production efforts.

The authors Alarcon [3] Blair [16] are of the opinion that, the factories are living organisms. The healthiest organisms move and change in a flexible relationship with their environment. Implementation of the five pillars is the starting point in the development of improvement activities to ensure any company's survival and, of course, survival of the company is necessary in order for the company's employees to keep their jobs. The two most important elements are Organization and Orderliness. The success activities depend upon "5 S implementation". The five pillars are defined as Organization, Orderliness, Cleanliness, Standardized Cleanup, and self discipline
Harry. M et.al [39] have discussed that there is a close relationship between DMAIC principle & Lean manufacturing tools. The tools used in DMAIC can be used in the implementation of Lean Manufacturing.

One-piece flow is accomplished by implementing a flow of material through production operation one piece at a time without being placed in containers for transport to subsequent operations. The parts are optimally produced in "U" shaped cells by one operator. Hunter [46] states that, cellular manufacturing is the basic building block of the Lean Production system and deals with lean production implementation and training issues.

Shah [79] provides a useful summary of cellular manufacturing and highlights some important issues that still need further research.

Schroer [1] also identifies the importance of cellular manufacturing in high variety just-in-time (JIT) production and later goes on to describe the importance of cells as a responsibility centre, pointing to the social aspects which are missing from other more technical treatments.

Suzaki [84] lists the organization of the workplace as the first principle of process improvement and notes that a U-shaped layout promotes the handling of multiple processes while minimizing wasteful walking.

According to Nightingale, [67], Manufacturing factory floor simulations are invaluable tools in the implementation of lean manufacturing. Many manufacturers will not make a change to the process before a simulation is performed to determine the impact of
the change. Simulation can be considered as inexpensive insurance against costly mistakes.

Wong [90] in his doctoral research paper has stressed that, the Simulation models are the final products of atoms, database & model generators and by changing the data in the database, a simulation model that corresponds to the new data set can be analyzed without much effort. He opined that it is possible to analyze various scenarios of Value Stream Mapping (VSM) within a short period of time and it is possible to obtain feedback information.

Adams, et al, [1], proposes the overview of how simulation could be used within the lean manufacturing strategy.

Christopher have discussed the role of Simulation in manufacturing activities, discusses the advantages of simulation in solving critical problems in the manufacturing setups.

Diamond et al, [26] discusses that, identifying and specifying the role of simulation within the lean approach seems valuable and even necessary in expanding the simulation application base.

Katz [54] discusses clearly the guidelines for the effective utilization of Simulation tools in the Industrial environment to improve productivity.

Bhasin [13] have carried out single piece analysis on 4 workstations and each workstation has a cycle time of 1 min per piece. They have used Little's law to calculate the effects of the batch size & have demonstrated the outcomes of the
different batch sizes in overall cycle time, throughput in pieces per minute and throughput in pieces per hour.

2.11 Total Productive Maintenance / Manufacturing

TPM is a Japanese idea that can be traced back to 1951 when preventive maintenance was introduced into Japan from the USA. Nipponenso, part of Toyota, was the first company in Japan to introduce plant wide preventive maintenance in 1960. The concept of quality circles was introduced in Nipponenso. Thus Nipponenso of the Toyota group became the first company to obtain the TPM certification. Peter Willmott and Dennis McCarthy [71] in the book titled “TPM- a route to World Class performance” have defined TPM as a company-wide team-based effort to build quality into equipment and to improve overall equipment effectiveness. The TPM manual provides the aspects of TPM principles and helps the employees in applying various tools to explore the possibilities of successful implementation measures.

Willmott [71] has identified various categories of losses in TPM. He opines that the teams can use these losses to identify and measure plant problems so that they can prioritize them and progressively reduce or eliminate them. He categorizes broadly the losses due to non availability, improper performance, and improper quality in the output.

Peter Willmott, [71] in his book on TPM discussed that, establishing a company-wide perspective places equal emphasis on strategic direction and delivery. This helps managers at all levels to present a consistent set of leadership values and behaviours.
- an effective counter measure to a shop floor battleground littered with incomplete initiatives.

Murman [66] have discussed the issues relating to the Set-up reduction (SUR) beyond the productive maintenance. They discuss that the set up reduction can happen due to many maintenance issues.

2.12. KAIZEN TECHNIQUE

Imai [48] has defined, Kaizen (Ky'zen) is stated as “Kai” means “change”, “zen” means “good (for the better)”. Gradual, orderly, and continuous improvement ongoing improvement involving everyone. Kaizen is a Japanese word meaning, “to change for the better”. Simply put, it means "Continuous Improvement". Kaizen is a methodology of continuous improvement which focuses on the elimination of non-value added activities throughout an organization.

Wittenberg [86] discusses that, Kaizen forms an umbrella that “covers many of the management techniques including quality circles, total quality control, total productive maintenance, suggestion systems, Kanban, just-in-time, productivity improvement, robotics and automation”.

Berger [11] has discussed that, Kaizen encourages learning by doing, requires all employees’ commitment towards attaining goals and enhancing performance, calls for management’s solid determination to act upon resistance to change, and fights waste in all its forms.
Chen [22] discusses that, a Kaizen-oriented organization attempts to reduce cycle time which is "the period between a product's design and the time of delivery of the product to the customer" and tries to get it closer to the Takt time which is "the theoretical figure that tells us how much time is needed to make one product at each process".

Shingo [81] states that, Jidoka is a Japanese word comprised of three Chinese characters, ji-do-ka. The first, "ji" is the worker. If there is something wrong or a defect, the worker must stop the line. This implies that workers and machines have the intelligence to identify errors and take quick countermeasures for correction.

Kimura [57] has identified the following causes of wastes in lean manufacturing.

Hines [43] has discussed the importance of the human dimensions of motivation., Nick [70] have discussed the Employee disappointment and discontent and have opined that it is difficult to ascertain how much of the problems that can be observed within any plant which is due to cultural differences rather than problems within the lean system that is being applied.

James [50] proposes a scheme of applying Lean & ERP principles with respect to 5 S principles.