CHAPTER 1
INTRODUCTION

1.1 Introduction to Lean Manufacturing

Lean manufacturing is one of the production control systems being implemented in industries with an aim for minimization of wastes and inefficiency which add to the cost of the product and does not add value to it. The implementation of lean manufacturing system in any industry helps in achieving an edge in a competitive market conditions by reducing costs and improving efficiency. This is reached by implementing the appropriate tools of lean which helps in eliminating the identified wastes in production process in a systematic and continuous manner.

Increasing demand in global markets while leading to manufacturing of high variety of products makes it essential for reducing cost in manufacturing, lesser lead time and perfect quality. This makes it necessary for manufacturing industries to adopt lean concepts. Lean philosophy is universal and can be applied to manufacturing, design, quality control, administration, order taking, accounts receivable or any activity that needs to be improved. Lean has been recognized as one of the key approaches not only in enhancing the productivity but also gaining competitive advantage.

1.1.1 Definition of Lean Manufacturing

Lean is nothing but manufacturing without waste, lean is centered on preserving value with less work “A systematic approach to identifying and eliminating waste called non-value added activities through continuous improvement by flow of the product at the pull of the customer in pursuit of perfection”. Lean manufacturing concepts also focuses on reduction of cost by eliminating the Non Value Added activities (NVA) and reduction of Necessary Non Value Added activities (NNVA). Value added activity means that which physically changes the material while non-value added activity means that which takes time, space and material but does not change the physical material.
Lean manufacturing is a process that aims at consistent elimination of waste through continuous improvement and strives for perfection. Lean manufacturing uses set of tools and methodologies to eliminate all the waste that occurs in the process of manufacturing. The ultimate aim of lean manufacturing is to reduce the production cost, increase efficiency and shorten the production lead time. Lean manufacturing is used in many of the manufacturing industries including automobile industries and their suppliers. According to the dictionary the word ‘Lean’ refers to strong and efficient and it also refers to thin and fit so this indicates that the lean manufacturing only gives facilities to get only required resources for an organization to be strong, efficient, thin and fit. Lean manufacturing shall be the core paradigm in elimination of waste.

1.1.2 History and Evolution

Lean manufacturing started at the beginning of 20th century in Japan by Mr. Sakichi Toyoda in a textile factory. Toyota production system started its journey way back in 1934 when it entered into car manufacturing with a concept called Just In Time (JIT). It later evolved as lean manufacturing system by assimilating various concepts into it aimed mainly at improving the efficiency of the production process. As stated by lean manufacturing paradigm Toyota production system identified seven types of waste but due to some practitioners it has been modified and expanded that includes transportation, inventory, motion, waiting, overproduction, over processing, defects and knowledge disconnection. Though there are many tools and methodologies that can help an organisation for lean transformation some of the essential tools are standard work, visual management, value stream mapping, 5S, preventive maintenance, total productive maintenance, changeover, batch size reduction, Kanban, etc.

Lean Six Sigma is another concept being implemented widely which incorporates both lean tools and statistical tools for improving the existing process. Data generated in industries analyzed using statistical tools along with Six Sigma concept will help to achieve control in the production systems within a range. Many a times the control charts will help to maintain the quality of the products and services in an optimum range in order to achieve lean production. Otherwise the system tends to over process the products in the guise of delighting the customers or sometimes the process will go out of range and ultimately the product gets rejected by the customer.
1.2 Seven Types of Wastes

Lean manufacturing, in general identifies seven types of wastes in any manufacturing process. They are identified through a systematic diagnostic study during the starting of lean journey in any organisation. Most of the small and medium enterprises are being started and managed by technocrats who have gained considerable experience working in other industries. They are very good in solving technical issues in manufacturing whereas they lack the expertise in other managerial areas. Lean manufacturing, through seven types of wastes helps to identify the non value adding activities. Once these wastes are identified, lean manufacturing offers a variety of appropriate tools to address and eliminate or reduce them. By this process it helps to reduce the variation in any process and thereby the cost of production. The seven types of wastes are discussed below.

1.2.1 Transportation

Transportation is moving materials between processes which may not add value to the product, hence minimizing of the transportation costs is very much essential. Waste of time and energy can be minimized by locating the machines or plants closer to one another in the order of production chain, and by using better material handling. Transportation involves resources used in handling the material, staff employed in operating transportation, implementing safety precautions, training and using space. Unnecessary transportation involves waste of time in waiting, as the production chain stations are made to wait for materials from previous station to arrive.

1.2.2 Inventory

Inventory is the buffer stock of raw materials, work in process and finished products maintained by any industry to manage uninterrupted production and supply. This includes occupying more storage space, the capital invested in this unprocessed inventory, the transporting involving the inventory, the containers used for holding the inventory, lighting, etc. Moreover, the excess inventory hides the mistakes and defects in the production process and management of inventory. The other impacts of inventory waste are
packaging, deterioration or damage of work-in-process, additional raw materials required to replace obsolete and damaged inventory, the energy required for lighting, heating or cooling the inventory space, etc. The cash help up in this sort of inventory is not made available for other needs.

1.2.3 Motion

This waste is related to human ergonomics and is observed in all instances of lifting, bending, stretching, reaching, walking, etc. These lead to health and safety related issues for the workers. Hence jobs with excessive motion have to be analyzed and redesigned for improvement in a work environment by involving the plant personnel. Wasteful motion is the motion that can be minimized whether it involves a person or a machine. If more motion is used to add value which can be done by less motion, then the extra motion is termed as waste. Motion could also refer to additional wear and tear of machines which results in capital depreciation which must be replaced. Excess motion also leads to many environmental costs such as waste materials that are dumped collecting dust and dirt.

1.2.4 Waiting Time

Waiting is the wasted time in the production chain due to slowed or halted production in one step delaying the next step. The task which takes more time could be improved by using sophisticated equipments or redesigning the process, or by employing more personnel. The workflow has to be balanced and coordinated or scheduled properly in order to reduce waiting time. The environmental aspects of impact are wasted labor, energy for lighting, cooling or heating, during the waiting period. Also, material can be spoiled or damaged due to an inefficient workflow. Waiting time for any instructions / information should also be minimized.

1.2.5 Overproduction
Overproduction is manufacturing an item before it is actually required. This is the most serious of the seven wastes which leads to all other types of wastes and results in excess inventory. Excess inventory leads to increased material handling and increased labour. Overproduction is highly costly in a manufacturing plant because it inhibits smooth flow of materials and also degrades quality and productivity. “Just in Time” is a method where every item is made just when it is needed which helps to reduce overproduction. Overproduction results in excessive lead times, high storage costs, and makes it difficult to detect defects. The simple solution to overproduction is to maintain optimum inventory at all places. This requires a lot of convincing as the problems that overproduction is hiding will be exposed. The remedy is to schedule and produce only what can be immediately sold/shipped and improve machine changeover/set-up capability. Overproduction may also have very serious environmental effects as more raw materials than necessary are consumed which may spoil or become obsolete, which requires that it has to be tossed and, if the product is a hazardous material, it results in extra emissions, extra costs for waste disposal, possible worker exposure, and potential environmental problems resulting from the waste itself.

1.2.6 Over processing

Over-processing refers to any process which is more than what is required by the customer based on the specification. Essentially, it refers to adding more value than the customer requires which finds no use. Over processing also not only increases the cost, materials used and wear and tear of the equipments put to use, but also the time of the operator who could have been otherwise put to perform other value adding processes. Providing high surface finish or more aesthetic look for industrial products are examples of over-processing.

The environmental impacts involved are the excess of parts, labor, and raw materials consumed for production. Time, energy, and emissions are wasted when they are used to produce something that is unnecessary in a product. Simplification of the product
and production efficiency reduces these wastes and benefits the company and the environment.

Many organizations use expensive high precision equipment where simpler tools would be sufficient. Use of low-cost automation, well maintained machines, investing in smaller, more flexible equipment wherever possible, creating manufacturing cells, and combining steps will greatly reduce the waste of over processing.

1.2.7 Defects

Defects are the products deviating from the standards of their design or from the customer’s requirements. As defective products do not find any use, it either to be reprocessed or disposed of as scrap. Resources used to produce the defective product leads to inefficient or non-essential activities. Replacement requires additional work to process it. In due course it may lead to potential loss of customers. Moreover, a defective product means there is something wrong in the production process at some other levels that may have led to the defect. Hence it becomes more important to make a more efficient production system which will reduce the defects. The management has to increase the resources needed to address them in the first place. Environmental costs of defects include the raw materials consumed, disposal or recycling of the defective parts of the product, the extra space required and increased energy use involved in dealing with the defects. Having a direct impact to the bottom line, quality defects resulting in rework or scrap are a tremendous cost to organizations. Associated costs include quarantining inventory, re-inspecting, rescheduling, and capacity loss. In many organizations the total cost of defects is often a significant percentage of total manufacturing cost. Through employee involvement and Continuous Process Improvement (CPI), there is a huge opportunity to reduce defects at many facilities.

In the latest edition of the Lean Manufacturing classic Lean Thinking, Underutilization of Employees has been added as an eighth waste to Ohno’s original seven wastes. Organizations employ their staff for their nimble fingers and strong muscles but
forget they come to work every day with a free brain. It is only by capitalizing on employees’ creativity that organizations can eliminate the other seven wastes and continuously improve their performance.

Many changes over recent years have driven organizations to become world class organizations or Lean Enterprises. The first step in achieving that goal is to identify and attack the seven wastes. World-class organizations have come to realize, customers will pay for value added work, but never for waste.

1.3 Lean Implementation Methodology

Before starting the implementation of lean, there are some preparatory steps to be undertaken in any organisation. All the activities being carried out in the organisation have to be studied, analyzed and specified with respect to their contents, time taken for completion, sequencing of operations and the expected outcome from them. These specified activities should have defined path which will lead to the products manufactured or services rendered.

Once all the activities are specified then the process of improving them shall start. These improvements should be carried out using a suitable scientific method. This method can be chosen from the proven list of lean tools available. The tools shall be appropriately selected for micro level activities and macro level activities. This will help to achieve optimum levels of improvement in the process.

The Indian Small and Medium Enterprises (SME) are working under typical circumstances where a large variety of products with smaller quantities are being manufactured. For these small lot batch productions, as far as possible the production processes involving man, machine, materials and methods should have to be stabilized. The quality of the products manufactured or services rendered must be improved continually. Wherever possible the inspection at source have to be implemented to avoid the deviations in quality, which will cost more if found at a later stage. Ultimately, all the
works have to be standardized based on the improvements and repeatable human movements.

1.3.1 Rules for Implementation

For the successful implementation of lean manufacturing we may have to prepare the team for the change, be very clear about the goal and see that all understand the advantages that will accrue while implementing. All employees should be trained and proper assistance provided in removing of any obstacles that is observed and ensured that everybody is involved.

This means the all the persons irrespective of their position should find ways and means of carrying out their activities in the lean methods at optimum cost and time. Even the management and organization structure has to be lean, so that the decisions can be taken at a faster method. The top management should make it a habit to visit the shop floor and all the sections like quality, engineering, sales, etc. This will help to understand the problems in a better way so that learned decisions can be taken. In all the decision making processes the floor personnel have to be involved so that the decisions taken shall be implemented with full involvement without any resentment. Every activity shall have well laid out plan so that there will not be any surprises. Imparting training should be made a regular aspect in the organisation so that good employees will be retained. Even small improvements and victories must be celebrated and rewarded.

1.3.2 Collecting Baseline Data

Baseline data is information about the current conditions prevalent. Before starting lean implementation the baseline data in all departments pertaining to the production, time taken, quality control, inventory, energy consumption, manpower deployed, machine idle time, breakdown data, throughput, overtime, productivity, changeover time, etc. has to be collected and recorded. This helps to know where the organisation stands. The data has to be analysed to identify the bottlenecks in the organisation that requires improvement. At the end of each project this will also help to take credit for the improvements based on the projects implementation. It is not sufficient to know the macro details, the micro level data has to be gathered for better understanding and implementation.
1.3.3 Where and How to Start

Based on the data and on the analysis make proper moves have to be worked out has to be taken as to where the organisation needs to elevate itself at the end of lean implementation. The customer focus should be the guiding principle in terms of demand, quality and price. Accordingly the projects have to be identified. The projects have to be started in such a way to reap the low hanging fruits initially and quickly. This will boost the confidence in the minds of employees to create more acceptances for the lean culture.

1.3.4 Organizational Cultural Challenges

As we all know any changes if it is to be implemented will initially have a resistance. When a decision has been made by an organisation to implement lean for achieving greater efficiency it is paramount to create a culture that will sustain lean. The prevailing culture and the changes in it have an impact on the performance and the desired outcome. Proper communication and co-operation among all the employees of the company will lead to a greater success in addition to having a common understanding, participative culture brings expected performance.

In order to overcome the resistance the older employees have to be taken in to fold and convinced of the lean benefits initially. These people will in turn lead the new younger persons to adopt the lean culture. After this the external consultants have to be brought to have a fresh perspective of the operations and suggest ways. The expectations of the top executives have to be converted into goals and standards for the projects. These goals and standards have to be measured in a periodical manner as the project progresses. Any union issues can be solved by offering profitability sharing of the benefits of the projects. Ultimately you can create any improvement you want in the organisation.

1.3.5 The Principles of Lean

Once the stage is set for lean implementation the following guiding principles can be adopted for its efficient implementation. The value of any operation has to be based from the customer’s point of view, for determining the time required for manufacturing, delivery and the price. Once this is determined, the entire value stream has to be analysed to reorganize the actions that do not create value for the customers. The value creating steps have to be created by eliminating those which does not create value and ensure that the product flows smoothly to the customer on time through pull. Once this cycle of creating
value is accomplished, it has to be seen that the improvement is maintained by repeating it again and again until a perfect state of value creation with no waste is reached.

Therefore the following steps shall represent the principles of lean.

- Identify the expectations that is value in the process
- Map the value stream
- Create smooth flow by eliminating waste
- Establish the pull
- Achieve perfection by repeating the above

The core idea of maximizing customer value by minimizing waste that consumes resources but does not add value to the customer shall be kept in mind. In general lean is not about eliminating people and resource it is better utilization of the resources and expanding the capacity of the organisation.
1. CHAPTER 2

2. LITERATURE REVIEW

3.

4. An organisation to be successful not only requires proper care and surveillance but also certain good practices and strategies. Organizations require a clear understanding on what is to be done to be more competitive. To achieve success an organisation shall have a commitment to science based practices; it is here that lean manufacturing plays a very vital role.

5.

6. Several industries have already adopted the lean techniques or already in the process of adopting the same in their production houses. Industries that have already done the lean implementation have been able to gain efficiency to increase production by identifying and eliminating wastes that do not add value.

7.

8. Only value added activities are focused upon, in lean manufacturing. This helps in cost reduction. Process improvement is used right from concept to completion – including inventory, lead time, set up time. This can be implemented in all types of manufacturing. Manufacturing of new products; continuing to produce existing products; making variations in existing products; quick prototyping of other similar products; analyzing the market and competition – all become easier with the help of lean manufacturing. Cost reduction at every stage is essential. The industrialists need to understand the emphasis to be laid on implementation of lean principle as stated by Neha et al. (2013).

9.

10. According to Nallusamy (2016d), industries need to look at their existing production processes; retain only the relevant and essential procedures and processes; eliminate all the irrelevant and non value added activities, however small or big, each of those activities be. This helps in reduction of costs to a major extent. Once the unwanted activities are eliminated, the production processes improve thereby improving the overall quality of the product. This results in increased sales.
volume and an enhanced profit. Lean system has a great impact on the industries. There are several measures to assess the impact of the lean
11. System in the industries. Study of the business as a whole; the business during the usage of lean; benefits achieved after the implementation of lean; study of various activities concerning lean; turnover rate before and after the lean implementation; providing proper and adequate training for the employees; study of customer satisfaction indices are some of the critical factors that reveal the impact of lean on the industries. The study takes each critical issue and proves through hypothesis testing. Successful implementation of lean in automotive industries had had a very positive impact on the performance of the employees as well as the industry as a whole. The objectives were arrived at, after a thorough study conducted through questionnaire mode for employees at various levels in manufacturing industries. The hypothetical co-relations were found out, based on frequency analysis of various issues. The outcome of the study proved that every single issue had contributed for the success of lean production.

12. There are various tools to identify opportunities for implementation of lean techniques. One of the key tools is Value Stream Mapping (VSM). VSM helps in identifying the status of various aspects of the production process, before and after the lean implementation initiative. Only when the benefits and the potential benefits could be determined, lean could be implemented successfully. VSM helps managers to determine the same. VSM helps managers to identify the time taken for the inventory processes; the actual production lead time; the quantum of time to be reduced; the quality of time saved to be utilized for other value added activities etc. VSM can be applied for all the steps of the various processes including value added and otherwise. Analysis through VSM makes managers take proper decisions regarding the various production processes. It is also a significant tool for effective waste management. Classifications of waste, finding out the quantum of hidden waste and identifying the sources of waste are all possible through VSM. The production floor processes are mapped in a document, without any deviations and represented in exactly the same manner in which the floor operates. Then, another map is drawn representing the design of lean process flow. Of course, care is taken to eliminate all unnecessary and unwanted minor and non value adding activities to get the same products in a lesser time, with more quality output for the entire process. This futuristic map points out the root causes of waste and directs the
processes towards zero waste process. Systems, procedures, processes involving men, machine, material and all other aspects are considered and the map is documented for linear implementation. The step by step implementation plan is detailed so that the Lean Production (LP) objectives are attained in a systematic and simple manner. (Rahani and Muhammad 2012) have in detail described the mapping process for the current and future. The study clearly establishes the fact that the usage of VSM results in improvement in production. VSM also helps in identifying the wait time and to take proper efforts to reduce the same. The wait time affect productivity. Reduction in wait time had resulted in quantitative and qualitative improvement in systems and processes and on the overall productivity. The quality of the products improved. Higher the quality of products, lesser will be the defects. Lesser the defects, lesser would be the rejection percentage. Thus a simple wait time reduction results in increased bottom-line through enhanced performance.

14. Meanwhile, it was also found that lean manufacturing model was yet to be applied in certain cases of products. One among those products was gear shaft. VSM was developed in late 1980s by Toyota Motor Corporation in Japan. Thereafter for about one decade VSM was applied to identify the waste and evolve suggestion to overcome the same in manufacturing companies. Lean manufacturing model has widely been adopted in organizations during the past three decades. The analysis of gaps between standardized work and real work helps in understanding the fact that continuous improvement could happen with the long term commitment by the operators towards ensuring sustained improvement of the entire production process.

15. Nallusamy and Adil Ahamed (2017), explained that Value Stream Mapping could help in spotting outwaste, removing and eliminating waste in manufacturing, production and business processes. The speed of the processes increases when the value adding time increases. The increase in value added time is because of the reduction or elimination of waste in the processes. The changed process enhances effectiveness and efficiency of all the aspects involved in the business. Investments become lower; expenditure decreases; revenue increases; quality improves; costs are less and more economical; the entire process becomes smooth and simple; the
flow chart in the future map – after lean implementation – documents all. The successful implementation thus benefits the industry and the economy as a whole. With the help of tools like 5S, VSM and Line balancing in a manufacturing industry, the existing layout was analysed; the non value added activities were eliminated and redesigning of the process was done. The results showed a reduction of 13% in non value added time and an increase of about 10% in process cycle efficiency. Virtual simulation was conducted to verify and validate the existing situation as well as to propose the results and the effectiveness of lean principles in a systematic manner with the help of ARENA.

18.

19. Oberhausen and Plapper (2015), discuss the concept of flexibility, an important aspect of the common approach. In a value stream diagram, there should be flexibility to hide or show details to groups of different levels. The items can be segregated as per the needs of the users. This would help in quick and easy understanding of the processes pertaining to a particular group or groups. This helps in avoiding wastage of time in understanding an entire process by a particular group – if that group is involved only in one aspect of a product. Thus it is important for VSM to be made as flexible as possible. This helps in reviewing of the whole process in a quick manner wherever necessary and also of the whole process in a detailed manner wherever essential. The classifications of the different levels were indicated by different colours. The different sections could be adjusted flexibly which is the essence of the concept of flexibility.

20.

21. Nallusamy and Saravanan (2016a) state that, it is imperative to adopt lean techniques if the manufacturing industries are to compete effectively in the global market. Successful implementation of lean techniques leads to increased customer satisfaction. Over the past three decades, many large scale business houses had designed and implemented lean manufacturing successfully. Lean helps in creating more value with fewer resources. Its ultimate aim was to provide customer delight. For both product management and management of services, lean implementation could be very beneficial. The customer needs are ever changing and desires are ever growing. Industries face the challenge of meeting the varied requirements of the various customer segments, without any compromise on quality, ensuring low
cost. Minimum cost, Maximum Production, Ultimate Customer Delight, Increased benefit for all the stakeholders, strengthening of the economy were the results of successful implementation of various lean techniques.

22. An industry that implements lean techniques finds that information management in the entire network – bottom up, top down and across – becomes simple, fast, dynamic and accurate. In a small scale automotive component manufacturing unit, a study was conducted using lean tool applications regarding set up time, transportation time and particularly in the production floor where the operators had to understand and agree on the description of the various parts. The existing and future operations were mapped and documented and areas of reducing time for set up and transportation were identified. The rescheduling and rearrangements helped in significant reduction in disagreement among operators because of parts description.

24. Kanban scheduling system was also introduced thereby reducing the cycle time. Standardization of work helped in reduction of cycle time by about 350 seconds and setup time got reduced by about 1500 seconds. The reduction in cycle time through work standardization and introduction of Kanban, helped in making quicker deliveries. After the implementation of Standard Operating Procedure (SOP), the overall lead time got reduced about 32% (5780 seconds to 3946 seconds). All these in turn, resulted in increased customer satisfaction.

26. According to Rohac and Januska (2015), VSM helps in making small and continuous improvements in operations. It also helps in generating capital intensive projects, in line with the growth strategies of the companies. VSM directly contributes to the company to march ahead in the correct path towards attaining its goals, in adherence to its mission statement and achieve its vision.

28. VSM is basically an analytical tool. VSM identifies bottlenecks and the root causes for the same. VSM also spots the potentials for improvement at various levels of the process, spreading across the entire network of the business – including
production, procedure, processes, floor operations, sales, marketing, management within the particular company; within an industry; and among competition globally.

30. Ratheesh (2015) emphasizes on the need of standardized procedures in a manufacturing industry and lays stress on improving the quality of standard procedures. In every organization, standardization of procedures is important because standardization always leads to smooth and efficient material flow, maintain high quality and ensure optimum productivity. Standardization of procedures is the best solution for problems that crop up during production process due to uncertainty and variability. Most of the factories redesign their layouts whenever there is a change in the production requirements. With well thought out procedures which pave way for flexibility, modularity, and re-configurability, factories need not have to strain on changing the layout every time.

32. He also suggests that, if a technique had been successful in one machine or one department, the same could be spread to the other machines and other departments, of course considering the overall nature and operations. Spotting the non value adding items; squeezing them out and reworking the process need to be done. Standardization of work helps in documentation of the various processes. It reduces variability. Training of new operators, becomes easier and better. Workplace injuries and strain are reduced considerably. There is a solid improvement in each of the line of activities. Standardization of work results in greater discipline among the entire workforce and discipline becomes the culture and need not have to be enforced. Standardization of work is supportive of inspection and audits, minimizes time taken for inspection and audit, has more transparency and also ensures involvement of all the team members in the respective areas of operation.

34. Despite the fact that standardization of work is beneficial to all stakeholders, implementation of the same had been a very tough task always. For implementation of standardization of work, every single and minute aspect needs to identified; the requirements and needs have to be spotted and weighed carefully; all the information pertaining to every single factor has to be unearthed, collected and compiled; new questions and concerns have to be properly addressed; necessary
training needs are to be given etc. Work study is a highly time consuming process. The study itself has to be effectively and efficiently done. Only then the implementation can be successful. Generally, work study is considered an unpopular exercise by the plant floor. Standardization of work is not a onetime exercise. Lean techniques are steps towards perfection; they do not achieve of 100% perfection. Lean manufacturing is to be carried out as a continuous exercise. The standardization of work changes, with every step taken towards achieving perfection. The benefits that can be reaped are countless. Some of the benefits are safe work environment, optimum productivity, enhanced quality, increased customer satisfaction, well trained and disciplined workforce, swelling balance sheet size.

36. For effective and optimum utilization of machines, many suggestions were made. Change in layout to ensure improved utilization; introduction of new machines; much more advanced material handling system; developing the employees as multi skilled employees were some of the suggestions. Introduction of Computer Numerical Control (CNC) machines helps to improve plant lay out. Improved lay out design would help the company to reduce production cost.

37. Key Performance Indicators (KPI) relating to inventory and finance are very vital for any business. (Nallusamy 2016g) states that, the ability of a business house to identify, define, monitor and take necessary actions on these determine the success of the business. Total average revenue, average inventory carrying cost, average safety stock, days payable outstanding, forecast accuracy, inventory turns, inventory days of supply, products with more than a specified number of days of inventory, fraction of time out of stock, non-moving stock valuation and purchase from other sources are some of the main critical KPIs. In any industry, raw material, work-in-progress and finished goods have a cost. The expenditure incurred towards them and the amount blocked indicates the responsiveness of the supply chain to market demand.

39. A study was conducted in a machine shop of a manufacturing cell of a small scale unit manufacturing automotive engine casing by (Nallusamy and Saravanan 2016b), by using value stream mapping. Line balancing was adopted to improve the
performance of the manufacturing cell. Production data of the past were collected and compiled. Based on the information gathered and deciphered, gaps were identified and documents mapped for necessary rectification of problems and for enhancement of processes and overall performance. Single Minute Exchange of Dies (SMED) was used to regulate production. In all the workstations, Kaizen was also introduced. Leveled operator loading for output consistency was suggested. It was observed that even without infusing any major capital investment, capacity could be intensified further. Set-up time and idle-time were reduced significantly because of lean implementation.

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42.
43.
44.
45. Sheth et al. (2014) have cited that VSM has four major steps as given below in their article

- Select a product family
- Draw Current state map
- Draw future state map
- Develop work plan for implementation future state.

47. He modified it to implement a six step model as given below

- Step-1 Calculate TAKT(Tori Amos Khang Trang Time)
- Step-2 Understand customer demand
- Step-3 Map the process flow
- Step-4 Map the material flow
- Step-5 Map the information flow
- Step-6 Draw the Time line

49. In the extremely competitive market of today, smaller lead times and minimum costs are highly essential for a company’s success. Equally essential, if not more, is high level of customer service. Value Stream Mapping is the one of the lean manufacturing tools to reduce lead time. The study was about VSM in an automotive industry. The aim was to identify waste – the hidden and the obvious waste - in terms of non-value added activities. Current map detailing the existing
position and problems was prepared. Future state map was drawn to show the implementation action plan.

50.

51. According to Nallusamy (2016a), for waste reduction in any industry, lean manufacturing is an effective strategy. Where there is waste reduction, there is improved productivity. Waste reduction and improvement in productivity are directly proportional. The more the waste reduction; the more is the improvement in productivity. (Nallusamy et al. 2015a), analyses, lean philosophy in manufacturing as the concept which mainly focuses on waste reduction. If manufacturing industries have to survive and succeed in the global economy as good competitors, they need to adopt all the new technologies and tools. Lean manufacturing is one of the basic techniques for improving the production rate with the minimum available resources. Lean identifies some wastes namely Excess Inventory, Over Production, Equipment breakdown, Material shortages, Yield loss, Rework, and Scrap, Non-optimal performance, Changeover, Material transport, Material storage, Inspection, Delays, Walking and Idle time. Green manufacturing is an up-and-coming philosophy of manufacturing aiming at reduction of negative impact on the environment.

52.

53. According to Suganthini Rekha et al. (2016a), cycle time is one of the most significant characteristics in manufacturing. It is an interval of time during which a set of consecutive actions takes place repeatedly. This in turn is defined as the time of longest operation in a sub-assembly and assembly line. When there is proper line balance and when the sub-assembly layout is put to optimum utilization, the cycle time is reduced. Value Stream Mapping, is a technique to study the current state and design a future state for a series of activities that takes a product from its beginning through to the consumer. VSM has been the main tool used to identify the opportunities for various lean techniques. Customers look for customized products as well as unique products. The expectations of the customers have made the manufacturers to necessarily shift from mass production to flexible manufacturing. When there are multiple product needs, productivity becomes a very vital element. The study was done in a passenger vehicle seat manufacturing industry. The industry was deeply affected by manufacturing problems due to
various reasons – including higher cycle time, workload imbalance and improper layout. The main aim was to study the existing system of the seat manufacturing industry and to improve productivity using lean methodology without affecting the current working systems. Non value added activities were identified and methods required for improvements were recognized. Layout optimization was done using spaghetti diagram. The total cycle time was reduced by about 26.28% after implementing the revised layout.

54.

55. Nallusamy and Gautam Majumdar (2017), state that, in the competitive global market, companies are under compulsion to continuously strive to meet the demands of the customers. At the same time, it has also been observed that because of various problems like machine breakdown, delays in machining and setting process, it has become difficult to meet customers' demands on time. The objective of the study was to inspect the manufacturing losses arising on account of such problems by prioritizing the root causes with the help of a Pareto diagram and finally suggesting the solution to overcome these problems. Total Productivity Maintenance (TPM) helps to adopt a systematic work inside the shop floor which reduces the losses in production activity, increases the equipment life and ensures effective utilization of equipments and organized employee behavior. Introduction of new fixture reduced the idle time of machine during component setting and achieving cycle time reduction by analyzing cutting tool and its parameters which helps to increase the output to meet the customer demand. From the final results, it was observed that there was reduction in setup time, cycle time, breakdown losses and rework time, while the overall equipment effectiveness was also found to have increased by about 15%.

56.

57. There are several issues faced by different manufacturing industries. (Suganthini Rekha et al.2016b), explained that, an extensive range of lean manufacturing tools are available to take care of all kinds of such issues. It also helps for successful cost reduction of the manufacturing component and to assure the quality of manufacturer and customer. According to them, these days lean manufacturing technique is used as an imperative vertebral column of the production system in manufacturing divisions. The end users increasingly expect
their manufacturing vendors and suppliers to be responsive in delivering products on time. Hence, the industries are continuously striving towards reducing the cycle time in all the processes.

58.

59. Lean manufacturing has been already implemented in most of the large-scale automotive manufacturing industries. However, with reference to small and medium industries, there is not enough, systematically gathered information on the implementation of lean manufacturing techniques in their production line. The ever increasing demands for various products in the highly competitive market, necessitates the manufactures to focus more on the reduction of cycle time in the entire manufacturing process. Computer Numeric Control machines are a great boon to the manufacturers. Advanced and highly sophisticated, CNC machines help the manufactures to produce a variety of products within the stipulated time. The CNC machines also help in maintaining high quality because the machines can be utilized to produce unique and customer specific products. The cycle time is very much reduced and the products reach customers on time; thereby increasing the various benefits for the company as well as its stakeholders.

60.

61. A steering gearbox manufacturing industry was taken up for study. Kaizen was introduced for continuous improvement. Other scheduling systems and line balancing activities were implemented. The research focused on definite line of gear box manufacturing for continuous improvement through kaizen and other inventions. After the brainstorming session with the different levels of stakeholders who were responsible for the entire production process, the various issues were identified, collected and analyzed thoroughly. Finally, it was decided to execute the necessary lean tools. The focus was on ensuring that the whole process would be within TAKT time. Many suggestions were given to get maximum utilization machines. After implementing the lean tools as per the decisions taken, the total setup time was reduced by about 180 minutes and cycle time decreased by about 98 minutes. The total lead time was thus reduced considerably. Productivity increased and the gearbox manufacturing industry benefitted from the lean implementation.
63. Nor Azian Abdul Rahman et al. (2013), state that it is imperative for the success of an organization to design and offer the best products and services always. Further, to stay ahead in the global market, continuously facing the challenges due to unprecedented market changes, organizations need to introduce new and unique products, in tune with the requirements. This can be done only when the organizations realize that it is utmost essential to improve the manufacturing operations. Deploying lean techniques in manufacturing practices is one of the strategies for improving the operational performance. An industry, for its production processes needs to have only the required amount of men, material, machine and other resources. Anything other than this minimum required amount necessary for the production is Waste. Though many organizations have the best of knowledge and resources, they have not become lean yet. It is important that such organizations evaluate and assess the current state of operations in their manufacturing facilities. Implementing an effective Kanban system and other good manufacturing practices in the manufacturing facilities will enable organizations to become zero waste organizations.

64.

65. Kanban system is one of the lean tools that help in achieving minimum inventory at any point of time. There are very many advantages of Kanban to effectively and efficiently manage operations and business of the organization. Use of Kanban in production lines of the industry, is a strategic operational decision. It helps in improving the company's productivity and also, at the same time, minimizes hidden and obvious waste in production. The Kanban system advocates production to be taken up only when there is a demand for products. In countries like Japan, the manufacturing companies have successfully implemented Kanban system. Kanban originated from Japan. However, it was found that in Malaysia, particularly, in the small and medium enterprises of manufacturing sector, not all the companies are deploying Kanban system. Even though there are some SMEs using the Kanban system, they are facing problems in making the system effective. Understanding and implementing Kanban helps a manufacturing industry to be highly successful.

66.
67. The study concludes that, implementation of Kanban yielded excellent results. It minimized wastes, cut down on losses, work stations became more flexible and simple to use, over production of stocks were controlled and the overall process became much more smooth and easy to handle. The operational costs decreased and production was on time. Ineffective inventory management is a major obstacle to implement Kanban in a manufacturing industry. Lack of participation by employees and suppliers; inadequate or nil efforts towards quality improvements and quality control; non committal attitude of the top management are other major hurdles in the successful implementation of Kanban in a production process. The study implies that further research needsto be done on SMEs – particularly on the barriers in implementing Kanban in SMEs. The study also stresses the need for developing standard operating procedures for every process involved in production line. Improvement in the existing policies with reference to effective processes will help industries maximize the process effectiveness.

68.

69. According to Nallusamy et al. (2017), for any manufacturing business, a global market inventory management is one of the largest and most significant resources. For classification of inventory, ABC analysis is one of the methods used extensively in manufacturing industries. ABC inventory classification approach is a more popular approach. Under this approach, the inventories are classified as A, B and C classes depending on their annual consumption value. The inventory managers regularly classify and group all the inventory items to direct and control the maintenance and flow of inventory.

70.

71. According to Bhalwankar and Mastud (2014), VSM is a value stream that includes all elements- both value added and non-value added that occur to a given product from its inception through delivery to the customer. VSM mainly deals with three steps: current state map, future state map and action plan. Main steps to achieve an optimized value stream consists of selection of product family that is of high demand and lesser variety, forming of multidisciplinary teams, understanding the customer demand, mapping the process, material and information flow, calculating the TAKT time, lead time and change over time. Understanding and
application of mapping symbols in designing material, process and information flow and data collection are vital parameters for the success of mapping.

72. According to Nallusamy (2016b), Total Quality Management (TQM) is an important technique for any successful business. TQM practices guarantee survival in a highly competitive global market. TQM can be broadly conceptualized into flexible and rigid practices. TQM practices identified play a significant role in assessing quality levels. In earlier decades, several studies were made on Total Quality Management practices in small and medium scale enterprises. The limited level of investigations made so far, on the various research works, has led to identifying different factors that influence TQM practices in SMEs and its supplementary growth. It gives a broad overview of how TQM practices are constructed and how it acts on the various quality improvements.

74. Nallusamy (2016c), states that, reduction in lead time; increase in quality standards; maintaining competitive costs are essential for production units. This is mainly due to the growing universal competition. It is important for business houses to design and flexi-design their manufacturing amenities to provide for facing the new challenges of the global markets so that they could survive and develop in the tough marketplace. Generally, maintenance is considered a support function and is seen as non-productive in nature, mainly because it does not generate any direct revenue. For any company to deliver the goods at the right time to the end users, the right quality and quantity of products are to be ensured. To produce the right quality and quantity of products, the machines must operate in the right manner, efficiently and smoothly. The production cost needs to be minimum so that the attractive and reasonable pricing can be done and maximum profits be earned. This is possible only when the machines are well maintained on a regular basis. Only when the maintenance is effective, availability of machines can be maximized. Maintenance also helps in minimizing equipment downtime due to unwanted, unwarranted and unnecessary stoppages. The equipment reliability increases with an effective and economically feasible maintenance system. Else, the equipment reliability suffers and the production plant suffers due to poor availability and increased downtime. The conditions of the machines have a direct
impact on the key performance indicators. The poor KPIs are the direct result of poor machine conditions. Non maintenance of machines, poor maintenance or improper and inadequate maintenance affect the quality of the machines and in turn results in decreased employee morale thereby affecting the production on the whole. When the machines are not in condition and when the spirit of the employees is low, there is a negative impact on the company’s operational effectiveness. Hence instead of treating maintenance as a mere supportive function, it is important that maintenance is treated as one of the main functions. The process and organizational engineers should necessarily design an effective maintenance system for the plant and its machines.

76.

77. Nallusamy (2016h), states that, in the present scenario, right quality, right delivery at right time has assumed high importance. Overall Equipment Effectiveness (OEE) of a machine plays a significant role in ensuring all these three major factors influencing the customers. The aim of the research was to study the impact of implementing an independent maintenance system in a machine shop for enhancing OEE with the help of Total Productive Maintenance and 5S techniques using a systematic approach. The focus was on minimizing breakdowns, increasing the performance and quality rate of machines. During the research discussions, reviewing of documentation and sequential records and direct observations were used as data collection methods. This research work dealt with the aspects of availability, performance and quality that are used to calculate the OEE of a machine. The TPM techniques such as 5S, preventive maintenance and cleaning were effectively applied on the machine. The final result showed that the OEE improved by 5% in horizontal machining center and by 7% in vertical machining center. In order to accomplish this goal, well organized maintenance, autonomous maintenance groups, better communication and excellent group work were developed. Current and accurate information were made available to management, efficient data recording systems were created in the industry.

78. According to Rajenthirakumar et al. (2015), lean manufacturing is the backbone of an effective production system in a manufacturing sector. It has wide variety of tools to treat all kinds of problems faced by an industry. Lean manufacturing also helps in making cost effective products and benefits all the
stakeholders including the customer and manufacturer. VSM and work standardization are key tools used in lean manufacturing and lean transformation which makes the process smoother and helps in reduction of lead time and ultimately increases productivity. On the other hand, line balancing ensures optimum utilization of resources reducing the idle time. This paper makes a case study on how a VSM, standardization and line balancing have to be carried out in a shop floor consisting of different types of Computer Numerical Controlled machines arranged in cells. Work Standardization was carried upon both cycle time and setup time of the process. Video analysis tool was used for time study. Effective man utilization is seen through line balancing. Results and benefits show the capability of lean tools over CNC production lines.

79.

In summary, the conclusions reached from this work are

- Standardization and line balancing provides appreciable results upon implementation over CNC machine cells
- Standardization resulted in a setup time reduction of 290 minutes and a reduction of about 118 minutes in cycle time
- The process has become smooth without any mismatch between planned time and production time, enabling trouble free work atmosphere
- Kaizens made for standardization had made it easy for operators to work freely without any stress
- Line balancing approach of effective man power utilization resulted in manpower reduction without affecting output

81.

Nallusamy (2015), through his studies reveal that lean manufacturing implementation enabled the companies to become competitive through elimination of wastes while producing products and offering services. Various tools like 5S, Poka Yoke, Kaizen, Kanban, JIT, etc have been used while implementing lean manufacturing model in various types of organizations. Both researchers and practitioners have found that Value Stream Mapping technique serves as a powerful vehicle in enabling organizations to implement lean manufacturing model. Lean manufacturing specifies the elimination of wastes by improving quality and productivity of the processes carried out in industries. This aspect reduces the manufacturing cost of products significantly and ensures delivery of the same at the
right time. This facility enables the company to produce high quality products with lesser costs. This ability improves the competitive strength of the organization. Because of this credibility, lean manufacturing has been implemented in automotive products manufacturing organizations producing several transmission products.

83.

84. Nallusamy et al. (2015d), studied Supply Chain Management (SCM) which plays an essential role in the industry development, market survival, rate of production and the vibrant communication among the suppliers and customers. SCM has been met with increased recognition during the last decade both by academicians as well as practitioners. SCM of a medium scale cast iron foundry was taken up and its system dynamics were studied. System Dynamics (SD) is a methodology whereby complex, dynamic and nonlinear interactions in the systems could be evaluated and new structures and policies designed to develop the system behavior. SD modeling requires two types of flows, one is the physical flow, and another is the information flow. They need to have an efficient quality control aspiring for defect free castings with minimum production cost. Strategic decision makers need extensive models to guide them for efficient decision ensuring that their profitability in the entire chain increases.

85.

86. Nallusamy (2016e), states that lean manufacturing techniques lead to the elimination of non-value added activities in the industrial ambience and identify the current manufacturing procedures, processes to achieve improvement in terms of cost reduction, increase in quality and profit. The study aimed at effective utilization of resources and productivity improvement by introducing lean techniques in a gas stove burner manufacturing unit by reducing lead time. The process flow of existing system was analyzed by using visual study and time study for individual processes. The current layout for the process flow was studied and the proposed layout was derived. The proposed layout was used for successful work flow to meet the future production requirement. To minimize the material movement and reduce work in progress inventory, the Kanban storage system was established. Rank position method was used for line balancing which gives optimum resource allocation for the process based on the Tori Amos Khang Trang
time. The proposed layout reduced the material movement from 97 meters to 63 meters and production also increased by about 20%.

87.

88. Vamsi Krishna Jasti and Sharma (2014), again explained in their paper, Value stream mapping as a lean manufacturing (LM) tool used for analyzing material and information flow on a specific product family. The purpose of this article was to address the importance of VSM in LM environment in the Indian auto components industry. According to the current state mapping, the study conducted analysis and identified the areas of improvement needed in terms of work in process, lead time and cycle time. The study further implemented kaizen on the current state map and developed future state map while including these Kaizens. The study clearly showed that VSM brings out positive impact on process ratio, TAKT time, process inventory level, line speed, total lead and process time and reduced man power.

89.

90. Nallusamy (2016f), studied the public transport system and suggested that, it is important to set up a well organized and efficient maintenance system with clear supply chain and excellent communication line between the production, planning and other departments. The main objective of maintenance work is to assure the delivery of properly maintained vehicles on time. Improvements are much quicker and important when Lean and Theory of Constraints (TOC) are combined together in manufacturing, where lean reduces wastages and TOC identifies the constraints. The mixture of Lean and TOC generates a good circle whereby the organization becomes continuously more effective by eliminating any additional expenses.

91.

92. In this case study where the passenger transport vehicle assembly is involved for the passenger’s transport service, the lead time taken for refurbishing the vehicle has to be minimized. To meet this requirement, all the subsystems which are undergoing refurbishment are to be closely monitored for servicing, testing and delivery to the final assembly line. In addition, some of the assemblies can be carried out parallel to minimize the lead time. This has resulted in improving the lead time taken from 60 days to 45 days i.e. 25% of lead time has been reduced. This had increased the availability of passenger transport vehicle 15 days ahead to
the passengers. Managing maintenance, repair and refurbishing are more challenging tasks than managing most manufacturing facilities since high degree of uncertainty has to be overcome in such operations.

93.

94. The production or the service units which have followed the TOC with Lean at their work areas have improved their performance without incurring any additional expenditure. Here the major requirements are refining and re-designing of the existing processes and their implementation. This will ensure improvement in lead time in refurbishing of the main assembly process in public passenger transport vehicles. The breakdown rate is the benchmark to measure the quality and reliability of public passenger transport services and the vehicles to be maintained without breakdown and also making the vehicles available as early as possible after the maintenance work by increasing the reputation of the service provider in the minds of passengers.

95.

96. Nallusamy et al. (2015b), states, proper selection of suppliers can considerably decrease production lead time, reduce manufacturing cost, increase customer satisfaction, and strengthen corporate competitiveness. Recent literature shows that Original Equipment Manufacturers (OEM) now-a-day’s aim to build long-term relationships with suppliers for sustainable business and purchase managers always face the challenges and difficulties. While selecting the right suppliers, careful assessment is required because suppliers have their own strengths and weaknesses. The supplier selection would be straightforward if only one criterion is considered but in real situations range of criteria are adopted for the purpose of defining the real situations then the problem gets multi-criteria decision making. In multi-criteria decision making problem, a set of criteria depends upon situations adopted by researcher.

97.

98. Nallusamy et al. (2015c), goes further in another paper and states that, supplier selection is the method of determining the appropriate suppliers to provide the right quality of products, at the right quantities, at the right price in the right time. So the latest multi-criteria decision making tools such as Analytical Hierarchy Process (AHP), Fuzzy Logic (FL) and Artificial Neural Network (ANN) were deeply
studied. The prime domain for existing fuzzy decision making was uncertainty. There are several states under the decision making process. There may be situations when even though decisions made are good, the output may be adverse. When good decisions are made continuously for a longer period, advantageous of situation may prevail. The AHP is a theory of measurement through pair wise comparisons and relies on the judgments of experts to derive priority scales. These are the scales that measure intangibles in relative terms. The comparisons are made using a scale of absolute judgments that represents, how much more one element dominates another with respect to a given attribute. The judgments may be inconsistent and how to measure inconsistency and improve the judgments, when possible to obtain better consistency is a concern of the AHP. The derived priority scales are synthesized by multiplying them by the priority of their parent nodes and adding for all such nodes.

ANN is another kind in its way such that it has a special learning feature and weights are calculated by assumption. It does not need the help of an expert or a fuzzy integration method. An artificial neural network is an information processing system that has certain performance characteristics in common with biological neural networks. Artificial neural networks have been developed as generalizations of mathematical models of human cognition or neural biology based on some of the assumptions. A neural network is characterized by neurons, method of determining the weights also called training the neuron and its activation function. Each neuron is connected to other neurons by means of direct communication links, each with an associated weight. Each neuron has an internal state called its activation state or activity level which is a function of the inputs it has received.

Nikunj and Chetan (2015), explains, the core of Lean is based on the continuous pursuit of improving the processes, a philosophy of eliminating all non-value adding activities and reducing waste within an organization. The Value adding activities are simply only those things the customer is willing to pay for, everything else is waste, and should be eliminated, simplified, reduced, or integrated. There are a number of lean techniques available such as, value stream
mapping, visual workplace, setup reduction, cellular/flow manufacturing, pull systems and total productive maintenance just to name a few; however, it is absolutely essential that lean is viewed from a total system perspective. Otherwise, either a company risks putting all of its efforts into the wrong areas, and/or the improvement process will come to a grinding halt after the initial project. This research provides a roadmap and implementation of lean manufacturing tools in manufacturing industries. The main objectives were reducing inventory, better utilization of space, reducing wastages.

Anna Dorota Rymaszewska (2014), stated that, the results of a diagnostic study present an assessment of the company’s current situations. The results uncover their readiness for lean implementation and identify the challenges that might hinder lean implementation. Early identification of weaknesses will make companies more aware of their own capabilities. Moreover, it has potential for making them better prepared for lean implementation and more consistent in their process. The importance of addressing certain aspect of lean implementation in the specific context of SMEs characteristics might contribute to the successful implementation of lean.

Ajay Johnson et al. (2017), lean manufacturing techniques are used to improve the industrial benefits by reducing the wastages. Wastages mean the non-value adding processes or works. This study focus on how lean manufacturing techniques are used to reduce the manufacturing lead time of a scaffold manufacturing company. To obtain this, there is a wide variety of lean manufacturing techniques used, such as value stream mapping, 5S, SMED and kaizen. Even though the main objective is to reduce lead time, there are also other objectives like increase in productivity, increase in quality, improvement in meeting the customer demands, improvement in on-time delivery, improvement in customer satisfaction, and machine utilization with reduction in wastages, inventory, huge material handling, and idle time, down time, setup time, space consumption and labor cost. Instead of investing huge amount in new machines to increase the working efficiency, it is much better to adopt these lean techniques in Indian Small and Medium Enterprises.
Melesse Workneh Wakjira and Ajit pal Singh (2012), made a study to evaluate the contributions of total productive maintenance initiatives towards improving manufacturing performance in Ethiopian malt manufacturing industry. The correlations between various TPM implementation dimensions and manufacturing performance improvements have been evaluated and validated by employing overall equipment effectiveness in boiler plant. The research focuses upon the significant contributions of TPM implementation success factors like top management leadership and involvement, traditional maintenance practices and holistic TPM implementation initiatives, towards effectively improving the manufacturing performance in the Ethiopian industry. The study establishes that focused TPM implementation over a reasonable time period can strategically contribute towards realization of significant manufacturing performance enhancements. The study highlights the strong potential of TPM implementation initiatives in improving the organizational performance. The achievements of Ethiopian manufacturing organizations through proactive TPM initiatives were evaluated and critical TPM success factors identified for enhancing the effectiveness of TPM implementation programs in the Ethiopian context.

This study was done in the manufacturing sector at Asella Malt Industry, Asella, Ethiopia, Africa. Major industry losses identified were shut down (planned maintenance), production adjustment, equipment failure (mainly boiler), process failures, normal production loss, abnormal production loss, quality defects, and reprocessing. The bottleneck was boiler plant for malt manufacturing process due to which productivity was going down most of the time and this plant was selected as equipment for OEE calculation. Through TPM process focus, the cost and quality were improved significantly by reducing and minimizing equipment deterioration and failures. Cost of rework and repairs were reduced after TPM implementation due to very limited products getting rejected due to equipment failure. Thus, the overall equipment effectiveness also improved significantly. Additionally, equipment deterioration was eliminated as the equipment operated efficiently. Autonomous maintenance activities were carried out with total
employee participation. The investment in training and education managed to boost operators’ morale and the commitment towards company’s goals.

111. Ahuja and Khamba (2008), experimented TPM in manufacturing and explained, maintenance has traditionally been viewed as a support and ‘non-value adding’ function of a business. Managing equipment performance has not been a top priority until recent years in manufacturing industry. The inadequacies of maintenance practices in the past, have adversely affected organizational competitiveness. The manufacturing sector globally has witnessed drastic changes in the later part of the 20th century. In the highly challenging environment, the quest for reliable manufacturing equipment has necessitated manufacturing organizations to accept equipment maintenance as an indispensable function for ensuring sustained profitability of enterprises. As organizations across the globe have faced stiff cut throat competition in the last three decades, Indian industry too could not escape the brunt of globalization. The purpose of this study was to highlight achievements of an Indian manufacturing enterprise through strategic Total Productive Maintenance initiatives. TPM implantation initiatives in an Indian manufacturing organisation have been investigated to ascertain benefits accrued as a result of successful TPM implementation.

113. Shahryar and Tan Ai Fen (2017), analyzed the application of lean manufacturing in service industry. Lean manufacturing philosophy seeks for minimizing unnecessary time, material and efforts in the production processes. Although lean tools are being implemented in manufacturing industry for a long time, there are a very few in service industry. But in fact there is a lot of waste in a service industry which reduces the productivity. A framework for the applicability of lean tools to practice in the service industry is developed as a framework will be useful for the industry. A study made in the service industries by researchers found out the lean tool 5S/workplace organization to be most applicable in overall service industry. The next four top tools were Work Balancing, MUDA (Elimination of Waste, Kaizen (Continuous Improvement) and Just-in-time. In contrast to the most applicable, the five lean tools that are least applicable in overall service industry are
Andon, Autonomation / Jidoka, Failure Mode and Effect Analysis (FMEA), TAKT Time and single piece flow.

115. Ahuja and Khamba (2008b), have studied the application of TPM in various published literature. They had identified the issues in total productive maintenance as ranging from maintenance techniques, framework of TPM, overall equipment effectiveness, TPM implementation practices, barriers and success factors in TPM implementation, etc. The contributions of strategic TPM programmes towards improving manufacturing competencies of the organizations have also been highlighted. They also highlighted the approaches suggested by various researchers and practitioners and critically evaluated the reasons behind failure of TPM programmes in the organizations. Further, the enablers and success factors for TPM implementation have also been highlighted for ensuring smooth and effective TPM implementation in the organizations.

116. Arvind Kumar Shrimali and Soni (2017), have analyzed the barriers to implementation and the results show that one of the highest barriers in implementing lean manufacturing practices is resistance to change by middle management and absence of a lean implementation team or Lack of skilled people and followed by lack of flexible working arrangements and little support from the top management. Another finding in context to the Indian SMEs where lean has been implemented, as per the results obtained, that there is significance difference between micro, small and medium enterprises on “Little Support from Top Management”, “Poor Lean Training” and “Absence of Lean Implementation Team” as barriers.

117. Gnanavelbabu et al. (2017), explained in their paper, today lean faces a major challenge for implementation in industries. Many industrial organizations have started adopting various techniques for ensuring productivity improvement and to stay in the market. Process mapping was done for the crank case cell and individual process mapping was done for all the above sections. The problem was solved using the 8 step practical problem solving methodology. In crank case cell, the number of output per shift before optimization was 148 whereas
the number of output per shift after optimization was 161 components per shift. The number of components increased from 444 to 483 components in crank case cell. The types of lean waste analyzed were waiting time reduction, motion, transportation and over processing. The lean tools used were concepts of process mapping, 8 step problem-solving methodologies, elimination of waste, set up time reduction. Increase in the output in the industrial data analysis results after setting the optimized loading and unloading time increases the number of components per shift. The results indicate that there is impact of lean systems for the productivity improvement in automobile industries.

120.

Vasantharayalu and Surajit Pal (2016), made a survey and empirically tested the relation of TQM practices on operational performance in both service and manufacturing industries. The study used 300 participants from 50 service and manufacturing industries in India. The data was collected from respondents by using the survey method. The questionnaire was designed on the relation of TQM practices on operational performance. Questionnaire covered the following TQM factors namely leadership, process management, employee management, continuous improvement, and customer focus. These questionnaires were shared to 300 respondents and the collected data was tested by using various tests such as frequency tests, descriptive, SEM analysis, correlation, multiple regression analysis tests etc. The study found that the operational performance views Leadership, Strategy and Planning, Customer Focus, Information and Analysis, People Management and Quality Performance to be statistically significant in both kinds of industries. Hence the application of TQM practices in both service and manufacturing industries would be necessary to maintain the quality of the work as well as to enhance the competition level in the society.

122.

Al Mannai et al. (2016), made a study of TQM implementation in Bahrain industries. The aim of this study was to assess the degree of TQM implementation in Bahrain industries and reveal its effectiveness in Bahrain industries performance. From the operational and strategic TQM success factors assessment, it was found that the degree of TQM implementation over the industrial and manufacturing organizations surveyed in Bahrain was (92%). These results
indicate that TQM implementation is adequately established in the investigated organizations, and reflected top management awareness of the importance of TQM program implementation. Furthermore, this study revealed that TQM implementation had positive and significant effect toward organizational performance improvement. Overall TQM implementation resulted in (75%) improvement in the organizational performance. The investigation of the relationship between TQM implementation and the performance indicators revealed an overall significant improvement in workforce performance dimension, sales performance dimension, and quality performance dimension with overall average of 87%, 86%, and 84% respectively.

124.

125. In addition the results revealed that the most implemented quality improvement tool was Plan Do Check Act (PDCA) cycle (80%). Therefore, as a recommendation for further enhancement of performance, attention was to be directed towards Statistical Process Control (SPC) and Quality Function Deployment (QFD) initiatives. The adopted research methodology is a survey based on self completion questionnaires. The study led to the identification of the operational and strategic measurement indicators and success factors that assist in successful TQM implementation and performance improvement. The research analysis confirmed a significant positive relationship between the examined performance indicators in Bahrain industry and TQM implementation, and highlighted the key performance improvements. In addition the results revealed that the most implemented quality improvement tool was PDCA cycle (80%). Therefore, as a recommendation for further enhancement of performance, attention was to be directed towards SPC and QFD initiatives.

126.

127. Al Mannai et al. (2017), made a study of TQM, TPM and JIT implementation in Bahrain industries. The results of the study showed that TQM quality program had the highest positive effect on industrial performance. With an overall implementation of 92%, TQM resulted in a 76% improvement in organization performance. TPM with an implementation of 82% had a moderate effect on the organization performance, improving it by 55%. However, with an implementation of 80%, JIT had a relatively low effect on organization
performance, only improving it by 33%. The study also revealed the effects of the TQM, TPM and JIT implementations on distinct performance improvement indicators. TQM implementations resulted in greatly improving the workforce performance, sales performance and quality performance (87%, 86%, and 84%, respectively) and had the least effect on cost reduction (61%) of the organizations where it was implemented. The TPM implementations had the most positive effect on process performance (75%), closely trailed by improvements in cost performance (67%) and had the least effect on quality improvement (42%). The JIT implementation had the highest effects on delivery and cost performance (50% and 46% respectively) and had the lowest effect on the workforce performance improvement (10%). The paper concluded that the implementation of TQM, TPM, and JIT had positive effect, and that the TQM quality program to be the most effective and beneficial program to improve the performance of industry in Bahrain.

128.  
129.  Abhiram et al. (2016), studied lean implementation in construction industry and states that, Lean construction is a new production methodology which will bring a radical change in the construction industry. Construction companies have improved their work effectiveness and quality of work, and reduced waste and costs and increased their profits to ensure their survival in today’s competitive market. Workers mistake rank top among wastes generated in construction industry. It is also found that wastes generated are mostly in operational stage and followed by material procurement and handling stages. Lean contributes to improve the efficiency of construction industry. Application of lean, results in system performance improvement and development of project. Thus, Lean construction is required for the adoption of lean techniques to get a developmental change in construction field and to achieve the substantive minimization of wastes generated in construction industry.

130.  
131.  Diego Fernando and Leonardo Rivera (2007), made a study aimed to integrate a set of metrics that have been proposed by different authors in such a way that they are consistent with the different stages and elements of Lean Manufacturing implementations. To achieve this, two frameworks for Lean
implementations were presented and then the main factors for success were used as the basis to propose metrics that measure the advance in these factors. A tabular display of the impact of “Lean activities” on the metrics was presented, which proposed that many prior assumptions about the benefits on many different levels of improvement to be accurate.

132.

133. They concluded that, Lean Manufacturing implementations require the establishment of an environment that makes the rest of the elements of the process possible. This environment (set up by management) was to ensure that employees feel empowered and have the necessary tools to gain product and process ownership, focused team work and autonomy in the development of solutions and process improvements. Five main dimensions can be measured to assess the degree of evolution in a Lean transformation. These are Elimination of Waste, Continuous Improvement, Continuous Flow and Pull Driven Systems, Multifunctional Teams and Information Systems. Four or five metrics were defined for each of the dimensions. Lean Manufacturing is much more than a manufacturing technique. It is a different way of viewing the labor relationships, the way operations are done, the way value is added and therefore the way used to measure it ought to be different.

134.

135. Rabiha et al. (2015), states that resistance to change is one of the challenges faced during the implementation of lean. So change management is very much essential to address the resistance, provide support and impart the knowledge to implement and sustain the change. They had proposed a conceptual framework for change management which provides a three step model unfreezing, changing and refreezing. These steps lead to a lean service implementation from conventional service operation through transition. The success of this model requires an atmosphere of management commitment and employees involvement.

136.

137. Andres-Lopez et al. (2015), states that after decades of lean principles implementation in manufacturing companies, there is no debate about its benefits on waste elimination and efficiency improvement. Service organizations, a growing stake of the global economy, are committed to achieve such improvements.
Considering current economic scenario, marked by budget cuts and cost reduction, outstanding results are expected from the application of lean manufacturing in service industries. However, results may not be as expected when trying to apply technical tools, developed for industrial processes, to intangible products. They tried to redefine value and waste concepts, focused on the inherent characteristics of service: intangibility, perishability, inseparability, variability and lack of ownership. Based on this approach, an analysis of customer value and customer life cycle (end-to-end process) was performed.

Schnellbach and Reinhart (2015), studied the use of energy in manufacturing processes which provides great saving potential. Independent studies estimate possible energy savings up to 30%.

In order to benefit from these potentials, manufacturing companies need guidelines, which support them in identifying energy waste. The methodology presented provides a four-step approach to increase energy productivity.

- Energy oriented value stream mapping
- House of energy productivity
- Generic system dynamics model
- Extended economic efficiency calculation

After creating transparency with an energy oriented value stream mapping and the identification of possible measures to reduce energy waste, the effects of measures on existing key performance indicators of Lean Production Systems (LPS) were analyzed. For that purpose an impact network was generated, which showed possible effects. Based on that impact network, a generic system dynamics model helps to simulate dynamic effects on important target figures out of the LPS key performance indicators. With that information, manufacturing companies could increase energy productivity without having negative effects on existing manufacturing structures.

Alexandra Teneraand Luis Carneiro Pinto (2014), in their article presented a Lean Six Sigma (LSS) project management process improvement model and a case study test developed in a real enterprise environment which has a formal and
established project management system. The LSS proposed approach was a Define, Measure, Analyze, Improve and Control (DMAIC) cycle-based proposal. Given the nature of the project management available data, some classical six sigma tools were tested and also adapted during the implementation of the DMAIC cycle-based proposal, including the integration of nonparametric tools on the classical statistical six sigma analyses and that new tools like text mining can be useful to support factual data treatment. The study results showed that through the LSS proposed approach, processes improvement on project management stable practices could be reached through a continuous identification and evaluation of improvement opportunities in project management processes and decisions, enabling organizational results and process waste reduction. The study also indicates that classical LSS tools could be used and adapted to formally and continuously improve project management processes and practices in organizations, if stable project management systems were put to use.

Sundar et al. (2014), made a survey of various literature and stated that, the concept of lean manufacturing was developed for maximizing the resource utilization through minimization of waste, later on lean was formulated in response to the fluctuating and competitive business environment. Due to rapidly changing business environment the organizations stand forced to face challenges and complexities. Any organization whether manufacturing or service oriented to survive ultimately depends on its ability to systematically and continuously responds to these changes for enhancing the product value. Therefore value adding process is necessary to achieve this perfection; hence implementing a lean manufacturing system is becoming a core competency for any type of organizations to sustain. The majority of the study focuses on single aspect of lean element, only very few focuses on more than one aspect of lean elements, but for the successful implementation of lean the organisation had to focus on all the aspects such as Value Stream Mapping, Cellular Manufacturing, U-line system, Line Balancing, Inventory control, Single Minute Exchange of Dies, Pull System, Kanban, Production Leveling etc. An attempt could be made to develop a lean route map for the organization to implement the lean manufacturing system. Analyses of the exploratory survey results were summarized in this paper to illustrate the
implementation sequence of lean elements in volatile business environment and the finding of this review was synthesized to develop a unified theory for implementation of lean elements.

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 Leveling 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 issues such as lack of direction, lack of planning, lack of sequencing and interdependency factors of lean elements. To overcome these dreary issues, the lean elements are to be 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.

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.

Erwin Rauch et al. (2015), made a literature survey and found that, after the application of Lean Management in production, the Lean philosophy has been successfully implemented in many other areas. Through lean methods, processes in manufacturing were designed free of waste and through Lean Construction on-site
installation follows the customer pace. Actually the Lean approach swaps also increasingly on indirect areas such as Engineering and Product Development. Rising cost sensitivity in product development, even shorter product life cycles and partly unsynchronized processes between research and development manufacturing made Lean Product Development (LPD) interesting. This research shows an Axiomatic Design based approach to deduce a catalogue of design guidelines for the design of Lean Product Development processes. Based on these guidelines, generally applicable process templates for LPD were to be elaborated for lean product development processes.

154. There were different approaches in the design of a more efficient and value-oriented lean product development process. This research was based on the increase of customer value and thus on the reduction of waste in product development. Using Axiomatic Design as methodology, the seven types of waste were analyzed for product development. The axiomatic design matrix showed very often a decoupled design. Therefore a defined sequence was to be adapted in the implementation of the identified design guidelines. In addition to the top-down mapping approach Axiomatic Design could be used to determine such an ideal sequence in applying the guidelines to avoid inefficient loops and circular references.

156. Kogel and Jauergui Becker (2016), took up application of the lean philosophy during the design of a new production system that would result in a production system which shall be more lean from the beginning and needs less improvement during its lifetime. In this paper a design support tool for new Lean production systems was presented. It combines the theory on lean and production system design. The design support tool consists of three elements with a strong interaction. The first element of the tool prescribes the steps in the design of a production system in general. The second element illustrates the flow of different types of information during the design process. The third element consists of guidelines for Lean design. Following the workflow that combines the three elements would result in a new lean based production system.

158.
159. More specifically, how can one take care of implementing Lean correctly from the starting phases of manufacturing design? This paper proposed to answer this question. It presents information driven method. It supports designers in determining which aspects of lean are to be taken into consideration and when to apply them during the development stages of the design process of a new manufacturing system. Lean is often referred to as a philosophy, as a way of thinking. Nonetheless it also embraces methods and tools to support its implementation. Determining when to apply which tool in the improvement processes is not bound by any formal guideline. Indeed, a large Lean implementation experience has been gained by industry on this topic. This has contributed to the development of an empiric, and yet solidly demonstrated, body of knowledge on the sequential application of methods and tools for achieving a lean system. However, how to start a green field design of a manufacturing system fully integrating lean remains poorly documented in both lean literature and best practice cases.

160. Nguyen Thi Lam et al. (2016), made a study on assembly line balancing in an electronics industry and found that, line balancing was required in most of production lines, where bottleneck point often happens. There are many methods and tools to balance the line as well as eliminate wastes. In this paper, a lean line balancing was studied as a simple tool, but impressive results were brought out. It could be applied in improvement of any electronics assembly line. Analysis on the current line was done to figure out wastes and conceive the ideas to solve them. The quality of production line was to be shown on the productivity, line balancing index, and effectiveness on resources. Actually, many benefits for the studied electronics assembly line were brought, which could be considered as a force to apply lean line balancing tool for other production lines.

162. The quality of the electronics assembly line was enhanced in terms of line balancing index, overall labor effectiveness, productivity and elimination of wastes. Although human resource was decreased by 25%, the industry was able to meet the customer demand. This research showed that there are many wastes which could be eliminated with the simple lean tools. It is not very complicated but it would bring
essential benefits. After the line is balanced, standardization of works should be done. The guidelines should be developed in detail for training and assuring the quality of jobs. Other lean tools such as 5S, Kaizen, or TPM should be integrated, which could support setting up the lean environment for the company.

164. Minh-Nhat Nguyen and Ngoc-Hien Do (2016), also made a study on electronic industry. Lean Manufacturing is a popular term, which is applied widely and brings a lot of benefits. As a result, there are a large number of companies applying lean in manufacturing and achieving success. This paper presents a process to transform a traditional production model to lean one. A case study of applying lean techniques in reengineering an electronics assembly line was done. The suggested process begins from realizing current state value stream mapping, drawing future state value stream mapping to establishing implement plan. Reengineering focuses on some aspects such as reducing wastes, standardizing works, internal logistics, workplace designing and changing layout. Some positive results were recorded like reduced manpower by nearly 40% with the same daily output with a 30% saving floor area and a reduced average delivery time from 7.5 days to 3 days.

166. Jafri Mohd Rohani and Seyed Mojib Zahraee (2015), made a study of lean implementation in a paint industry. They stated that, Lean Manufacturing is a business strategy that was developed in Japan. The main role of lean manufacturing was to determine as well as to eliminate the waste. Companies implement LM to keep their competitiveness over their competitors by improving the manufacturing system’s productivity and quality enhancement of the product. The goal of the study was to apply one of the most significant lean manufacturing techniques called Value Stream Mapping to improve the production line of a paint industry as a case of study. To achieve this goal, lean fundamental principles were implemented to construct VSM for identification and elimination of wastes by using team formation, product selection, conceptual design, and time-frame formulation through TAKT time calculation. It also aimed to reducing lead time and value added time to increase the total throughput. Based on future VSM, final result showed that by implementing some lean manufacturing techniques such as 5S,
Kanban method, Kaizen improvements were obvious. Based on the future VSM, final results showed that by implementing some lean thinking techniques, Production Lead-time decreased from 8.5 days to 6 days, and the value added time decreased from 68 minutes to 37 minutes. More investigation could be done by combining the VSM and computer simulation to evaluate more effective factors that have a significant effect on the total throughput based on decreasing wastes.

Amir Azizi and Thulasi Manoharan (2015), found out from their survey that, many manufacturers struggle to improving productivity, producing the right products or services at the right place and meeting on-time delivery. To survive in today’s era competitive world, manufacturers need to find new ways to reduce the manufacturing lead times in order to improve productivity and operating principle. Nowadays, it is targeted to improve the productivity performance by reducing the production lead time and production waste that are the most important goals for almost all manufacturing companies. The main objective of this study is to design an efficient value stream mapping to improve the productivity in small medium enterprise by eliminating non-value added activities. The methodology of the study is to firstly analyze the production waste in current state map, secondly to use the Kaizen activity with single minute exchange of dies to effectively support future state for process improvement of the action plan. It was concluded that, future value stream map could be designed which helps to effectively identify wasteful activities and production processes. VSM and Kaizen serve as an input for continuous improvement by reducing the manufacturing lead time using SMED in SMEs.

This study showed that the implementation of VSM in Printed Circuit Board assembly line reveals obvious and hidden wastes that affected the productivity of smart tag production. Improvement process was designed to reduce the Work In Progress (WIP) and lead time using SMED and Kaizen techniques. The SMED technique was implemented at the insertion process that was a bottleneck. SMED technique was successfully implemented because the machine setup time in the insertion process was reduced from 145 seconds to 54 seconds. This study
recommended that the insertion process could be converted from batch operation to continuous flow operation to reduce more wastes.
CHAPTER 3

PROBLEM DEFINITION AND OBJECTIVE

Industries face challenges on maximizing the benefits in their processes. One of the methods to be followed is by reducing costs which helps to be more competitive which in turn helps to achieve increased market share. Reducing costs is possible by eliminating wastes that may be occurring in the various processes.

Traditionally Lean manufacturing had been practiced in large industries with huge improvements in cost cutting and quality improvements. Recently lean manufacturing is also being implemented in many SMEs in India. However lots of other SMEs are wary of its effectiveness in improving the performance of the firms. The Indian government is also helping these SMEs financially for Lean implementation. Under this scenario it is imperative to demonstrate the benefits of lean manufacturing implementation and document them so that the Indian SMEs are convinced of the advantages. The global competition also necessitates the SMEs to cut costs and improve performance in terms of quality, delivery, etc.

This research attempts to implement various proven lean tools in selected SMEs representing major industrial sectors such as CNC machine shop, foundry, pump manufacturing industry, engineering industry, etc. which comprises the major chunk of SMEs in India. This research also tries to identify the Tools suitable for implementation in these SMEs which will provide the maximum improvement so that they can be replicated in similar industries. Each tool has been selected for implementation based on the diagnostic study of the chosen SME unit and the problems identified.

Value stream mapping has been used invariably in all the units at the beginning of the project to identify the potential areas of intervention to reap maximum benefits. The project starts with implementation of 5S, so that the members have a confidence as they can see visibly the benefits of it.
A Lean Enterprise Team (LET) is formed comprising around 5 members which will oversee the lean implementation and report to the chief executive officer on regular basis. Then slowly groups are formed among the employees for various purposes like brainstorming the issues, implementation of specific tools and among the different sections. Teams and individuals are rewarded for their contribution which results in cost and time savings in order to motivate other employees also to participate in the process of Lean implementation.

It is a well known fact that lean manufacturing is a scientifically proven concept which encompasses all proven tools for elimination of wastes in manufacturing. This must be implemented in all industries in order to become competitive in the market. It must be implemented on a continuous manner to reap maximum benefits. But very few industries are even aware of it and only a small number of SMEs are implementing it. Without implementing lean manufacturing it is very difficult to enhance the competitiveness of the organization in the global market. Lean manufacturing encompasses all the best practices in the manufacturing industries to reap the maximum benefit out of its implementation.

As the researcher made a study of various SMEs in India, the general observation is that, the industries focus more on the production output rather than measuring the efficiency. Very few industries concentrate on the optimum utilization of the resources available with them. Most of the SMEs in India are ancillary to large industries from where the raw materials are received. Hence the SMEs are not concentrating too much on the optimum utilization of the raw materials. By doing so they are wasting many other resources like manpower, space, power, etc. which lead to increase in cost of production.

As most of the Indian SMEs are being headed by technocrats who with their experience in some large industries, think that the methods which they adopt and implement for production are the best ones and there is no scope for further improvement. They rarely consider the suggestions from the employees and never allow any outside consultant due to the fear of losing business as outsiders may copy their method of production and even come to know of their customers.
SMEs fail to attach importance to quality and efficiency improvement activities as they think that these are all small and trivial issues and they devote their time and attention only on issues like marketing, raw material purchase, diversification, procurement of machinery, etc. They do not understand that if small issues are addressed, it will lead to larger benefits.

Government statistics reveals that 40% of the total industrial production comes from the SME sector. Hence to achieve a sustainable growth, this sector needs to be competitive and should be able to face the challenges arising on account of globalization. Lean manufacturing helps SMEs to reduce their manufacturing costs through proper personnel management, improved process flows, reduced engineering time, etc. As lean manufacturing is a business initiative to reduce wastes in manufacturing, it helps in improving quality of products and lowering of costs which are essential for competing in international markets.

The need for lean manufacturing is felt in the ever changing globalized environment which has been posing challenges of competitiveness and survival to all the constituents in an economy. It has been more so for MSME units in the manufacturing sector. It has been noticed that units engaged in the day to day issues that they don’t have time and resources to dedicate for a strategic understanding of the need and acquiring means of various techniques which would help them in enhancing their productivity and be competitive. Lean manufacturing is a set of techniques, which have evolved over a long period and are based on various minor to major breakthroughs that help in reducing cost and hence increase productivity. A list of main LM techniques with brief description of each is given below.

- **5S System**: The 5S systems is generally a better way of housekeeping that helps in getting the “junk” out of the work area and develops a feel of ownership of the work area by maintaining better working environment. 5S stands for Sorting out, systemising, shining, standardizing and sustaining.

- **Visual Control**: Visual controls such as cartoons, charts, light signals, Lane marking on floor, safety instructions, warning signs, poka-yoke instructions etc., can be displayed all over the work place. Such visuals help in passing the information faster at a glance.
• **Standard Operating Procedures**: All verbal instructions should be converted to written instructions as a document. By recording them as standard operating procedures to ensure knowledge is maintained even while certain employees retire or go on leave and helps in achieving required product quality level, consistency, effectiveness and efficiency

• **Just in Time**: It’s a Japanese manufacturing philosophy to make the right product in right quantity at the right time. This almost results in zero inventory and shortest possible cycle time. JIT helps in avoiding three of the seven wastes defined in the Toyota production system

• **KANBAN System**: In this, components are pulled by assembly or subsequent work centres and the containers are replenished with the right quantities by the previous work centre, which reduces the inventory of unwanted components. KANBAN is better communication through visual signals or cards communicating on what work is to be done and where, helping in reducing waste

• **Cellular Layout**: In this improved manufacturing system, familywise component completion is aimed at within the smaller self-contained cell, which is a part of a big factory, as compared to operationwise completion in traditional functional layout. This is nothing but designing of work cells containing a smaller number of employees and machines which manufactures similar products and helps in the smooth movement from one process to the next

• **Value Stream Mapping**: It covers all activities from supplier to customer indicating the flows of products and information, both value adding and non-value adding processes and helps in arriving at best layout of all resources required for making the product

• **Poka Yoke or Mistake Proofing**: It is again a Japanese technique used to prevent errors occurring at their source of origin, and decreases TAKT time and it finally leads to a ‘Zero Defect’ situation

  • **Single Minutes Exchange of Dies or Quick Changeover**: Applying ingenious methods, set up time is minimized and brought to less than ten minutes; thereby smaller batches as required by the customer can be taken up for manufacturing, with quick changeover

  • **Total Productive Maintenance**: TPM involves operators, maintenance staff and management working together to improve overall equipment effectiveness. Operators, who first identify noisy or vibrating motors, oil or air leaks, can be trained to make simple repairs to prevent major and costly break downs
• **Kaizen Blitz or Rapid Improvement Process:** It is an intense management programme, which focuses on improvement. Improvements through machines and computers normally focusing on a particular process.

195. The objectives of lean manufacturing are to increase the competitiveness of the SME sector through the adoption of lean manufacturing techniques with the objectives of

- Reducing waste
- Increasing productivity
- Introducing innovative practices for improving overall competitiveness
- Inculcating good management systems
- Imbibing a culture of continuous improvement

197. After an elaborate study on the SMEs, it was observed that though there are many scientifically proven tools available to enhance the competitiveness, SMEs have not been focusing in improving the system through their implementation. Instead they have been concentrating only on achieving the production targets and marketing activities. For long term survival of SMEs they should move forward by implementing lean on its internal processes with its available resources. They are unaware of the large benefits a small improvement could lead to compared to the benefits reaped out of increasing the production and marketing.

199. Hence it is the need of the hour to device a framework for lean manufacturing implementation which will document the best methodology by providing the step by step method for lean implementation in any SME. The broad generic guideline will be provided in the lean manufacturing framework with only flexibility in the core technical field which has to be solved by the workers participation through lean manufacturing tools like kaizen, etc.

201. In this research, it has been decided to concentrate mainly on SMEs related to mechanical engineering field. This field mainly comprises of foundry, general engineering, automobile components manufacturing and CNC machine shops. Hence sample units were selected for implementing the lean tools and concepts.
with their impact over a period of time in these sectors. After the study, the best practices were recorded for disseminating among the other SMEs. Major lean tools like lean six sigma, total productive maintenance, value stream mapping, productivity improvement, PPM reduction, etc were implemented and tested in these units and their results analyzed.

203.

204. Six Sigma is a tool for process improvement and methodology for defect reduction implemented to increase company’s outturn and achieve the organizational excellence by implementing appropriate statistical tools. Six Sigma is a methodology driven by customer, hence the projects necessary to provide satisfaction to buyers have to be taken on priority with utmost care to reap more gain for the enterprise through fulfillment of their demands and achievements. Success of Six Sigma mainly depends on project selection and prioritization. The critical success factors for accomplishment of Six-Sigma mechanism are the project selection and the preceding exercise. The selection criteria specifically focuses on cost and delivery, quality, which impacts the project. Selecting the right Six Sigma project is difficult and cumbersome task but failing to do this, is likely to impact the cost and efforts as well lead to frustration of the team members.

205.

206. India has emerged as one of the major automobile components manufacturing centre in Asia and will soon play a significant role in the global automotive supply chain in the near future. Indian automotive sector’s manufacturing competence is much higher than that of machinery, electronics and process industries. Vast range of automobile products is manufactured in the SME sector and the quantum of exports is also found to be larger, but it has been noticed that this sector has rarely improved their quality and exportability through supportive interventions towards product and process innovations, diversification and larger market access.

207.

208. As the SME sector has continued playing an important role in the Indian economy, the Indian government has recognized explicitly the dynamic role to be played by the SMEs in an increasingly globalised world. Feeling the need to recognize the SME industries, it had brought out an exclusive legislation in 2006
called the MSMED Act 2006 in order to provide the adequate protection to this sector. The thrust of the recent policy initiatives ensures that it enhances the competitiveness through encouraging innovative processes amongst firms and making them quality conscious; increase linkages with multiple stakeholders in order to benefit from networks both domestically and globally; and strive for a larger market presence beyond the domestic market. With the domestic market becoming more and more quality-conscious and competitive, high quality standards would be necessary for any SME even to survive in the domestic Original Equipment Manufacturers market. Otherwise, in a significant way, this will lead to get in to the trap of low quality, low price and essentially aftermarket supplier. Even the replacement market needs high quality and the share will shrink for low capability firms.

As a global hub in the manufacturing of automobile components Indian automobile components sector has a bright future. But, quality is a major issue for achieving competitiveness in global market. In recent times, a number of many quality management systems and frameworks were developed to improve the competitiveness. ISO 9000, Statistical Process Control, Benchmarking, Kaizen, Total Quality Management, Total Productive Maintenance, Theory of constraints, Business Excellence Models and many more quality programs are being adopted by large Indian companies. But a large portion of small and medium enterprises that make up a huge supply chain base for large organizations have been found to be unable to compete even in domestic market in terms of price and quality. In order to remain competitive, SMEs are to be capable of delivering high quality products and services on-time at a reasonable cost.

The reasons for not practicing the proven improvement methods may be many, like due to lack of awareness of the new process improvement strategies and techniques, non-commitment of top management, wrong notion of huge investment, and employees’ resistance to change.

In all manufacturing companies, process improvement is the one most important task for the management. For achieving the strategic goals in the existing
business conditions of extremely turbulent environment with frequent technological changes, it requires constant adjustment of all activities with emphasis on improvement of business and production process. Six Sigma is one of the commonly used techniques recognized in modern business practices for process improvement. Hence, Six Sigma is a systematic and organized method for strategic process improvement. Development of new products and services relies on statistical and scientific methodsthat helps in reducing the end defect rates.

215.

216. Six Sigma is more comprehensive than the earlier quality initiatives such as Total Quality Management and Continuous Quality Improvement. The Six Sigma method focuses on customer issues, makes use of measured and reported financial results, uses advanced data analysis tools, project management tools and methodology. Six Sigma approach was first applied in manufacturing operations and once organizations realized the benefits, it was rapidly expanded to different functional areas such as marketing, engineering, purchasing, servicing, and administrative support. The DMAIC methodology of Six Sigma offers a structured and disciplined process for solving business problems. Six Sigma uses tools designed to identify root causes for the defects in processes that keep an organization from providing its customers with consistent quality products that the customers require on time and at the most reasonable price.
The tools selected for developing a framework for implementing lean manufacturing in Indian SMEs as part of this research work have been discussed below.

4.1 Value Stream Mapping

Value stream mapping is a method of drawing a flowchart to demonstrate, analyze and develop the steps involved to deliver a product or service. Whenever lean manufacturing is to be implemented in a unit, it is better to start with VSM which helps to review the existing processes involved from the start to the customer. It involves depicting the flow of materials and information through various symbols. Items that don’t add value are identified for reduction or elimination. Customers only appreciate the value and usefulness of the product or service and not the efforts it takes to manufacture that. This process maintains that focus. Ideally it is better to draw a current state VSM and then move on to a better way with a future state and/or ideal state VSM. One should always start off sketching by hand and then may move to using software for better communication, analysis and improvement.

While drawing the value stream map five basic principles are to be adopted. First the value should always be specified from the end customer point of view. Second the value stream map should be drawn for each product family separately. The third principle is that the product flow must be ensured in such a way that it is always available at any required point. Fourth the customer should be able to pull the product or service at anytime. Finally the lean system should be moving towards perfection always. There is always scope for improvement. So the VSM should be drawn again and again after each time the project gets completed.
227. The values that flow to the customers are price, quality, reliable delivery, rapid response to changing needs, etc. The items that flow through the value stream are materials
in manufacturing, designs in design and development, external customer needs in service, internal customer needs are the items in administration. The analysis always begins with part of a total value stream that part of the value stream also has customers too.

There are lots of symbols available for use in value stream mapping which can be chosen according to the process being analysed. Once the process is drawn, the TAKT time has to be calculated.

Effective Working Time per Shift

\[
\text{TAKT Time} = \frac{\text{Customer Requirement per Shift}}{}\]

This is the time available to produce a single unit of customer demand. Based on this time the production process has to be streamlined. A time study of the process has to be undertaken with the help of a stopwatch. Video analysis tools are available now a days for this purpose. With the data collected the current state value stream mapping has to be drawn. From the map total lead time and total cycle time have to be calculated. Total lead time is the time taken to produce an item from the start to the end. Total cycle time is the total time the product is actually being under some processing. From the current state value stream mapping the bottleneck operation and the non value adding operations are to be identified. The bottleneck operation will be the maximum time taken in the process, once this is addressed and the time reduced, the process can be streamlined. It is also very important to eliminate or reduce the non value adding activities.

After eliminating them the future state value stream mapping has to be drawn and given to the shop floor for implementation. After sufficient time the improvement has to be studied and again a new future state value stream mapping has to be drawn taking the last one as the current state value stream mapping. In this way the process has to be continuously improved till perfection is achieved.

4.2 Standardized Work

In lean manufacturing environment, standardized work is very important for success. By standardization of a set method, the process becomes more organized
and improvement opportunities are seized. The process should be human centered, ensure that the repeatable processes are ergonomically correct. The main elements of standardized work are TAKT time, line balancing, work sequencing. Standardized work is a tool for maintaining high level of productivity, quality and safety. The definition of standardized work is the work in which the sequence of job elements has been efficiently organized, and is repeatedly followed by any team member. The standardized work is a dynamic one and has always scope for improvement. If it does not improve there is every chance of regression and it will go back to the original stage.

240. The benefits of standardized work are as follows.

- A standardized work provides a basis for employee training
- It establishes stability in the process
- Clear start and stop points are defined for each process
- It is used as a tool in audits and problem solving
- Kaizen can be initiated taking it as a baseline
- Employee involvement is more effective and pokayoke
- It is maintained as an organizational knowledge resource

241. The elements of standardized work are TAKT time, cycle time, work sequence, in process stock, value added time, etc. The TAKT time is calculated as “TAKT Time = Daily operating time available / customer demand per day”. Cycle time is the actual time spent on the process. The goal of standardized work is to synchronize the TAKT time and cycle time effectively. Work sequencing is the order which is followed when the work is done in any given process. Work sequencing can be used as a powerful tool to design safety and ergonomic work atmosphere. In-process stock is the number of unfinished work pieces available in the work place. More work in progress will lead to huge investment in raw materials and hence the cost of production will go up. This has to be kept at the minimum required level for the operator to avoid idle time. The more work in progress will also hide the inefficiency in various departments of the organisation.

244. **4.3 TAKT Time**
TAKT time is the time available in which one part needs to be produced based on available time and customer requirements. It is obtained by time available per shift divided by the customer requirement per shift. If there are 27,000 production seconds available per shift (8 hours less breaks) and the customer requires 500 parts each shift, the TAKT time would be 54 seconds. This means that a part needs to be produced every 54 seconds in order to keep up with customer demand. Once TAKT time is determined, the work sequence and line balancing can be followed. So the TAKT time is the most desired time to produce one unit of the product. It is customer driven based on the customer demand. TAKT time helps to arrive at the stabilized operation by avoiding unnecessary inventory buildup. It also helps to avoid unscheduled stops and starts of the production line as it helps with proper planning. It helps to balance the assembly line by ensuring the arrival of the components when they are needed. Hence it facilitates to put in place a synchronized system with all pieces and stations working in a concert and a balanced assembly line.

The TAKT time need to be set properly for each operation by overcoming the resistance from the workforce which needs to speed up the work at some stations. Once the TAKT time is set further it will be difficult to change the pace of work as in an assembly line as change in one station will affect the entire sequence of operations in the line. This will only control the workers who are in the assembly line. The other operators also have to be fixed with their own TAKT time. The percentage of workers who come under the fold should be slowly increased. A system should be put in place to take care of the fluctuations in the customer demand. Hence it should be used in conjunction with all other lean tools and not separately. It is the basic of the value stream mapping.

4.4 Line Balancing

Line balancing is the next step in standardized work. This involves time studies of all the different work stations within the process. The concept is that all jobs in a line will require the same amount of time to complete (cycle time). The more detailed is the time study, the easier it will be to balance work load between operators. The two basic concepts are to ensure that no operator has a cycle time
greater than the TAKT time and have every operation as close in cycle time as possible.

252.

253. The task is to arrange all the work stations in a single line and to optimize the time at each station so that all take equal time. Most of the times it is found to be very difficult to achieve this. Hence the aim should be to minimize the variations in the times of each station. The maximum time at any station should not be more than the TAKT time. The precedence constraints have to be taken care while designing the assembly line. The tasks at workstations have to be reorganized by breaking down them in to smallest task size. Then they may be combined at different workstations by considering the precedence constraints. The sum of task times will become the workstation time.

254.

255. The bottleneck station which takes the largest time has to be given more attention to bring down the time of this station below the TAKT time. Line balancing will ensure that everyone is doing almost same amount of work and also meet the customer demand. The variation in workload and workflow is smoothened to a greater extent. It is ensured that no worker is overburdened and no worker waits for a part to arrive for his work and every worker works with balance and in a synchronized manner. The new line balancing should be displayed in a manner that everyone can see it. This will pave the way for more Kaizens to improve the system.

256.

257. **4.5 Total Productive Maintenance**

258. From the tools and methodology given by the lean manufacturing technique, the Total Productive Maintenance is a proactive approach and it is best suitable for any manufacturing industry which has installed huge machines where the production output mainly depends on these machines. Looking at the revolution there are three types of revolution that took place the agrarian revolution, industrial revolution and the ongoing information technology revolution. After the industrial revolution due to the competition among the manufacturers the manufacturing organizations started to equip complex machines to manufacture products. This led to employ maintenance engineers in a manufacturing organisation to execute
maintenance activity to restore the working of machines that failed to work. This kind of maintenance strategy which means allowing the machine to work till its failure and repairing is called break down maintenance.

259.

260. After this the engineers and the management began to develop a new maintenance approach that needs to eliminate the breakdown failures, so they came with the preventive maintenance and predictive maintenance as a proactive approach to reduce the breakdown of machines. In this progress came the origination of total productive maintenance. TPM is a plant improvement methodology which enables continuous and rapid improvement of the manufacturing process through use of employee involvement, employee empowerment and closed-loop measurement of results and is incorporated with preventive maintenance concept. On one side TPM was expanded for maintenance activities and on other side it was extended to other strategies such as TPM in lean manufacturing.

261.

262. TPM is a methodology which has to be implemented in a manufacturing organisation by each and every people in it. It is the implementation of a collection of tools, techniques and principles to maximize the output from all the machines installed. The aim is to create a culture in the company for maximizing the benefits. It is a methodology to prevent losses and wastages by achieving zero breakdowns, zero failures, zero accidents, zero defects, etc. TPM encourages teamwork through small group activities to maintain the conditions of the machines to achieve zero loss. It involves everyone from the top management to the bottom most worker.

263.

264. The proactive method of maintenance is cheaper than the reactive breakdown maintenance as it reduces the need for spares, maintenance resources and loss of production. The TPM encompasses eight pillars of maintenance management. They are

- Autonomous maintenance
- Focused improvement
- Planned maintenance
• Quality maintenance
• Education and training
• Development management
• Safety, health and environment
• Office TPM

265.

266. TPM works on the principles of restoring the machines, maintain them and continuously improve the existing facilities. The role of maintenance personnel is to carry out the major repairs after breakdowns. They have to improve weak points in the machines and eliminate deterioration of machines. Also their responsibilities include to plan and carryout periodic preventive maintenance. The analysis of the performance, breakdowns are to be done by them so that effective predictive maintenance can be undertaken.

267.

268. But the role of operators of the machines is crucial as they have to maintain the machines on day to day basis to prevent deterioration. The machinery effectiveness has to be monitored regularly and recorded. Cleaning the machines daily and inspect them to detect problems in advance before they lead to breakdowns. They themselves can carry out simple repairs and improvement Kaizens in the machines.

269.

270. Most of the times, the faults will lead to stoppages or breakdowns or slowdown of the processes. Sometimes, the problems will lead to operator slowdown and make his life difficult. The changeover from one product to the next will be difficult in problematic machines. It will lead to oily, dirty and smelly workplace. It may lead to inconsistency in production and rejects in final products. It makes the operation of the machines dangerous and leads to safety hazards.

271.

272. The TPM identifies six big losses, recognizes them, measures them and reduce them through effective maintenance of machines. These losses are classified as

273.
274. Availability losses = Breakdown losses due to failures and repairs +
275. Setup and adjustment losses

276. Performance losses = Idling and minor stoppage losses + speed losses

277. Quality losses = scrap and rework losses + start up losses

278. Availability = \( \frac{\text{Available Time} - \text{Unplanned Downtime}}{\text{Available Time}} \times 100\% \)

279. Performance = \( \frac{\text{Ideal Cycle Time} \times \text{Actual Output}}{\text{Available Operating Time}} \times 100\% \)

280. Quality = \( \frac{\text{Parts Made} - \text{Defect Quantity}}{\text{Parts Made}} \times 100\% \)

284. The Overall Equipment Effectiveness is calculated as

285. OEE = Availability \times Performance \times Quality

286. Overall Equipment Effectiveness is a total measure of performance which relates the availability of the machines to the productivity and quality. OEE is a Key Performance Indicator that can measure the impact of change on a process caused by eliminating process, or equipment losses. OEE can be used in the following ways.

- OEE is only a measure, its benefits will be lost if the shortfalls it identifies are not acted upon
- OEE is a total measure of performance but the data used to produce it must be used to prioritise improvement tasks
- The purpose of measurement is to identify losses, remove waste and drive improvement
- OEE should be used to support the Total Productive Maintenance approach and the tools it supplies

288. 4.6 Root Cause Analysis

290. Root cause analysis is a systematic approach for identifying the “root causes” of problems that occur in an organization and address them. It is a method of treating and elimination of the cause rather than the symptoms and
finding ways to prevent them from reoccurring. Focusing on corrective measures of root causes is more effective than simply treating the symptoms of a problem or event. It is performed most effectively when accomplished through a systematic process with conclusions backed up by evidence. There is usually more than one root cause for a problem or event. The focus of investigation and analysis through problem identification is why the event occurred, and not who made the error.

291.

292. “Five whys” is a powerful technique for analyzing any problem to find out the root cause. It does not involve any collection of data and analyzing them through hypothesis. The method is very simple as one has to ask the question why for five times starting with the problem in hand. Each time you ask why it will give an answer and that answer has to be questioned again why. In this way it will lead to the root cause at the end. Sometimes we may have to ask why more or less than five times depending on the problem till we reach the root cause. The number five is a thumb rule as most of the root causes are obtained after five whys. Hence this technique is known as five why method. This is one of the simplest tools without the need for any statistical analysis. This is more effective when the human factors or interactions are involved in the problem.

293.

294. Fish bone diagram or Ishikawa diagram is another tool to find out the root cause of any problem. In this technique a fish bone is drawn with the problem at the head of the fish at the right side and various reasons at the bones extending to the left. The major bones normally represent the categories of problems arising out of man, machine, method, material and environment. In manufacturing environment these are the major factors that contributeto any defect or problem. Then all the potential and real causes are listed in the minor fish bones of the branches in the diagram. After this the five whys can be used to narrow down to the real root cause of the problem. All the members of the team are to be involved in this exercise as then only all the reasons could be listed in the diagram.

295.
296. **4.7 Lean Six Sigma**

297. Six Sigma methodology improves any existing business process by constantly reviewing and re-tuning the process. To achieve this, Six Sigma uses a methodology known as Define opportunities, Measure performance, Analyze opportunity, Improve performance, Control performance. Six sigma combined with lean tools is very effective in eliminating the wastes and non value adding activities and thereby reduces the cost of the products and services. Six sigma is a quality level where only 3.4 defects may occur in one million products produced. The sigma levels required in any product depends on the product and its application. But this methodology helps an organisation to travel towards achieving six sigma levels of quality.

298. 
299. This methodology makes us understand the variation in the production processes, voice of the customer and voice of the process. The variation in the process leads to the defects and hence it has to be kept under the control limits. There are various statistical tools through which the variation can be measured. Then the appropriate lean tools are to be applied to bring down the variation under the control limits.

300. 
301. The voice of the customer is described as the quality from the customer point of view. This is the limit to which the customer will accept the product for the price he pays. In engineering terms it is described as the specification limits or tolerance levels. Hence the goals set by the organisation for any process or project should be aligned with the voice of the customer.

302. The voice of process is the variations observed in the process parameters. The process capability is measured in terms of $C_{pk}$ which describes the variation in the process with respect to the boundary limits. This can be calculated by measuring the variation in the process, the number of defective products produced and the process average. Then if the variation is beyond the boundary limits, appropriate lean tools are deployed to reduce the variation. In this method the inputs which are important to achieve the quality standards are found out. The following 7Quality Control (7QC) tools are used in six sigma methodology.

- Check Sheets (to collect data and make improvements)
Pareto Charts (to define the problem and frequency)

Cause and effect diagram (to identify possible causes of the problems)

Histogram (bar charts of past data to evaluate the distribution)

Scatter diagram (to plot the data points and find pattern between two variables)

Flow Chart (to identify non value adding steps)

Control charts (to plot the process data around control limits)

303.

304. The six sigma is methodology used to align key business processes and to achieve the quality requirements. It utilizes data analysis rigorously to minimize the data variation in these processes. The methodology is useful in driving sustainable and rapid improvement in the business processes.

305.

4.8 Pareto Analysis

307. Pareto Analysis is a decision-making tool which uses statistical techniques for the selection of a limited number of tasks to act upon that produces significant overall effect. It uses the 80/20 rule also known as the Pareto principle, which states that by doing 20% of the important work you can generate 80% of the benefit of doing the entire job. Also it is found that about 80% of the vast majority of problems are produced by 20% of a few causes. This technique is also known as the vital few and the trivial many. It is done by listing out all the problems that occur in a process and enumerating the number of times each problem is repeated during a certain period. Then the percentage of occurrences of each problem is calculated and plotted in a bar chart starting with the highest to lowest. The top most contributors are identified and addressed using other tools like root cause analysis to eliminate and prevent them from reoccurrence. The pareto analysis is done by using a bar chart by following the following steps.

- A table listing the problems and their frequency of occurrence over a selected period and percentage of the total problems is prepared
- Then the rows are arranged in a descending order of the value (i.e., the most occurring problem first)
- A cumulative percentage of the problems column is added to the table, then the information is plotted on a chart
• Problems are marked on the $x$-axis and cumulative percentage on $y$-axis and a curve is plotted.
• A bar graph is drawn with causes on $x$-axis and percentage of frequency on the $y$-axis.
• A horizontal dotted line at 80% from the $y$-axis shall be drawn to intersect the curve. Then a vertical dotted line shall be drawn from the point of intersection to the $x$-axis. The vertical dotted line separates the important causes (fall on the left) and trivial causes (fall on the right).
• The chart has to be explicitly reviewed to ensure that at least 80% of the causes for the problems are captured.

308. Pareto Analysis is a useful tool to identify and prioritise major problem areas based on frequency of occurrence. It helps to separate the ‘vital few’ from the ‘trivial many’ things to do. It also helps to identify major causes and effects. The technique is often used in conjunction with Brainstorming and Cause and Effect Analysis. Sometimes the most frequent may not always be the most important. Hence the impact of other causes on Customers or goals should also be taken care of.

309. Pareto analysis is a statistical technique which is used where many possible courses of action are available and competing for attention. Pareto analysis is a creative way of looking at the causes of problems because it helps to stimulate thinking and organise thoughts. This method appeared in the first place from Pareto’s suggestion of a curve of the distribution of wealth in a book which states that 80% of the total wealth in the world lies in the hands of 20% of the people. Whatever may be the source, the phrase of ‘the vital few and the trivial many’ finds a place in every manager’s thinking. It is one of the most important concepts in modern management. The results of thinking and action taken along Pareto lines are huge.

310. Some of the difficulties associated with using the Pareto analysis in industries would be:
• Misrepresentation of the data by the shop floor people
• Depicting the measurements inappropriately leading to wrong decisions
• Lack of understanding of the tool on how it should be used for a particular problem
• Not knowing how and when to use Pareto Analysis
• Erroneous plotting of cumulative percent data will lead to missing out some important causes.

311. In order to overcome the difficulties the following points are to be kept in mind.
• The purpose of using the pareto analysis tool must be clearly defined
• Identify the most appropriate parameters of measurement.
• Check sheets could be used to collect data for likely major causes.
• The data to be arranged in a descending order of value and then % frequency and cumulative percentage should be calculated.
• Cumulative percent to be plotted from and at the top right side of the first bar.
• Careful scrutinisation of the results has to be done with the help of experts.
• Finally it is to be analyzed whether the exercise has clarified the situation.

312. 4.9 Control Charts

The control chart is a graph used to study how a process changes over time. Data are plotted in time order. A control chart always has a central line for the average, an upper line for the upper control limit and a lower line for the lower control limit. These lines are determined from historical data. By comparing current data to these lines, you can draw conclusions about whether the process variation is consistent (in control) or is unpredictable (out of control, affected by special causes of variation). Control charts for variable data are used in pairs. The top chart monitors the average, or the centering of the distribution of data from the process. The bottom chart monitors the range, or the width of the distribution. If your data were shots in target practice, the average is where the shots are clustering, and the range is how tightly they are clustered. Control charts for attribute data are used singly.

313. Generally the data used in the control charts are samples of a population. The commonly used control charts are X bar and R Charts. The following example on control charts for blades manufacturing during 15 hours become 15 subgroups representing the total population of razor blades and each subgroup has 5 data values n = 5.

314. The mean (X) and the range are found out for each subgroup by

\[ X = \frac{\sum x_i}{n} \]
\[ R = \text{Max} (x_i) - \text{Min} (x_i) \]

315. Then the mean of the X and Range are found by the equations

\[ X = \frac{\sum X_i}{\text{No. of sub groups}} \]
\[ R = \frac{\sum R_i}{\text{No. of sub groups}} \]
319. **Limits to Control charts:** Upper and lower control limits represent 3 standard deviations above and 3 standard deviations below the mean line respectfully. These are calculated using the following equations.

320. \[ X \text{ (UCL}_x) = X + A_2 \times R \]

321. \[ X \text{ (LCL}_x) = X - A_2 \times R \]

322. \[ R \text{ (UCL}_R) = D_4 \times R \]

323. \[ R \text{ (LCL}_R) = D_3 \times R \]

324. Where \( A_2, D_3 \) and \( D_4 \) are constants taken from the table.

325.

326. To analyze the control charts it is important to remember that the data is represented over six standard deviations, there are three standard deviations from the mean line to the upper control limit and three from the mean to the lower control limit. To help analyze the charts, it is important to divide the chart area into six sections A, B, and C representing the standard deviations.

327.

328. The interpretation of the data is very crucial as we first look at the R chart. The R chart represents the variety in the data and if the variety is too great than there is no need to look at the X control chart. The chart is out of control if one or more of the points lie beyond the UCL or LCL control limits lines.

329.

330. **Fig 4.1 X bar control chart**
4.10 Cost of Poor Quality

The cost of poor quality includes the costs involved in fulfilling the gap between the desired and actual product/service quality. It also includes the LOST opportunity costs due to the loss of resources used in identifying and rectifying the defect. This cost includes all the labor cost, rework cost, disposition costs, and material costs that have been added to the product up to the point of rejection. Cost of Poor Quality (COPQ) does not include detection and prevention cost. Emphasizing that quality is neither intangible nor immeasurable, Philip Crosby, in his book “Quality is Free”, maintained that quality is a strategic imperative that can be quantified and used to improve the bottom line. Quality has always been difficult to measure for most organizations, largely because there are several factors, which may or may not be linked to each other, that contribute to poor quality. Difficulty in tracking quality quite often translates into millions of dollars being lost every year. However, this COPQ is not insurmountable. An organization’s COPQ can be reduced by identifying the different areas in which there are potential wastes, failures, and additional costs.
Producing the goods in the required quality specifications in the first instance is the aim of this tool. The cost of quality has to be quantified in money value. This will explain how much the organisation is spending in order to maintain the quality the customer expects. Any process output must meet the customer expectations and defect free. The cost of poor quality is calculated using the formula

\[
\text{COPQ} = \text{Costs (external failures + internal failures + appraisal + preventive action)}
\]

The six sigma methodology uses the defect costs to quantify savings out of its implementation in money value. Lean Manufacturing focuses even on reducing the appraisal costs which are done during the production. One should not measure any parameter just because it is measurable. A good design engineer should try to reduce the inspections as far as possible by introducing controls such as poke-yoke. Design Controls should focus on early review and test activities to prevent defects at the earliest stage.

Cost of external failures include monthly defect reports, reports of corrections and removals, field service corrections, field service bulletins and software patches. Cost of internal failures include unclear requirements, improper design and implementation, incorrect test documentation, incoming inspection defects, in-process testing defects, final acceptance testing defects and rework. Cost for appraisal includes review of system specifications, review and inspection during manufacturing processes, review of quality records and audits. Cost for preventive action includes use of techniques for better understanding of requirements, employment of programs to reduce design defects, implementing tools to reduce manufacturing defects and implementation of quality improvement programs. The quality improvement activities in manufacturing may be achieved through the following techniques.

- Reduce errors with process design changes (poka-yoke)
- Addition of test fixtures to simplify manual processes
• Capability studies to define optimum parameter settings
• Enhance supplier controls to refine part specifications
• Redesign of device for improved manufacturability
• Addition of automated manufacturing equipment
• Enhanced automated test equipment
• Refinement of acceptance test criteria
• Real time automated test data trending
• Refinement of work instructions/formulations

(Source : http://www.ehcca.com/presentations/devicecongress1/olivier_a.pdf)

4.11 Standard Operating Procedures

A Standard Operating Procedure is a set of step-by-step instructions compiled by an organization to help workers carry out complex routine operations. SOPs aim to achieve efficiency, quality output and uniformity of performance, while reducing miscommunication and failure to comply with industry regulations. Standard operation procedures document the steps of key processes to help ensure consistent and quality output. Standard operating procedure is developed from the process documents.

Process documents show how every operation fits together, the flow of work through various stages and it transcends cross procedures and across time, whereas SOPs document the directions on how a task should be performed irrespective of the person who is at the station. It handles one task at a time and describes how it has to be performed. It is clear and accurate without any ambiguity and spells out what the operator needs to do and how. SOPs can be used for training and competency assessment programs in the organization. Newly recruited personnel can become competent more quickly with the use of SOPs. It is a way to identify, label, and correct process problems.

SOPs detail the regularly recurring work processes that are to be conducted or followed within an organization. They document the way activities are to be performed to maintain consistency with technical operations and to support data quality. They describe the analytical processes, and processes for maintaining, calibrating, and using equipment. SOP’s maintain quality control and quality
assurance processes and ensures compliance with governmental regulations. SOPs are usually specific to the organization or facility and must address the following.

- Process Identification
- Controls
- Equipment Checks
- Potentially Hazardous Situations
- Waste Management
- Any Requirements for Obtaining Authorization

353. The following points may be followed as general guidelines for writing any standard operating procedure.

- Use clear, simple, direct wording in short sentences
- Write procedures as chronological sequences
- Use ‘shall’ or ‘must’ for mandatory actions and ‘should’ for advisory actions
- Procedures should reflect current practice
- If any section is not applicable to the procedure, include “N/A” under the heading –DO NOT leave blanks.

355. 4.12 Kaizen

356. Kaizen is the practice of continuous improvement. Kaizen was originally introduced to the west by Masaaki Imai in his book Kaizen: The key to Japan’s competitive success in 1986. Today kaizen is recognized worldwide as an important pillar of an organization’s long-term competitive strategy. Kaizen is continuous improvement that is based on certain guiding principles:

358.

- Good processes bring good results
- Go see for yourself to grasp the current situation
- Speak with data, manage by facts
- Take action to contain and correct root causes of problems
- Work as a team
- Kaizen is everybody’s business
• And much more

359.

360. One of the most notable features of kaizen is that **big results come from many small changes accumulated over time**. However this has been misunderstood to mean that kaizen equals small changes. In fact, kaizen means everyone is involved in making improvements. While the majority of changes may be small, the greatest impact may be Kaizen’s that are led by senior management as transformational projects, or by cross-functional teams as kaizen events.

361. The advantages of implementing Kaizen are as follows.

• **Utilization of Resources** – Kaizen focuses on improvements in products and processes through utilization of existing resources to achieve incremental and continuous improvement. It is centered around making small changes instead of relying on massive changes or expensive equipment investments to gain improvements.

• **Increased Efficiency** – Central to Kaizen methodology is the importance of providing a well-planned work area, eliminating unnecessary movement or operations and proper training for all employees.

• **Employee Satisfaction** – Kaizen is about creating an atmosphere of teamwork and change, where new ideas are encouraged. Team members are asked to really examine the processes and make suggestions for improvement.

• **Safety Improvements** – A safer work environment is another benefit of Kaizen. The safety improvements occur when new ideas to clean up and organize the work area are developed and implemented.

362. Kaizen involves everyone in the improvement effort. It does not rely on huge capital investments or attempt to make enormous strides at one time. The roots of Kaizen are in making small, immediate, incremental improvements in the processes and work standards. It is about looking for ways to improve every day. In due course, these small steps can result in giant leaps in quality, safety, efficiency, productivity and a positive impact on the bottom line.

363.
364. CHAPTER 5

365. DATA COLLECTION AND ANALYSIS

366.  5.1 Implementation of TPM to Reduce Lead Time in a Foundry

367. Lean implementation was carried out in a foundry by executing total productive maintenance. The company was following only breakdown maintenance. This led to delay in meeting the production targets. To address the problem a study was carried out to identify the causes of breakdown by collecting the data.

369.  5.1.1 Methodology

370. The TPM proactive approach implementation was carried out using methodology which is shown in Fig.5.1. It starts with the existing study of the manufacturing system in the selected industry and to identify the problem. The objective of the study after being defined, the existing data collection was made for about six months. Then the breakdown analysis was carried out to find out the bottleneck areas and the necessary preventive maintenance actions were recommended. The corrective maintenance was carried out to implement the necessary predictive maintenance. The results were validated and the efficiency of TPM was proved.

373. Fig.5.1 Methodology Flow Chart
5.1.2 Data Collection and Analysis

Maintenance is nothing but a non-value added activity in functions of business organisation and in manufacturing industry. After the industrial revolution the manufacturing industry faced a challenging environment in the maintenance of equipments. Indian manufacturing industry including could not escape from the technological development and globalization. This study was carried out in an industry manufacturing automobile parts. During the study it was found that that the breakdown hours to be high when compared to the industry norms. The objective of this study was to implement the TPM proactive approach of preventive maintenance, corrective maintenance and predictive maintenance along with the other pillars of TPM such as autonomous maintenance and planned maintenance. The problem on being identified, the necessary activities for the entire study were planned accordingly.

The existing manufacturing system of the industry was studied and the related data were collected for necessary investigation. The data on actual breakdown for the period from February 2017 to November 2017 were collected. This includes the following areas of operation viz. pattern making section, sand plant, mould and core making, furnace, fettling and finishing. The sand plant consists of one maintenance head, one facilitator, three technicians and six labors. A team was formed done with the above members who were also informed TPM and proactive approach. The data relating to the months from February 2017 to April 2017 and May 2017 to July 2017 are shown in Table 5.1 and Table 5.2 respectively. In Table 5.1 as per the data available it could be seen that the average breakdown hours per month to be 93 hours. In Table 5.2 the data reveals that the average breakdown hours per month as 92 hours. Against industry norms of breakdown hours of 8 hours per month, the occurrence of breakdown hours in this plant was noticed to be 92 to 93 hours per month.

Table 5.1 Actual No. of Breakdown Hours for the Months from Feb to April 2017

<table>
<thead>
<tr>
<th>Breakd</th>
<th>Feb’1</th>
<th>Mar’</th>
<th>Apr’</th>
<th>Average hours/ month</th>
</tr>
</thead>
<tbody>
<tr>
<td>384.</td>
<td>385.</td>
<td>386.</td>
<td>387.</td>
<td>388.</td>
</tr>
</tbody>
</table>
### Table 5.2 Actual No. of Breakdown Hours for the Months from May to July 2017

<table>
<thead>
<tr>
<th>Breakdown Item</th>
<th>May’17</th>
<th>June’17</th>
<th>July’17</th>
<th>Average Hours/ Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical</td>
<td>413.</td>
<td>414.</td>
<td>415.</td>
<td>416. 64</td>
</tr>
<tr>
<td>Electrical</td>
<td>418.</td>
<td>419.</td>
<td>420.</td>
<td>421. 28</td>
</tr>
<tr>
<td>Total Hrs</td>
<td>423.</td>
<td>424.</td>
<td>425.</td>
<td>426. 92</td>
</tr>
</tbody>
</table>

#### 5.1.3 Breakdown Analysis

The break down analysis was carried out to find the root cause for the frequent breakdowns. Generally, the breakdowns are classified into mechanical breakdown and electrical breakdown. A brainstorming was conducted with the help of the maintenance head and the facilitator of sand preparation department. From the analysis it was found that, the major breakdown took place in the foundry division and the analysis also showed that one of the major contributors for the breakdown in the foundry was the sand plant and hence the study was taken up to reduce the breakdown hours in the sand plant. The methodology followed for
breakdown analysis is shown in Fig. 5.2 and the list of breakdowns with appropriate
time lost is shown in Table 5.3. The root cause of the relative breakdown was found
with the help of Pareto diagram as shown in Fig. 5.3. From the chart it could be
observed that, the major problem areas to be bucket elevator, mixer wheel and
sensor failure. The main causes for the breakdown and the reasons for the same were
also investigated and are given in the Table 5.4.

### Fig. 5.2 Methodology-Breakdown Analysis

### Table 5.3 Breakdown Time Lost

<table>
<thead>
<tr>
<th>Sl.</th>
<th>Breakdowns</th>
<th>Time (Minutes)</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bucket Elevator</td>
<td>72</td>
<td>February, May</td>
</tr>
<tr>
<td>2</td>
<td>Mixer Wheel</td>
<td>10</td>
<td>March, July</td>
</tr>
<tr>
<td>3</td>
<td>Cleaning</td>
<td>75</td>
<td>June</td>
</tr>
<tr>
<td>4</td>
<td>Underground Sand Spillage</td>
<td>11</td>
<td>April</td>
</tr>
<tr>
<td>5</td>
<td>Belt Contractor Failure</td>
<td>75</td>
<td>June</td>
</tr>
<tr>
<td>Breakdowns</td>
<td>Route Cause</td>
<td>Reasons for Breakdown</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>-------------</td>
<td>-----------------------</td>
<td></td>
</tr>
<tr>
<td>Bucket elevator</td>
<td>Drum wear out</td>
<td>Misalignment of the belt due to overload of return and prepared sand</td>
<td></td>
</tr>
<tr>
<td>Mixer wheel</td>
<td>Bearing failure</td>
<td>Sand and dust accumulation</td>
<td></td>
</tr>
<tr>
<td>Sensor</td>
<td>Frequent damage</td>
<td>Due to bearing failure</td>
<td></td>
</tr>
</tbody>
</table>

5.1.4 Actions Recommended

After finding the root causes for the breakdown actions to be taken were recommended. The recommended actions were as per the TPM proactive approach such as preventive maintenance, corrective maintenance and predictive maintenance based on the pillars of total productive maintenance such as...
autonomous and planned maintenance. By implementing the total productive maintenance through autonomous maintenance and planned maintenance and by following the steps of corrective maintenance, preventive maintenance action and predictive maintenance the level of breakdown hours were found reduced. The breakdown canalization report is given in Table 5.5 lists the corrective maintenance actions.

Table 5.5 Breakdown Canalization Report

<table>
<thead>
<tr>
<th>Machine</th>
<th>Breakdown</th>
<th>Root Cause</th>
<th>Corrective Maintenance Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand plant</td>
<td>Bucket elevator</td>
<td>Drum wear out</td>
<td>Belt alignment to be monitored regularly</td>
</tr>
<tr>
<td>Sand plant</td>
<td>Mixer wheel</td>
<td>Bearing failure</td>
<td>Time based maintenance plan</td>
</tr>
<tr>
<td>Mould track</td>
<td>Sensor</td>
<td>Frequent damage</td>
<td>Change of control voltage and supply voltage board</td>
</tr>
</tbody>
</table>

5.1.4.1 Preventive Maintenance Action

The preventive maintenance action check sheet was prepared with the help of the maintenance engineer and the facilitator head. This preventive maintenance check is to be done by the operators on daily and weekly basis. The preventive maintenance check sheets for daily and weekly basis are shown in Table 5.6 and Table 5.7 respectively. Preventive maintenance actions were suggested based on the checklist. The suggestions for bucket elevator were plumber block designs to be changed to encloser tube and extra oil seal fixing and bearing to be changed every nine months. The suggestions for mixer wheel were oil seal to be changed every month and change of bearing cup design and bearing to be changed every year.
### Table 5.6 Daily Check Sheet

<table>
<thead>
<tr>
<th>523. Daily basis check list</th>
<th>524. Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>525. Check for belt alignment</td>
<td>526.</td>
</tr>
<tr>
<td>527. Check for belt condition</td>
<td>528.</td>
</tr>
<tr>
<td>529. Sensor work condition</td>
<td>530.</td>
</tr>
<tr>
<td>531. Check for sand leakage in bearing</td>
<td>532.</td>
</tr>
<tr>
<td>533. Check bearing temperature</td>
<td>534.</td>
</tr>
</tbody>
</table>

### Table 5.7 Weekly Check Sheet

<table>
<thead>
<tr>
<th>540. Weekly basis check list</th>
<th>541. 1&lt;sup&gt;st&lt;/sup&gt; week</th>
<th>542. 2&lt;sup&gt;nd&lt;/sup&gt; week</th>
<th>543. 3&lt;sup&gt;rd&lt;/sup&gt; week</th>
<th>544. 4&lt;sup&gt;th&lt;/sup&gt; week</th>
</tr>
</thead>
<tbody>
<tr>
<td>545. Check bearing temperature</td>
<td>546.</td>
<td>547.</td>
<td>548.</td>
<td>549.</td>
</tr>
<tr>
<td>550. Oil level checking</td>
<td>551.</td>
<td>552.</td>
<td>553.</td>
<td>554.</td>
</tr>
<tr>
<td>555. Belt alignment checking</td>
<td>556.</td>
<td>557.</td>
<td>558.</td>
<td>559.</td>
</tr>
</tbody>
</table>

### 5.1.4.2 Predictive Maintenance Action

The predictive maintenance check list was also prepared and is given in Table 5.8. This maintenance check was to be carried out by the facilitator head in the sand plant. The maintenance activities suggested were to be standardized and the activities were to
be carried out regularly which would help in reducing the breakdown hours in the foundry. Kaizen tool shall be implemented in the foundry for improving the process continuously.

Table 5.8 Monthly Check Sheet

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>603. Bearing lubrication</td>
<td>604.</td>
<td>605.</td>
<td>606.</td>
</tr>
<tr>
<td>607. Bearing temperature</td>
<td>608.</td>
<td>609.</td>
<td>610.</td>
</tr>
<tr>
<td>611. Belt alignment to check (if needed change the belt)</td>
<td>612.</td>
<td>613.</td>
<td>614.</td>
</tr>
<tr>
<td>615. Oil seal wear out</td>
<td>616.</td>
<td>617.</td>
<td>618.</td>
</tr>
<tr>
<td>623. Muller bearing cup check (if needed change the cup)</td>
<td>624.</td>
<td>625.</td>
<td>626.</td>
</tr>
<tr>
<td>627. Noise checking</td>
<td>628.</td>
<td>629.</td>
<td>630.</td>
</tr>
<tr>
<td>631. Gear box temperature</td>
<td>632.</td>
<td>633.</td>
<td>634.</td>
</tr>
<tr>
<td>635. Sensor rod distance</td>
<td>636.</td>
<td>637.</td>
<td>638.</td>
</tr>
<tr>
<td>639. Oil level</td>
<td>640.</td>
<td>641.</td>
<td>642.</td>
</tr>
<tr>
<td>643. Cleaning dust and sand</td>
<td>644.</td>
<td>645.</td>
<td>646.</td>
</tr>
<tr>
<td>647. Check sand spillage in the bearing</td>
<td>648.</td>
<td>649.</td>
<td>650.</td>
</tr>
</tbody>
</table>

5.1.5 Results and Discussion

The result in total loss of hours as compared with before and after the implementation of total productive maintenance from February to November 2017 is given
in Table 5.9. The result of total loss in hours before and after implementation of TPM is shown in Fig.5.4.

### Table 5.9 Results of Total Loss in Hours before and after Implementation of TPM

<table>
<thead>
<tr>
<th>Month</th>
<th>Before Implementation of TPM</th>
<th>After Implementation of TPM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Loss (hours)</td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>80</td>
<td>85</td>
</tr>
<tr>
<td>March</td>
<td>115</td>
<td>84</td>
</tr>
<tr>
<td>April</td>
<td>84</td>
<td>75</td>
</tr>
<tr>
<td>May</td>
<td>107</td>
<td>72</td>
</tr>
<tr>
<td>June</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>July</td>
<td>86</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 5.4 Comparison of Total Loss in Hours**
From the above it was observed that, the average breakdown hours before implementation of TPM which was 93 hours got reduced to 78 hours after implementation of TPM.

Table 5.10 Breakdown Time before and after Implementation of TPM in the sand plant

<table>
<thead>
<tr>
<th>S</th>
<th>Breakdown</th>
<th>Before Implementation Time (minutes)</th>
<th>After Implementation Time (minutes)</th>
<th>Period (after implementation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bucket Elevator 7</td>
<td>698. 7 25</td>
<td>699. 3 80</td>
<td>September, November</td>
</tr>
<tr>
<td>2</td>
<td>Mixer Wheel 7</td>
<td>703. 1 070</td>
<td>704. 4 95</td>
<td>August, October, November</td>
</tr>
<tr>
<td>3</td>
<td>Cleaning 7</td>
<td>708. 7 5</td>
<td>709. 5 5</td>
<td>September</td>
</tr>
<tr>
<td>4</td>
<td>Underground Sand Spillage Cleaning 7</td>
<td>713. 1 15</td>
<td>714. 4 5</td>
<td>October</td>
</tr>
<tr>
<td>5</td>
<td>Belt Contractor Failure 7</td>
<td>718. 7 5</td>
<td>719. 6 0</td>
<td>August, November</td>
</tr>
<tr>
<td>6</td>
<td>Sensor Failure 7</td>
<td>723. 1 50</td>
<td>724. 6 0</td>
<td>September, October</td>
</tr>
<tr>
<td>7</td>
<td>Low Water Level 7</td>
<td>728. 6 0</td>
<td>729. 3 9</td>
<td>August</td>
</tr>
<tr>
<td>8</td>
<td>Belt 7</td>
<td>733. 7</td>
<td>734. 6</td>
<td>N</td>
</tr>
</tbody>
</table>

86
Breakdown time in the sand plant before and after implementation of TPM has been tabulated and shown in Table 5.10. A comparative chart on the breakdown time before and after implementation of TPM is shown in Fig. 5.5. From Table 5.10 it could be observed that the breakdown time lost in the sand plant had come down from 39 hours to 19.9 hours after implementation of TPM which is a significant reduction of 51%.

Fig 5.5 Comparative Chart on Breakdown Time Before and After Implementation of TPM

5.1.6 Concluding Remarks

In this study after collecting the necessary data and analysis an attempt was made to implement the lean tool of TPM for reducing the overall breakdown hours in a manufacturing industry. From the results the following conclusions were observed.

- Introduction of Kaizen sheet had helped in reducing the maintenance rate which in turn had reduced the overall lead time
• From the breakdown analysis it was able to locate the areas of causes for the breakdown
• TPM proactive approach had helped in reducing the total breakdown time from 93 hours to 78 hours a reduction of 16%
• Major breakdown time lost in the sand plant was reduced from 39 hours to 19.9 hours a reduction of 51%
• By introducing preventive maintenance action it was possible to suggest for auto lubrication to the bearing and also was able to develop a plate near sand filters to prevent sand and dust settling near the bearing
• TPM proactive approach had significantly improved the work culture of the employees

5.2 Optimization of CNC Cell through Various Lean Tools

This study was taken up to focus on the work level in the CNC machine cell area, where the cell produces gearbox housing unit. Already lean tools like 5S, continuous flow, just-in time, overall equipment effectiveness had been implemented in this CNC manufacturing cell. In order to improve the productivity further and to meet the customer demand at right time by introducing work standardization through the Standard Operating Procedures (SOP) with line balancing layout optimization, a brainstorming session was carried out with the process engineers, team leader, cell brigadier and operators to identify the issues faced and the bottleneck areas was attempted in the machining cell area.

5.2.1 Methodology

The problem was found to be that the weekly demand being not met and operator idle time to be high. By analyzing in detail the housing line, the objective was concluded in a brainstorming session as to eliminate the lean waste from the manufacturing process by improving productivity and also to improve the man utilization by line balancing. Data collection was done by using stop watch time study and work study was done by video analysis.
TAKT time was calculated based on demand, then compared against cycle time and value stream mapping was developed to analyze the lead time using i-Grafix software. Waste identification was done through video analysis. Value added and non-value added activities were found to be getting optimized. In this non-value added activities the necessary non value added activities were categorized which need to be reduced while others were to be eliminated by providing potential measures. Line balancing was to be done for balancing the workload between operators and to improve the man utilization using ARENA package for optimizing results. The entire research work methodology for fulfilling the objectives is shown in Fig5.6.

5.2.2 Review on Product and Process

The existing plant layout was studied as the first step of this research methodology. The study was carried out in a gear box manufacturing process unit and housing cell was identified as the bottleneck for the manufacturing process which needs the improvement. This research focuses in CNC machining cells, where they produce housings for wind mill gear box. The cell produces more than seven models of gear boxes and one model was chosen for this study purpose.
Table 5.11 Product Description

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Processes</th>
<th>Sub Parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AA</td>
<td>Cover (Upper Housing)</td>
</tr>
<tr>
<td>2</td>
<td>BB</td>
<td>Carter (Lower Housing)</td>
</tr>
<tr>
<td>3</td>
<td>CC</td>
<td>Housing</td>
</tr>
<tr>
<td>4</td>
<td>DD</td>
<td>Inspection</td>
</tr>
</tbody>
</table>

Fig. 5.7 Sequences of Processes

Table 5.11 shows list of sub parts in housing and process description. Fig5.7 shows the process sequences and also it gives overall view of material flow and operation sequences.

5.2.3 Value Stream Mapping

Value stream mapping is a special type of flow chart that is used to evaluate the value added and non-value added activities from the process flow. The data collected for building up of current state value stream mapping includes cycle time, setup time, change over time, number of operators, percentage of value and non-value added activities, demand, inventory, information flow. The current state value stream mapping with necessary information and cell observation is shown in Fig.5.8. It was found the total lead
time to be 2718 minutes for completion of a manufacturing process. Similarly the TAKT time was also calculated as per the current data as follows.

793. TAKT Time is the time to produce the product to meet the customer demand.

794. Customer Demand = 140 pieces per month

795. Available time per day = 1440 minutes = \([3\text{ shifts} \times \{8\text{ hours} \times 60 \text{ minutes} - (60 \text{ minutes})\}]\)

796. TAKT Time = Available time/day.

797. Customer demand/day = 1260/5 = 252 minutes

798.

799. 5.2.4 Future State Value Stream Mapping

800. The future state VSM was developed based on the existing VSM model with suggestions for improving the current position of the company as shown in Fig. 5.9. From the future state VSM it was observed that using suitable lean tools the total cycle time could be reduced from 988 minutes to 868 minutes. Similarly the lead time could be reduced from 2718 minutes to 2598 minutes and the total value added time also could be reduced from 694 minutes to 605 minutes by implementing the appropriate lean tools.

801.

802. Fig. 5.8 Current State Value Stream Mapping

803.
5.2.5 Cycle Time Study

By using stop watch and video analysis cycle time study was done and analysed for single gear box model. The cycle time difference between actual and standard cycle time is shown in Fig 5.10. Cycle time study and video analyzing helps to optimize Value Added (VA) activities, for which the customer would be willing to pay and also helps to find the percentage of NVA activities present in the entire operations.

Non-value added activities could be classified as Obvious Waste (OW), which need to be eliminated. Hidden Waste (HW), which needs to be reduced and these wastes cannot be eliminated from the process and varies, depends on man and material. Material handling (MH) needs to be checked whether it can shift to logistics or combine the process to reduce the cycle time. Periodic activities are the current state in the process. The total process were categorized by value added and non-value added activities for process AA, process BB, process CC and deburring as shown in Fig 5.11, 5.12, 5.13 and 5.14 respectively.
Fig. 5.10 Cycle Time Difference

Fig. 5.11 NVA in Process AA

Fig. 5.12 NVA in Process BB

Fig. 5.13 NVA in Process CC

Fig. 5.14 NVA in Deburring
5.2.6 Work Standardization

Work standardization is needed for appropriate planning and positioning of employees, materials, machines, supporting elements and facilities for obtaining perfection in manufacturing environment. The work standardization methodology implemented in this research is shown in Fig. 5.15. Standardization of the operations is carried out as per the methodology mentioned earlier. Three cycles were performed for time study during the data collection.

Fig. 5.15 Methodology in Work Standardization
About twenty improvement ideas were identified and Kaizen’s were suggested to improve the value in process. Reduction of about 140 minutes in cycle time and potential measures for improvements was suggested. By adapting the standard operating procedure in housing cell, 12% of NVA was able to be reduced from current process. Standard operating procedure was created based on 92% efficiency of operator with 8% of allowances per shift. The results of Floor to Floor (FTF) cycle time reduction in process AA, BB, CC and deburring are shown in Fig.5.16, 5.17, 5.18 and 5.19 respectively.
5.2.7 Line Balancing

Line balancing concept was applied in this study to manage workload between operators and for reducing the man idle time occurring due to high auto machining time. Hence, the schedule for every operator was assigned. The study was carried out by using the simulation to optimize the man utilization and to improve productivity by eliminating non-value added activities. For the existing layout, line balancing concepts were applied based on data collected for the
standardization operations. The operators’ movement and periodic activities were followed and a new concept of two machine-one operator was proposed for effective utilization of man power. Fig. 5.20 shows the existing line balancing layout of the housing area with one machine-one operator concept by reviewing the periodic activities done by each operator in respective machine.

Fig. 5.20 Existing Line Balancing Layout
The proposed line balancing concept as proposed with the simulation done after waste reductions in process and with the allocation of resources are shown in Fig.5.21. From this line balancing concept man idle time was reduced and the man and machine utilization was balanced to 80%. In the existing concept man involved in work was 2 hours and 18 minutes in the total cycle time of 5 hours and 35 minutes which was just around 58% only. Hence a single operator for two machines could be used, which is nearby balanced with the man and machine utilization. It was observed that around 80% of utilization by both machine and man increased up to 72% by the arena simulation which helped to increase total output from 5 to 6 components per day after implementing the proposed line balancing.

### 5.2.8 Concluding Remarks

A study and analysis to identify and remove the wastes in the activities that do not add value to the final product in the manufacturing process and to reduce the overall lead time by applying of lean tools in a CNC manufacturing cell was undertaken. Based on the study and analysis the following conclusions were arrived.

- Lean tools like work standardization were applied to eliminate non value added activities in manufacturing area
- By implementing standard operating procedure, 140 minutes of floor to floor cycle time was able to be reduced which covers about 12% of reduction in total NVA
• From the results, it was observed that the total output increased from 5 to 6 components per day after implementing the proposed line balancing.
• One operator-two machine line balancing concept was possible to ensure better utilization of man.
• Using Arena packages, non-value added activities were eliminated and also productivity got improved to meet the customer demand.

851.

852. This research was focused based on value stream mapping only in CNC machining chamber. This could be further extended in the operations of parallel manufacturing parts with additional lean tools like TPM, SMED etc.

853.
854.
855.

856. 5.3 Reduction of Defects in Pump Manufacturing Through Lean Six Sigma Tools

857. Six Sigma methodology provides the techniques and tools to improve the capability and reduce the defects in any process. In spite of the usefulness and wide application of Lean Six Sigma tools in various manufacturing units of various sizes, there is an apprehension among the industry regarding the benefits reaped from the implementation of this tool. Under this background, an attempt was made to explain the benefits of this tool implemented in a medium scale unit where the tool was applied to improve a particular process. The various steps involved in implementation were analyzed for the purpose of this study and explained in this paper. To achieve this, Six Sigma uses a methodology known as DMAIC.

858.

859. During this project study the following questions were asked. Where are we? What is the problem? Where do we want to be? How will we get there? How will we know when we are there? Without understanding the answers for these questions, the project study to resolve the problem would flounder aimlessly, wasting needed resources and frustrating personnel to the point of not supporting the improvement culture.

860.
It was proposed to select and implement Six Sigma methodology for improvement in the pump manufacturing process in a unit for the purpose of this study. It was decided to collect the data regarding the defects generated in the pump before delivery from the unit and after it was put in to operation by the customer and analyze them using various tools during implementation. For this purpose the data pertaining to the internal rejection in quality control and the defective pumps returned from the customer were collected. The final objective was to identify the defects at the place of its origin and implement measures to redress them and show improvement in the process. A project charter was made which spells out the scope, aim, team members, various deadlines and resources needed, expected cost savings, etc. This charter was approved by the champion of the team i.e. the CEO of the unit.

5.3.1 The DMAIC Project Methodology

Define the problem, the voice of the customer, and the project goals, specifically. Measure key aspects of the current process and collect relevant data. Analyze the data to investigate and verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered. Seek out root cause of the defect under investigation. Improve or optimize the current process based upon data analysis using techniques such as design of experiments, Poka - yoke or mistake proofing, and standard work to create a new, future state process. Set up pilot runs to establish process capability. Control the future state process to ensure that any deviations from target are corrected before they result in defects. Control systems such as statistical process control, production boards, and visual workplaces are to be implemented and the process is continuously monitored.

As per the DMAIC methodology, the following specific steps were followed while implementing this project.

- Study of the rejection / failure rates in various departments of the unit
- Analyze them using Pareto chart
- Select the most important / alarming areas for improvement
- Study them and find the root cause
- Measure the various data regarding the problems
- Apply suitable tools for reducing / eliminating the problems
- Achieve higher sigma levels of quality
- Provide control points for sustenance
- Estimate the cost savings through the implementation of the project

Six sigma methodology measures the total number of defects that are recorded in any organization's performance. Any type of defect, apart from the customer specification, is considered as a defect, according to Six Sigma. With the help of the statistical representation of the Six Sigma, it is easy to find out how a process would perform on quantitative aspects. A defect according to Six Sigma is nonconformity of the product or the service of an organization. Six Sigma methodology emphasizes on continuous efforts to achieve stable and predictable process results (i.e. reduce process variation) in all the processes of vital importance to business success. Manufacturing and business processes should have characteristics that can be measured, analyzed, improved and controlled. Achieving sustained quality improvement requires commitment from the entire organization, particularly from top-level management. Features that set Six Sigma distinct from previous quality improvement initiatives include a clear focus on achieving measurable and quantifiable financial returns from any Six Sigma project. There is an increased emphasis on strong and committed management leadership and support. A special infrastructure comprising of "Champions," "Green Belts," "Black Belts," etc. are put in place to lead and implement the Six Sigma approach. There is a clear commitment to making decisions on the basis of verifiable data, rather than assumptions and guesswork.

5.3.2 Reducing the Defects in Pump Manufacturing

The management noticed that there were lot of defects and reworks occurring in the manufacturing of single phase water pump. Various methods were attempted to reduce them but failed. Hence it was proposed to implement Six Sigma methodology for improvement in the pump manufacturing process for the purpose of this study. It was decided to collect the data regarding the defects generated in the pump manufacturing process and analyze them by using various tools.

5.3.3 Problem Statement and Objectives
Reduce the defects in the pump assembling process with reference to Quality assurance department. Identify the defects at the place of its origin in the manufacturing process. Analyze the reasons for their occurrence and ways to eliminate them. Sort the defects Department-wise for selecting the problems for redressal. Collect the data analyzed and find out the Root cause and the Rolled Throughput Yield (RTY). Assess the defects with respect to Quality Assurance dept and find the Cost of Poor Quality towards reducing the defects.

5.3.4 Data Collection and Analysis

The data on the various defects in the manufacturing process were collected at each section over a period of 16 days and analyzed using the Pareto chart as given in Fig. 5.22 to find out the most occurring defects. One defect seal leak which falls in the vital few of top twenty percent of defects contributing to about eighty percent of the defects was chosen for this project as the total control was well with the supervisor and the project can be implemented with full freedom. The various factors contributing to the seal leak were analysed using the cause and effect analysis as tabulated in Table 5.12 using brainstorming sessions involving all the persons in the processes.
880. Fig.5.22 Pareto Chart

881. Table 5.12 Cause and Effect Analysis

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>888. Soap water contaminated</td>
<td>889. Scratches on ceramic, carbon, rubber</td>
<td>890. Improper selection of fixtures</td>
<td>891. Fixing of ceramic in housing</td>
<td>892. Dust</td>
<td>893. Improper selection of instrument for rubber items inspection</td>
</tr>
</tbody>
</table>
The risks involved in each cause were calculated using failure mode effects analysis based on the severity, occurrence and detection. A number from 1 to 10 was assigned for each potential effect causing the failure and Risk Priority Number (RPN) was calculated for each cause and tabulated in Table 5.13. This again helps to prioritize the most important causes to be addressed on priority.

The next tool used for analysis was FMEA. The risk priority number was determined by three risk parameters which include:

- Severity rating (S): Severity is ranking according to the seriousness of the potential effect of the failure rated.
- Occurrence rating (O): Occurrence is ranked according to relative probability that the potential failure will occur.
- Detection rating (D): Detection is an assessment of the ability of a design to detect a potential failure before the part or assembly is released for production.

The multiplication of Severity, Occurrence and Detection values leads to what is known as the RPN. 

\[ \text{RPN} = S \times O \times D \]

FMEA can be divided into two phases; the first phase to identify the potential failure modes and decide the value of Severity, Occurrence and Detection. In the second phase, the recommendations made for corrective actions. The RPN needs to be re-calculated after corrective actions. The implementation of FMEA in a service area can be considered as a step towards a new direction in this unit.
FMEA had been done three times for this project before final recommendations for control points were provided.

Table 5.13 Failure Mode Effects Analysis

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Phase Pump Assembly</td>
<td>940, 941, 942, 943, 944, 945</td>
<td>953. Seal Leak</td>
<td>955. Improper lapping of ceramic</td>
<td>957. No Control</td>
<td>959. 196</td>
</tr>
<tr>
<td></td>
<td></td>
<td>962. Seal Leak</td>
<td>964. More clearance bet. Shaft and ceramic bore</td>
<td>966. No Control</td>
<td>968. 196</td>
</tr>
<tr>
<td></td>
<td></td>
<td>971. Seal Leak</td>
<td>973. Crack in carbon</td>
<td>975. Random sample checking</td>
<td>977. 140</td>
</tr>
<tr>
<td></td>
<td></td>
<td>980. Seal Leak</td>
<td>982. Variation in compression length</td>
<td>984. Incoming inspection</td>
<td>986. 63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>989. Seal Leak</td>
<td>991. Variation in seal bore dia.</td>
<td>993. Incoming inspection</td>
<td>995. 42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>998. Seal Leak</td>
<td>1000. Variation in seal length</td>
<td>1002. Incoming inspection</td>
<td>1004. 42</td>
</tr>
</tbody>
</table>

A list of recommended actions to address all the causes is as given in Table 5.14. The recommended actions are implemented for a sufficient period of time and the defect rates are checked. FMEA is done again to find out the new RPN numbers. This process is repeated till all the potential causes are identified and eliminated. The FMEA along with cause and effect analysis is found to be a powerful tool for elimination of defects.

The results of analysis phase provide various suggestions for improvement in the assembling process so that the defects are reduced for achieving higher sigma levels.
The various recommended actions against each potential causes, the persons responsible to implement them and the actual actions taken in the assembling section are tabulated and provided below.

1008.
1009.
1010.
1011.
1012.
1013.
1014.
1015.
1016.
1017.
1018.
1019.
1020.
1021.
1022.
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1024.
1025.
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1029.

Table 5.14 Actions Recommended Addressing the Defects

<table>
<thead>
<tr>
<th>Potential Causes of Failure</th>
<th>Current Process control</th>
<th>Recommended action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improper insertion of ceramic in adaptor housing</td>
<td>Fixture is used for insertion</td>
<td>Training to be provided for proper insertion of ceramic</td>
</tr>
<tr>
<td>Improper lapping of ceramic</td>
<td>No control</td>
<td>Periodic checking of fixture</td>
</tr>
<tr>
<td>More</td>
<td>No</td>
<td>Inspection plan to be made and incoming inspection strengthened</td>
</tr>
</tbody>
</table>

1030.
1031.
<table>
<thead>
<tr>
<th>Clearance between shaft and ceramic (2 mm)</th>
<th>Control</th>
<th>The ceramic bore dia. from 14 mm to 13 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1054. Dry running of motor</td>
<td>1055. Instruktion manual</td>
<td>1056. 9</td>
</tr>
<tr>
<td></td>
<td>1057. Dealer to give training to the end user</td>
<td></td>
</tr>
<tr>
<td>1058. Improper assembly of NRV plunger</td>
<td>1059. Assembly operator self checking</td>
<td>1060. 7</td>
</tr>
<tr>
<td></td>
<td>1061. Change in design of stage plunger to accommodate rubber seating dia.</td>
<td></td>
</tr>
<tr>
<td>1062. Variation in seal total length</td>
<td>1063. checked at incoming inspection</td>
<td>1064. 8</td>
</tr>
<tr>
<td></td>
<td>1065. Inspection planned to be made and carried out</td>
<td></td>
</tr>
<tr>
<td>1066. Adaptor working length variation</td>
<td>1067. checked at incoming inspection</td>
<td>1068. 7</td>
</tr>
<tr>
<td></td>
<td>1069. Working length to be changed</td>
<td></td>
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<tr>
<td>1070. Adaptor seal housing ID variation</td>
<td>1071. checked at incoming inspection</td>
<td>1072. 8</td>
</tr>
<tr>
<td></td>
<td>1073. Inspection planned to be made and carried out</td>
<td></td>
</tr>
<tr>
<td>1074. Adaptor seal housing leak</td>
<td>1075. checked at incoming inspection</td>
<td>1076. 8</td>
</tr>
<tr>
<td></td>
<td>1077. Inspection planned to be made and carried out</td>
<td></td>
</tr>
<tr>
<td>1078. Improper finishing in adaptor seal housing</td>
<td>1079. checked at incoming inspection</td>
<td>1080. 8</td>
</tr>
<tr>
<td></td>
<td>1081. Inspection planned to be made and carried out</td>
<td></td>
</tr>
<tr>
<td>1082. Variation in shaft seal length</td>
<td>1083. checked at incoming inspection</td>
<td>1084. 8</td>
</tr>
<tr>
<td></td>
<td>1085. Inspection planned to be made and carried out</td>
<td></td>
</tr>
<tr>
<td>1086. Improper alignment of SS washer</td>
<td>1087. Checking during assembling</td>
<td>1088. 4</td>
</tr>
<tr>
<td></td>
<td>1089. SS washer to be mounted in the plastic impeller</td>
<td></td>
</tr>
<tr>
<td>1090. Improper primer coating in seal housing</td>
<td>1091. Checking while assembling</td>
<td>1092. 7</td>
</tr>
<tr>
<td></td>
<td>1093. Painter is to be instructed to coat the primer properly</td>
<td></td>
</tr>
<tr>
<td>1094. Variation in compression length</td>
<td>1095. Incoming inspection</td>
<td>1096. 8</td>
</tr>
<tr>
<td></td>
<td>1097. Inspection plan to be made and carried out</td>
<td></td>
</tr>
<tr>
<td>1098. Variation in seal bore dia.</td>
<td>1099. Incoming inspection</td>
<td>1100. 8</td>
</tr>
<tr>
<td></td>
<td>1101. Inspection plan to be made and carried out</td>
<td></td>
</tr>
</tbody>
</table>

5.3.5 Defect Preventive Measures Taken

- A weekly report of failure/rejection was made
- A weekly meeting was arranged to brainstorm on newer ideas to prevent defects further
- Responsibility was given to the team and the worker/employee who really does the work at the shop floor.
• Incoming components inspection was made more stringent for seal
• New method for inspecting graphite surface was developed. Go – no go gauge was developed for measuring shaft dimensions
• New methods were developed for fixing bearing and casing
• Casing dimensions tolerance limits were reduced
• Proper training to assembling workers were provided
• Material handling and storage methods were improved
• Proper greasing technique for bearings were obtained from supplier and technicians were informed

5.3.6 Concluding Remarks
• The data on defects collected after the project showed substantial reduction in defects
• Rolled Throughput yield showed that 20% defects were generated by the two defects under study
• There is lot of scope for reducing the defects if rest of the defects are taken up for further implementation
• Further detailed study and corrective measures were recommended
• The implementation of Six Sigma tools in pump manufacturing definitely led to reduction of defects

5.4 Implementation of Lean in Auto Components Manufacturing Industry
• Implementation of lean manufacturing is gradually being taken up in Indian SMEs. Some of the SMEs attempt it individually whereas many others do it in a group. The groups of SMEs come together on the basis of geographic proximity, common customer, similar product manufacturing, similar manufacturing processes, etc. These groups are known as cluster of SMEs. They undertake a
diagnostic study of all the units in the cluster. Based on the findings of the study an
action plan is prepared comprising of the projects to be implemented in the
respective units.

1115. A common training is organized for the key members of the units. This
reduces the cost of implementation to a great extent. Then the implementation is done in
the individual units to address the areas identified in the diagnostic study for potential
improvement. Unit wise trainings and shop floor implementation of Lean Tools are taken
up. The implementation takes place over a duration of 18 to 24 months during which the
units meet in a common place at periodic intervals to share their experience and success
stories. They also discuss the problems encountered and discuss possible solutions for
them. This cluster approach reduces the cost and also accelerates the phase of improvement
through cross learning. Under this background this study attempts to capture the
methodology adopted and the results achieved in a cluster having nine SMEs
manufacturing auto components.

1117. 5.4.1 Methodology

1118. Under Lean manufacturing program organized for improving the
performance and capability of SME units, a cluster comprising of nine units based in and
around Chennai was formed. A common customer who is the manufacturer of farm
equipments helped in formation of this cluster. The units were involved in different
business activities (machining, sheet metal forming, fabrication and forging). The major
objective of this program was to improve the overall performance of these units in terms of
their systems and practices. Lean manufacturing techniques were taken as the way to
achieve the objective of the program. The turnover of the participating units ranged from
INR 20 million to 150 million per annum. The style of management differed from an
owner driven unit to professionally managed organizations. The whole program was
planned for a period of 18 months divided into five phases. Initially a detailed diagnosis
was carried out to baseline the current level of performance, understand existing systems
and practices. Various studies were used to identify the bottlenecks in the production
process.

1120.
1121. Based on the diagnosis made, unit specific projects were identified in consensus with the unit heads. A formal review meeting was held once in two months along with the OEM customer to review the progress of various activities and provide necessary guidance. The details of visits to the units and the various activities undertaken were periodically reported by the units in these meetings. A detailed phase wise reports were also circulated among the units for cross learning. At the end of each phase an audit was also performed to monitor whether the projects were being implemented as per the action plan finalized at the end of the Diagnosis phase. Mid way corrections were suggested during the discussions with the Chief Executive Officers (CEO).

1122.

1123. The process of implementation in these nine units involved the following steps.

- Diagnosing the current level of these units – capturing the current conditions and levels of adherence to lean principles using lean evaluation tools
- Setting targets / milestones – includes both unit specific and common projects to be undertaken
- Detailed project list and the milestone based targets for all the units for each phase activities
- Broad action plan for the subsequent phases – after Diagnosis phase four milestones were planned
- Formulation of review mechanism to monitor progress and targeted milestones

1124.

1125. At the end of the diagnosis, it was very clear that the overall status of all the unit members were the same except for a few. Hence after discussions with the CEOs and based on their consensus, the overall approach for the project was formulated. The activities planned included both common projects across all units and unit specific projects. The common projects were aimed at building the fundamental systems, data collection practices, analysis in these units to ensure growth and sustainability. The unit specific projects included the areas where they had abundant scope for improvement using the existing infrastructure without investing in fresh resources. Some of the projects undertaken were

- Product Quality improvement – Parts Per Million (PPM) reduction
• Delivery schedule achievement – improving delivery performance
• Productivity improvement – elimination of idle time
• Setting time reduction – elimination of non value adding activities
• 5S Score – improving the workplace organization
• Kaizen – improving the culture of worker involvement

Some of the other systems introduced in the units were internal kanban system, visual controls, tool development time line plan, cutting tool inserts issue monitoring plan, etc.

5.4.2 The Results Achieved

By implementing the different lean tools in the above projects and systems in the units the productivity and competitiveness of the units increased in terms of reduction of in-house rejections, improvement of overall equipment effectiveness and 5S, implementation of more Kaizens reducing change over time, optimizing inventory, improving productivity, etc. The benefits achieved was measured in terms of money value wherever possible and given in Table 5.15. Other qualitative benefits and performance measures were captured and are provided in Table 5.16. From the Table 5.15, it was found that there was a direct savings of about rupees six million for these nine units through lean implementation over a period of one and half years. More than the direct savings, the improvement in the productivity and competitiveness provided the units an edge over their competitors. It had brought them more jobs as they were in a better position to offer competitive prices and higher quality. Also they were able to take up more challenging jobs as they were equipped with employees who can solve any challenge through brainstorming and Kaizens. Their machines were always available for production as they had implemented total productive maintenance and improved their OEE considerably. Similarly, the graphical representations of improvement in two parameters of productivity by PPM reduction and delivery performance by 5S are shown in Fig. 5.23 and 5.24.
<table>
<thead>
<tr>
<th>Nature of Project</th>
<th>Quantitative Benefits</th>
<th>Qualitative Benefits</th>
<th>Monetary Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimizing In-house rejections</td>
<td>PPM reduction was about 55%</td>
<td>Importance of data collection and data based decision making, Awareness of Pareto analysis, Cause and effect diagram, Why-why analysis to find the root cause of the problem</td>
<td>Rs. 31.02 lakhs</td>
</tr>
<tr>
<td>OEE Improvement</td>
<td>OEE improved by about 70%</td>
<td>Major downtime was addressed, Machine utilization improved</td>
<td>Rs. 1.05 lakhs</td>
</tr>
<tr>
<td>5S Improvement</td>
<td>5S levels increased by about 145%</td>
<td>Unwanted items were removed and maximum space was utilized, Searching of items reduced by proper arrangement, Visual controls for better shop floor maintenance</td>
<td>Rs. 6.30 lakhs</td>
</tr>
<tr>
<td>Kaizen Implementation</td>
<td>Fifty different Kaizens were implemented in all nine units</td>
<td>Employee morale was improved, Active participation of employees in day-to-day shop-floor problems and coming forward with suggestions to solve it</td>
<td>Rs. 3.06 lakhs</td>
</tr>
<tr>
<td>Changeover time reduction</td>
<td>Reduction in changeover time by about 54%</td>
<td>Awareness on SMED, VA and NVA, Importance of tool kits in changeover to reduce the time taken</td>
<td>Rs. 2.52 lakhs</td>
</tr>
<tr>
<td>Optimization of inventory</td>
<td>Reduction in inventory by about 43%</td>
<td>Importance of raw material planning, Better delivery performance</td>
<td>Rs. 4.03 lakhs</td>
</tr>
<tr>
<td>Productivity Improvement</td>
<td>Improvement in productivity by</td>
<td>Awareness on identifying and optimising operating parameters</td>
<td>Rs. 10.04 lakhs</td>
</tr>
</tbody>
</table>
Table 5.16 Overall Benefits in Terms of Productivity and Competitiveness

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Description</th>
<th>Performance Measures Before</th>
<th>Performance Measures After</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1189</td>
<td>1190. Delivery performance</td>
<td>1191. 5%</td>
<td>1193. 85%</td>
<td>1194. Five units achieved&gt;90%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1192.</td>
<td></td>
<td>1195. Four units achieved&gt;80%</td>
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<tr>
<td>1196</td>
<td>1197. PPM reduction</td>
<td>1198. 7 430PPM</td>
<td>1199. 3150 PPM</td>
<td>1200. Overall 58% reduced</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1201. while in three units&gt;70% reduction</td>
</tr>
<tr>
<td>1202</td>
<td>1203. Kaizen’s 0 no’s</td>
<td>1204. 3 0 no’s</td>
<td>1205. Five units-30 to 65 no’s</td>
<td>1207. 100 no’s of Kaizen’s have been received.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1206. Four units-15 to 30 no’s</td>
<td></td>
</tr>
<tr>
<td>1208</td>
<td>1209. 5S implementation</td>
<td>1210. 3 0%</td>
<td>1211. 82%</td>
<td>1212. Overall 52% improvement while in</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1213. 8 units above 80%</td>
</tr>
<tr>
<td>1214</td>
<td>1215. Change over time reduction</td>
<td>1216. 1 30mins</td>
<td>1217. 60 mins</td>
<td>1218. Reduction by about 54%</td>
</tr>
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<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>1219</td>
<td>1220. Inventory turnover ratio</td>
<td>1221. 7</td>
<td>1222. 13</td>
<td>1223. Improved by about 86%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1224</td>
<td>1225. Improving OEE</td>
<td>1226. 5 0%</td>
<td>1227. 75%</td>
<td>1228. 25% improved while in</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1229. three units above 70%</td>
</tr>
<tr>
<td>1230</td>
<td>1231. On-time tools development</td>
<td>1232. 0 %</td>
<td>1233. 70%</td>
<td>1234. Significant Improvement</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1235</td>
<td>1236. Training</td>
<td>1237. 5S, Lean practices, Tool monitoring, Maintenance</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
programmes, practices, Financial management, etc.

1250. Fig 5.23 S Score improvement

Fig 5.24 Productivity Improvement

1255. Fig 5.25 Delivery Performance Fig 5.26 PPM Reduction
1256.

1257. **5.4.3 Other Systems introduced**

1258. As part of the project following systems were also implemented in these units.

- Internal Kanban system
- Insert planning
- Tool development time line plan
- Visual controls

1259. **5.4.3.1 Internal Kanban system**

1260. The background of the problem was that the unit was unable to meet the customer schedule on weekly basis. In order to meet the demand the unit was maintaining a high inventory level of finished products. This resulted in high cost of product as lot of raw materials and other working capital was infused to maintain the stock. In order to overcome this problem it was decided to introduce internal Kanban system.

1261. The underlying Principles of internal Kanban system are as follows.

- Bin size was fixed based on the customer’s bin size.
- Separate bin sizes were fixed for forging, machining and finished goods as a multiple of customer pull quantity
- Maximum and minimum order quantity was fixed based on the past data
- Kanban system was followed based on the traffic signal system

1262. By following the above production planning tool the results achieved were

- Inventory was controlled at the optimum level
- Customer’s weekly demand was met on time

1263.

1264. **5.4.3.2 Inserts planning**
1266. The problems faced by the unit were that no standard system for monitoring the issue and receipt of the inserts was in place. Due to this life of inserts were not monitored and multiple ordering of same inserts had happened.

1267. Procurement of inserts was part of the planning activity which took some considerable amount of time. In order to save time in planning, a tool was developed which could automatically calculate the number of inserts required for the month. The inputs used for calculating the inserts were customer schedule and closing stock of inserts.

1268. The benefits reaped out of this project were as follows.

- Time spent in planning got reduced
- Wrong ordering practices were eliminated resulting in better inventory control
- Stock information was available at any point of time
- Inserts issue-receipt were able to be monitored
- Calculating the monthly requirement by considering the current stock was possible

1269. 5.4.3.3 Tool development time line plan

1271. One of the unit in the cluster was finding it difficult to complete the new product development on time, hence a tool development plan was created in excel to monitor the entire development activity. Initially a process flow chart was created consisting of development activities, the process flow chart consists of all the activities involved in developing a tool viz., Receipt of drawing, machining and sizing, hardening, wire cutting and assembly. The development activity was further classified into type of tools developed viz., open tool, pillar set, receiving gauge and welding fixture. Time taken for each of the type of tool was arrived, capacity was planned in advance and target for each month was monitored. The following were the problems faced by the unit before introducing the system.

- No monitoring of the plan against the actual time taken for completion
- Reasons for delay in development was not known
- Number of days delayed because of the reason was not known
- Capacity analysis not done before taking up project

1272. The benefits reaped out of implementation of the project were as follows
90% of the tool development activities were completed on time
Better management of sub-contractors was ensured
Tool room 5S was improved which helped in saving searching time

1274. 5.4.3.4 Visual Control

One of the important aspects of lean manufacturing is visual control. As a part of the lean program all the units were audited for the adequacy of visual controls. After the audit 36 visual controls were listed down for implementation across units, the following are the list of visual controls that were implemented.

- Display of Materials Requirement Planning (MRP) board with target vs. actual
- Display of 2 bin board with target vs. actual
- Display of shadowboard
- Display of one point lessons
- Display of raw material stock board
- Display of Kaizen board
- Display of poka yoke board
- Display of daily production target vs. achieved
- Display of absenteeism board
- Display of Q alert board
- Display of calibration status board
- Display of machine maintenance board
- Display of my machine
- Display of skill matrix
- Display of SOP
- Display of employee corner
- Display of 5S board (zone layout, audit result, scoreboard)
- Display of red tag board
- Display of first aid location board
- Display of fire layout and location of fire extinguisher
- Display of navigation sign board
- Clear gangway
- Display of zero accidents board
- Display of department sign boards
- Display of product information board
- Display of part defect board
- Display of first piece board
- Display of part identification board
- Display of tools colour code
- Display of gauge and instrument colour code – calibration status
- Display of maintenance location at each machine
- Display of daily meeting board or corner
- Display of control charts based on production
- Safety related display
- Display of shift communication board
- Display of factory layout

1276. The major benefits out of implementation of the above visual control boards were as follows.

- Reworks and rejections had come down after SOPs displayed visually
- Raw Material planning improved by using a stock status board
- Production planning improved by using MRP display board
- Calibration of gauges done on time
- Searching time of tools had come down

1277. 5.4.4 Key success factors in this cluster program case study

1278. The major factors for successful implementation of lean manufacturing in this case study as analyzed and provided below. The major contributors had been the active involvement of OEM and periodic review meetings held to monitor the progress.

1279.

1280. 5.4.4.1 Role of OEM

1281. The cluster was primarily formed with the direct involvement of an OEM to whom all these units were suppliers. The OEM played a major role in successful execution of the programme.

- The commitment levels of the units were better with the involvement of OEM. The intervention had helped in building a positive energy among participating units.

- Need based support offered by OEM helped in keeping up with the milestones.

- It was a mutual benefit to both the OEM and the participating units and hence a win-win situation.

1282. 5.4.4.2 Periodic Review meetings

1283. Periodic review meetings were conducted every month at the factory premises of the participating units on rotation basis and it was proved to be a better decision. The activities carried out during these monthly reviews were presentation
by each member unit on the progress of activities undertaken and informal discussions among the cluster members on common problems faced and sharing of solutions.

1284. The benefits of this approach are

- Improvement in relationship among cluster members
- Cross learning and benefiting from each other’s experience
- The hosting company is motivated during these visits and also ensures that shop floor 5S, safety and visual control are well maintained in place. In many cases, it had helped in sustaining them as well
- Positive peer pressure to show improvement and also to create a sense of competition among members

5.4.5 Challenges faced in the project

1285. There were some challenges as well during the implementation of the project which were overcome through discussions and brainstorming. Some of the challenges were

- Lack of knowledge about lean and its benefits among the employees
- Cases where the unit is owner driven, it was difficult to carry out activities since the people hesitate to do things on their own
- Due to man power shortage, a single individual present in the unit was burdened with all the work and hence the initiated activities failed to take shape fast
- Participating units took longer to trust and hence collecting information had been tedious
- Some of the units didn’t have past data and hence base lining the current level and taking up subsequent improvement activities were difficult
- Attrition rate of people at second level of management shot up and the challenge included briefing the new personnel about the project and initiating the activities again affected continuity and took longer time
5.4.6 Sustainability

1286. In order to sustain the benefits achieved, the following suggestions were made to the participating units.

- Top management commitment towards improvement activity to be continued

- Appointing a project champion for every project to be ensured

- Top management to constantly encourage the workers by suitably rewarding them

- Periodical assessment of 5S to be carried out

- Internal failures to be addressed with same priorities as like the customer related issues
1293. CHAPTER 6
1294. CONCLUSIONS

1295. In this research various lean tools were implemented in about twelve SMEs in a systematic manner and their results were recorded. The results had led to very important learning’s which could be adopted for implementation in other SMEs. There were three projects implemented in individual unit’s viz. a foundry, CNC machine shop, pump manufacturing unit which were all related to mechanical engineering field. Then a group of nine units was selected for implementing lean tools. This group comprised of units manufacturing auto components for a large industry. The OEM farm equipments automobile manufacturer was instrumental in bringing together these nine units for forming the group. The entrepreneurs of all these twelve units were highly motivated towards manufacturing quality products at the lowest cost. They had already implemented and experimented with various quality tools and systems. Hence they had understood the importance and benefits of lean manufacturing once explained.

1297. The results of all these four projects implemented in twelve units were recorded and studied for developing a framework for implementing lean manufacturing. The documents of the results show that if the lean manufacturing implementation is done in a systematic manner the results would be many folds. This section tries to develop a generic framework for lean implementation in all SMEs. The following paragraphs analyze the results in a broader sense for developing the framework.

1299. 6.1 TPM in foundry project

1301. A foundry was chosen for implementing lean tools to improve its productivity to meet their customer demand. The unit had invested on latest machines in order to make high productivity. But their breakdowns led to high levels of loss in production and also they were not able to meet the customer
demand. Total productive maintenance is a tool which when implemented systematically reduces the breakdowns drastically so that production
planning can be made more effectively. This project aimed to reduce the overall lead time and breakdown hours of machines in the foundry. After implementation of TPM, it was found from the result that, about twenty percentages of reduction in the breakdown hours was achieved in the industry after implementation of lean tool.

The project started with the collection of breakdown data for six months and the reasons thereof. During the study it was found that that the breakdown hours were high when compared to the target set by the industry. The objective of this study was to implement the TPM proactive approach of preventive maintenance, corrective maintenance and predictive maintenance along with the pillars of TPM such as autonomous maintenance and planned maintenance. Through breakdown analysis the bottleneck areas were identified and suitable preventive actions implemented. The problem was identified in the industry and the necessary activities for the entire study was planned and explained. The breakdown data showed that the average breakdown hours per month was around 92 hours compared to the industry target of 8 hours per month.

A brainstorming session was held with the key persons of the foundry and it was explained that the major contributor for the breakdowns was the sand plant. It was decided to concentrate on the sand plant to bring down the total breakdown hours. Various causes of the breakdowns were analyzed using Pareto diagram. From the chart it was found that, the major contributors for the break downs were bucket elevator, mixer wheel and sensor failure. The main causes and the reasons for them were also analyzed and listed.

The TPM proactive approach such as preventive maintenance, corrective maintenance and predictive maintenance were carried out according to the pillars of total productive maintenance such as autonomous maintenance and planned maintenance. As part of the preventive maintenance, check sheets were designed to record the data regarding the maintenance activities carried out daily, weekly and monthly. Regular maintenance schedule for various components were suggested and implemented for prevention of breakdowns. All these activities were standardized for future implementation in order to bring down the breakdowns.
The total reduction of breakdown time was calculated in the sand plant before and after implementation of TPM and the results was tabulated. The comparative chart of breakdown time reduction was plotted and it was found that, maximum breakdown had occurred in mixture wheel, it was about 1080 minutes got reduced to 505 minutes and also bucket elevator had taken 720 minutes before implementation of TPM which was reduced to 385 minutes after implementation. From the results it was found that there was a total reduction of 19.1 hours in the breakdown hours after implementation of TPM. The effectiveness of TPM implementation in sand plant was autonomous maintenance, planned maintenance, reduction of breakdown hours in foundry, operator’s involvement in maintenance activities and improvement of operator’s morale and work place culture.

The research also showed that TPM proactive approach had a significant effect in improving the work culture of employees in the manufacturing industry. TPM reduces the downtime and makes availability of the machines so that the productivity could be improved which brings down the cost and improves the quality. The tool helps in identifying potential causes of breakdowns in advance so that predictive maintenance breakdowns can be avoided. TPM also helps to improve the quality of the products manufactured as the machines are kept in good condition. The employees’ morale goes up as they can always work with well maintained machines. The management is also benefitted as the OEE goes up and thereby the production schedules are met on time.

6.2 Various Lean Tools in CNC project

The application of lean tools in a CNC machining cell was studied and analyzed. The objective was to identify and remove the wastes in any activity that does not add value to the final product in the manufacturing process and also to reduce the overall lead time. Based on the study and analysis the following conclusions were arrived. Lean tools like work standardization could be applied to eliminate non value added activities in the manufacturing area. By implementing standard operating procedure, floor to floor cycle time could be reduced which covers most of the NVA. From the results, it was observed that the total output increased after implementing the proposed line balancing. Better utilization of man
power was possible to be implemented in the working area by assigning more than one machine to each employee wherever possible.

1316. The project of lean implementation in the unit started with a diagnostic study of the existing process in the unit. The study had shown that the unit had already implemented some of the tools like 5S, continuous flow, standard operation procedures, line balancing, layout optimization, etc. The unit had shown some improvements through these measures. However the benefits were not up to the optimum level. The diagnostic study showed that the unit was not able to achieve the weekly demand as per the schedule and there was a high level of operator idle time. In order to address these two issues a methodology was designed and adopted for implementation in which various lean tools were used.

1318. The unit chosen was manufacturing gear box housing for wind mills. The process comprised of four operations. The TAKT time was calculated based on the weekly demand and available time. The current state VSM was drawn and the NVA and NNVA time was identified through video analysis. After optimizing the timings future state VSM was drawn using optimum times for the process, that showed the TAKT time, total lead time, total cycle time, total value added time, etc.

1320. The next step was work standardization by doing the cycle time study. This was done by using a stop watch through video analysis. This was done for one model of the gear box. The cycle time difference between actual and standard cycle time was calculated. By implementing the appropriate lean tools the cycle time was reduced from 988 to 868 minutes, lead time was reduced from 2718 to 2598 minutes and value added time from 694 to 605 minutes. About twenty improvement ideas were identified and Kaizen’s were suggested to improve the value in process. Reduction of about 140 minutes in cycle time was achieved and potential measures for improvements were suggested. By adapting the standard operating procedure in housing cell, 12% of NVA was reduced from current process. Standard operating procedure was created based on 92% efficiency of operator with 8% allowances per shift.

1322.
1323. Line balancing concept was used to manage workload between operators and to reduce the man idle time which occurs due to high auto machining time. The study was carried out by using the simulation to optimize the man utilization and to improve productivity by eliminating non-value added activities. For the existing layout, line balancing concepts were applied based on data collected for the standardization operations. In this study movement and periodic activities were followed and a new concept of two machine-one operator concept was proposed for effective utilization of man power. The existing line balancing layout of the housing area with one machine-one operator concept was replaced by two machines one operator method.

1324.

1325. This research was focused based on value stream mapping only in CNC machining chamber. This could be more extended in the operations of parallel manufacturing parts with additional lean tools like TPM, SMED etc.

1326. 6.3 Lean Six Sigma in pump manufacturing project

1328. It was proposed to select implementing Six Sigma methodology for improvement in the pump manufacturing process in a medium scale unit. It was decided to collect the data regarding the defects generated in the pump manufacturing process. The objective was to identify the defects at the place of their origin, analyse the reasons for defects, find out the root cause and implement measures to redress them and show improvement in the process.

1329.

1330. Various defects were collected during the pump manufacturing and analysed using Pareto chart. The defects which contribute for the maximum defects were selected for addressing through six sigma methodology. The root causes for the defects were found out through cause and effect analysis. Solutions were found and recommended for implementation. The cost of poor quality due to the defects chosen for addressing were calculated and it was observed to be large enough to justify the project being taken up.

1331.

1332. This case study serves as a good example to show that the implementation of “Lean Six Sigma” methodology in small and medium enterprises
definitely leads to reduction of defects and thereby increased profits. The COPQ calculation indicated that 20% of the total defects were generated by the two defects under study and the money value lost was significantly large at INR.23.83 Lakh per annum. After implementing the project for about three months duration the average defects per day were noticed to have come down from 70.30 to 11.69, a significant reduction of 83.37%. The percentage of total rejections had come down from 18.5% to 3.079%. It was felt that still there shall be lot of scope for reducing the defects if the rest of the defects were taken for addressing under this methodology. Further detailed study and corrective measures were recommended. The implementation of Six Sigma tools in pump manufacturing had definitely led to reduction of defects. After implementation of Six Sigma for a production lot of 6074 pumps we were able to get 5887 ready for sale, resulting in 3.4 sigma. With further efforts it would be possible to reach the Six Sigma level.

1333.

1334. DMAIC methodology under Lean Six Sigma would be very much suitable to bring down the defect rate of the finished product. As it adopts all other lean tools combined with the statistical tools, it would be very much effective in mass production of high volume low variety atmosphere. Six Sigma methodology improves any existing business process by constantly reviewing and re-tuning the process. Various systems were placed in the organization which would improve the working culture of the personnel. The commitment levels of the units were found to be better after lean implementation.

1335.

1336. 6.4 Implementation of Lean Tools in a Cluster

1337. The lean intervention in a cluster mode helped in building a positive energy among participating units. Need based support offered by the top management helped in keeping up the morale. It was a mutual benefit to both the management and the workforce and hence a win-win situation. Improvement in relationship among cluster members and cross learning had benefited from each other’s experience. Positive peer pressure to show improvement had created a sense of competition among members. Informal discussions among the cluster members on common problems faced and sharing of solutions had helped each other.

1338.
1339. Lack of knowledge about lean and its benefits has led to a slow start. Cases where the unit was owner driven, it was difficult to carry out activities since the people hesitated to do things on their own. Due to man power shortage, a single individual in the unit was burdened with all the work - the initiated activities fail to take shape. Participating units took longer time to trust and hence collecting information had been tedious. Some of the units didn’t have past data and hence base lining the current level and taking up subsequent improvement activities were difficult. As the attrition rate of people at second level of management was high leading to challenges like briefing the new personnel about the project and initiating activities again affecting continuity. For better results top management commitment towards improvement activity was received. Appointing a project champion for every project helps to show better results. Top management has to constantly encourage the workers by suitably rewarding them. Periodical assessment of 5S has to be carried out. An internal failure has to be addressed with same priorities as like the customer related issues.

1340.

1341. More than the direct savings, the improvement in the productivity and competitiveness of the units had given the units an edge over their competitors. It had brought them more jobs as they were in a better position to offer competitive prices and higher quality. Also they were able to take up more challenging jobs as they were equipped with employees who could solve any challenge through brainstorming and Kaizens. Their machines were always available for production as they had implemented TPM and improved their OEE considerably.

1342.

1343. The employees were highly motivated and many systems were in place. The achievement in 5S practices keeps the working environment pleasant and accident free. On-time development of the Tools required in Press shop which was very rare earlier helped in achieving the production target and in keeping the customer delighted. The inventory turnover ratio had increased from 8 to 14 which mean the inventory turnover was able to undergo six more cycles in a year. The reduction in change over time from 135 min to 45 min had increased the production time by 90 min for every change over. More than 300 Kaizens were implemented at an average of 30 per unit which resulted in saving of material, process time, effort,
etc. leading to overall benefits. The reward scheme for Kaizens had highly motivated the employees and had made them involve more in their jobs. Reduction in PPM as a result of using the data more effectively helped in applying more lean tools to eliminate the root causes of rejections. On account of these practices all the units in the cluster were able to achieve a holistic improvement.

6.5 The Frame Work for Lean Implementation

Through the extensive research of implementing various Lean Tools in about 12 Small and Medium Enterprises the following steps could be suggested for reaping the maximum benefits.

- Lean Manufacturing implementation should be started from the CEO level by convincing him about the benefits that could be achieved
- A thorough diagnostic study to identify the problematic areas and potential opportunities for improvement to be done
- A Lean Implementation Team to be formed in the unit which shall identify the projects to be undertaken based on priority
- The sequencing of the projects to be carefully designed in order to harvest the low hanging fruits initially which will convince all other employees about Lean benefits and trigger interest in taking up new projects
- The projects chosen to be unit specific and not generic
- A project champion to be designated for each project who will own the project implementation and it’s results
- Trainings on various Lean Tools to be provided on regular basis
- Monitoring of the projects to be done at regular intervals so that midway corrections can be suggested
- Wherever sufficient savings are done it should be properly recognized and suitably rewarded
- Results of each project to be displayed and disseminated for adopting the best practices in other sections and departments
- Wherever sufficient data is generated, it is to be analyzed and put to use through some Lean Tools so that improvement is realized
Implementing Lean in a cluster mode leads to better dissemination of best practices among the members through cross learning.

Results of all projects to be recorded and archived for future reference.

With the above steps a framework was developed and has been suggested for implementation in Indian SMEs as shown below in fig 5.27. Five stages have been recommended for better implementation of lean implementation in SMEs as explained below.

Fig 6.1 Framework for Implementing Lean Manufacturing in Indian SMEs

6.5.1 Preparation Phase

The above chart depicts the framework for better implementation of lean manufacturing in Indian SMEs. The CEOs of Indian SMEs always need an external push and constant motivation for implementing some new changes. In the framework five stages have been identified. The first one is preparatory stage. Here
the top management needs to be educated and convinced about the benefits of lean implementation. For this purpose an experienced external consultant needs to be identified who will act as a mentor, motivator and trainer for the entire organisation. He will train the key personnel of the organisation. These few trained, responsible people will form a lean implementation team. They will in turn train other people in the organisation and form groups for each departments. The teams along with the help of top management and the external consultant will create a favorable atmosphere for change through lean implementation by motivating each and every one in the organisation.

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1356. **6.5.2 Project Identification Phase**

1357. The next stage is identification of various lean projects in the organisation. Various lean tools have to be utilized for this purpose. Initially the consultant along with the help of lean implementation team will do a walkthrough audit during which major areas for intervention could be identified. Then the lean implementation will start from implementation of 5S tool. This will help to reap the low hanging fruits of success such as freed space, clean environment for safe working, ease of access to tools and thereby reducing the working time, discarding the unwanted and rarely used materials and thereby generating some funds from idle materials, etc. The successful implementation of 5S and taste of the benefits out of its implementation will develop a motivation and conducive atmosphere among the employees to go for bigger projects and higher achievements.

1358.

1359. This will be followed by the implementation of value stream mapping tool. The current state VSM shall be drawn manually by using a freehand sketch. This can be followed by using software and tools available for the purpose. The analysis will help to identify non value adding activities. Once the NVAs are identified then it will help to identify the projects which can be taken up one after the other or simultaneously for implementing lean tools to reduce or eliminate them. The VSM analysis also helps to identify the bottlenecks in the production process and convert them in to lean projects. Throughout this phase the external consultant will train and guide the team in drawing the VSM and identifying the projects.
1360.

1361. After this the future state VSM could be drawn to show where the team wants to take the organisation through the implementation of lean manufacturing. The difference between the current and future state VSMs will help to set the metrics for improvement in the processes. Also it will lead to work standardization and developing standard operating procedures.

1362. 6.5.3 Tools Implementation Phase

1364. The next and third phase in lean implementation is the most important and active phase where much of the improvement activities takes place. During this phase the consultant organizes series of training programs on various lean tools and techniques. This helps to familiarize the lean tools among the employees. Once some amount of training has been completed, a list of lean tools and techniques that could be suitably applied for the projects as identified in the previous phase can be prepared.

1365. Appropriate tools shall be selected and applied in the projects. Some times more than one tool and combination of lean tools may have to be applied in a single project. The sequences in which these tools have to be applied also have to be decided appropriately for getting the maximum benefits. The role of the consultant will be crucial in this phase as his expertise will be more helpful.

1367. Once the lean tools are selected, the relevant data required for them have to be collected. Both past and current data have to be collected so that the current position will be clearly known. This will help to quantify the benefits achieved through lean tools implementation in the chosen projects. This phase is the most active phase where lot of real and practical lean activities and elimination of wastes and NVAs take place. A number of lean tools are also put in to operation which will be tested and refined over a period of time. In future these lean tools will become the culture of the organisation.

1369. 6.5.4 Analysis Phase
1371. The fourth phase is the analysis phase. The post implementation data shall be collected in this phase relevant to the projects chosen for implementation. These data shall be analyzed using various analysis tools. This helps to identify the improvements achieved through lean projects implementation. In this phase a dashboard will be developed which will provide the current level of achievements in certain parameters chosen by the top management for taking further decisions. The consultant’s role in developing the dashboard will help fine tune the structure.

1372. 6.5.5 StandardizationPhase

1374. The final phase is the standardization phase. In this phase all the projects implemented in earlier phases have to be standardized, sustained and improved. For this purpose work standardization methodology will be helpful. This will help to standardize each work identified in the organisation. Ultimately standard operating procedures be developed and put in place. These SOPs will help to train the new employees and also serve as a guideline for their operation. Anyone will be able to operate the work through following the SOPs without any deviation.

1375. 1376. All the achievements reached through lean implementation have to be recognized properly by the top management. This will motivate the employees to further implement the lean with more involvement. A reward mechanism is also needed to be in place to improve the system further continuously. Ultimately a smooth lean functioning and continuous improvement mechanism have to be put in place. The sustenance of lean implementation depends on this lean mechanism which has been put in place. The mechanism must be robust enough and at the same time should provide scope for new ideas and continual improvement.

1377. 1378. The dashboard developed should cover all major activities with some measurable parameters. This dashboard should be updated periodically by the concerned personnel so that the top management gets the information on the functioning at any instance. The data on the dashboard has to be continuously monitored and necessary comments and suggestions to be passed on to the respective section heads. This will put them on their toes to achieve the targets set by the top management.
1379.

1380. The above five stages if implemented systematically with full involvement of all employees will lead to better results. Also at the end, a lean enterprise system will be in place with sustainability and scope for continual improvement. The Indian SMEs need constant support and handholding with external support for any system implementation. Lean implementation is not an exemption. So the selection and appointment of lean consultant is a crucial step to ensure successful implementation of lean manufacturing.

1381.

1382. The framework suggested may be repeated after every cycle and in every section of the organisation. This is a general framework and the tools selection has to be done appropriately with respect to the nature of the organisation.

1383. **6.6 Future scope of research**

1384. The future research in this area may be taken up in different types of manufacturing industries. This will lead to more refinement of the framework and development of individual frameworks for each sector specific industries. This may include the best suitable tools for different sections of that particular sector.