A Dissertation Report

On

IMPLEMENTATION OF LEAN TOOLS FOR PROCESS IMPROVEMENT IN A MANUFACTURING INDUSTRY- A CASE STUDY

submitted in partial fulfillment of the requirements for the Degree of

MASTER OF TECHNOLOGY

in

INDUSTRIAL ENGINEERING

by

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2015PIE5192

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CERTIFICATE

This is to certify that the dissertation entitled "**Implementation of Lean Tools for Process Improvement in a Manufacturing Industry- A Case Study**" being submitted by **Bhavna Pandey** (2015PIE5192) is a bonafide record of the dissertation done under my supervision and guidance, and hence approved for submission to the **Department of Mechanical Engineering**, **Malaviya National Institute of Technology, Jaipur** in partial fulfillment of the requirements for the award of Degree of **Master of Technology (M.Tech.) in Industrial Engineering (2015-2017)**. The matter embodied in dissertation report has not been submitted anywhere else for the award of any other degree or diploma.

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CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in this dissertation entitled "**Implementation of Lean Tools for Process Improvement in a Manufacturing Industry-A Case Study**" in partial fulfilment of the requirements for the award of the degree of **Master of Technology (M.Tech.)** in **Industrial Engineering**, and submitted to the **Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur** is an authentic record of my own work carried out by me during a period of one year from July 2016 to June 2017 under the guidance and supervision of **Dr. A.P.S. Rathore** of the Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur.

The matter presented in this dissertation embodies the results of my own work and has not been submitted anywhere else for award of any other degree or diploma.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Dr. A. P. S. Rathore
Supervisor

Place: Jaipur
Dated: June 201

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During whole course of work, various doubts regarding lean manufacturing came in my mind. Like, is it possible to implement lean in a semi-automatic or small scale industries and how to convince management and employees to start lean thinking concept in their organization. Support of my supervisor **Prof. A. P. S. Rathore** and knowledge I received during my academic course by respected faculties helped in analyzing these doubts. My research gave me an opportunity to understand and experience lean concept in real life scenario. Above all, I learned how a best quality hand woven carpets are prepared and importance of Indian carpets industry.

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Bhavna Pandey
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TO

MY GRANDFATHER

LATE SHRI SHIV DUTT PANDEY

THIS REPORT

IS

AFFECTIONATELY DEDICATED.

ABSTRACT

Market demand is changing continuously and customers are expecting more customized, high-quality and low-cost products. These factors have been found to play key role in global competition. To gain competitive advantage, a company has to deal with these factors seriously. Frequently varying market demands forces companies to become more responsive. Therefore, companies need to change their organizational culture to survive in the global market. Lean manufacturing is broadly accepted and successful manufacturing philosophy across the globe. Lean mainly focuses on continuous improvement of product quality, service, eliminate wastes and minimizes time and cost. Lean has been successfully implemented in various industries including manufacturing, processing, service, healthcare etc. Moreover, lean has economic impacts on the business for example it helps the organization to become a business that can better strive to fulfill the customer's expectations. Besides, in an industry, if we focus on improving the value or effectiveness of an individual process and not of a group of interdependent processes as a whole, results cannot be optimized. Since implementation of lean philosophy focuses on overall supply chain, this problem can be overcome and optimum results can be obtained.

Manufacturing industries are growing at a fast rate due to technological advancement. Though, some manufacturing industries are found to face specific challenges. For example, handloom, apparel, stone & marble and electronic goods industries have challenges of effective management of work-in-process (WIP), reduction of production lead time, providing good quality product, keeping the pace of product development and innovation high etc. Aim of present study is identification of wastes in carpet manufacturing industry, eliminating these wastes by implementing appropriate lean tools, effective utilization of manpower and working space, reduction of manufacturing lead time, and minimizing material handling time and cost. The study also provides the opportunity to learn lean philosophy, lean origin, lean tools, and benefits of lean implementation. It has been found that implementation of appropriate lean tools in a manufacturing firm can help in reduction of production lead time, better usage of working area and resources, reduction of labour cost, improvement of employee morale, enhancement in product quality and finally increment in overall profit of supply chain.

Keywords: Lean manufacturing, Lean tools, Process improvement, 5S, VSM, Layout, Capacity plan, Continuous improvement

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List of Abbreviations

WIP	Work in progress
VA	Value Added
NVA	Non-value added
VSM	Value stream mapping
TPS	Toyota production system
ERP	Enterprise resource planning
SD	Standard deviation
SME	Small medium enterprise
SC	Supply Chain
LM	Lean manufacturing
BOM	Bill of material
PO	Purchase Order
RPO	Regular production order
PPR	Production progress report

CHAPTER 1

INTRODUCTION

Indian carpet industry is primarily a cottage industry and comes under ministry of textile. Indian handmade carpet sector is perhaps the only sector in rural India that is highly export oriented and providing employment to thousands of people. This sector has shown continuous growth in last 5 decades. Industries producing hand-knotted carpets have achieved a leading position in the world (Bano, 2015). Most of the carpet weaving work is performed manually that increases production time. This industry has cultural and economic significance. To lead the global market, company needs to set certain standards and implement certain techniques to deliver good quality items at promised time (Carpet Export Promotion Council Magazine, 2013).

1.1 Lean Thinking

Lean philosophy is a popular approach for waste reduction. The word 'lean' in lean manufacturing stands for 'using less of everything' in contrast with mass manufacturing. The idea of lean manufacturing was originated in Japan after world war second. Japanese manufacture realized that they could not afford to invest huge resources required to manufacture facilities similar to those in America. The aim of lean manufacturing is to minimize wastes, inventory, time to launch the product, manufacturing space and human effort while providing best quality products in highly economic manners (Womack & Jones, 1990). Customer's perspective is changing continuously at this stage of competition (Gupta & Jain, 2013). Mahapatra & Mohanty (2007) found that all these expectations can be fulfilled when workers are involved intellectually. Jasti & Kodali (2015) found that researchers required focusing on suggesting stepwise lean implementation procedures for different industries. They found three wastes having the highest frequency of occurrence as inventory, waiting and defects and these can be reduced by commonly known lean tools kaizen, VSM, and kanban. Lean is a highly evolving management philosophy that focuses on improvement of processes at all level of an organization. During last few decades companies are making a big investment in tools and technologies. They want to reduce time, money and optimize processes. Different improvement tools help the organization to optimize its processes to achieve more reliable results. Lean manufacturing is a significant way of producing goods through waste elimination. The study shows that by implementing lean tools, managers have successfully identified and removed manufacturing wastes from their production processes. By improving process efficiency, they have optimized their resources. This study explores the process of implementation of lean at scattered finishing centers. Main goal of the study is to develop a theoretical framework that suggests detailed perspective of lean implementation in the organization that considers it as a performance enhancing tool.

Efficient ways of reducing costs and increasing product's quality are required to be developed for staying competitive in the market. Lean manufacturing is considered to be the potential approach for enhancing organizational productivity (Motavallian & Settyvari, 2013). There are several benefits of applying lean in an organization. The aim of implementation of lean tools in an organization is to enhance quality, productivity, reduce lead time and costs (Sánchez & Pérez, 2001). Different sectors including aerospace, automobile, IT, healthcare, apparel industry, etc. have adopted lean. Various models, philosophies, tools, and techniques have been developed by researchers to evaluate the performance of lean implementation (Qadri, 2016). Before implementing lean, organization needs to understand Toyota Production System (TPS) which shows the respect and commitment to the people to achieve success (Sreedharan & Raju, 2016). People and continuous improvement are two important factors for implementing lean culture.

1.2 Carpet Industry at a Glance

The origin of the carpet weaving is mostly linked to the Turkish emperors, who have also originated the technique of pile making. Earlier it was used for floor covering but later it became an art. Carpet making is one of the oldest weaving arts (Selvi, 2008). Other than Turkey various countries like Iraq, Iran, and Afghanistan are also considered as the place of origin of carpet. Developed countries like America, Germany, and Canada are the biggest importer of carpets (Carpet Export Promotion Council Magazine, 2013).

Indian handmade carpets are getting world's attention for its fine weaving quality. The graph below shows the growth of Indian carpet industry over the years. Most of the carpets are exported, so it is an important source of foreign reserves. Indian carpet industry is a rural based industry that has a large potential for employment creation (Bano, 2015). The Graph 1 shows the export report of carpet to the world in million US$. Figure 2 shows the share of Indian carpet industry to the world. The graph shows the growth of carpet industry in terms of export value. It is highly encouraging fact in the development this industry.

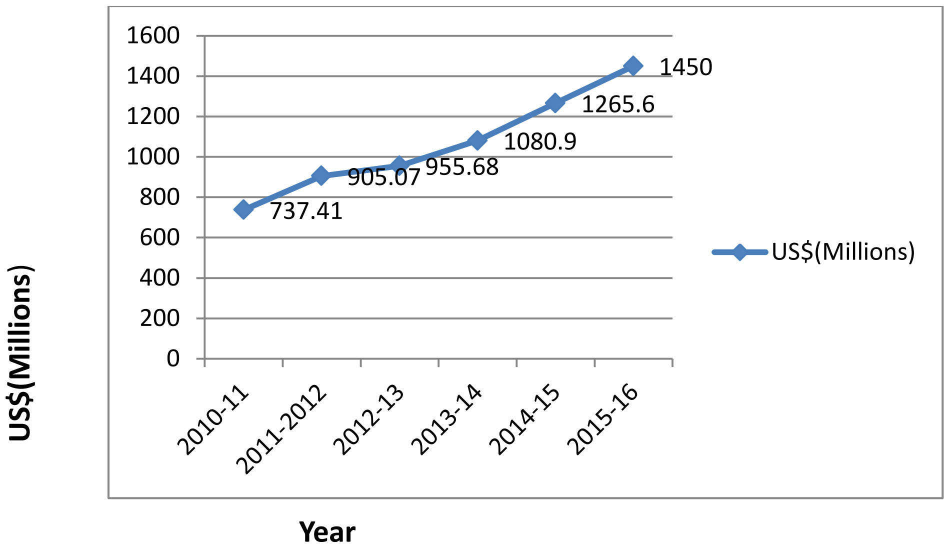


Figure 1 Export performance of carpet (Source: Carpet Export Promotion Council)

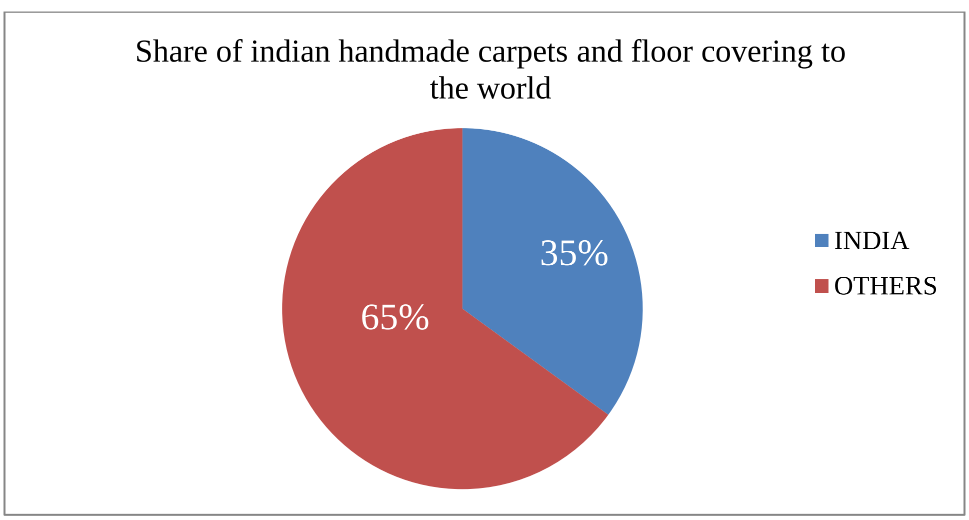


Figure 2 Share of Indian handmade carpets (Source: Carpet Export Promotion Council)

1.3 Introduction of Case Organization

ABC Ltd. was established in 1978 and its head office is located in Rajasthan. The company is famous for its hand-knotted carpets and its main customers are western countries. The company produces a variety of products in rugs, pillows, and floor covering in different design, quality and sizes but the leading product of the company is hand-knotted carpet. It has twenty branches in ten states of India along with more than 40000 artisans.

The company has the state-of-the-art facility catering to around 40 countries across the world. It has a separate entity all together to serve the US market, i.e. XYZ acts as the trader for ABC and other manufacturing units with products ranging from carpets to pillows & poufs. ABC has the made-to-order (MTO) environment as the final product belongs to the niche category. The raw materials for carpet manufacturing basically include wool, cotton and silk Fibers that are produced as five different types of yarn called as silk, tani, wool, theda and lachchi. The details of raw material, tools used and method of carpet weaving are given below.

- **Raw Material for Hand Knotted Carpets**

  There are three parts of a hand knotted carpet: warp, weft, and pile. The raw material requirement is based on these different parts. The warp is made of cotton only as it is stronger than wool. For making weft in carpets cotton is preferred over wool. Carpet piles are made by wool, silk viscose, and their combination. Cotton is procured from Bikaner and Australia, and silk from China. Table 1 presents the raw material required for carpet weaving.

- **Types of Tools and Dyes Used in Carpet Industry**

  Dyes are used for dying woolen yarn. Mostly synthetic dye called acid and chrome dyes are used for dyeing yarn. Tools are very simple in all the units of hand knotted carpet manufacturing. Tools used for carpet weaving are in Table 2.

Table 1 Raw materials used in carpet

Sl. No.	Parts of Carpet	Raw material required
1	Warp	Cotton
2	Weft	Cotton Wool Cotton and Wool
3	Pile	Wool Silk Viscose Wool and Silk Wool, Silk, and Viscose

Table 2 Tools used in carpet weaving

Sl. No.	Name	Common Name	Application
1	Scissors	Kaichhi	To cut the pile of carpet
2	Scale of steel	Patti	To straighten the knots in front
3	Comb	Kanga	To tighten the threads of the weft against line of knots
4	Beater	Panja	To beat weft & pile threads
5	Knife	Churi	To cut threads of knot

- **Carpet Weaving Process**

Steps of carpet manufacturing may vary from manufacturer to manufacturer but the basic procedure is same. The first step is to prepare a map of carpet design. According to map woolen yarns are dyed and loom is prepared. A vertical roller beam mounted with cotton warp yarns is used as a loom. Weaver can start weaving carpet after mounting the warp. Weaver starts making knots after completion of weaving with dyed woolen yarn according to the map. After knotting each row a thread called weft thread or tani is inserted horizontally between the warp thread above each row. The rows of each knot and wefts are beaten using comb commonly known as kanga. Scissors are used to cut the extra or uneven piles. This operation is repeated after each row till the carpet is completed.

The entire supply chain of the case organizations is very diverse and consists of a large number of scattered vendors in different rural parts of the country. The products have a large variety and the process is highly innovative. Selection of vendor and taking a follow-up from them on regular basis from all vendors is difficult. Supply of raw materials from different places to them consumes time and cost. The leading issue of companies makes co-ordination among all suppliers, vendors, lead time reduction, waste reduction, space utilization and process improvement.

The study presents case study approach to present the importance of implementation of lean tools in carpet industry. The case study approach is generally used to identify applicability of any tool and propose new theories (Jasti & Sharma, 2014). The present case study is based on a leading Indian carpet manufacturing industry. The continuous growth of this sector motivates to improve the scope of Indian carpet industry. The study has applied certain lean tools in Indian carpet manufacturing company to show how it can help to improve the current performance.

1.4 Problem Statement

Longer lead time affects the growth of company. Shorter delivery time of products helps in gaining competitive advantage. Shorter delivery time builds adaptability, reduces requirement for big stocks and brings down the obsolescence risk. Aim is to increase the customer satisfaction by lead time reduction and quality improvement. The entire supply chain of ABC Ltd. is very diverse and consists of a large number of scattered vendors in different rural parts of the country. The products have large variety and the process is highly innovative. Selection of vendor and then following them up is not an easy task. All these vendors are located far from company's head office and hence supply of raw materials consumes a lot of time and cost. All the handloom centers are decentralized; so daily inspection of carpets under weaving process is difficult. Other major issues are making coordination among all suppliers, and improvement of processes. Some of the other issues are:

- WIP positioning: Absence of real-time tracking system for WIP movement.
- Quality issues: Pending Color Requirement not properly fulfilled and color Cut issues in the final product
- Lead time tracking: No clear visibility for total lead time required for the end item
- Lack of innovation: Traditional weaving is still in the practice in the carpet making region
- Identification of lot wise losses: Process-wise losses in a particular Carpet starting from loom cannot be quantified.

1.5 Thesis Outline

This dissertation has been divided into six chapters. The brief outline of the remaining five chapters is given as:

Chapter 2 is devoted to a description of lean manufacturing, Toyota production system (TPS), Lean tools and their implementation method. This chapter reviews the relevant literature on the background of lean manufacturing, various lean tools, their implementations methods and impact of lean tool implementation in various sectors. On the basis of literature and practical observations, problems in current processes of case company have been identified. These problems were set as objectives of the dissertation. Chapter 3 proposes the research methodology for the current research objectives. This chapter consists research concept, research approach and detailed research flow process. Research methodology gives the broad description of dissertation flow.

Chapter 4 presents the description of lean tools implementation for process improvement in the case company. This chapter describes the current value stream using value stream map tool, highlights eight deadly wastes and bottleneck areas in detail. This chapter also discusses the various tool used for improvement in the current value stream. 5S check-sheet, capacity plan model, and layout redesign are prepared to process improvement. Chapter 5 concludes with a summary of research and possible outcomes. Chapter 6 is devoted to research gaps and future works to the concerned area are discussed.

CHAPTER 2

THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1 Definition of Lean Manufacturing

Lean manufacturing (LM) directs the focus of management to the elimination of wastes along the entire value stream. To achieve this, Lean develops processes that consume less space, human efforts, capital and less time to finish the products with the fewer defects compared to the traditional manufacturing system (Womack & Jones, 1990). According to Bhasin & Burcher (2006), it is a process of continuous improvement. Lean manufacturing works as a model for continuous improvement and gives organizations the flexibility to meet the market demands and changes in the competitive environment (Alves et al., 2012). For Ohno, Lean manufacturing is a management philosophy that fulfills the demands of customers in the less time with best quality and cost. According to (Bhamu & Singh, 2014), it is a theory based on Toyota production system that focuses on lead time reduction between end product and customer by continuous improvement. Lean manufacturing helps in reducing material movement throughout the production process (Liang & Wang, 2013). Shah and War (2013) defined LM as an integrated system that correlates various management philosophies including cellular manufacturing, 5S, Just-in-time (JIT), Kaizen, etc.

2.2 Origin of Lean Manufacturing

The fundamental of LM was originated from Toyota Production System or Just-in-Time system. Henry Ford discovered a continuous moving assembly line for mass production systems. Ford model of worker performance added the job rotation to change the repetitive and simple tasks, which not only improved the morale and enthusiasm of workforce but also resulted in benefits in terms of higher quality. The concept of the mass production model was supported by scientific management school's founder Frederick Taylor and the model's efficiency was not questioned till the Taiichi Ohno of Toyota Group noted some flaws of the previous model. Mass production requires a large amount of inventory stock, a large amount of space and capital and doesn't provide desired quality levels. Lean manufacturing concept was defined by Toyota group by contrasting two existing production approaches i.e. craft manufacturing and mass manufacturing (Hall, 2004). LM was developed or governed by TPS and sets an example for world class manufacturing.

2.3 Brief Introduction of Toyota Production System (TPS)

The most used pillar of TPS is the idea of JIDOKA confined in 1902.This concept leads to build in quality at production process by eliminating root causes of problems. This concept was originated at Toyota Weaving and Spinning Industry began by Sakichi Toyoda. He made the loom that automatically halted at whatever point a broken string was identified by it. It reduced the production of defective parts. Later in 1924, he invented automatic looms that allowed one operator to control multiple machines.

Another important pillar of TPS is JIT that was invented in 1937 by Kiichiro Toyota after the start of Toyota Motor Corporation. Due to the scarcity of resources the company could not afford to waste resources. Hence they just followed the concept of JIT in their production system. Taiichi Ohno an engineer in Toyota Company was appointed as production shop manager at engine plant and was assigned the task to improve the operational productivity. Ohno and various other people contributed to the improvement and overall development of TPS. There are various other tools developed by TPS such as takt time, standardized work, kanban, 7 Wastes, 5S, Single-Minute Exchange of Dies (SMED), Visual Control, Error Proofing and others (Hall, 2004).

Lean manufacturing focuses more on technical approach. A well-structured lean implement strategy may consider as the basis for implementation of many lean tools but it doesn't focus on the development of people in problem identification and problem-solving. TPS focuses on the development of people to the max (Hall, 2004). TPS starts with optimizing the processes separately to achieve zero defect targets. So it takes detailed perspective in the account before connecting the means ideally. Lean begins with a more extensive view by taking the process as whole to identify the source of waste. After that, it implements the lean tool accordingly.

2.4 Lean Principles

There are five principles of lean manufacturing: Value, Value Stream, Flow, Pull system and Strive towards Perfection.

Value: It is the starting point of lean thinking and can be defined by the end customer. Value is defined as the ability to fulfill the customers demand at the right time, quantity and price (Shingo and Dillon, 1989).

Value-Added: the activities that create value to the product are called value addition process. Rest of the activities is called waste or non-value added activities that are of two types:

Type one waste: The activities that create no value but they are unavoidable with the current production system.

Type two waste: The activities that create no value but there is a possibility to avoid them.

Value-Stream: According to (Hislop, 2013) the value stream is defined as the set of activities that are used to describe the flow of product at each stage of production, from concept to the dispatch of the product.

Flow: It defines the movement of product and information along value stream. Flow analyzes the processing load, interruptions, delays, bottlenecks and differentiates between value-added or non-value added activities.

Establish Pull: Customer demand pulls the products and information throughout the production system. It works in contrast with Push system which is unresponsive to the customers and results in higher inventory levels. It reduces the amount of inventory and follows JIT.

Seek Perfection: Perfection means complete elimination of wastes along the value stream. Possible improvement opportunities are analyzed and implemented. It includes the reduction in customer response time, cost, utilizes capacity, space and increases customer satisfaction.

2.5 Lean Tools

Pavnaskar et al., (2003) have introduced approximate 101 lean tools in their research work. This classification makes the tool selection easier by identifying mentioned system levels. Van (2014) described methods to implement lean tools and also figured benefits associated with these tools. Figure 3 shows few lean tools that can be implemented for waste reduction. Taleghani & Seyedhosseini (2013) has identified seven dimensions to measure the leanness in industries and also showed the relationship of lean dimensions with industrial wastes. Bozdogan (2010) explained lean system as a framework which can improve their performance through continuous improvement. According to Jasti & Kodali (2015), researcher required to focus on suggesting stepwise lean implementation procedures for different industries. They also described 3 wastes having highest frequency of occurrence as inventory, waiting and defects and it can be reduced by commonly known lean tools Kaizen, value- stream -mapping (VSM), and Kanban. Lean manufacturing suggests various tools but according to Gupta & Jain (2013), usage of these tools is situation dependent. At this stage of globalization customer's perspective is changing continuously in manufacturing processes. Mahapatra & Mohanty (2007) found that all these expectations can be fulfilled when workers are involved intellectually. Most common tools are discussed below.

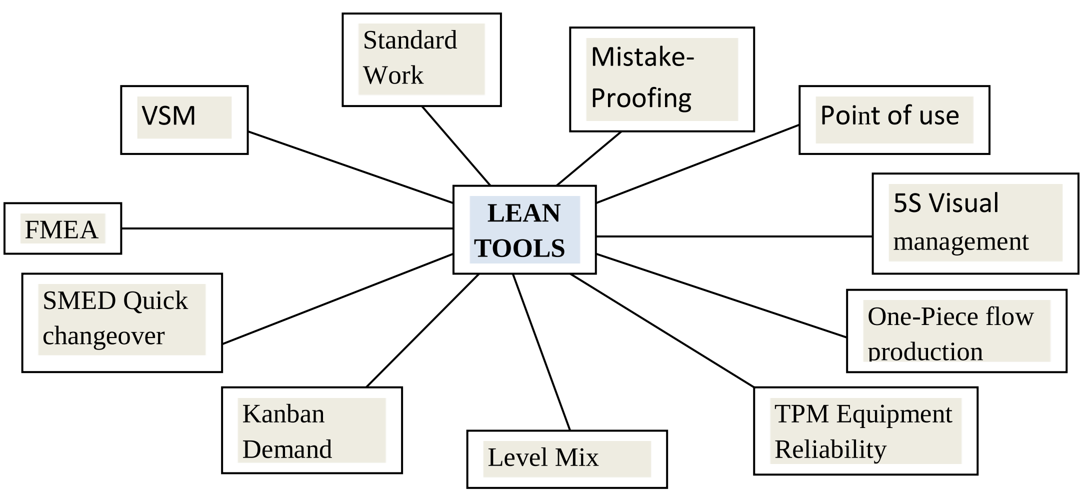


Figure 3 Different Lean manufacturing tools

2.5.1 5-S

5-S was first used in the manufacturing industry of Japan. The word was introduced by Takashi Osada in 1980 (Gapp et al., 2008). This tool aims to improve work area efficiency by sorting the necessary and unnecessary items, arranging them to appropriate locations. The 5S in translated version stands for Sort, Systemize, Shine, Standardize and Sustain. Successful implementation of 5S provides a way to implement TPM (Moradi et al.,2011). Sánchez & Pérez (2001) said 5S has a positive impact on four factors i.e. quality, productivity, mechanical security and hierarchical atmosphere of any organization. Gapp et al. (2008) through multi-case study showed 5S gives motivation, loyalty, better space utilization and continuous improving practices. Better usage of working area, work process improvement, accidents prevention and proficiency is enhanced from 65% to 89% in the progressive weeks (Rojasra, 2013). 5S has been identified as a very basic tool to implement and standardize Lean processes in any industry by (Gupta & Jain, 2013). Using 5S one can get motivation, loyalty, better space utilization & continuous improving practices. According to Jain et al. (2014), 5S provides a method used to rearrange the layout, enhance the discipline & orderliness can reduce searching waste and the waste of returning items to their proper place.

2.5.2 Value Stream Mapping

Value Stream Mapping (VSM) is a procedure used to decide the value added to an item as it experiences the production framework. It is pictorial representation used to show the flow of material and information. Value Stream Mapping is a three step process first step is to identify product family, second is to draw current state map used to show how things are going currently and final step is to draw future state map, shows how the system looks after removing inefficiencies (Abdulmalek & Rajgopal, 2007). According to Kumar & Kumar (2014), VSM helps to visualize material, information flow, Identify Bottleneck operations, WIP, Calculate processing and production lead time. According to Yan et al. (2015), lean helps to eliminate non-value- adding activities from the production processes while VSM helps to identify value adding and non-value adding activities through visual representation. Gurumurthy & Kodali (2011) said that the implementation of VSM with simulation can give significant improvement in the productivity while the reduction in inventory, lead time and floor space. A case study by Taleghani & Seyedhosseini (2013) used pert technique to analyze critical value stream through time-phased product structure. Highest probability calculated by pert helps to identify critical value stream, the activity with the lowest probability was considered to be the best one.

2.5.3 Just-in-Time

It is a system where demand is generated and then products or parts are produced. The parts arrive where they needed and placed in order of the right time. Just-in-Time (JIT) suggests three basic elements required to change the production system of the company: Continuous flow, where we make manufacturing cell to allow materials to flow in the process. Takt time, this marks the production rate for each process. And the Pull System, which allows the flow of parts or products without any inventory, or within a minimum range of work in progress. The principle of JIT is to provide each part in required amount at the required time. JIT is the occurrence of any activity in desired time, in the desired place and in the desired quantity (Karlsson & Ahlstrom, 1996). Reduction in lot sizes, buffer inventory and lead time is the objectives of JIT. The final objective is developing the single piece flow processes.

2.5.4 Cellular Manufacturing

A Manufacturing Cell is an organization of people, machines or workstations in a group. The cell may be arranged for a particular process or similar products. Different machines and workstations arranged within the floor in a sequence that gives smooth and continuous flow through the entire processes, with negligible movements and delays. It helps to accomplish two vital objectives of lean manufacturing: One-piece flow and High-variety product generation (Abdulmalek & Rajgopal, 2007). According to Glass et al. (2016), most important factor for successful implementation of the cellular layout is separation on the basis of work content. The optimum utilization of machines and manpower is necessary for economic benefits. Das et al. (2007) have designed a cellular manufacturing system that optimizes the cost and reliability objectives by considering an alternate route for machine flexibility during breakdowns. Line balancing, flow manufacturing, group technology, U-line manufacturing are important factors of successful implementation of cellular manufacturing (Sundar et al., 2014).

2.5.5 Standardized Process

Standardization is the process of developing and agreeing upon technical standards. It simplifies the coordination and control between subsidiaries and business functions. It is a method of completing the operations in the shortest time by effective utilization of resources. Standardized process has a set of standard operating procedures (SOP's) that contains sequence of different tasks, cycle time, number of operators, inventory etc. According to Flinchbaugh (1998), Toyota's principle of continuous improvement is based on standardized work. They used to hire and lay off the manpower according to the variation in demands while American automobile sectors used to scheduled overtime or complete shutdown to adjust the demands.

2.5.6 Total Productive Maintenance

It is a holistic approach that focuses on proactive and preventative maintenance of machine tools to maximize the operational time and efficiency. Total Productive Maintenance (TPM) is an upkeep system intended to incorporate tools and equipment support into the manufacturing procedure. Study by Belekoukias et al. (2014) revealed TPM doesn't have certain positive impact on quality but reduces the breakdown and changeover time to optimum level. He showed TPM has negative impact on operational management. TPM focuses on total involvement of employees in production or other activities. TPM enhances the production capacity by training the operators for maintenance of each machine tool which helps to reduce downtime. Arslankaya & Atay (2015) prepared a computerized maintenance form which is used to record all the data regarding the maintenance in dairy products. According to them, in this time of huge competition any organization can reduce the cost of maintenance by implementing lean manufacturing and maintaining management tools. These techniques help to reduce wastes due to failure of machine tools and increase productivity. TPM provides full and productive utilization of machine tools with zero breakdowns, zero pollutant emission, zero losses, and zero accidents with good quality products (Miyake, 1995).

2.5.7 Total Quality Management

It is a system of continuous improvement with employee participation and focused on customer needs. Some of key features of total quality management (TQM) are quality improvement, cost reduction, delivery execution, morale boosting and environmental protection (Abdulmalek & Rajgopal, 2007). The focus of TQM is totally based on the demands of customer. According to Miyake (1995), TQM is a theoretical approach which requires the support of top management for the production of high quality goods.

2.5.8 Kanban

It is a system in which parts or material movements in between the stations are based on different cards. It is used to make a Pull based production system. Gupta & Jain (2013) found kanban system reduces lead time and WIP. It reduces inventory and overproduction wastes and shows the movements of material in any production systems by automatic replenishment of material through signaling the Pull cards.

2.5.9 Kaizen

It is a Japanese term made of two different words Kai and Zen that mean continuous improvement. It is the process of incremental improvement and involves everyone in the plant from workers to top management. Origin of inefficient exercises is recognized and eliminated. The objectives are achieved through Deming cycle as shown figure 4. Kaizen has a modest impact on quality, speed and overall performance of the company (Belekoukias et al., 2014). According to Gupta & Jain (2013), it is slow and continuous value addition process that attacks the root cause of the problem. Reductions in quality issues, rejections, rework of products are some of the wastes that are reduced after implementing Kaizen. The part mismatching very common problem of automobile assembly line can be reduced by Kaizen (Sreedharan & Raju, 2016). It is a strategy that focuses on combining the talents of organization for targeting wastes and achieving slow and continuous improvements.

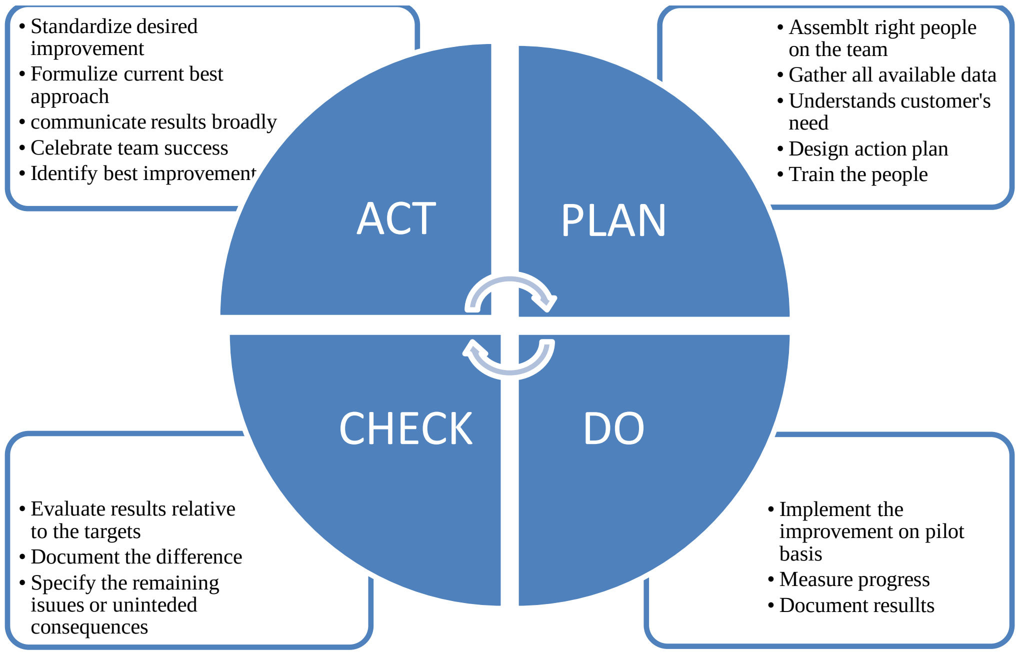


Figure 4 Four stages of deming cycle

2.6 Types of Waste

The ideal approach to cut the expenses is to create in an opportune way and just those items which can be sold and to take out all waste in assembling them. There are different approaches to cost reduction, from the planning to all the way through assembling and dispatching. One of the objectives of the Toyota Production System is to find defects and dispose of it. TPM concentrates on the end of seven types of wastes by (Elrhanimi et al., 2016).

- **Overproduction-** It affects the process flow smoothness and leads to excessive lead and storage time. Due to overproduction work-in-process inventory increases at every stage and results in dislocation of operations. Overproduction results in large inventory that increase holding and obsolescence costs. It consumes extra resource and degrades working conditions.
- **Defective parts**- Defects are produced due to improper work. It may cause large loss of resources. Sometimes they become harmful to the environment and society. Rework generates an additional cost to for the company. The Toyota philosophy is that defects ought to be viewed as chances to make improvements.

- **Unnecessary inventory-** Waste created by keeping excess stock of the requirement. It causes a burden to the logistics department. This is caused by long lead time, overproduction and forecasting errors. It lowers the competitiveness of the organization.
- **Unnecessary movement-** It involves ergonomics of production where operators have to perform certain actions that can cause excessive fatigue to workers and reduce their productivity or often affects quality. This includes stretching, bending and pick up.
- **Excessive processing-** The waste that is made when we prepare more than the market needs. A powerful technique to recognize wastes in procedures is to draw value stream mapping to show the flow at various stages.
- **Waiting-** It occurs in a particulars stage if the material doesn't move for a longer period or being worked on. It occurs due inefficient time management and affects both material and manpower.
- **Transportation-** It is also a non-value added or waste activity. Excessive transportation in the factories is likely to cause damage to the materials (Elrhanimi et al., 2016). Recently in Lean Manufacturing classic Lean Thinking, Underutilized employees have been mentioned as an eighth waste to TPM original seven wastes. By utilizing employees' creativity and innovation organizations can eliminate the other seven wastes and move towards continuous improvement in their performance.

2.7 Effects of Lean

Lean methods ensure that weaknesses of any company can be revealed by the influence of lean tools. Some effects are reduction in quality issues, defects, rework, safer work environment, reduction in inventory, workplace utilization, and identification of an area of possible improvement, lead time reduction, increases manufacturing flexibility and bolster employee morale (Van, 2014). According to Cherrafi et al. (2016), lean works as a driving tool to improve operational processes and increase productivity by optimizing flows of resources. It reduces the impact on environment by eliminating all environmental waste produced by production operations. Various case studies have demonstrated potential change as the consequence of Lean. A case study by Rojasra (2013) showed better usage of working area, work environment improvement, reduction in accidents, proficiency is enhanced from

67% to 88.8% in the progressive week. Yang et al., (2015) results showed that mapping the process flow can expand benefit level and decrease WIP by less than 29.41% and 33.92% individually. Lean tools can be applied to any industry to get better utilization of resources.

Systematic application or implementation of lean tools could be used to identify, distinguish, characterize, analyze and attack sources of wastes in a defined or systematic manner. Lean Manufacturing suggests various tools but according to Gupta & Jain (2013), usage of these tools is situation dependent. At this stage of globalization customers perspective is changing continuously in manufacturing processes. Mahapatra & Mohanty (2007) found that all these expectations can be fulfilled when workers are involved intellectually. Some important benefits are given below:

2.7.1 Economic Benefits

There are financial benefits of lean tools implementation. It can save capital resources by optimally utilizing available resources. Implementing JIT we can reduce WIP and stock, and their corresponding holding and obsolescence costs. There are immense effects of lean implementation in businesses. The reduction in defects, waiting and overall cycle time increases company benefits. Benefits from lean are generally far more than can be achieved by any other techniques along with control of the quality of products and services (Van, 2014).

2.7.2 Cultural Benefits

For successful implementation of lean, acceptance of new mindset and some changes in organizational culture are required. According to Punnakitikashem et al. (2009), for the success of any organization or for successful implementation of any technique, a better level of understanding is also required. The actual advantage of lean demands the general reinforcing of the framework. The heart of any organization is the employee who does the actual value creating work and they need to be supported by many individuals. Some kind of reward system should be introduced to bolster their morale (Bhasin & Burcher, 2006).

2.8 Lean Implementation Techniques

Executing lean and accomplishing anticipated outcomes has demonstrated to be a troublesome task. The study revealed that just 10% of the organizations are effective to execute lean. The greater part of the study on lean components concentrates on just a single or two components or involves a few components. For effective execution of lean, we have to consolidate on every single lean component. The study by Sundar et al. (2014) proposed ideas for execution of various lean tools along with other reliant factors. An essential way to actualize the lean tool results starts first with the implementation of VSM to picture the stream. The region of issues and takt time to recognize the issues. In order to categorised different issues, the leam strategy is prepared. Next step is gathering information of complete value stream. The third step is the usage of Cell Manufacturing. Cell development relies on innovation and allocation of the part family. VSM along with the effective execution of U-line framework and flow manufacturing, promote streamline through Line**.** Gupta & Jain (2013) suggested four steps for Lean implementation.The first step is to identify all bottlenecks of the processes. Second is to identify various types of wastes and their possible causes.The third step is to find the root causes of these bottlenecks and their solutions.And the final step is to implement the possible solutions**.**

Beginning with just one single tool of the famous lean tool is not adequate. The execution strategies ought to consider the comprehensive perspective of the procedure and show conceivable outcomes to actualize different lean tools. A study conducted by Shah & Ward (2003) showed the negative correlation between plant size and outcome of lean tool implementation. It shows that small size organizations are less capable of lean tool implementation. But by combined effects of lean practices, lean appears to make a substantial gain to operational performance in the small organizations too.

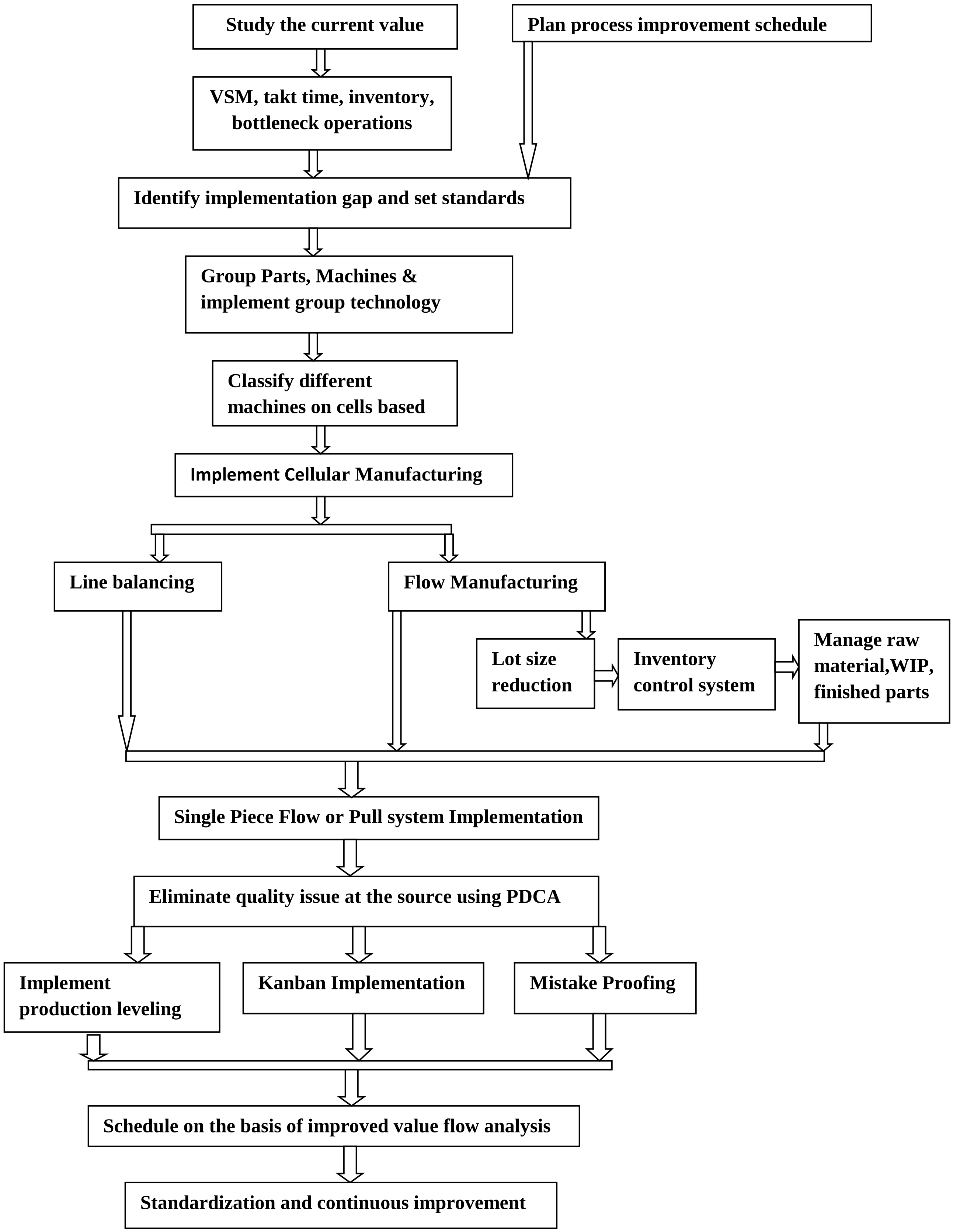


Figure 5 Lean tools implementation steps

Begam et al. (2013) highlighted some challenges in implementing lean system. Figure 6 shows the challenges in implementing and sustaining lean culture. Implementing this is a tedious task as the lean process relates to the resource, time, cost, interest, employee, and association of new change for advancement in a firm. The study by Begam et al., (2013) proposed that new organization implement lean manufacturing and other inventive strategies than the old organizations. The supporter and barrier to lean are shown in figure 6 below. These are certain factors which resist the change in any organization.

- Fear to change the legacy framework with the new fruitful patterns and procedures.
- Not using the open opportunities and points of interest of the new strategies.
- Market destabilization will prompt to drive the change, which will be in a non-standard configuration.

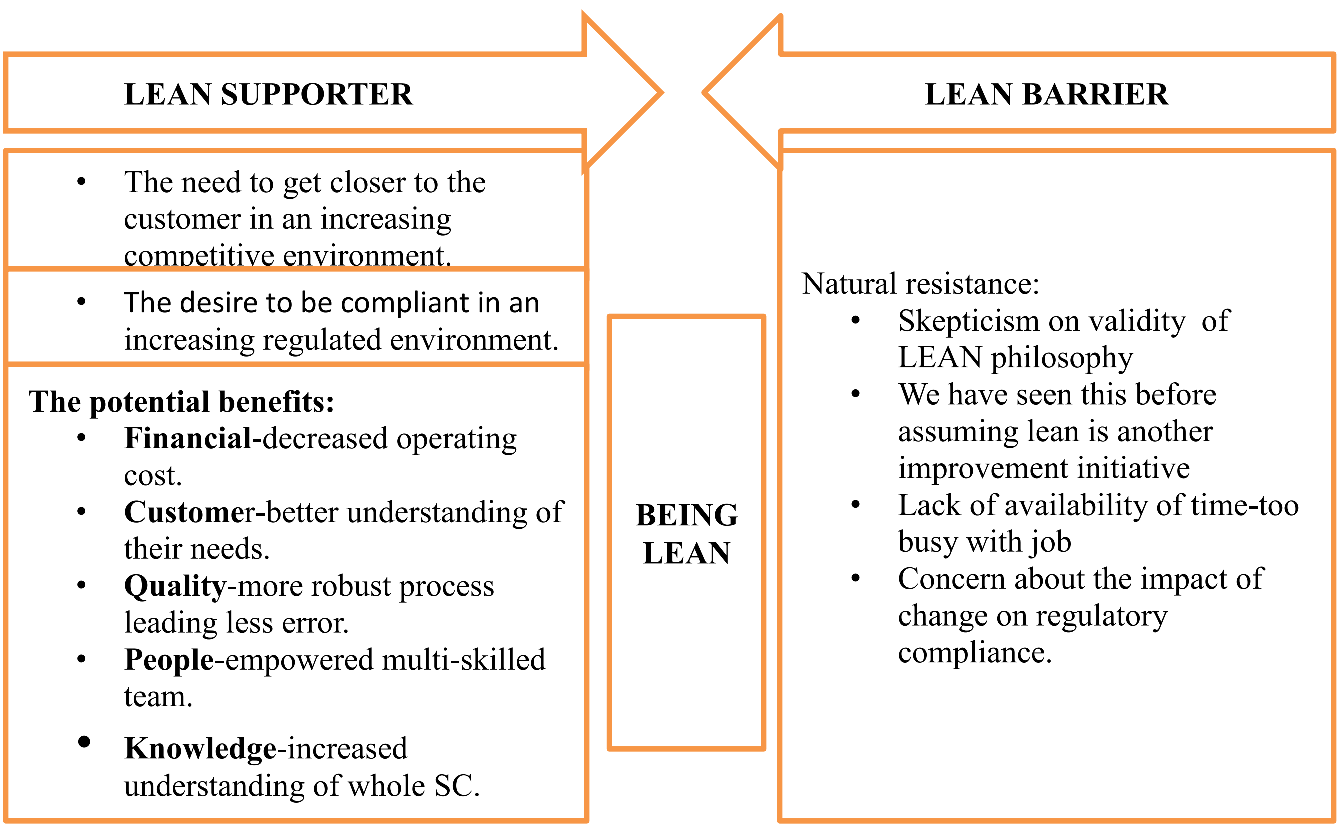


Figure 6 Challenges to lean implementation

2.9 Lean Tool Implementation in Various Sectors

2.9.1 Automobile Sector

According to (Kumar & Kumar (2014), Lean philosophy helps to identify wastage of time and eliminated it. A case study conducted by him shows a reduction in the cycle time to 37.5 min from 90 min and increase in efficiency from 17.5 to 30.09%. Arunagiri & Gnanavelbabu (2014) suggested 5S, overall equipment effectiveness, 8 step problem solving methodology, Pareto analysis, elimination of wastes are the most effective tools used for productivity improvement in automobile sectors. Lean results in reducing inventory from 4.1 to 1.88 and lead time from 81.9 to 28.8 hrs. (Paranitharan et al., 2011). According to Glass et al. (2016), missing acceptance of employees, insufficient personal capacity, missing experience and documentation, financial aspects and a missing support by management are the barriers to Lean implementation. While guidance of the management, the involvement of employees, clear goals and the motivation of employees are the most success factors of Lean.

A study by Jayaram (2008) revealed that any organization should firstly build close relationships with their customers and suppliers. It further helps to enhance lean strategies. According to Liang & Wang (2013), LM Logistics helps in reducing material movement problems. According to the author, the material route should be minimized, the warehouses should be closer to the start of machining lines, and end of the machining lines should be close to the beginning of the assembly lines.

2.9.2 Manufacturing Sector

Gupta & Jain (2013) said that the usage of lean tools is situation dependent. At this stage of globalization customers perspective is changing continuously towards manufacturing processes. According to Bhamu & Singh (2014), there is need to standardize the LM definition, scope, tool, methodologies, and objectives to fulfill some critical objectives. A study done by Jasti & Kodali (2015) focused on stepwise implementation procedures of lean in different industries. They found 3 wastes having the highest frequency of occurrence as inventory, waiting and defects and it can be reduced by commonly known lean tools kaizen, VSM, and kanban**.** Sreedharan & Raju (2016) said that there are no standard procedures for application of lean tools at different stages of implementation. For a better understanding of lean concepts, need to focus more on conceptual based research in Lean systems. According to them, there is a strong requirement to implement lean with other philosophies like Six Sigma, Agile, green and sustainable manufacturing etc. It is required to research on the barriers and critical success factors of LM in various sectors.

2.9.3 Healthcare Sector

According to Hicks et al. (2015), 3P (production, preparation, process) helps to analyze seven flows of medicine. The redesign of healthcare facilities has a remarkable influence on the efficiency of healthcare sectors. Their study focuses on the development of a new endoscopy facility on an existing platform. There required the complete interrelated operations improvement rather than localized one (Tay, 2016). Burgess & Radnor (2013) presented various approaches based on the topological order to identify the lean implementation methods in hospitals. Their study showed an individual trend rather than universal. Based on data they also analyzed that the trend is moving towards universal or holistic approach. Lean implementation in health sectors requires a change in the thinking of staff and professionals towards the support of lean thinking. It demands a shared vision of continuous improvement (Spagnol et al., 2013).

2.9.4 Construction Sector

Ansah & Sorooshian (2017) performed an evaluation of construction project based on AHP and showed that the most effective lean tools to reduce construction delays were concurrent engineering, last planner system (LPS) and daily huddle meetings with priorities 0.425, 0.379 and 0.371. While the tools having least priority as 0.026 was SMART Goals. According to Nowotarski (2016), easier access to materials, availability of more storage, less in plant movement thus money saving are some of the expected benefits of lean. Lean techniques are used to analyses the risk in construction projects and it also finds a suitable solution in terms of time and cost. Marhani et al. (2012) suggested pre-construction and constructions are the perfect time to implement the lean concepts. These stages are important due to the determination of man, material, equipment and other resources during pre-construction. At this stage, it is effective to eliminate construction waste.

2.10 Research Objectives

2.10.1 Objective 1: To identify various wastes in the current value stream.

Lean implementation targets on doing the things first time right, to the right place, at the right time and in the desired quantity with minimum wastes. Lean focuses on making the work as simple to analyze, understand and manage.

2.10.2 Objective 2: To reduce total lead time and WIP between facilities.

Longer lead time affects the growth of the company. In global markets, the ability to deliver the products in short duration leads the business away from competitors with similar product features, quality, and price. In all cases, shorter lead time increases flexibility, reduces the need for inventory buffers and lowers obsolescence risk. The objective of this study is to increase the customer satisfaction by lead time reduction and quality improvement in a carpet industry.

2.10.3 Objective 3: Process improvement by implementing lean tools at carpet industry.

There are so many approaches to improve such problems. In Chapter 2, various improvement tools are discussed. The result has shown the improvement in current facilities (chapter 4). Implementation of lean tools results in a reduction in lead time, WIP, better facility arrangement, best utilization of resources and finally, helps to increase the profit of the organization.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter describes the research methodology followed in research work. This chapter includes the concepts of research strategy, methods followed in current research and details of data collection and analysis.

3.1 Research Concept

This dissertation work presents the combination of the literature review and the case study. The literature review is based on the articles, thesis, and textbooks of the research area. Articles and thesis give specific and current information of research field while the textbooks usually give the basic knowledge of the area. The research is based on both theoretical and empirical studies. The literature review helped to identify the problem and different tools were chosen to solve the problem. A case study carried out to investigate how these tools provided a solution to these research problems. Then the implementations of the solutions were made and results were presented. There are a large number of papers publishing every year focusing various areas of Lean manufacturing such as an automobile, aerospace, processing industry, healthcare etc. Hence, it is not possible to quantify exact numbers of papers in lean manufacturing literature.

3.2 Structure of Work Methodology

The study starts with a literature review that includes a selection of research papers of various journals between the horizons of 1989 to 2016. Various literature on Lean implementation and lean tools from different publishers like Elsevier, Taylor & Francis, Science Direct, Springer etc. is collected for review. The review gives ideas how lean is implemented in various sectors and its cultural and economic benefits.

Based on the review, we can observe lean manufacturing is mainly developed in the automobile industry. To research our case organization we need to focus on lean implementation in small-medium-enterprise (SME's) through immense literature. The automobile sector has to tackle with a few distinctive problems but they have to manage thousands of parts, with large variation and fluctuations in demands. In such organizations, lots of research has been done, so it is more likely to understand how results are achieved with lean methods.

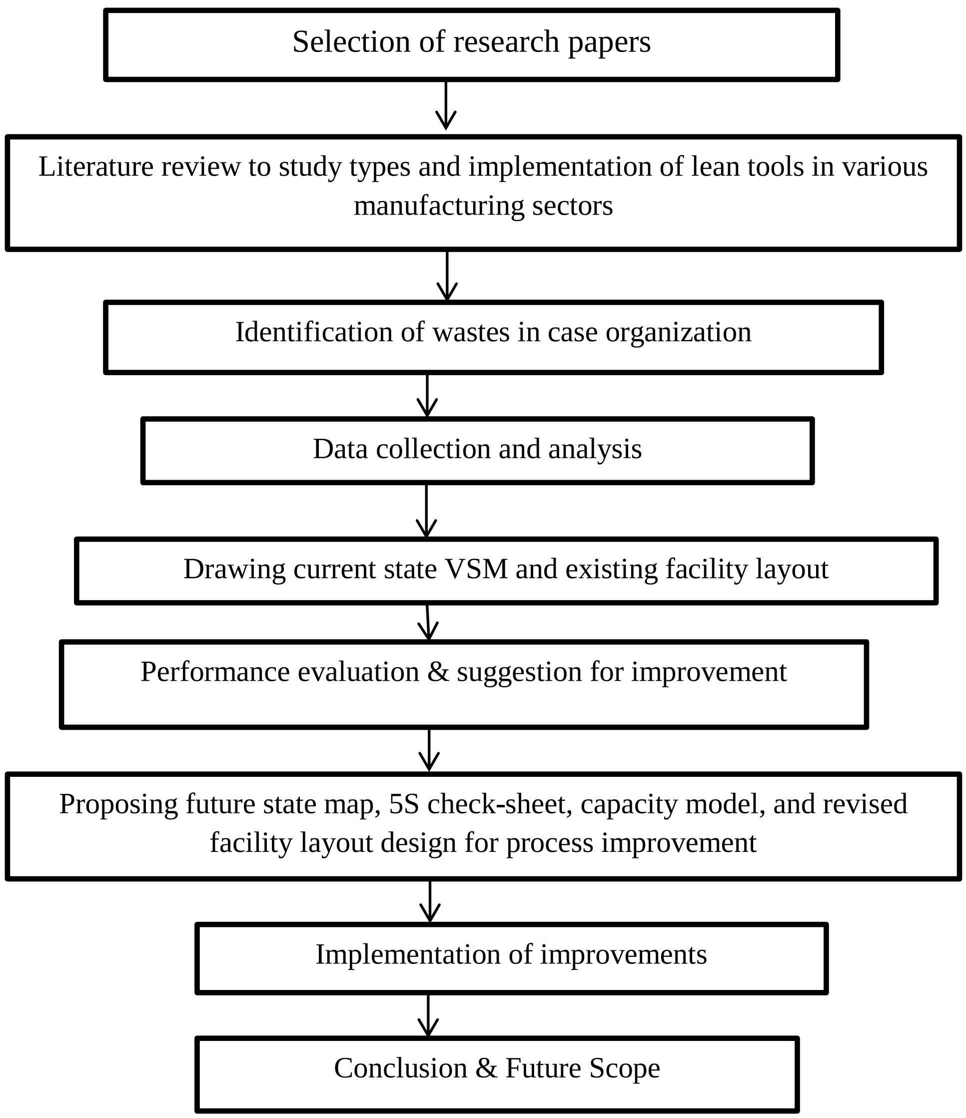


Figure 7 Research Methodology

Our case organization is an Indian firm that produces carpets and floor covering. There is not much literature available in this sector so I have taken some literature from apparel industries. The company is facing the issues of large lead time and quality. The company has large vendors at different locations, so it is a big issue to take regular follow-up. I visited whole supply chain once during the whole research then I used to visit the finishing centers regularly for observations.

The observations, conversations with employees and management helped to identify the problems. Various problems like high lead time, product quality, layout arrangement and manpower management are some of the issues that company has to tackle**.**

3.3 Data Collection and Analysis

Most of the data is collected from ERP file, rest is collected during the process study. Data were collected for all the sub-processes in the carpet production. To calculate the cycle time and lead time at various stages of production I collected the data from receipt and dispatch order files at different locations while rest of data was collected manually. There was a large variation in the data. To normalize the variations the data was sorted and outliers were removed manually and using the average to 3 SD rule. Due to highly scattered and distant vendor location, it was not possible to study all the stages of carpet supply chain thoroughly. The study includes all the stages except carpet weaving loom centers.

Fluctuations in demand are one of the important facts that the case organization needs to tackle. We have analyzed the current situation of case organization by using information from company's process study and ERP system. The product family is selected using Pareto law to draw current state map. With the help of Current state map, the total value added and non-value added time is calculated. This also helps to visualize process flow and helped to identify bottlenecks in the processes. Current state layout of finishing centers helped to identify the flow of man, material, and WIP with the process. Root cause analysis of bottleneck processes helped to identify the root cause of the problems. Common lean tools 5S and VSM is identified to improve the processes. 5S is a tool used to maintain good housekeeping and helps in sorting the necessary and unnecessary items in the floor area. It helps to keep the regular follow-up of the floor. A 5S check sheet is prepared to mark the progress and improvement on the floor. As the case organization shares some characteristics with the apparel industry, but the volume and variation in the products are less than the apparel industry. Hence the most of the lean implementation techniques are based on their literature. There is a lack of Innovation, the higher margin on products and long product life in products case organization. Another tool is VSM that used show various waste and flow in the processes. Seven wastes are identified in detail and the possible ways to reduce them will be suggested. Most of the suggestion will be based on literature analysis.

CHAPTER 4

IMPLEMENTATION OF LEAN TOOLS IN CASE ORGANIZATION

There are various lean tools used for process improvement in manufacturing industries. It depends on the types of process that which of these tools will be used in manufacturing firm. Value stream mapping has been used as a decision-making tool to visualize the bottlenecks in the current value stream. The future state mapping has been suggested in subsequent stages.

4.1 Selection of Product Family

As shown in Table 4 the initial step of value stream mapping (VSM) is a selection of product family. The case company produces a variety of hand knotted and tufted carpets in different quality. Using Pareto analysis we found that the 8/8 HS WL quality is the most important product for the company in terms of sale. The hand knotted carpets are the most produced and appreciated product. Due to this, the hand-knotted group of products was selected to draw the VSM.

4.1.1 General Process Information

Flow of carpet manufacturing process in case organization is shown in Figure 9. After receiving orders, production department generates production orders and plans for the loom. In parallel to this, design department prepares the map, attaches a bill of material (BOM), and prepares job card. Raw materials received from the suppliers and maps received from the design department are sent to the store. Thereafter, store transfers the raw materials along with the maps to different branch centers from where these are delivered to the loom.

Table 3 Product family selection based on sale of product using Pareto analysis

Row Labels	Count of Quality	Cumulative Count	Cumulative%	Category
8/8 HS WL	356	356	28%	A
14/14 HS WS	334	690	54%	
8/8 RWB	227	917	72%	
10/10 HS WS	129	1046	82%	
11/11 RHS WL	56	1102	86%	B
8/8 RHS WL	48	1150	90%	
14/14 MS PS	38	1188	93%	
11/11 RWS	22	1210	95%	C
10/14 HS WL	15	1225	96%	
10/14 RMS	13	1238	97%	
10/14 HS WS	10	1248	98%	
6/6 HS WL SW	9	1257	98%	
10/14 RHS WL	5	1262	99%	
11/11 RMS	5	1267	99%	
6/6	5	1272	99%	
10/10 HS WL	4	1276	100%	
10/10 RMS	1	1277	100%	
8/8 RHS TW	1	1278	100%	
8/8 RHS TW LP	1	1279	100%	

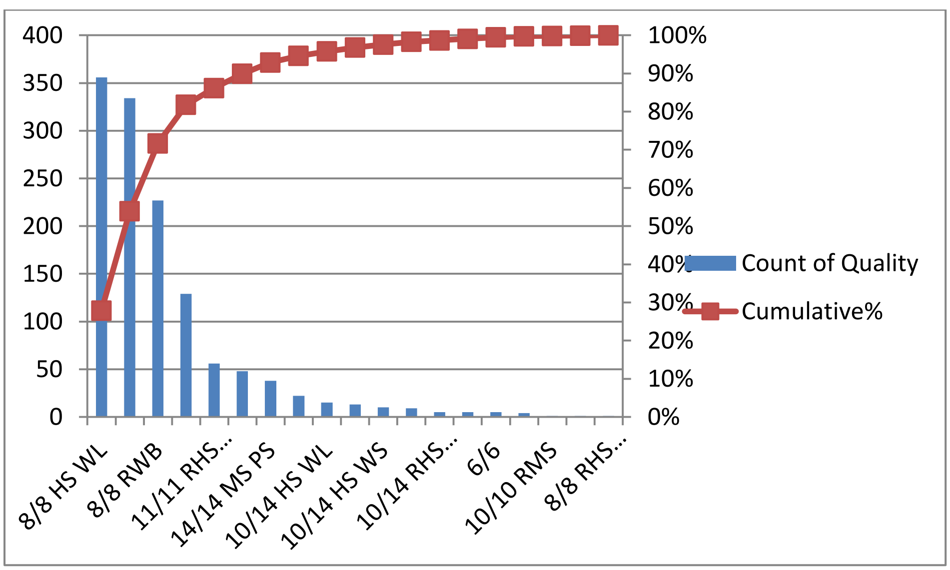


Figure 8 Pareto analysis for product family selection

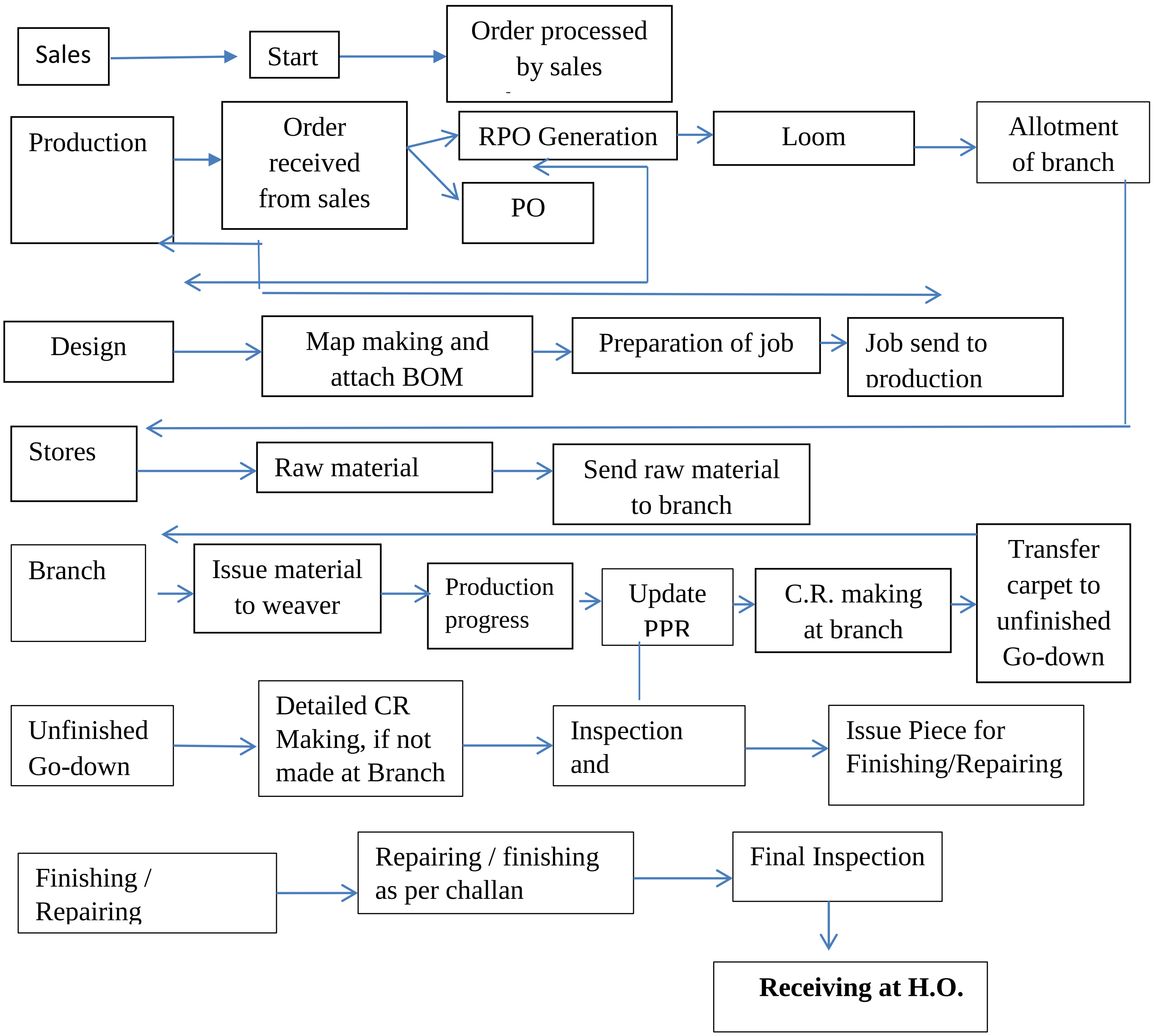


Figure 9 Carpet flow process diagram

After completion of weaving the carpets are transported to unfinished go down where measurement and inspection are performed. Then the carpets are issued for the finishing and repairing as per the priorities. The repairing operation includes carpet receiving, carpet checking, counting the knots, aligning and mending while finishing operation includes making back, primary cutting of piles, separating the piles of knots, back burn, washing, Stretching & straightening, Helix looking knots, Final Cutting of piles, embossing, pile separation, removing unwanted thread & fringe knotted, final inspection, packaging and dispatch to the head office and after final inspection carpets are transported to the head office, from where they are delivered to the customers. Between all these operations, production and supply chain department take regular follow-up of the product electronically.

4.2 Value-Stream-Mapping

Value stream mapping (VSM) is a tool developed from the Toyota Production System. The focus of this technique is based on the elimination of seven deadly wastes defined by TPS for overall customer value addition. VSM is a technique used for visualizing the manufacturing system and all other processes. This technique provides the visual model of the system processes with sufficient information flow. Identify Bottleneck operations and WIP. Calculate processing and production lead time (Kumar & Kumar, 2014).

4.2.1 Assumption

Most of the data is collected from enterprise resource planning (ERP) file, rest is collected during the process study. Data were collected for all the sub-processes in the carpet production. Data was sorted and outliers were removed manually and using the average to 3 standard deviation (SD) rule. Due to highly scattered and distant vendor location, it was not possible to study all the stages of carpet supply chain thoroughly. The study includes all the stages except carpet weaving loom centers.

4.2.2 Methodology

Value stream mapping (VSM) is used for the visualization and elimination wastes in any production system. The first step is a selection of the important product family. The next step is the creation of current state map. It is used to identify value added activities (VA), non-value added activities (NVA) and necessary NVA activities. Next step is to draw the future state map by the elimination of NVA activities and the final step is to implement the new production plan.

Table 4 Outline of the VSM technique implementation

Sl. No.	**Tasks**
1	Identify carpet as the main product on the basis of sales data, considering all relevant product family using Pareto analysis.
2	Create current state VSM using standard value stream mapping icons that show current processes, flows, and information.
3	Identify unnecessary non-value added activities and suggest improvements in order to create a flow of processes.
4	Create the future state VSM by waste elimination with the best flow.
5	Implement future state VSM progressively.

4.3 Current State Value Stream Map

After the selection of the product family, the next step is to draw the current state map. The figure shows the current state value stream map of 8/8 HS WL. Representation of the flow on the current state map as shown in Figure 10 should always start with the customer's demand, which is calculated from the sales data and then working one's way up to the upstream processes. Some information was collected through the ERP data and rest was observed during a walk on the floor. The observation includes cycle time or processing time, inventory level, the number of operators, shifts, production process flow and information flow manually or electronically. The current state value stream map of the selected product family includes the following information.

Customer Demand/Week =816 sqft for the selected product family is calculated electronically using previous four months data. The sales department communicates with the customer electronically and after consulting with production department they give the total lead time to the customer. If the customer accepts the term the order is finalized. Total time per shift is 1 Shift/day =9hrs that include Tea Break =2 each 15min and lunch break =30min. So the net Available time =48hr/week. The entire inventory shown in current state map is in square feet.

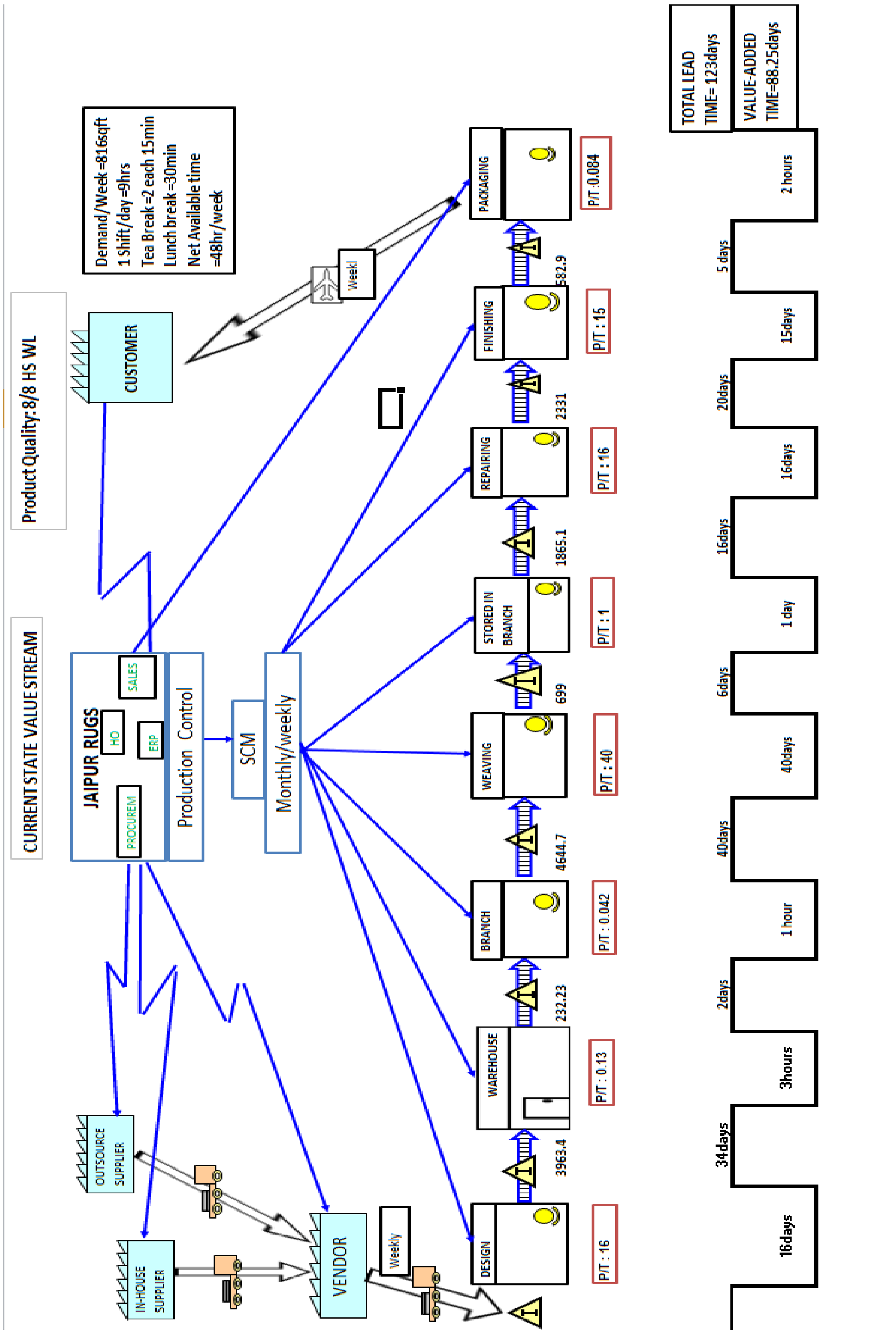


Figure 10 Current state value stream map

4.3.1 Wastes in value stream

There are several wastes in a manufacturing industry. Total productive maintenance (TPM) concentrates on removal of seven types of wastes (Elrhanimi et al., 2016). The wastes identified in case organization are given below.

- **Waiting**

It is observed that work in process inventories wait for approximately 10-15 days before being finished. It results in increase of inventory holding cost, occupies the floor space unnecessarily, and increases cycle time of manufacturing.

Figure 11 Inventory waiting for weighing

Figure 12 Carpets waiting for color issue

Carpets to mirzapur: Carpets sent to the Mirzapur for high-low are found to lie in working area 10 to 15 days and 5 to 6 people its completion. Then they mail the list of carpets packed to HO. Finally, head office gives the list (based on priority) of carpets to be dispatched in 2-3 hrs. This increases the rework and wastage of time. Sales department can prepare the priority list of carpets to be sent to Mirzapur before the showroom sends the carpet details. This will reduce the waiting time. The following steps are followed before dispatching:-

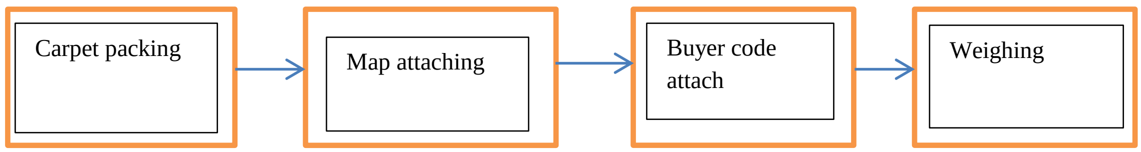


Figure 13 Showroom process of carpets

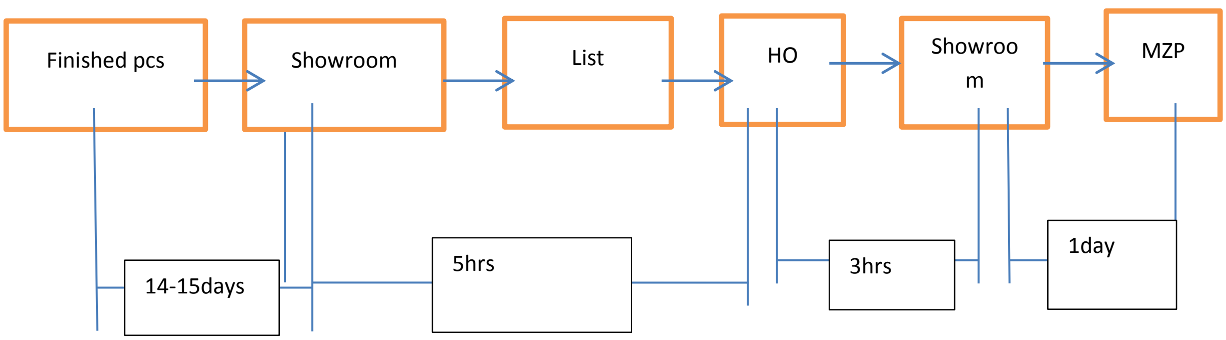


Figure 14 Carpet flow before transporting to mirzapur

Calculation:

Minimum worker cost=Rs. 6000/month

Worker cost/day=Rs. 200

Hours involved in packaging=4hrs

Working hours=8 hrs/day

No. of workers involved in packaging=6

Total worker cost= Rs. 600/day

Monthly plan of dispatch= 5/month

Total worker cost/month= Rs 3000/month

Solution

The capacity planning model need to be revised for proper allocation of manpower in finishing center to move the WIP inventories to further locations at right time. The revised capacity planning model has been shown in Table 9. Some processes can be completed before sending the carpets to Mirzapur.

- **Transportation**

In this case, because of variation in total lead time of carpet production, carpets are delivered thrice a week. Then these are kept in stocks for finishing. The table below shows the monthly variation of transportation of finished carpets to head office. Due to priority variation, the vehicle has to be scheduled randomly which increases the transportation cost.

Figure 15 Inventory for high-low work

Solution

Vehicle planning based on kanban pull system can be used to reduce the variations in transportation lot size. Table 5 shows the variations in transportation lot size. Appropriate transportation scheduling is required to reduce the transportation cost.

Table 5 Monthly inventory transportation data

Week	Truck received	Month	Total truck	No. of carpets received	Total/month	Carpet/truck	Production Cubage(Sqft.)
1	5	Jan	21	319	1265	60	899548.64
2	5			157			
3	5			406			
4	5			191			
5	1			192			
1	5	Feb	20	427	1468	73	969671.36
2	4			229			
3	4			327			
4	6			482			
5	1			3			
1	4	March	21	104	1889	90	1063461.46
2	6			509			
3	5			560			
4	5			711			
5	1			5			
1	5	April	23	486	1866	81	1298993.36
2	5			312			
3	6			411			
4	5			642			
5	2			15			
1	5	May	22	583	2176	99	1231836.03
2	6			458			
3	6			653			
4	4			372			
5	1			110			

- **Inappropriate processing**

Some methods of carpet processing are inappropriate which results extra manpower consumption. Acid is used for washing the carpets. It results in over washing which causes colour fading. Loose warp and pile due to inappropriate process of weaving cause shortage of dyed yarn which further results in colour cut.

Figure 16 Carpet washing process

Figure 17 Processing defects in loom

Solution

Over washing of carpets is caused due to extra use of acid. A beaker of required volume should be used to pour the acid so that over washing may be avoided. Day to day supervision and frequent inspection can be helpful in avoiding loose pile and warp.

- **Unnecessary inventory**

Excess inventory may reduce the possibility of identification of defects. WIP occupies more space. It increases material handling cost and time, and causes physical and mental fatigue.

Figure 18 Randomly piled up inventory

Solution

It is required to redesign the floor based on the types of inventory viz. inventory with colour cut problem, inventory with back issue problem, inventory with shine problem, some urgent inventory etc. It will reduce material handling time and cost.

- **Unnecessary Motion**

It is seen that workers carry the carpets manually from one workstation to other workstation. They also lift and drop carpets manually. Weaved carpets are received at first floor, then moved to second floor for inspection, then again moved down to ground floor for high-low work. Excess movement causes workers to the painful physical condition that can lead to serious physical injuries, energy losses and ultimately loss of productivity.

Solution

Use of trolley and tool for lifting the carpets are suggested to reduce manual handling of materials. Redesigning the facility layout can be considered to reduce unnecessary motion. Use of lifting tools and trolley will reduce physical effort by workers. Inspection can be done at ground floor and then at first floor high-low work can be shifted.

Figure 19 Lifting the carpets from floor

Figure 20 Lifting the carpets to certain height

Figure 21 Weighing the carpets before and after finishing

Figure 22 and 23 represents the proposed design of trolley and lifting tool. Use of trolley and lifting tool will improve grip and reduce stress on back and shoulders, contact pressure on shoulder and hands, effort in performing tasks.

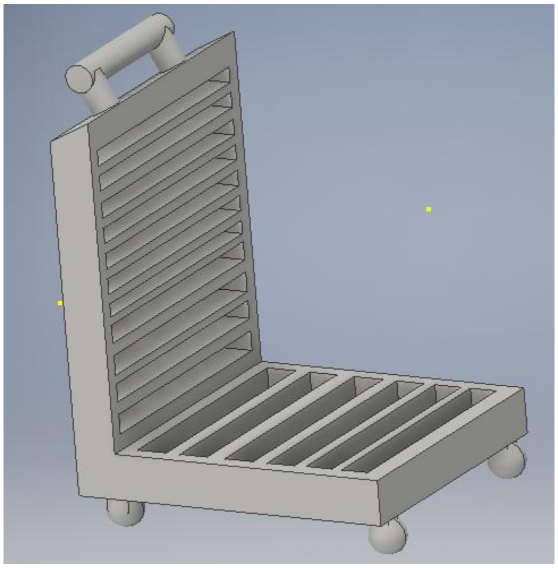


Figure 22 Proposed design of trolley for carpet transportation

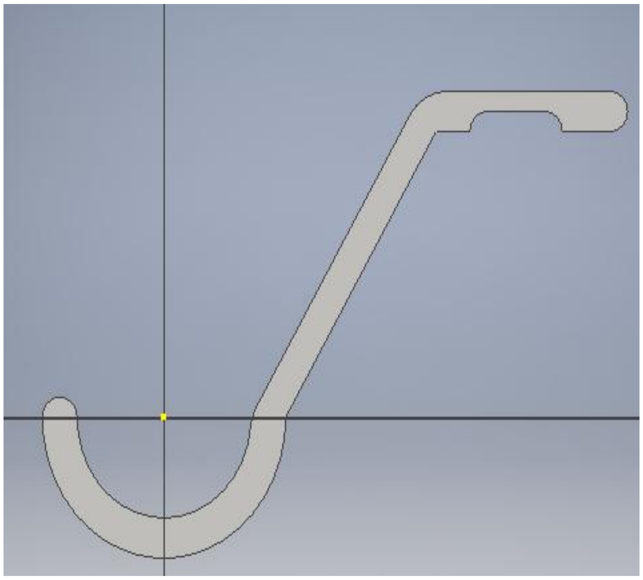


Figure 23 Proposed design of hand lifting tool

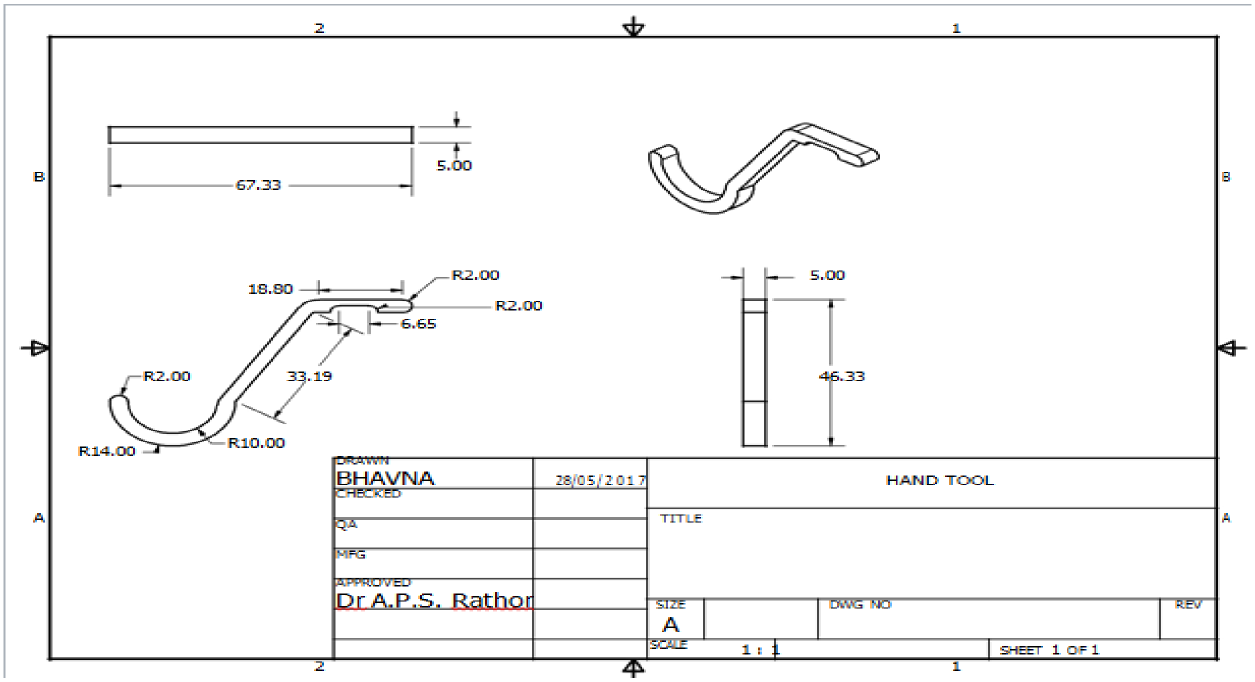


Figure 24 Different views of lifting tools using Inventor software

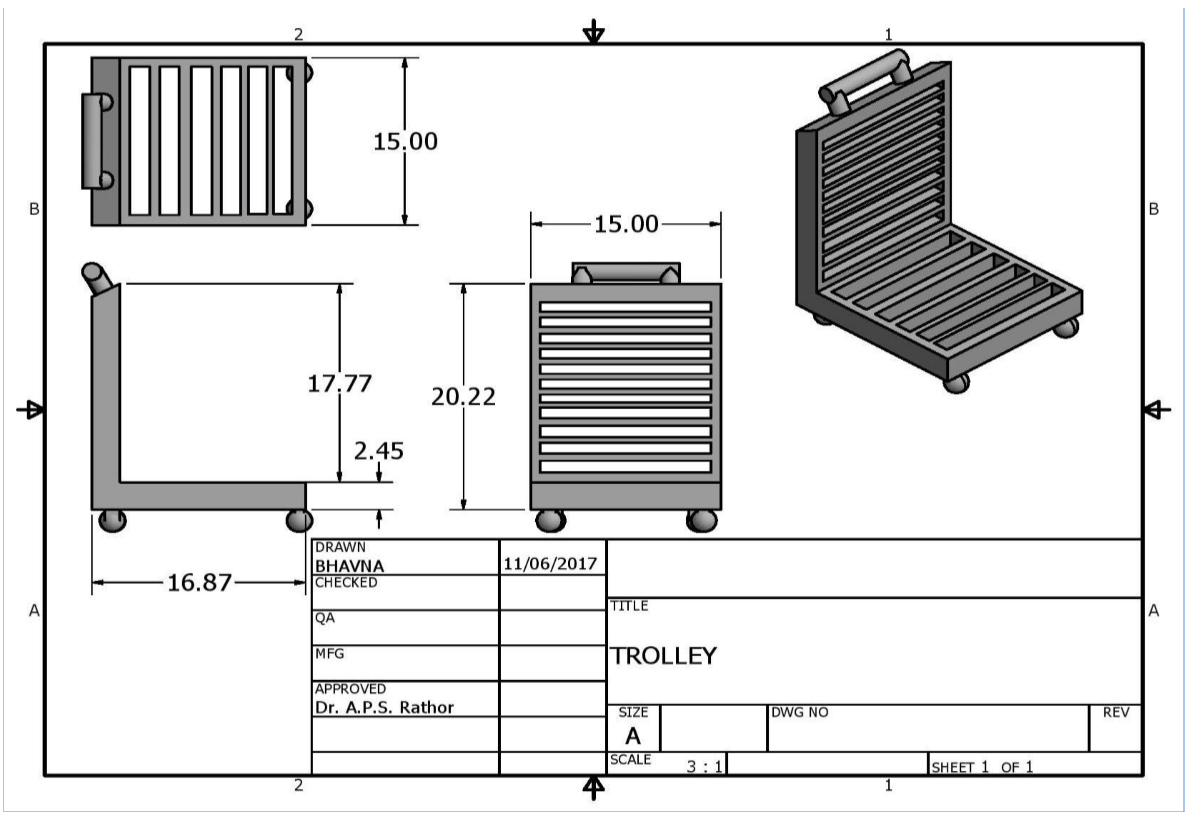


Figure 25 Different views of trolley designed using Inventor software

- **Defects**

Figure 26 Measurement of size variation in finished carpets

Based on previous data thirteen major defects were identified. Table 6 shows that colour cut is major defect which needs to be controlled effectively.

Figure 27 Removing the defects in carpets alignment

Table 6 Various defects in carpet production

Finishing Center			
Defects	count	cumulative	%defective
Color cut	255	255	30%
Back kharab/Back Issue	132	387	45%
Softness	107	494	58%
Chamak/Shine	103	597	70%
Yellowish	77	674	79%
Stain/spot	68	742	87%
Danti	49	791	93%
Birai/ Pile separation	45	836	98%
Kanni/Fringes	5	841	99%
Lehar/Swaying	4	845	99%
Gultarash/High-Low work	2	847	100%
Over wash/under wash	2	849	100%
Raffoo/Mending	2	851	100%
Total	851		

Solution

The root-cause analysis found pending color was the main reason for color cut defects. It is required to revise BOM calculations.

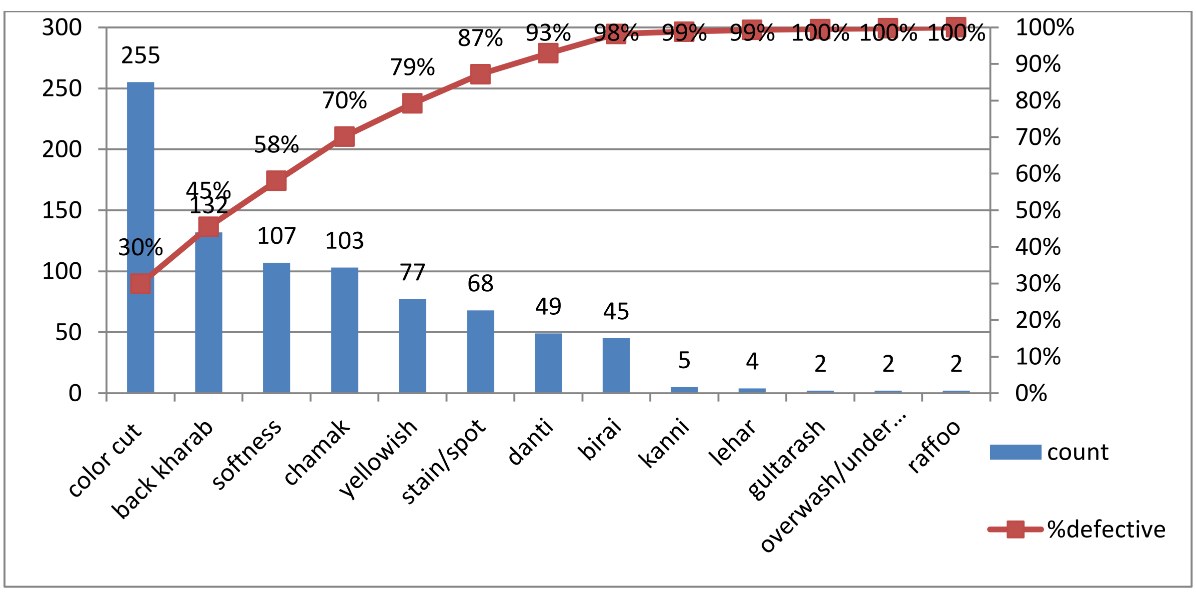


Figure 28 Calculation of major defects based on Pareto law

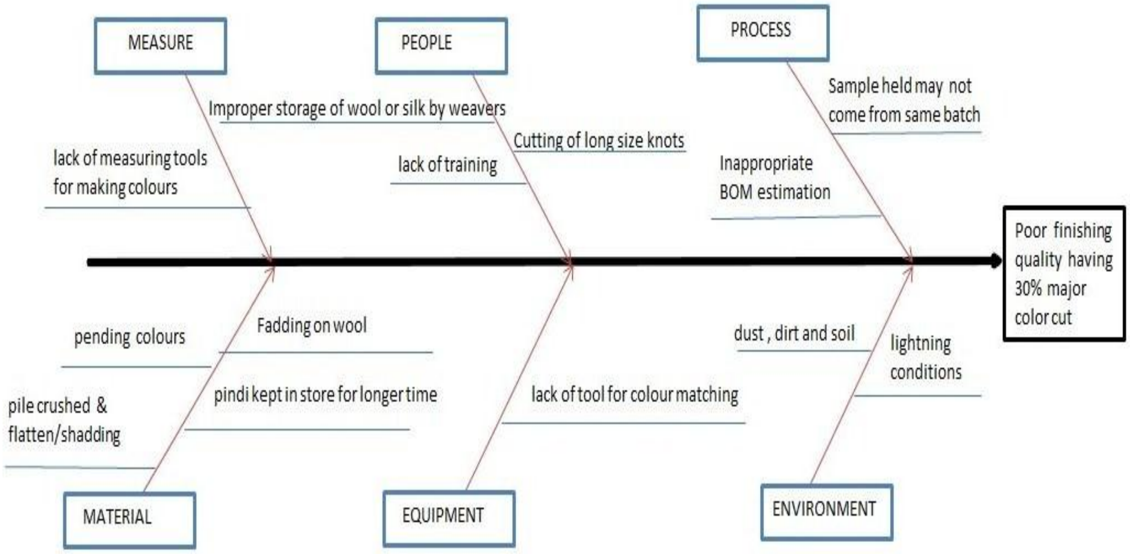


Figure 29 Root-cause analysis of major defect

4.4 Future State Value Stream Map

The previous part of this chapter gives a detailed description of current state map. The description indicates there are possibilities of improvements in the current process of carpet manufacturing. This section will deliberate some guiding questions about future state mapping along with the suggestions for improvement in the current process.

- What is takt time?

As discussed above, there are unpredicted and large variations in demands of carpet throughout the year. Takt time is time at which a product needs to be completed to fulfill the customer demand.

Demand/Week =816sqft, 1 Shift/day =9hrs

Tea Break =2 each 15min, Lunch break =30min, Net Available time =48hr/week

Takt time= Net Available Time/ Net Demand= (48*60)/816=3.53min/sqft

According to current situation company needs to produce 3.53 square feet per min in order to cope with demand.

- Finished goods direct shipping or supermarket?

Most of the carpets produced by ABC are customized. The customized carpets are directly shipped after finishing. The finished supermarket is required for make to stock type of carpets.

- Where to use continuous flow?

A continuous flow can maintain from weaving. It is possible to make one piece flow production from weaving. It is required to link material supply from local and global suppliers, design map from design department and priority list from sales department in order to maintain a continuous flow.

- Where supermarket?

A supermarket system with silk and wool would reduce the delivery lead time. However, it not economic to maintain the stock but company can make in-house dying plant to reduce the lead time. In order to deliver the product with large variation in demands, it is required to keep some inventory.

- Pacemaker process?

The process that sets the pace along the entire value stream is called a pacemaker process. It is usually near the customer end of the process flow. If products flow in FIFO or single piece flow sequence from an upstream process to the end of the stream, it can be placed in the upstream process. It difficult to identify the pacemaker process in carpets production, as work at each carpet varies. If the production at weaving end is scheduled on time the rest process could become continuous.

- How to level production?

As the current state analysis is based on product quality 8/8 HS WL, there is no requirement to level the production. But for all variety of products it required to level the production facility. It is required to plan the production according to sales data. According to employees and management, it is required to level load in finishing centers because of the large variation in finishing requirement.

- What improvements are needed?

To reduce the lead time of carpets production facility, various improvements in the current state are required. This part of the chapter describes key improvements related to the entire process. The following section focused on improvements requires rebalancing the current production processes.

- Align to takt time: To meet the future demands the company needs to produce 3.53 sqft in a minute and this frequency should be set for the entire production lines. In order to achieve this, we required providing a quick response to the unplanned or unpredicted problems in the value stream.
- Supermarket of dyed yarn or other raw material: In order to reduce the lead time significantly, it is required to have an inventory of some material in the work facility. This is pertinent to the dyed yarn that takes the time to come from vendors. It takes time in dying and drying.
- Stable delivery of finished carpets: As the facility will manufacture the carpets at a stable pace, the delivery of finished carpets will also be stable. If carpets are delivered in the right order starting from the order receiving, it can be delivered in a specified time when needed. It also decreases the handling time of the carpets within the production facilities.

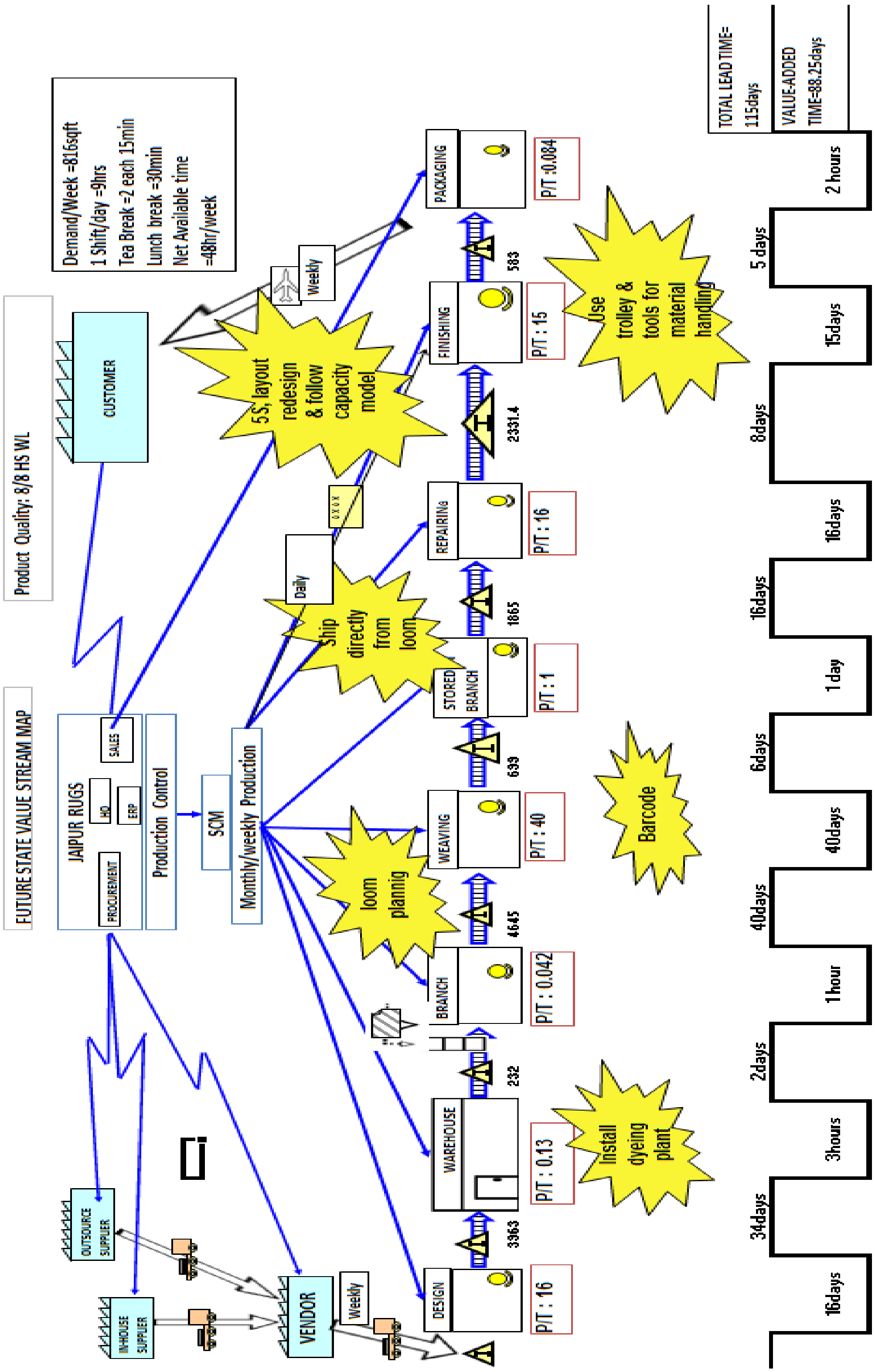


Figure 30 Future state value stream map

Improvements in process stream

During the observation, we found there are various possibilities of performance improvements within the process. Based on the discussion with employees and managerial staff the various changes are suggested. The improvements sets are as follows:

- **The quality of supplier material:** Quality of incoming raw material from various suppliers highly affects the quality and life of finished carpets. As the notably found color cut issue occurs due to variation in dyed yarn lot.
- **Clear and standard work instructions**: Most of the work is completed manually and there is variation in carpet defects, hence it is difficult to set work standards. The self-judgment and work experience can help to tackle these issues.
- **Place defected carpets closer to workstations:** Employees spend a significant amount of time to search and get the required carpets. Carpets placed in an unorganized way without demonstration of which carpet is where located. Carpets for specific work should be located closer to that particular workstation and they should be released only when they are required to their respective workstations.
- **Workplace redesign:** Currently all work areas are not aligned for a specific purpose within the value stream. This makes hard to find and locate the particular carpets. Specific tools should be designed to reduce the body force and fatigue. There should have sufficient waste bins to closely locate to the workstation to reduce cleaning time.
- **Capacity planning:** Due to variation in defects per carpet, it is difficult to align workers. The primary goal of capacity planning is to make production plans feasible to accomplish.

Conclusion of Future State VSM

- Figure30 depicts the future state map of the company. One of the major improvements decided upon by the company was to reschedule the transportation of carpets from finishing centers to Mirzapur by preparing the priority list parallel to weaving.
- Currently for the company color cut problem is a major issue among all the other defects. The approximate causes of this issue are incorrect BOM calculation, fading of color

or storage of wool for a longer time in the warehouse etc. As the dyeing process is outsourced; hence it is difficult to find the root cause of the problem. If the company sets its own dyeing plant, this problem can be tackled more precisely.

❖ Due to a lot of WIP and inventory, searching any carpet is a very tidy task. Use of barcode scanner can save the time and energy of workers and management both.

❖ Sometimes because of inappropriate BOM calculation or inappropriate processing the supplied raw material get finished before weaving the complete carpet. The branch has to reorder the stock from the warehouse. It consumes 3-4 days and even more in the case of unavailable stock at the warehouse. Keeping some safety stock at branch location is suggested as it can reduce the lead time.

❖ There is large manual material handling works which contribute to physical risks. These tasks are performed repeatedly for long periods of time. That can lead to wasted energy and time of employees. To eliminate these problems, it is suggested to use handling devices to improve the workplace. The approximate design of handling tool is also given.

4.5 Implementation of Suggestions

4.5.1 5-S

It was first used in the manufacturing industry of Japan. The word was introduced by Takashi Osada in 1980 (Gapp et al., 2008). This tool is used to improve work area efficiency by sorting the necessary and unnecessary items, arranging them to appropriate locations. The 5S in translated version stands for Sort, Systemize, Shine, Standardize and Sustain. 5S is a lean tool used for identification and elimination of wastes. Jaca et al. (2014) through multi-case study showed that 5-S gives motivation, loyalty, better space utilization & continuous improving practices. Better usage of working area, work process improvement, accidents prevention and proficiency is enhanced from 65% to 89% in the progressive weeks (Rojasra & Qureshi, 2013). 5-S has been identified as a very basic tool to implement and standardize lean processes in any industry by Gupta & Jain (2013). Using 5S one can get motivation, loyalty, better space utilization & continuous improving practices. It makes the work easy by placing the things in the right place. This also focuses on cleaning the entire workplace. The main objective is to check how the material is consumed every day. To carry out this a 5S check sheet was prepared. The main idea behind this was to assess the work area weekly and assign a rating on that basis. Here we divided each S in 3 to 5 basic questions to make a clear understanding.. Implementation of 5S in the case organization leads to improvement in the usage of the work area, time reduction in carpet searching, awareness about housekeeping among employees and management and prevention from carpet rusting. It also segregates the carpet based on their priorities as shown in the Figure 33 below.

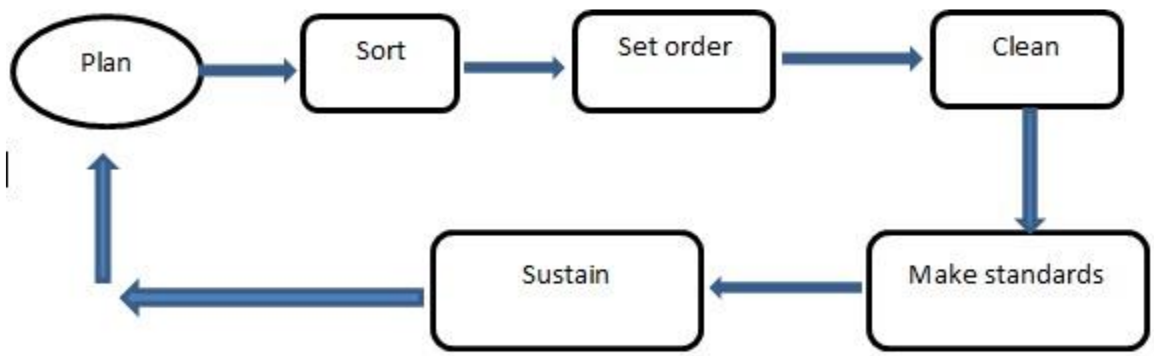


Figure 31 5S flow chart

Figure 32 Raw material and carpet stock before 5S implementation

Figure 33 Carpets and raw material housekeeping after 5S implementation

Figure 34 Carpet segregation based on priority list

Different tags of various colors are attached to carpets. The tags include basic carpet details helps in identification of carpets to anyone on floor. A different color tag and separate floor space are used for urgent carpet pieces to make them clearly identifiable. To assess the improvement in current environment a 5S rating sheet was prepared as shown below in the Table 7. The rating is given every week to each S out of given 5, then a graph is plotted to show the efficiency improvement every week.

Table 7 5S rating sheet for finishing area

6S Area:[ABC]		**Item Scored**	
		Week1	**Week2**
Sort	**Distinguish between what is needed & not needed**		
	All unnecessary items have been removed		
	Identify defective pieces		
	Procedure exist for removing unneeded items		
	Waste identification Rating		
	Walkways, work areas, locations clearly identified		
Set in order	**A place for everything and everything in its place**		
	There a place for everything		
	Everything in its place		
	Locations obvious and easy to identify		
	Space utilization		
	Carpet arrangement Consistency Rating		
Shine	**Cleaning and looking for ways to keep it clean**		
	Work areas, equipment, tools, desks clean		
	Cleaning materials available and accessible		
	Cleaning schedules exist		
	Cleaning Consistency		
	Accident Rate		
Standardize	**Maintain & Monitor for adherence**		
	All necessary information visible		
	All standards are known and visible		
	All visual displays up to date		
Sustain	**Following the rules to sustain**		
	Procedures being followed		
	An on-going audit and feedback system exist		
	A system exists to respond to audit feedback		
Total Score			
Evaluator's Name:			

Table 8 5S rating of 10 weeks

Week	**Total Rating (1s)**	**Total Rating (2s)**	**Total Rating (3s)**	**Total Rating (4s)**	**Total Rating (5s)**
Week 1	3.2	3.15	3.35	3.5	3.6
Week 2	3.4	3.35	3.5	3.7	3.7
week 3	3.6	3.6	3.7	3.82	3.8
week 4	3.7	3.7	3.8	3.8	3.7
week 5	3.9	3.8	4.1	4	3.8
week 6	4	3.9	4.36	3.9	3.9
week 7	4.1	4.1	4.14	4.2	4.3
week 8	4.24	4.2	4.21	4.2	4.3
week 9	4.4	4.3	4.4	4.44	4.5
week 10	4.5	4.5	4.5	4.4	4.5

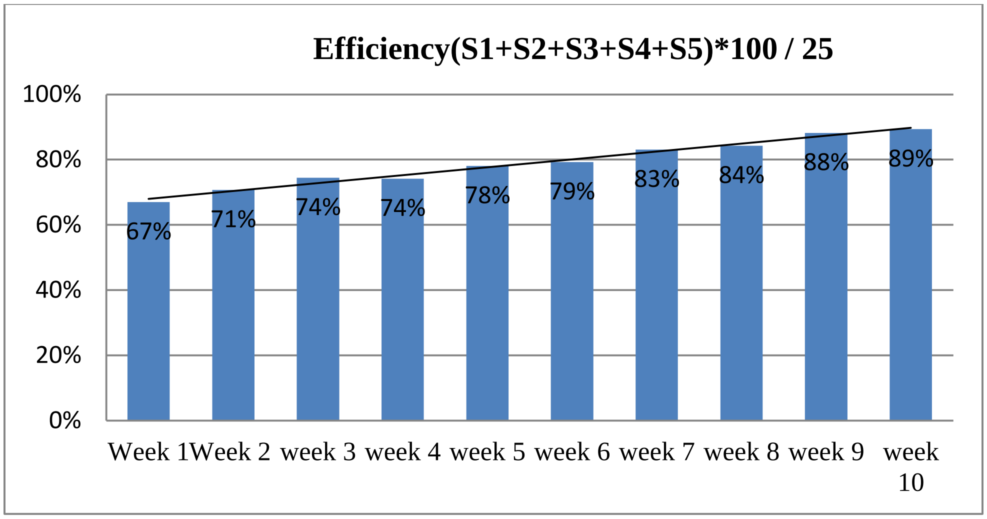


Figure 35 Graph describing 5S rating increment

The purpose of 5S implementation in carpet industry was performance improvement as it helps to minimize all non-value adding activities. This tool helped in carpet identification and priority based arrangement of carpets. The check sheet helped in rating the work area every week. The graph shows the continuous improvement in efficiency from 67% to 89%. Implementation of 5S helped in establishment and management of a better and organized workplace. Clean and organized workplace helped to keep employees motivated and enthusiastic towards improvement.

4.5.2 Capacity Planning

To reduce WIP and to utilize all resources efficiently, many companies are focusing on capacity planning. Using this technique company can also increase the possibilities to respond demand fluctuations. The purpose of this study is to find the gap between current situations without an organized capacity planning and observe the results of a planned model. By developing the model, company can develop an approximate idea about the utilization of manpower during fluctuations in demand and thereby sustain competitiveness. The objective of this work is to identify the problems in company's current capacity planning process and its relevant factor. Another objective is to find the solutions that can be applied in the current scenario.

Objectives of capacity planning

The primary objective is to increase flexibility in the current production process. It can be achieved by estimation of enough capacity requirements to be able to match with available capacity in future. As the resources are associated with costs, the capacity planning has a considerable influence on company's economic conditions. There must be a balance between available and required capacity. If availability overcomes the demand, this will lead to overcapacity and results in less resource utilization. Besides if manufacturer lacks availability it cannot achieve the targets and thus experience ultimate loss. Generally, the capacity imbalance can be observed in the companies where large demand fluctuation exists.

There are two strategies for capacity utilization: level strategy and chase strategy (Jonsson & Mattsson, 2009). In a level strategy to chase demand variation companies produce items according to aggregate demand without varying the existing capacity. The level strategy could results in excess inventory, subcontracting and back orders to fulfill the demands. While in chase strategy companies produces the goods to meet or exactly match the demands. Chase strategy could result in hiring and layoff of employees to meet organizational goals.

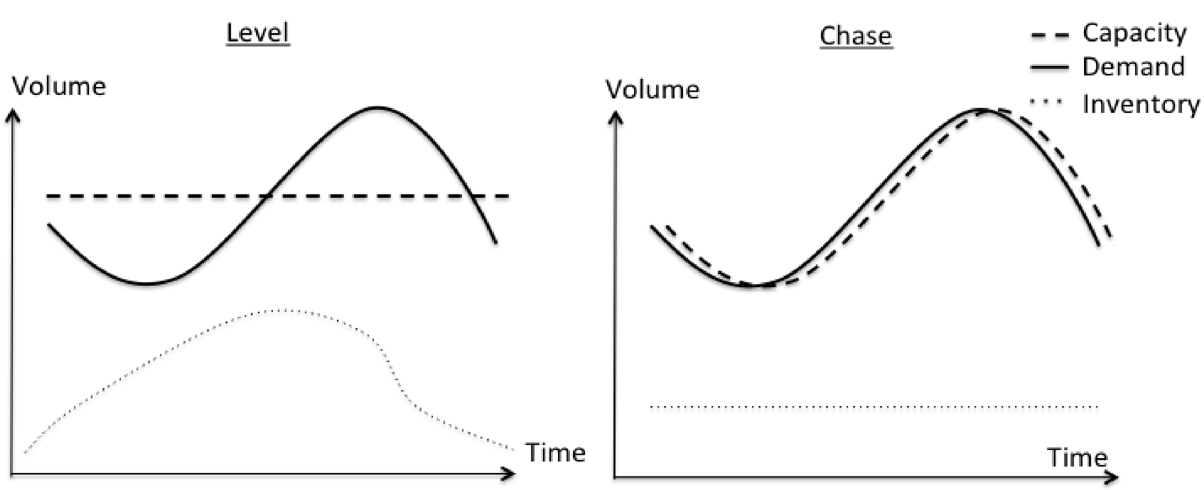


Figure 36 Level strategy and chase strategy (adopted from Jonsson & Mattsson, 2009)

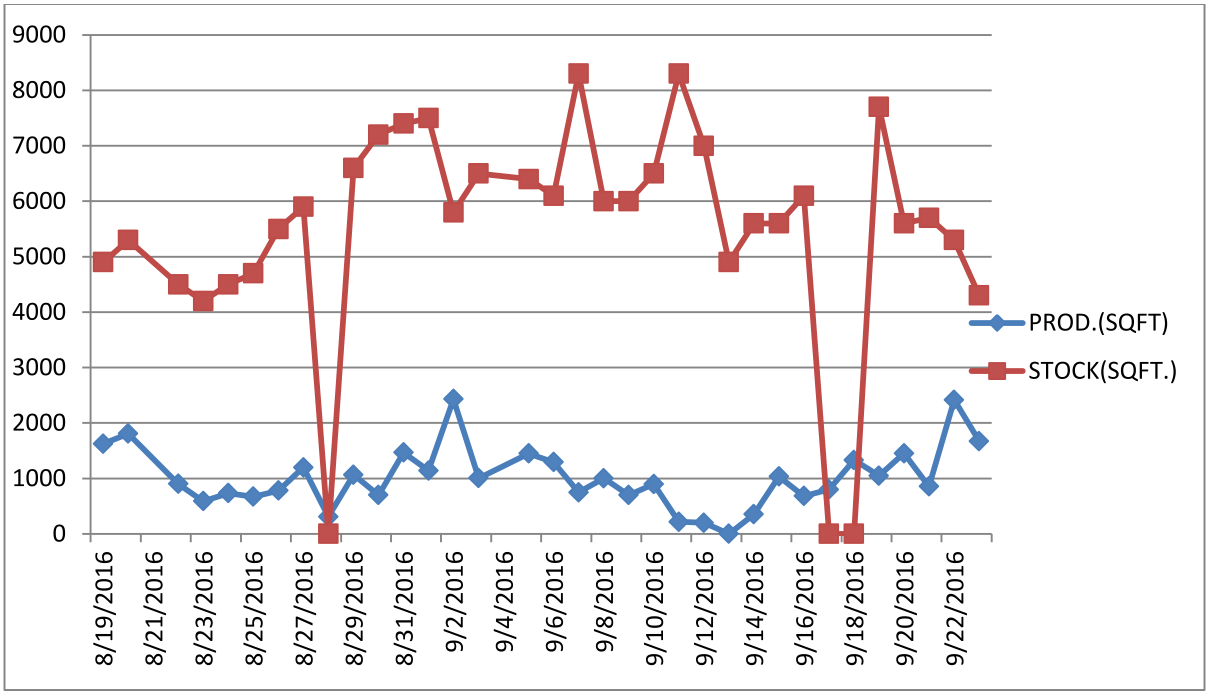


Figure 37 Weekly production and weekly inventory at color cut area

- **Conditions affecting planning**

There are a number of aspects that are important to consider during capacity planning. Some of these factors are as plant layout, manpower, manufacturing techniques, market demand and lead time. The production layout affects the capacity plan. All the major processes are shown in the layout of the company. An efficient production system requires a certain production layout. The layout represents the number of decision points. Decision point is the location where we need to locate the manufacturing resources optimally. The floor orientation and movement within the floor affect the manufacturing operations.

Figure 37 shows the weekly production drawn by blue line and weekly inventory drawn by the red line in the color cutwork area. There is a large difference between the requirement and availability of manpower. It becomes difficult to satisfy the demand in takt time. It is necessary for the case organization to re-plan their capacity management.

- **Structure of capacity plan**

Notations:

i = no of workstations

A_i = Actual production on lead time at workstation i

T_i = Target production on lead time at workstation i

OT_{Ai} = Available manpower for overtime at workstation i

OT_{Ri} = Required manpower for overtime at workstation i

Figure 30 shows a flow chart that demonstrates the new capacity plan model. The capacity plan model is prepared for one workstation on a particular floor but this model can be generalized for other workstations too. This model is based on quantitative analysis and gives a rough idea about manpower requirement during demand variation. The whole calculations are based on the previous data collected during observation period. The case organization is traditional carpet-making industry, where production is mapped in terms of square feet. The repair and finishing requirement varies in each carpet. So for such organization, it becomes difficult to define the standard capacity requirement. Currently, management shifts the available manpower to different workstations to tackle the demand variations. The flow chart in figure 38 illustrates the possible alternatives to complete the production on lead. And the most suitable alternative can be adopted as per the requirement. The top management has to prioritize all alternatives according to the sale and economic feasibility. These analyses are based strongly on previous data. So a real time-based data management system can help to plan more accurately. ERP systems are becoming a powerful tool that can assure the capacity planner. But there are some challenges in ERP system along with flexibility that a planner needs to know. Some of these challenges are technical issues, data quality, scope, type, size of system and problem selection.

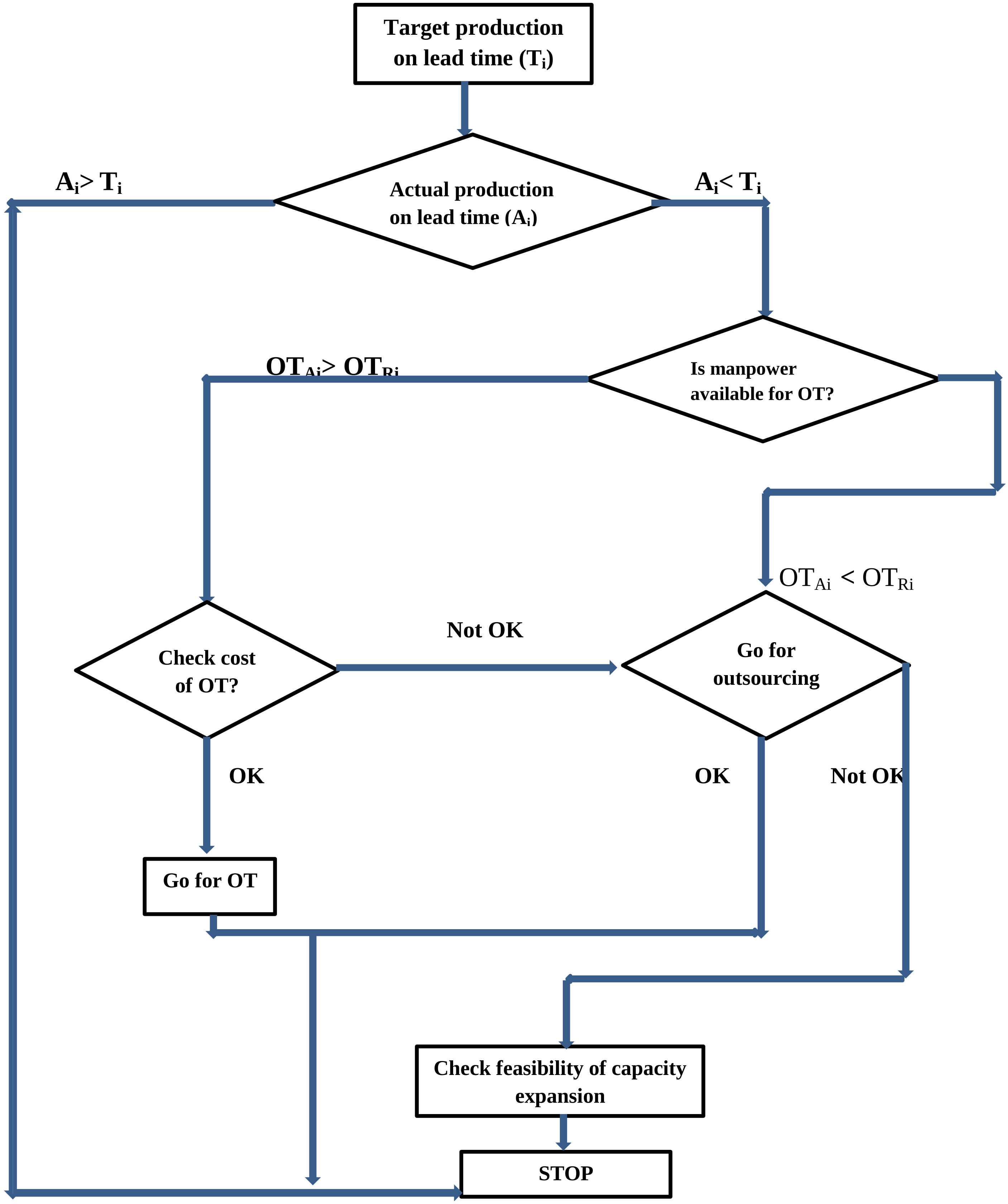


Figure 38 Capacity planning flow chart

Table 9 Capacity plan model

Color Issue		High-Low Area	
Sq.ft production	44132.2	Sq.ft production	4538.9
Man hours	968	Man hours	2432
Actual Man hours	1161.6	Actual Man hours	2918.4
Target Production+WIP	10000	Target Production+WIP	10000
Target lead time	15	Target lead time	15
Required man hours	263	Required man hours	6430
Daily man hours required	18	Daily man hours required	429
Hours worked	8	Hours worked	8
Manpower required	2	Manpower required	54
Per hr output per person	37.9926	Per hr output per person	1.55527
Required man hours	263.209	Required man hours	6429.752
Available manpower	2	Available manpower	10
Total working days	15	Total working days	15
	30		150
Daily required man hours per person	9	Daily required man hours per person	43
Shortage man hours	-2.23	Shortage man hours	31.87
Man hours required in OT	23.2092	Man hours required in OT	5229.752
Number of man for OT	2	Number of man for OT	30
Available hours	4	Available hours	4
Available OT man hours	120	Available OT man hours	1800
Percent	0.19	Percent	2.91
Person required in OT	5	Person required in OT	10
Sq. ft. to be Outsourced	0	Sq. ft. to be Outsourced	0

The study suggests a generalized capacity planning model that can be used in any manufacturing sectors. The suggested model is implemented in case organization. The model helps to give the basic idea of capacity requirement during demand variation. It also provides two alternates as overtime and outsourcing (as per the feasibility) to achieve the targets on takt time. The model also highlights the importance of strong ERP systems for real-time data tracking. The ultimate goal of optimum capacity utilization is to maximize the utilization of manpower and other related resources.

4.5.3 Facility Layout Redesign

This section of the chapter presents the design of production facilities layout by considering space utilization, motion reduction, and less material handling. Facility layout refers to the systematic arrangement of facilities in order to achieve least material handling. It is necessary to consider all processes within the functional area while designing plant layout. The designer must include flexibility for future expansion along with current needs (Kadane & Bhatwadekar, 2011). It is an important factor that has a major impact on productivity improvement. The logical orientation of facilities can enhance the efficiency of the plant, decrease waiting time and contribute to cost reduction. The optimum facility layout fulfills following objectives:

- Reduce distance between each facility
- Reduce distances across the workstations
- Reduce material movement within and across the workstations
- Reduce operators movement on the floor
- Reduce energy and cost consumed in excessive movement
- Allocate each resource efficiently
- Reduce queue length and waiting time

Based on the literature we observed there are various techniques to design layout. It can be divided into two categories based on optimization degree; heuristic techniques and optimal techniques. Optimal techniques are used to obtain the exact solution of the model, while heuristic algorithms give near approximate solutions. Misola & Navarro (2013) developed a mathematical model to optimize the distance between different workstations using a genetic algorithm. They used the swapped crossover technique to generate optimum result. Liu & Liu (2013) developed mixed integer programming model to optimize the logistics movement in a shipbuilding industry. They used PMX crossover algorithm in place of traditional crossover. Azadivar & Wang (2000) used suitable string structure to show each facility and analyzed it by genetic algorithm. They integrated simulation model and genetic algorithm and provided a convenient interface for users. De Carlo (2013) developed the facility layout design method using systematic layout planning techniques using relationship chart.

- **Current layout**

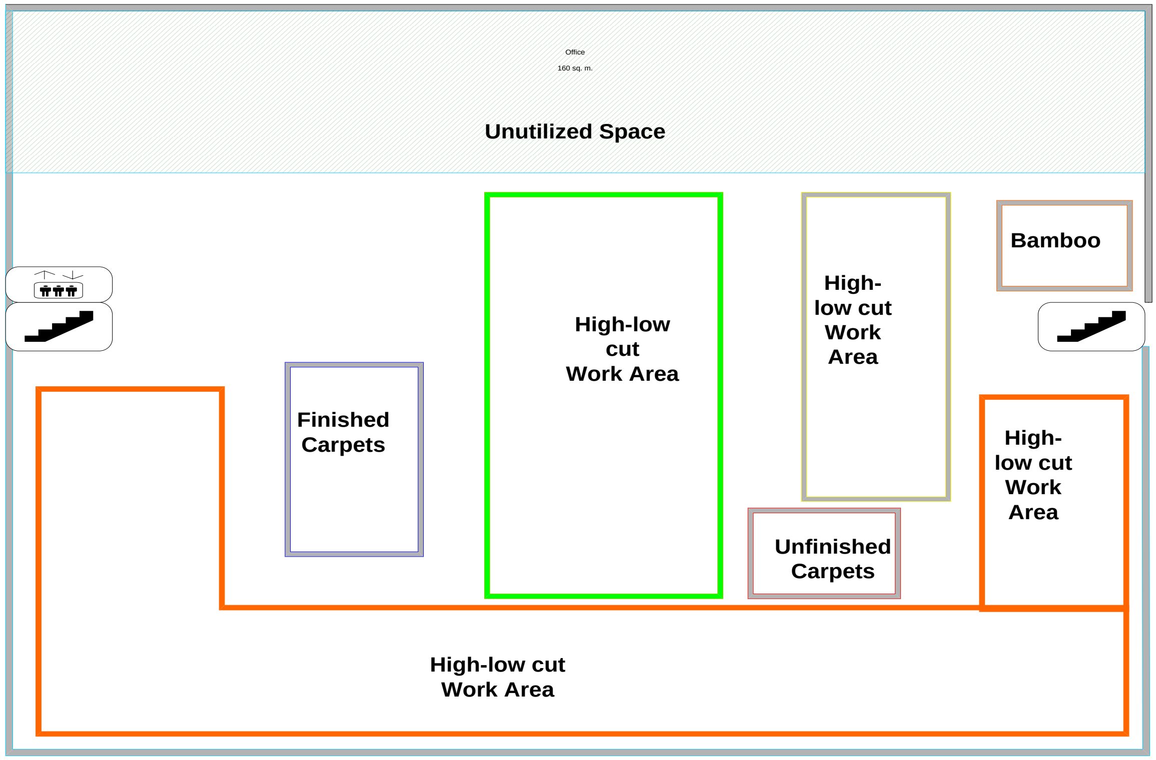
As carpet size varies with quality, the facility area also varies based on carpet size. We have designed facilities for maximum carpet size that is 14*14 square feet.

- **Work area improvement**

Current layout represents the layout of the various floor of finishing center. High-low work area is on underground floor, aligning area is on the ground floor, showroom area is on the first floor, and final washing area is on the rooftop. Some of the points noted during observations are as follows:

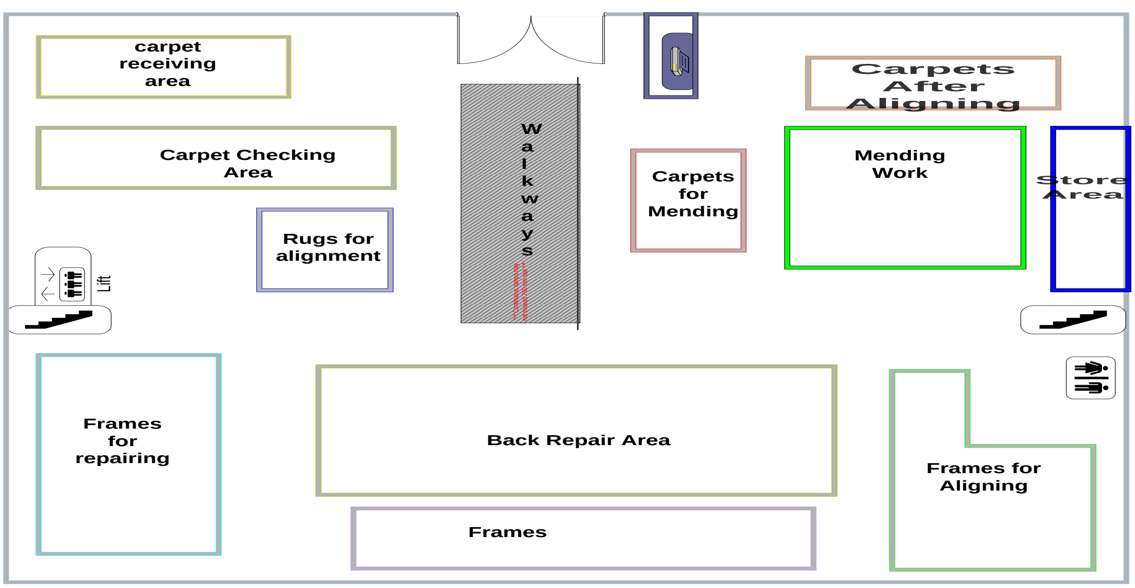
- ❖ Floor arrangement based on major buyer code that helps to reduce the search time and thus save energy and time.
- ❖ A separate location for urgent carpets that has least lead time.
- ❖ The Pile separating area is very dusty because particles of cotton circulate continuously in air.
- ❖ The bins are required to be placed near each facility to maintain the cleanliness.
- ❖ We can reduce movement in final dumping process by constructing a duct.
- ❖ Preplan of direct movement of carpets to finishing centers can save time and cost of transportation.

Existing layout of various facilities at carpet finishing centers is given in Figure 39, 40, 41 and 42.



HIGH-LOW CUT FLOOR LAYOUT

Figure 39 Current high-low cut floor layout



ALIGNMENT AREA LAYOUT

Figure 40 Current alignment area layout

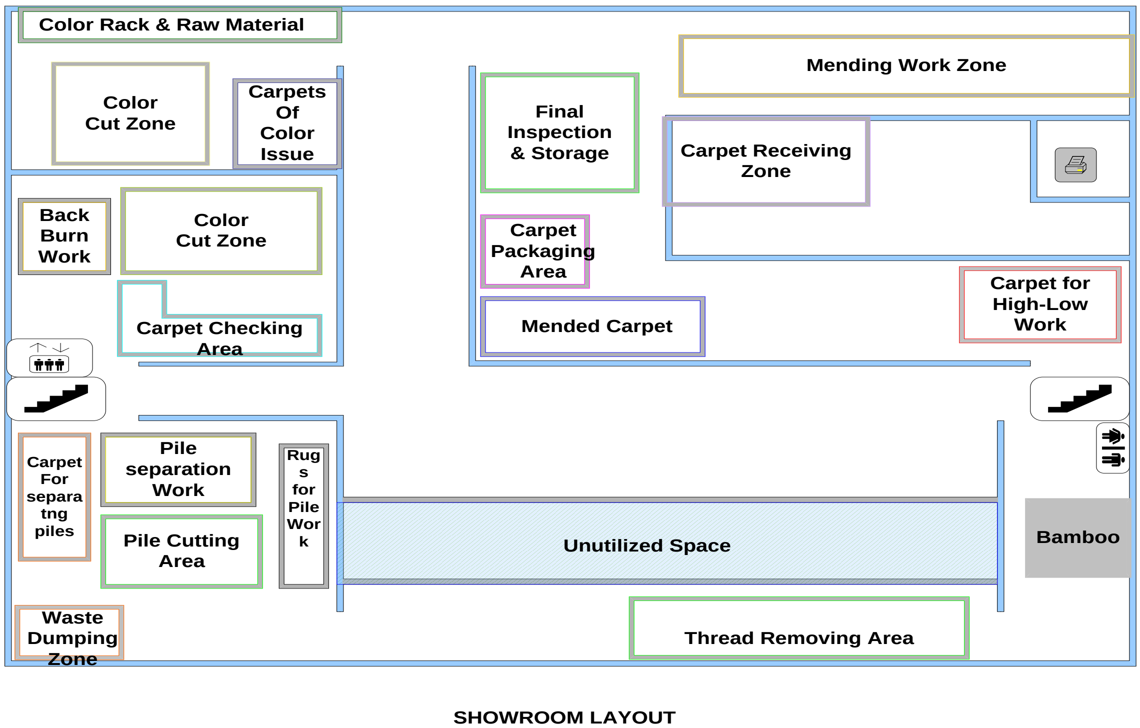


Figure 41 Current showroom area layout

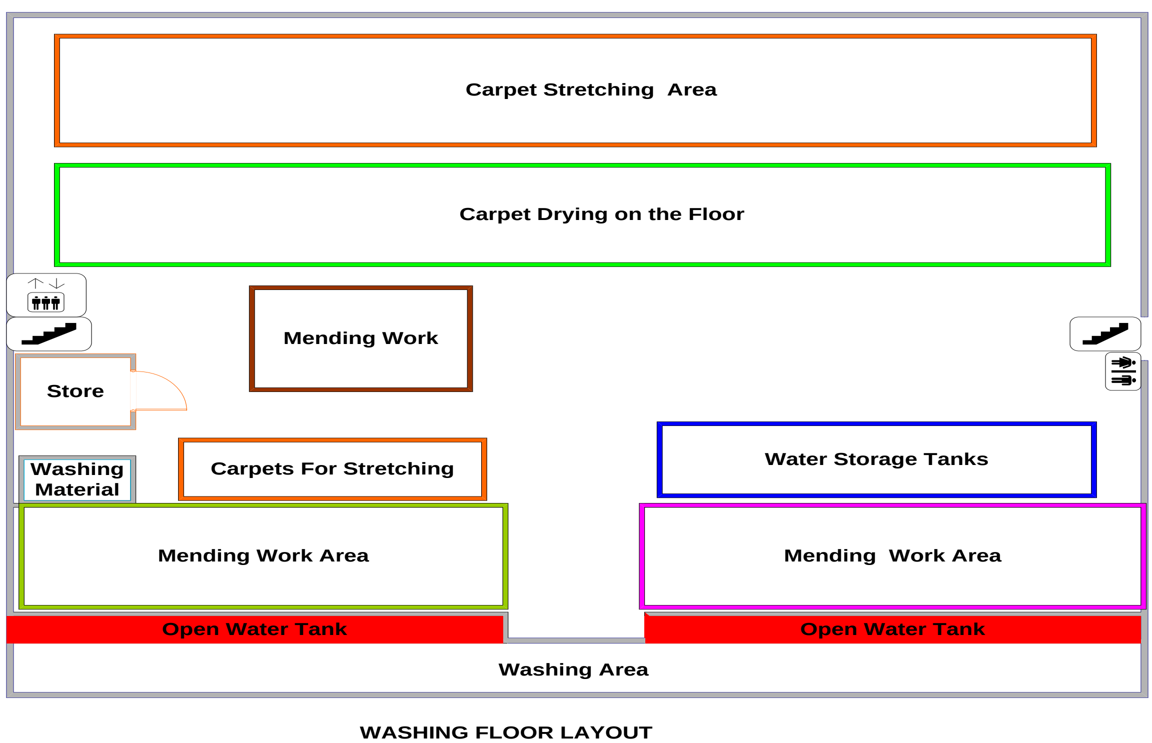


Figure 42 Current washing area layout

- **Implementation**

All the workplace area is equally separated in both sides of the floor. There is a separate location for urgent pieces of finished and unfinished stocks. This work area is located on the ground floor where the natural light doesn't avail, so the arrangement of proper lighting is one of the major issues. The work area is very dusty due to cotton piles, it is required to give strict instructions keep and wear mouth dust filter. High-low work is done by simple scissors continuously that causes hands strain to workers. The case organization required to focus on ergonomic design of hand tools for work improvement.

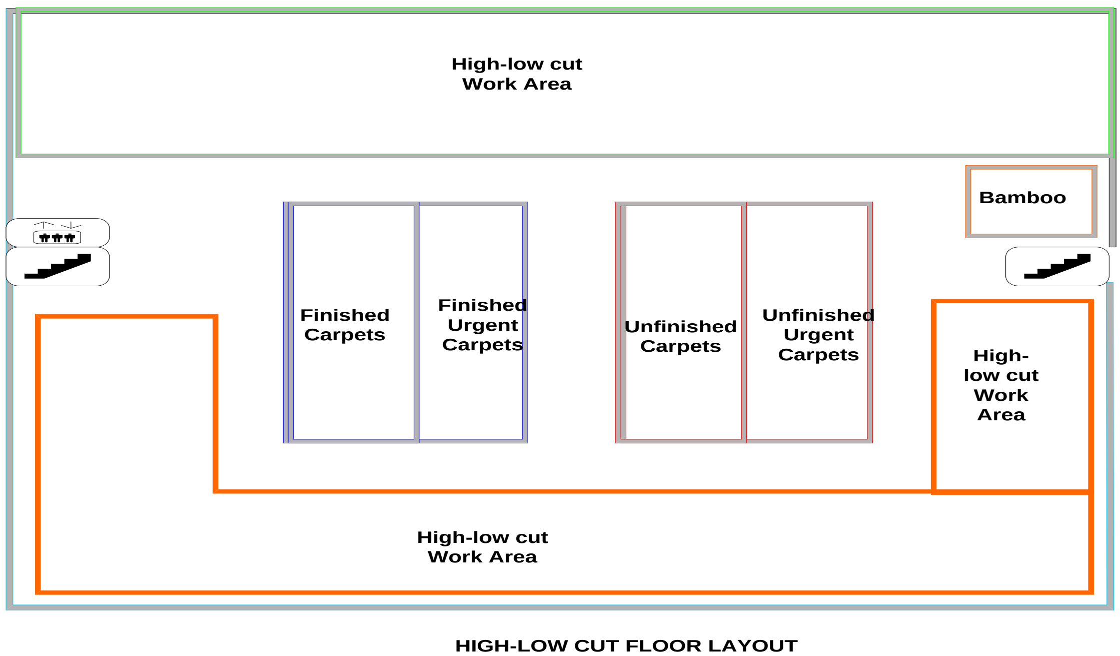


Figure 43 Proposed high-low cut area layout

Implementation of 5S helped to segregate and place the carpets to particular locations. The defined orientation of carpets and WIP helped in reducing unnecessary movement of material. After checking process carpets are placed closer to the lift for easy movement of carpets from one floor to the other. For internal movement use of trolley and for lifting use of simple lifting tool is suggested. Trolley and tools are not very costly while it helps in relieving the workers from excessive fatigue and stress.

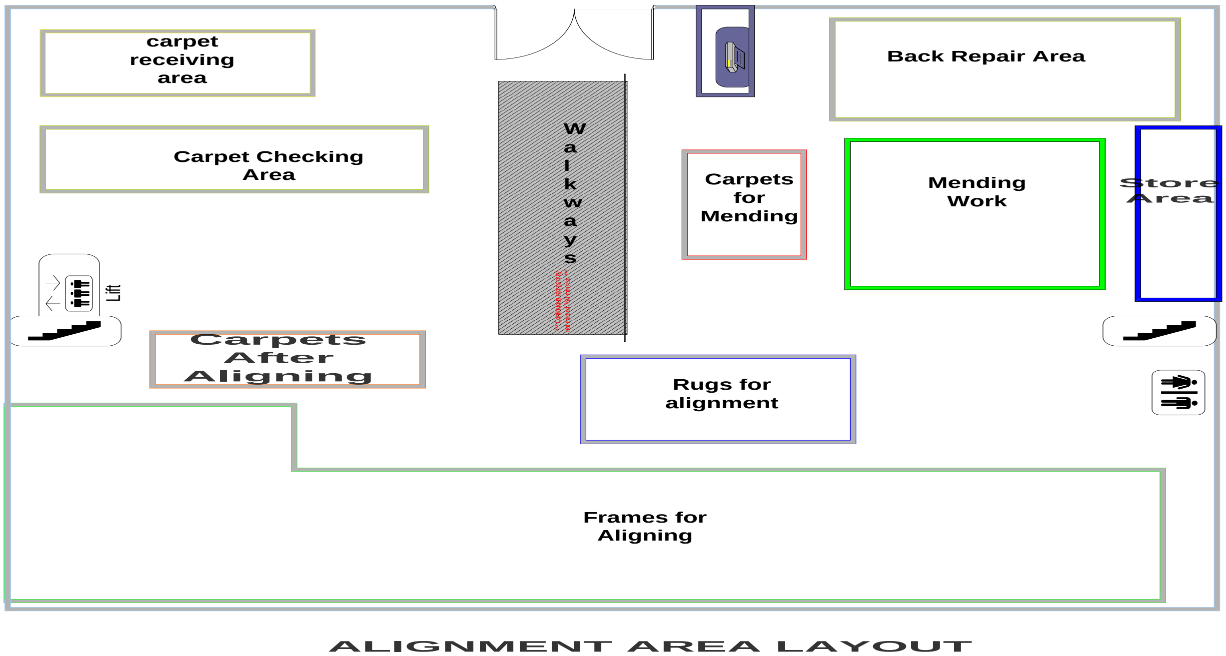


Figure 44 Proposed alignment area layout

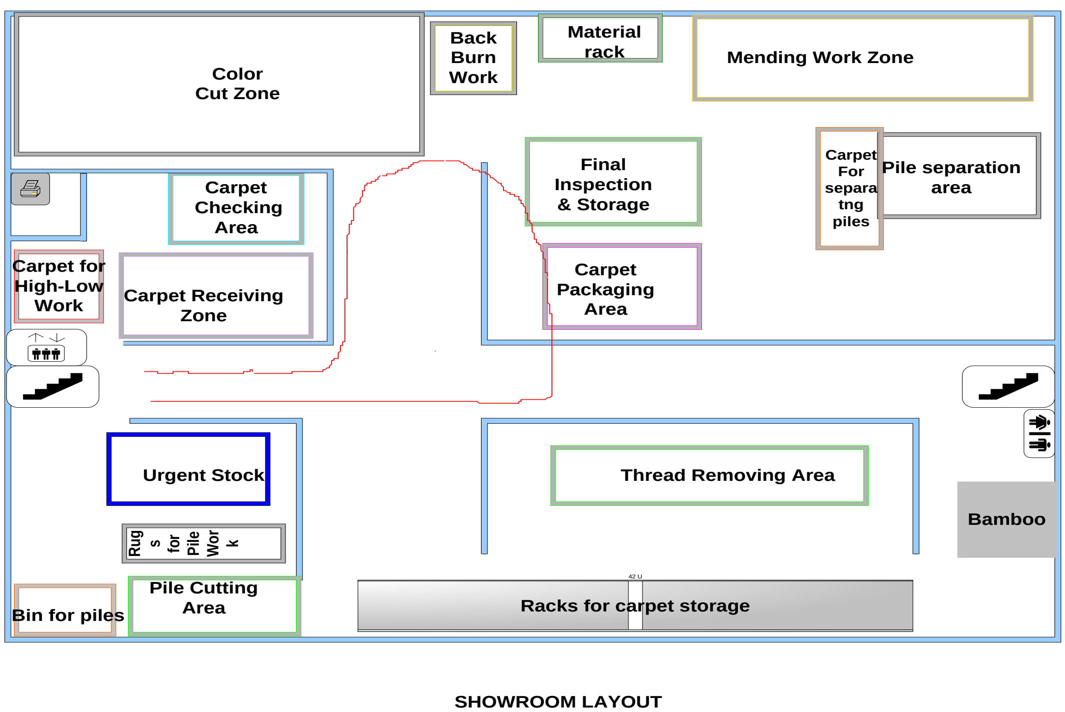


Figure 45 Proposed showroom area layout

In showroom area, the layout arranged is in such a way that the difference between the incoming and final outgoing carpet is minimal. The flow of layout is arranged according to the flow of the process. Carpet receiving facility is located closer the lift. Colour cut, and back burn facility are in similar work zone. So they are placed closer to each other. Pile removing area is located at corner side, so that the circulaton of dust can be minimised.

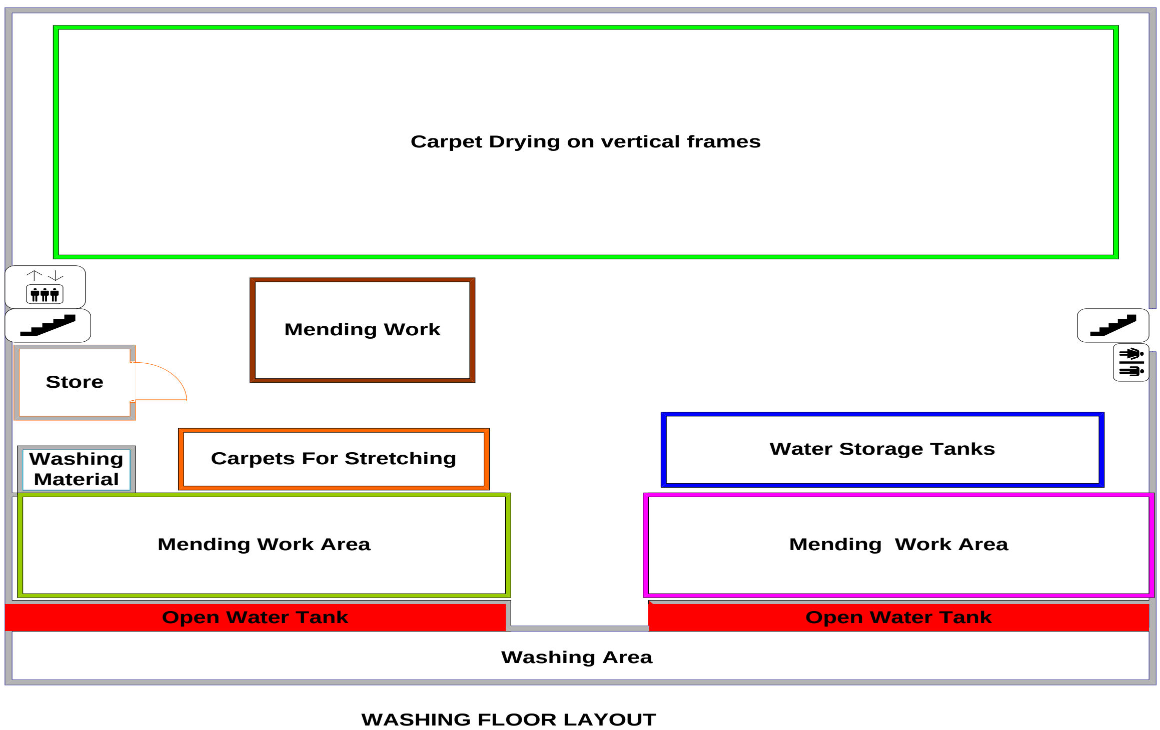


Figure 46 Proposed washing area layout

The dustbin is placed at each facility for collection of dust on daily basis. To save carpets from rusting and for easy handling of carpets. It is suggested to arrange racking system to store carpets for lng periods. In comparison to other floors the showroom has maximum numbers of facilities, hence the internal material movement is maximum. So the material handling tools are necessary to reduce the efforts needed to perform the work. Manpower can be utilised for actual value addition work.

Figure 47 Carpet arrangement based on requirement

In washing area, the case organization is using horizontal stretching or drying frames. There are currently eleven frames in washing area. The maximum capacity is restricted due to this orientation. In winters and rainy season it becomes a tedious task as a carpet can take more than a day to dry. The vertical frames can be helpful in set up arrangement and capacity enhancement.

CHAPTER 5

CONCLUSION

5.1 Summary

The purpose of this study is to implement lean tools in a manufacturing industry to improve the processes and to respond customer demands more competently. Literature review suggested that idea of lean implementation is not new in manufacturing industries. Various case studies in manufacturing and service industries showed that implemetation of lean tools gave desired results.

Different lean tools and their implementation method have been described in details. Wastes have been identified in trasportation, material handling, weaving, washing, dye making, workers' motion, inventory management, manpower utilization, and space utilization. Depending on the type of manufacturing process and identified wastes, some of the lean tools have been implemented which are VSM, 5S, kaizen, kanban, and production leveling. The 5S method was implemented on the finishing centers of the case organization while the current and future state VSMs were prepared for a unique product family selected by Pareto analysis. Observations, interaction with workers and executives, and database of ERP helped in collection of data for the entire value stream. Finishing center has been identfied as bottleneck area. A roadmap to implement lean tools for process improvement was formulated.

Comparison of current and future state VSMs highlights the potential improvement in process parameters such as lead time reduction, WIP reduction, space utilization and proper housekeeping. Revised facility layout will help in reducing excess motion of workers. Trolley and carpet lifting tool have been suggested to reduce material handling time and cost. A model for capacity planning has been proposed to analyze the capacity utilization. The model will help in manpower reallocation during demand variations.

The implementation of lean tools has resulted in reduction of lead time by 15 days, improvement in housekeeping from 67% to 89%, better usage of work area, improvement in capacity planning, less effort in carpet identification, decrease in material handling time and cost, improvement in employees' morale and awareness and increment in overall profit of supply chain.

5.2 Limitations

The study has some limitations too. The selected case study of a single company limits the generalizability of the results to other sectors. Implementation methods are not standard but inspired from literature review and self-made observations. Observations covering diverse similar organizations with several lean implementation methods can offer more comprehensive results in current case organization. Data collected from interactions with workers and executives may be less reliable than that from ERP database and observations.

5.3 Future Scope

Carpet industries are important for the Indian economy as it provides foreign exchange to the country. Researcher and practitioners should start to focus more on implementation of lean philosophy in these industries. Researchers should start the development of standard methods for lean tool implementation. A framework should be prepared that can grade the 'leanness' at initial state before implementing lean. This allows setting benchmark between the proposals. As the carpet industry is associated with manual jobs, so there is strong requirement to design tools ergonomically to relieve physical and mental stress.

5.4 Generalizability

The implemented lean tools can encourage various companies to become more responsive and productive. The other important factor of this study is the results can be generalized to other manufacturing sectors. As there is very less research available in carpet industries, so the results discussed in this study can set the benchmark for other carpet industries which have low volume large varieties and where manual work is prominent. The research contribution is also relevant for academic purposes. To analyze the critical success factors of lean implementation, it is required to have a thorough discussion on lean implementation methods. The work presented in this study is strongly relevant for future research on carpet industries with manual activities. The study presents the potential improvements in the current situation by implementing lean tools. The proposed improvements can improve the lead time and reduce wastes at limited investment.

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