CHAPTER 1

INTRODUCTION

Nowadays, manufacturing firms are in the position to redefine and redesign their manufacturing systems in order to meet the competitive demands raised by market challenges. The manufacturing systems exhibited a key transition from mass manufacturing to lean manufacturing. The Comparative aspects of lean production with that of mass production is presented as follows: The focus of lean production is customer whereas mass production focuses on product. Lean production is characterized with synchronized flow and pull whereas mass production is based on batch and queue operations. The overall aim of lean Production is to eliminate waste and add value whereas mass production focuses on cost reduction and efficiency improvement. Lean production focus on worker driven continuous improvement whereas mass production focuses on expert driven continuous improvement. Lean system is flexible and adaptable whereas mass system works on economies of scale. Quality is an inbuilt function in lean system. The features of lean system include waste elimination; limited flexibility to accommodate product complexities; non reconfigurable products and the system not suitable for turbulent market conditions.

The fundamentals of lean system include:

- Value defined by customer in terms of specific products and services
• Identification of value stream which maps out all end-to-end linked actions, processes and functions for transformations of inputs to outputs.

• Making value flow continuously by means of waste elimination

• Customers pull value enabling JIT production.

• Pursuing continuous improvement process striving to achieve perfection.

Activities in the context of lean system need to be categorized into Value Added, Non Value Added and Necessary but Non Value Added. Value added activities include the transformation activities concerned with conversion of inputs into output; done right for the first time and wanted by the customers. Non value added activities consumes resources, but creates no value from customer perspective. Necessary but non value added activities creates no value but cannot be eliminated based on the current practices.

Lean manufacturing include a comprehensive set of elements, rules and tools that focus on the elimination of waste and creation of value. It focuses on elimination of all non-value added activities and brings about a philosophy of continuous incremental improvement. Lean manufacture implies speedy, smooth and economical manufacture. Waste implies the entity that consumes resources and does not add value to the customer. Industries have identified the following forms of wastes namely high inventory, scrap, rework, repair, low productivity, downtime, poor yield, cycle time inconsistency, over time, delay, excess labor etc.. The symptoms that necessitate the adaptation of lean manufacturing principles include high cost of quality, delayed supply, high manufacturing cost and reduction in profit margin, high inventory of raw materials/finished goods, fire fighting on
The improvement in process can be brought about by identifying the process steps that do not add value, removing obstacles from the value stream, making the value flow smooth, and process steps that do not add value, removing obstacles from the value stream. Value flow must consider the inventory also. Over flow will result in heavy inventory of finished goods whereas low flow induces severe criticism from the customer. A smooth flow can be achieved with personal involvement of the customer. The five elements include customer value, value stream, value flow, customer pull and perfection by continuous improvement. The value flow in a manufacturing environment can be described as product production from order taking to delivery to the customer and collecting money from them for the same purpose. In any value stream, the processes need to be categorized as activities adding value to the customer, activities necessary for completing the product and activities not adding value. Value stream in a manufacturing environment can be described as product production from order taking to delivery to the customer and collecting money from them for the same purpose. In any value stream, the processes need to be categorized as activities adding value to the customer, activities necessary for completing the product and activities not adding value. Value flow must consider the inventory also. Over flow will result in heavy inventory of finished goods whereas low flow induces severe criticism from the customer. A smooth flow can be achieved with personal involvement of the customer.
time, maintenance of machinery and equipment, inventory management, over
time and low productivity and communication. In a push system, the product
is manufacturing without knowing the customer need and sold to the
customer. Pull system involves the production of goods/services based purely
on the customer requirement. It is equally important to sustain the processes,
procedures, standards, efficiency and ensure that the organization does not
deviate with what had been achieved. The strategic management or
management policy deployment is essential for the successful lean enterprise.
Team effort, management commitment and work force involvement also
enables the successful lean enterprise.

The basic elements of lean production include: flexible/multifunctional workers capable of performing more than one job. The
standard operating routine need to be developed for determining the idle time
associated with worker tasks. Cellular layouts/manufacturing cells comprised
of dissimilar machines brought together to manufacture a family of parts. Pull
system relying on a predetermined schedule, pull systems relied on customer
requests. Kanban card indicates standard production quantity. It authorizes
production and movement of goods. Various types of kanban include
production kanban, withdrawal kanban, kanban square, signal kanban,
material kanban and supplier kanban; Small lots requiring less space and
capital investment and making quality problems easier to detect. Quick setups
include defining products that can be produced using existing machines; defining machines for easier operation; changeover and maintenance; training and retraining workers to operate machines; purchasing machines that maximize productive potential. Supplier networks including supplier certification, precise delivery schedules. 5S concept – Seiri (sort) implies keeping only what is required; Seiton (Set in order) implies a place for everything and everything in its place; Seisou (Shine) implies cleaning and looking for ways to keep clean and organized; Seiketsu (Standardize) implies maintaining and monitoring the first three ‘S’; Shitsuke (Sustain) implies sticking to the values.

1.1 LEAN TOOLS/TECHNIQUES

Lean manufacturing implementation requires four primary tools and ten secondary tools. An organization requires adequate training and understanding. Lean manufacturing requires a team effort. The primary tools during implementation of lean manufacturing include 5s work place organization, total productive maintenance, process mapping/value stream mapping and work cell. 5s principles are not only for shop floor but also for the entire organization. The steps involved in the 5s work place organization are sort, set in order, shine, standardize and sustain. Sort is the procedure one can identify that adds and do not add value to the customer. After identifying and disposing the items which do not add value, next is to arrange the items in such a way that there is no waste. Shine indicate that keeping things clean which means to be ready for immediate use. Employees are required to strictly follow the standards, so as to achieve uniformity throughout the organization. To maintain the objective of eliminating waste, the organization has to sustain the cleaning and standardization process. 5s work place organization requires the top management commitment, training employee,
improving the work place areas, rewarding the teams and achieving significant results.

Total Productive Maintenance (TPM) is necessary to ensure availability of machinery and equipment to improve productivity. TPM refers to a maintenance strategy that involves the entire organization to improve the maintenance activities. The deterioration in the machine is caused due to down time, poor quality, supply delay, frustration and increased production cost. The basic conditions applicable for TPM success include improving the equipment effectiveness, implementing autonomous maintenance, initiating scheduling maintenance, improving skills and initiating equipment management. Overall Equipment Effectiveness (OEE) improves productivity. The steps involved in TPM include top management decision to implement TPM, establishing vision, formulating master plan, form teams, holding TPM kickoff event, calculate OEE, prepare process maps, revision, developing scheduled maintenance program, standardize process/procedure and continuous process improvement. The management may devise appropriate reward schemes and implement when a project is successfully completed.

A process map is a visual representation of the process step by step (in sequence). It serves as a tool in lean manufacturing to understand the current status of the process in steps. It is used to identify and eliminate process steps (waste) which do not add any value to the customer. It is used to identify the boundaries of a process and where the measurements gains importance. It is used to diagnose any problems existing in the process. There are two types of process maps namely high level process maps and detailed process maps. High level process maps provide a bird’s eye view of the entire process which gives the major steps in the process. Detailed process map shows each and every step involved in the process. The step involved in
process map starts with determining the boundaries, listing the steps, drawing appropriate symbols, creating a process map, finalizing it, analyzing it and preparing a revised process map. VSM is a advanced form of process map used to understand the value of flow and indicates all actions (both value added and non value added) to complete a product or service through to the customer.

A work cell is a logical and productive group of machinery, tooling and fully trained work force producing similar products. A cell can have a single product or family of products. The goal of the cell is to minimize waste by improving productivity. The major steps include selecting part families, determining the process, deciding on machinery and equipment, choosing jigs/fixtures, tools, selecting material handling equipment, designing the most suited layout, line balancing, calculating and selecting man power, train existing employees, having preventive maintenance schedule, formulating quality standards, introducing new production control system, automated testing, trial run, having clear visual boards and finalizing productivity standards.

Apart from four primary tools, ten secondary tools are used to eliminate waste. All these are useful and further improve the production process. Most of these tools are simple to understand and adapt. These tools are user friendly. Cause and effect diagram helps to identify the causes of a problem. It is a tool used to diagnose the causes of quality problem. This tool is also known as fault tree. Pareto chart is used to identify the major causes of any issue. This tool is based on Pareto principle in which 80 percent of variation can be found using 20 percent of the causes of that variation. Spider chart (Radar chart) is used to arrive at an overall view of various parameters at one glance. This is used for reviews and identifies the improvement areas.
Poka Yoke is called mistake proofing which ensures that operators do not make any mistakes while in operation. Kanban is a Japanese word meaning instruction card which can be any visual indication used to show the requirement of parts/assemblies. It is used in pull manufacturing systems where a product is manufactured based on the customer order.

Automation is an automatic signal that indicates the status of any machine, quality parameter which needs to be measured. In this system, there is no manual intervention and is fully automatic mechanism. Single Minute Exchange Die (SMED) is a discipline focused on simplifying machine setups. The jigs/fixtures must be made of standard elements and lighted at the same time. Design For Manufacture and Assembly (DFMA) enables the designers to concentrate on the end use of the component/assembly. The issues to be considered from perspectives namely raw material, customer requirements, manufacturing process, quality parameters, ease of assembly and safety. Just In Time (JIT) is a system that produces and delivers finished goods just in time to be sold, sub assemblies just in time to be transformed into fabricated parts. Visual work place focuses on visual information that helps the team to understand the project plan, achievement and targets.

In order to succeed with lean manufacturing, the following steps need to be adhered to: understanding the current situation, collecting data of competitors, having a clear vision of things to be achieved, people involvement and gathering their ideas, selecting a champion for implementation, selecting a management team for driving the projects, empowering the team, training all employees, deciding key areas requiring improvement, selecting project teams and projects, having a clear project plan, encouraging the teams, reviewing the project progress at regular intervals, ensuring the full support of teams, no fear of failures, celebrating
the success and rewarding teams, standardizing the project metrics and continuing with improvement plans. The best practices need to be shared among all the employees. The change in the organizational culture must be sustained and used for further improvement. The suppliers and customers must be involved in the organizations. Lean concept will provide higher safety and atmosphere of trust among employees.

Some of the benefits of lean production include reduced inventory, improved quality, lower costs, reduced space requirements, shorter lead time, increased productivity, greater flexibility, better relations with suppliers, simplified scheduling and control activities, increased capacity, better use of human resources and more product variety. Many organizations identified lean manufacturing as a potential solution to keep in pace with the competitiveness of modern manufacturing environment (Abdulmalek & Rajgopal 2007).

Lean starts from the refusal to accept waste (Ramamoorthy et al 2011). Lean manufacturing and related techniques/tools have been popularized over the last two decades since they can bring forth remarkable improvements in all segments of a manufacturing system. Lean practices mainly focus on pinpointing the source of wastes and by using tools such as Just In Time (JIT), Total Quality Management, Total Productive Maintenance (TPM), pull flow, Value Stream Mapping (VSM), Kanban, Kaizen, 5S, Single Minute Exchange of Dies (SMED), Workforce involvement etc (Abdulmalek & Rajgopal 2007). Among these tools, VSM is considered as the initial step to implement lean manufacturing. VSM is a paper and pencil tool drawn with the set of predefined standardized icons (Abdulmalek & Rajgopal, 2007; Pavnaskar et al 2003). VSM tool is used to map various value added activities (VA) and non value added activities (NVA), which the product comes
through during the transformation of raw material to the final product (Hines & Rich 1997; Seth & Gupta 2005).

VSM represents flow of both material and information in the whole process. The aim of VSM is to identify VA and NVA activities, then to eliminate (Sullivan et al. 2002) or to convert NVA to VA activities. In this context, in the doctoral work, four case studies were being conducted, where VSM tool was used to identify the current improvements. After the construction of current state map, possible proposals for streamlining the processes will be identified. In general, it is infeasible to implement all possible proposals. In order to scientifically prioritize the available proposals, Quality Function Deployment (QFD) was used (Mohanraj et al. 2011b). QFD was selected over approaches like Pugh selection matrix. As fuzzy logic can be integrated with QFD to eliminate vagueness and inconsistency associated with crisp values fuzzy QFD was used. The studies presented in the doctoral thesis were conducted in real time manufacturing environments.

It contributes Fuzzy QFD integrated VSM framework coupled with the practical feasibility. The novelty of the doctoral work is that it integrates fuzzy QFD with VSM framework for enabling the prioritization of improvement techniques to be deployed in industrial scenario. Three case studies are conducted by using fuzzy QFD integrated with VSM framework. Fourth case study uses the same framework but incorporated with environmental considerations also. The improvements in lean performance measures were quantified. Hence the contributions of the study are found to be valuable among academicians and practitioners.
1.2 LEAN MANUFACTURING RULES

Lean manufacturing contains few basic rules that need to be followed in the case organization desiring to implement lean concepts. The employees need to be trained in lean principles. Commitment from top management needs to be ensured and allocate resources for training. The rules to be followed during lean implementation include stability, standardized work, pull system, level production and continuous improvement. Stability forms the foundation for lean implementation. The analysis for reasons of instability need to be found. Most management personnel are not aware of the reasons for instability. The instability may be from different perspectives namely employee, machine, process, materials, and management. Standardization helps in achieving consistent results. It helps in controlling process variations and to achieve repeatable results. It forms the foundation for continuous improvement. Pull system permits factory synchronization of events by working backwards through triggers which cause production events to happen. Production takes place in a single piece flow or in small batches if there are quality problems which could be detected. Level production enables the balancing of work centers to the extent possible and reduces waiting. Finally continuous improvement needs to be achieved by forming groups that undertakes small group improvement activities. Continuous improvement ensures the achievement of successful lean implementation.

1.3 TRAINING AND IMPLEMENTATION FOR LEAN MANUFACTURING

The first step is to select a lean champion; lean leaders and lean associates need to be selected. A meeting has to be convened lean leaders and associates; CEO of the organization has to explain the necessity of training
and implementation; a detailed schedule need to be prepared; leaders and associates to be trained; Brainstorming need to be conducted in the context of selected projects; lean leaders to be identified for the projects; lean leaders need to select the associates for each of their projects; a project charter to be prepared with possible cost savings; lean leaders then prepare a detailed project plan; leaders and their associates have brainstorming sessions to finalize the plan for projects; commencement of project implementation; review of projects at regular intervals; calculation of savings during project implementation; training the employees in 5S implementation; implementation of 5S activity; measurement of results of 5S.

1.4 OBJECTIVES OF THE DOCTORAL WORK

Following are the objectives of the doctoral work:

Primary objective

- To develop a framework for VSM integrated with fuzzy QFD

Secondary Objectives

- To develop current state value stream map
- To identify wastes and improvement actions
- To prioritise wastes and improvement actions using Fuzzy QFD
- To develop future state value stream map
- To quantify leanness improvements
1.4 PROBLEM STATEMENT

In the process of VSM, after the development of current state map, wastes and improvement actions are identified; the wastes and improvement actions need to be prioritised and incorporated in the future state value stream map. This kind of prioritisation would enable the scientific deployment of improvement actions for enabling leanness improvement.

1.5 CHAPTER ORGANIZATION

Chapter 2 presents the literature review; chapter 3 presents the methodology developed in the doctoral work; chapter 4 presents the case study details conducted in a pump manufacturing organization; chapter 5 presents the case study details conducted in an automotive component manufacturing organization; chapter 6 presents the case study conducted in valves manufacturing organization; chapter 7 presents the case study incorporated with environmental data; chapter 8 presents the results and discussions; chapter 9 presents the conclusions derived from the doctoral research work.