AN APPROACH TO REDUCE THE MANUFACTURING WASTE AND IMPROVE THE PROCESS CYCLE EFFICIENCY OF A FOOTWEAR INDUSTRY BY USING LEAN SIX SIGMA MODEL

BY

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ABSTRACT

This study was a case analysis of lean tools and six sigma methodology implementation in shoe production lines of “X” footwear industry in Bangladesh. This work addresses the implementation of lean tools and six sigma methodology in the observed shoe production lines in order to evaluate present Process Cycle Efficiency (PCE), Takt time, Value Added (VD) and Non Value Added (NVD) activities, lead time, comparison of footwear industries various parameters in different countries and finally to develop an improved strategy to bring the improved PCE, Takt time and to reduce the lead time and NVD activities. Value Stream Map (VSM) and Pareto analysis were applied to evaluate the present and future state PCE and to find out the NVD activities. By this study the present state PCE of Derby, Casual, Court, Oxford, Boot and Moccasin shoe production lines were found consequently as 11.32%, 15.28%, 8.32%, 8.01%, 10.68% and 12.20% that could be 25.60%, 34.05%, 19.46%, 18.84%, 24.45% and 26.91% after the implementation of lean tools and SS methodologies within present production system. It is expected that after the implementation of lean tools the existing lead time of Derby, Casual, Court, Oxford, Boot and Moccasin shoe production lines could be reduced consequently by 55.78%, 55.09%, 57.23%, 57.44%, 56.28% and 54.64%. By this study an economic benefit is also evaluated where it is expected that after the proper implementation of lean tools and six sigma methodologies the total economic benefit would be 1206224160 Tk. or 1.2 billion USD per year. After all the production flow was optimized by minimizing several NVD times such as bottlenecking time, waiting time, materials handling time, etc. towards a lean environment establishment in management system of the studied “X” footwear industry in Bangladesh.

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LIST OF ABBREVIATION

LM= Lean Manufacturing

SS= Six Sigma

LSS= Lean Six Sigma

SSQ= Six Sigma Quality

AM= Agile Manufacturing

DFSS= Design for Six Sigma

DMADV= Define, Measure, Analyze, Design, Verify

DMAIC= Define, Measure, Analyze, Improve, Control

RDMAIC= Recognize, Define, Measure, Analyze, Improve, Control

DPMO= Defects Per Million Opportunities

EPA= Environmental Protection Agency

GDP= Gross Domestic Product

GE= General Electric

JIT= Just In Time

MDG= Millennium Development Goal

SDG= Sustainable Development Goal

MIT= Massachusetts Institute of Technology

VD= Value Added

NVD= Non Value Added

PCE= Process Cycle Efficiency

TPS= Toyota Production System

TQM= Total Quality Management

VSM= Value Stream Map

WIP= Work In Process

CHAPTER 1
INTRODUCTION

1.1 Context and Motivation

The world is very competitive where the basic concern of manufacturing companies is to increase their customers' satisfaction by constantly improving their delivery yet to keep quality at its best level. At the same time, the companies need to keep their costs and prices as low as possible to be able to compete with others by keeping their profitability. In order to achieve this, a company should have a very good control on its production systems. From previous study it is revealed that vision is as important as action to have the best control on the production system. A company should have a strong vision and clear idea of its future goals to establish the most effective production system. Lean philosophies, which were initiated in TPS are seen as bring the revolutionary change in the mindset of manufacturers in the search of quite protection with its effects to the actions as well as to the visions [1].

In the last century the main focus of any company was the customers. Due to global competitive business, customer's satisfaction has become more and more competitive to manufacturers lead time is defined from the time a customer release an order until the time they receive the finished product [2]. Consequently, to execute the business in a global market short lead times become the essential key to provide customer satisfaction. Organizations that have focused on cycle time as a productivity measure can reduce delivery time and improve quality, thereby creating more satisfied customer.

Before 1980, customers tolerated long lead times which enabled producers to minimize product cost by using economical batch sizes. Later, customers began to demand shorter lead times and searching the alternative producers, where they were able to get their product or service earlier. This is when the problem arose and companies started to look for changes to be more competitive. As soon as manufacturers focused on processes, they found waste associated with changeovers, quality defects, process control, factory layout and machine down time. In an attempt to reduce lead time, businesses and organizations found that in reality 90% of the existing activities are non-essential and could be eliminated. So they tried to find ways to reduce or eliminate waste. By eliminating the NVD activities from the processes and streamlining the flow of value towards the finished products and services significant optimization results can be realized [3].

To compete with the international company, the manufacturing waste would be reduced by keeping the improved PCE. Consequently with the endeavor of a number of reverent personnel, several number of new philosophies for manufacturing improvement have been developed, which include LM, SS, AM and DFSS. Lean tools and SS would be potentially effective to reduce the lead time and increase the PCE. Lean manufacturing is a generic process management philosophy derived mostly from the TPS in the 1990s and identified as "Lean". The implementation of Lean tools is focused on getting the right things to the right place at the right time in the right quantity to achieve perfect work flow, while minimizing the waste [4].

Footwear industry is a booming and one of the largest manufacturing sectors in Bangladesh. In the World it is the leading manufacturing industry. Based on raw material, geographical condition and work force, Bangladesh is highly favorable for the growth of footwear industry. The demand of processed footwear is rapidly increasing in the busy World and consequently it seems a rapid expansion of footwear industry in Bangladesh as like as other countries. It needs several processing steps to produce the finished goods from raw materials. The delay and manufacturing wastes is the common seen at every processing unit of footwear industry and thus the efficiency of production is very low with long lead time. In this regard to minimize and remove NVD time and works the author was invigorated to apply the Lean tools and SS in one of the largest footwear production industry X of Bangladesh.

1.2 Origin of Lean Philosophy

Empirically lean thinking and lean enterprise started in Japan with the attempts of the Toyota Motor Company to become a promising leader in the auto mobile manufacturing business thus surpassing American companies like Ford or General Motors. The concepts and principles of what later was going to be known as the lean enterprise model that had demonstrated their convinced effect in the auto industry in Japan where were later researched and documented by members of the International Motor Vehicle Program at the MIT. Based on the results from that research the landmark book 'The Machine that Changed the World' was published in 1990. The book extensively covered the principles and practices of TPS where lean philosophies were successfully applied to the production of cars and compared those with the more traditional methods of American and European companies. A remarkable change was required to regain competitiveness in the World market and the lean production model and its subsequent lean enterprise was the answer to that required change.

It was soon reasoned that the same methods were applicable to other industries and businesses as well. One of the most important movements towards lean implementations was done by American aerospace industry a highly competitive and complex business environment. MIT's Lean Aerospace Initiative a joint effort of the industry, government and academia was created almost a decade ago to respond to the lean implementation needs in the aerospace industry that was willing to project effectively to the 21st century. A lean enterprise is an integrated entity which efficiently creates value for its multiple stakeholders by employing lean principles and practices [5].

1.3 Socio-economic importance

The core goal of our entire endeavor is the happiness where a mother or a father evens a brother or sister of someone's are sacrificing hours after hours to bring the happiness in their personal and family life. But alas! Once upon a time this happiness was a dream rather than virtual, especially to the rural peoples of Bangladesh which could be lucid if we observe the socio-economic indicators of last two decades. In Bangladesh the indicators of Socio-economic development such as GDP, life expectancy, literacy and levels of employment are positively increasing and beyond this Leather sector are keeping a great contribution (World Development Report, 2008). GDP is the key tool for socio-economic improvement and footwear industry is the core wheel of industrial embodiment.

It is a riveting matter that every year huge amount of footwear are produced in Bangladesh which are the pivotal raw material of footwear industry and consequently the number of footwear industry are increasing so rapidly that at present there are near about 160 (with SMEs) footwear industry where more than 12 million peoples of Bangladesh are directly and indirectly involved to conduct their livelihood. Footwear industry brings the noteworthy socio-economic changes in the impoverished peoples of Bangladesh by giving a big employment and bringing the happiness. This will be more improved and dynamic if the Lean production and SS concept is involved in the footwear industry which is proved after the implementation of Lean tools and SS methodology in different manufacturing industries over the World.

In the 21st century, footwear industry continues to be a fundamental instrument for sustainable development and poverty reduction where Lean thinking will be able to add a new impressive proportion in the development of footwear industry which could also be considered as the promoter and imperative for meeting the SDG of reducing poverty and hunger by 2030. We know that an idle head is the source of all evil deeds like drug-addiction, prostitution, armed robbery and other forms of criminal activities which were the frequent incidents basically before the establishment of footwear industry and footwear business and if Lean production is adopted the profit will must be increased and by this the growth of footwear industry will be flourished and consequently the socio-economic status will also be improved at least by suppressing the evil deeds of our growing youth.

The life improving social amenities like tap water, medical facilities, accessible roads, electricity, etc. are indirectly but radically developing due to the establishment of footwear industry where Lean and SS could be more impressive integrated part for prompt rise of more immense productive footwear industry.

The leather business and different kind of footwear industries are very important components of Bangladesh economy as well as for socio-economic condition because of a big number of indigent and rural mid-level peoples are engaged with these industries and consequently rise and fall of footwear industry immersed with the sorrow and happiness of those peoples. But it's a piteous matter that by ignoring the booming scope the proper development in footwear industry is still at infancy stage in Bangladesh as compared to other developing countries where Lean tools and SS will be a harbinger beyond the proper development of footwear industry and thus to socio-economic development of involving human being.

1.4 Thesis Objectives

Firm goal or objective is the prime key beyond the success of any endeavor. There is a maxim that "a fickle minded person can do nothing in his life" and similarly with a fickle or fragile objective a thesis work can bring nothing in the success. So, the author of this thesis paper was headstrong with some specific objectives.

The objectives of this study were-

i. To identify and quantify the manufacturing waste
ii. To formulate the present VSM of the process lines
iii. To calculate the VD time and NVD time of process lines
iv. To calculate the present and future PCE
v. To formulate the future VSM of the process lines by using tools & strategies of LSS model in order to reduce the manufacturing waste & lead time and improve the PCE

1.5 Research Approach

The initial step in this research is to systematically study and define the history of the lean manufacturing concept and its different tools and techniques. It will then examine some most used lean manufacturing tools and techniques. This will be followed by the study of the existing production system of the case company for example the existing production layouts, existing manufacturing waste, inventory movement systems, identifications of VD and NVD works and times and other different variables which need to be improved for the betterment of existing system. The author was tried to address the current issues of the industry to find out the standard operation time for each operation.

1.6 Thesis Outline

The whole report consists of eight chapters. The first chapter describes the need of the research, research objectives and research approach. Lean concept development with lean manufacturing, lean thinking and common using lean tools are described in chapter two. Concept of SS with its beneficial application in industrial process and some important SS and strategy are described in third chapter. Chapter four is embellished with the LSS involvement in different industry at different corner of the World. The research methodology for this research work is described in chapter five. Chapter six is gathered with the methodology and implementation and chapter seven is the result & discussion of this research work. Chapter eight is the final chapter of this study which is contained with the conclusion, recommendation and limitation of this research work.

CHAPTER 2
LEAN CONCEPT REVIEW

2.1 Definition of Lean Concept

Once upon a time the word "Lean" was unknown to us but over the time it has become the most popular jargon which is associated with the lowest cost, highest quality and shortest lead time and with the desirable outcomes of any manufacturing company. The word Lean is considered as an approach comprises of a set of tools and practices which aim to improve efficiency of production line, quality of products and service of any organization and finally the responsiveness to customers. A number of researchers, scientists, engineers and institutions have been given the definition of "Lean" or "Lean Manufacturing". From a huge number of definitions of Lean a very few definitions are given by this study.

Lean is defined as a comprehensive set of techniques which in combined allows to reduce and eliminate the wastes that makes the company leaner more flexible and more responsive to customers [6]. Lean is a systematic approach to identifying and eliminating waste through continuous improvement by flowing the product or service at the pull of your customer in pursuit of perfection [7]. EPA (2009) defined the Lean as an approach that is used in order to develop the highest quality of products at the lowest cost with the shortest lead time by systematically and continuously eliminating waste while respecting people and the environment. Lean is considered as a set of tools to create the value to the customer with little or no waste existing in operation [8].

2.2 Lean Principles

With focusing on the improvement of process, product or service a number of set of lean goals and principles is formed by different engineers, researchers and institutions. Lean principles are defined as a series of actions that must be conducted properly in the proper sequence at the proper time to create value for a customer [9]. Different organizations and different researchers are given the lean principles at different ways keeping the same focus on process improvement. Lean principles which were given by the Lean Enterprise Memory Jogger as improving quality, eliminating waste, reducing lead time and reducing total cost of a process [10]

The description of lean principles were given as-

1. Specify what does and does not create value from the customer's perspective and not from the perspective of individual firms, functions and departments
2. Identify all the steps necessary to design order and produce the product across the whole value stream to highlight non value adding waste

3. Make those actions that create value flow without interruption, detours, backflows, waiting or scrap
4. Only make what is pulled by the customer
5. Strive for perfection by continually removing successive layers of waste as they are uncovered [11]

The Lean principles were mentioned in their book of "Lean Thinking" as follows-

i. Specify value
ii. Identify the value stream
iii. Smooth process flow
iv. Production based on pull and
v. Perfection through elimination of muda or waste [8]

In 2009, "Lean Enterprise Institute" assigned five Lean Principles as follows-

1. Specify the value of customer requirement
2. Identify the value stream for productions and reduce the waste steps
3. Make sure the remaining valued-added steps can work continuously
4. Introduce pull between steps that are possible for continuous flow
5. Conduct perfect management and eliminate the number of steps, the time and information (Lean Enterprise Institute, 2009)

It is required less resources to produce products throughout the lean principles as compared to conventional manufacturing principles with some alluring benefits as like as-

- Productivity gains of 300-400%
- Labor productivity increased an average of 25% a year
- Defect rates reduced from more than 2000 to less than 50 parts per million (PPM) and in many to less than 10 PPM
- Cost of quality cut by over 60%
- Work-in- process inventory slashed by more than 80%
- Revenue per 1000 square feet of factory space was raised 350% [12]

Different set of Lean principles focus the common goals of manufacturing of any organization although these are derived from different sources. To be a lean enterprise an enterprise needs a specific way of thinking, philosophy and management system. For example Toyota company were well-known as Lean enterprise due its specific philosophy of production which was consisted which for Toyota is following "4P" model of the Toyota way. The book "The Toyota Way" with fourteen principles presented the foundation of getting lean at TPS. The author divided these principles into four categories all starting with the letter "P" – Philosophy, Process, Peoples and Partners, and Problem Solving. This becomes known as so called "4 P" model of Toyota [13].

2.3 History of Lean

It is well-known that Lean started at Toyota in Japan although Henry Ford had been used similar concept about lean in early 1920's who established ever the first assembly line in 1913 which achieved the production of a vehicle within four minutes with the great success in the market with lower prices [14]. During the World War II the economy of Japan destroyed heavily. To remove this economic situation Toyota conducted a research to induce an approach to remove the manufacturing waste and to reduce the NVD activities and times because of the situation was too much hard to reinvestment in order to produce the profitable production as well as to be internationally competitive [15]. At the same time, Toyota realized that investing in people is more important than investing in bigger size machinery and continues employee training throughout the organization. This motivates all employees and they are more open to the improvement process and everyone started giving their input to the company. Consequently in 1950, Toyota produced 2,685 vehicles a tiny fraction of what American manufacturer Ford was producing per day around 7,000 cars but later forty years with 37,000 employees Toyota was producing four million cars per year half of General Motors' production of eight million units where the remarkable difference was Lean approach [16]. As a result of Lean implementation Toyota averaged 45 assembly defects per 100 cars while GM's averaged 130 assembly defects per 100 cars. Following these consequences of Lean approach is now well known as a set of promising manufacturing tools which was developed by Taiichi Ohno, Shigeo Shingo and Eiji Toyoda developed the system between 1948 and 1975 [16]. In 1988, the term "Lean" was only first coined by John Krafcik, an engineer at the NUMMI, Toyota - GM joint venture. Finally, Toyota established an approach that consisted of a set of tools to reduce the manufacturing waste and to improve the economic situation [19]. Over the time, Lean approach was consolidated into a new approach to operations that formed the basis of Lean or Toyota Production System which is widely using in the manufacturing World.

2.4 Lean Manufacturing (LM)

LM is a widely accepted and adopted approach across industries over the World. The ultimate goal of a LM is to create a smooth high quality finished products at the rate of customer demand in the quality looked-for with slight or no waste. The implementation of Lean tools resulted in more efficient and cost effective manufacturing. There are different manufacturing approaches where LM is one of the most successful philosophies based on records from other industries such as automobiles, aerospace or pharmaceuticals [10]. The basic principle of LM is reducing all the NVD activities and wastes in the whole supply chain to accomplish high quality reliability products at an appropriate cost and to gain the highest profit and reputation at the same time. LM is defined as an initiative whose goal is to reduce the waste in human effort, inventory, time to market and manufacturing space to become highly responsive to customer demand while producing world class quality products in the most efficient and economical manner [18]. The Lean operating system follows certain principles to deliver value to the customer while minimizing all forms of loss. Each value stream within the operating system must be optimized individually from end to end. Lean tools and techniques are applied selectively to eliminate three sources of loss: waste, variability and inflexibility [19]. In order to attain the LM the organization should have strong customer focus, should be willing to remove wastes from the processes they operate on daily basis and should have the motivation of growth and survival. The author of this thesis work was endeavored to bring the LM by reducing different forms of loss like waste reduction, removable of NVD activities, unwanted motion of labors from the existing production floor.

2.5 Manufacturing waste

A number of researchers and regarding peoples have been given the definition of manufacturing waste where they mentioned that based on Lean philosophy the manufacturing waste can be of various types. Waste was defined as any human activity which absorbs resources but creates no value; they identified eight primary types of manufacturing waste. These are:

i. Mistakes
ii. Rectification (of mistakes)
iii. Production of items no one wants (as a result, inventories and remaindered goods pile up)
iv. Unnecessary production steps
v. Unnecessary movement or transport of employees
vi. Unnecessary movement or transport of goods
vii. People waiting downstream
viii. Goods or services that do not meet the customer's needs

Unused employee creativity was also added to the list of the eight types of waste. These wastes reduce production efficiency, quality of work as well as increase production lead time [13]. Different kinds of wastes in a process can be categorized in following categories.

1. Overproduction – Producing items more than required at given point of time i.e. producing items without actual orders creating the excess of inventories which needs excess staffs, storage area as well as transportation etc.
2. Waiting – Workers waiting for raw material, machine or information etc. is known as waiting and is the waste of productive time. The waiting can occur in various ways for example due to unmatched worker/machine performance, machine breakdowns, lack of work knowledge, stock outs etc.
3. Unnecessary Transport – Carrying of Work in Process (WIP) a long distance, insufficient

transport, moving material from one place to another place is known as the unnecessary transport.

4. Over processing – Working on a product more than the actual requirements is termed as over processing. The over processing may be due to improper tools or improper procedures etc. The over processing is the waste of time and machines which does not add any value to the final product.

5. Excess Raw Material - This includes excess raw material, WIP, or finished goods causing longer lead times, obsolescence, damaged goods, transportation and storage costs, and delay. Also, the extra inventory hides problems such as production imbalances, late deliveries from suppliers, defects, equipment downtime, and long setup times.

6. Unnecessary Movement – Any wasted motion that the workers have to perform during their work is termed as unnecessary movement. For example movement during searching for tools, shifting WIP, etc.

7. Defects – Defects in the processed parts is termed as waste. Repairing defective parts or producing defective parts or replacing the parts due to poor quality etc. is the waste of time and effort.

8. Unused Employee Creativity – Loosing of getting better ideas, improvement, skills and learning opportunities by avoiding the presence of employee is termed as unused employee creativity [20, 21].

2.6 Lead time

Lead time is the total required time or a period of time that is required in order to produce certain amount of product. Lead time could be defied from various sources. Lead-time is the time elapsed in between the receipt of customer order until the delivery of finished goods to the customer [22]. Lead-time is made up of several components besides the fabricating itself: (information) moving time, waiting time, setup time, lot size, and rework time [25]. Lead-time normally also includes the following elements: order transit, supplier lead-time, order preparation, delivery time and set-up time [24]. Furthermore queue time to the Lead time [25].

There are different types of Lead time which is discussed in chapter six. Lead time is consisting of some factors like Moving time, Order transit/ Conveyance, Set-up time, waiting time, Supplier lead time / delivery time, Queue time and Order preparation.

Different factors of lead time:

Factor (Information) of Lead time	Definition
Moving time	The time needed for moving products, goods or assemblies or information within or between organizations, departments and processes [26].
Order transit/conveyance	Transit time is occurred between manufacturers and retailers [27] and conveyance is the movement of goods [28].
Set up time	Set up time is the sum total of all of the internal setups involved processing job [25].
Waiting time	Waiting time was defined as inventors of goods waiting further processing or consumption [29, 30]. Furthermore, it is also considered as the time between the arrival of the part and the time it is needed for assembly [31].
Supplier lead time/ delivery time	Supplier lead time/delivery time was defined as “the time that lapses between the time an order is received by a supplier and his shipment of the items” [32]. Later has the same definition but includes transport time (order transit) from supplier to the customer organization.
Queue time	Queue time is the time spent waiting in line for work centers become available [25].
Order preparation	Order preparation is the time that is needed between receiving a customer order and staring the processing of that specific order [33].

According to Business dictionary lead time can be defined as the number of minutes, hours or days that must be allowed for the completion of an operation or process or must elapse before a desired action takes place [34]. It is a time period between the order and delivery of a new product or service. In a broad sense lead time terminology has been defined in greater details-

- Order lead time
- Processing lead time
- Delivery lead time
- Manufacturing lead time
- Production lead time

Each lead time is using with specific concern and purpose based on the nature of industries. In this study the processing lead time was considered as lead time. Processing lead time is the time period that is required to process or produce an item or to produce a batch production of an item.

2.7 Cycle Time

Cycle time is defined as how frequently a finished product comes out of our production facility [35]. Cycle time includes all types of delays occurred while completing a job. So cycle time can be calculated by the following formula.

Cycle time = processing time + set up time + waiting time + moving time + inspection time + rework time + other delays to complete the job.

To meet customer demand or monitor productivity the cycle time and takt time should be balanced in parallel. The higher cycle time as compare to tact time may result the late delivery and customer dissatisfaction whereas shorter cycle time than takt time may cause the excess inventory or excess use of resource.

2.8 Lean Tools

LM consists of a large number of tools and techniques. Twenty two LM practices that are frequently mentioned in literatures and categorized them into four bundles associated with Just-in-Time, Total Quality Management, Total Preventive Management and Human Resource [36, 37]. Some other researchers also categorized the lean tools and techniques according to the area of implementation such as internally and externally oriented lean practices. For example, lean practices were divided into six areas which are process and equipment; manufacturing, planning and control; human resources; product design; supplier relationships; and customer relationships [39]. The first four areas are grouped as internal oriented lean practices whereas supplier relationships and customer relationships are under external oriented lean practices. But the most frequently using Lean tools are Value Stream Mapping, Process Cycle Efficiency, 5S, Kanban, Poka-yoke, Key performance indicators, Overall Equipment Effectiveness, Ishikawa diagram and Spaghetti diagram [40].

Throughout this study Value Stream Mapping, Process Cycle Efficiency, 5S, Kanban and Overall Equipment Effectiveness were applied in order to attain the objectives of this research work.

CHAPTER 3
CONCEPT OF SIX SIGMA

3.1 Genesis of Six Sigma (SS)

Once upon a time about 1920's the word 'Sigma' was used by mathematicians and engineers as a symbol for a unit of measurement in product quality variation. In the mid-1980s, SS is developed by Motorola as a customer-centric system to produce almost defect free products by minimizing variability on their respective processes. SS can be viewed as a metric, as a methodology and as a business initiative. In 1995 Jack Welch made the SS as a central focus of his business strategy at GE, later it became well known and today it is used in different sectors of industry. Besides Motorola and GE, other major corporations have embraced SS including AlliedSignal, Lockheed-Martin, Polaroid and Texas Instruments. Although SS is originated within manufacturing in the electronics industry but it has been implemented across many other industries and has spread into the service sector even though in a few government organizations [41]. At present, SS is considered as a global brand and something of a revolution to the manufacturing World. The maturity of a manufacturing process can be described by a sigma rating indicating its yield or the percentage of defect-free products it creates. A SS process is one in which 99.99966% of the products manufactured are statistically expected to be free of defects 3.4 DPMO.

3.2 Definitions of SS

From many aspects of quality of any product or service SS is a very promising way of branding and packaging. Over the time, SS brings the different meanings from different corners in case of defect free production of manufacturing World and still now it is evolving with new dimension with its meanings and application. By SS it is refers to the philosophy, tools and methods used to seek, find and eliminate the causes of defects or mistakes in business processes by focusing on the outputs that are important to the customers [42, 43]. It is not a single thing rather a set of tools and strategies for process improvement [44]. It is represents a highly disciplined and statistically based approach to quality [41]. The Department of Trade and Industry, UK (June, 2005) says SS is a data-driven method for achieving near perfect quality. Six Sigma analyses can focus on any element of production or service and has a strong emphasis on statistical analysis in design, manufacturing and customer-oriented activities. The SS as a well-structured continuous improvement methodology to reduce process variability and remove waste within the business processes [44-46]. It is defined as a set of statistical tools adopted within the quality management to construct a framework for process improvement [47]. It is also as an operational philosophy of management which can be shared beneficially by customers, shareholders, employees and suppliers [48, 49]. SS methodically analyzes underlying data and identifies the root causes of problems as opposed to using subjective opinions. Hence, every step in a process represents an opportunity for a defect to occur; SS seeks to reduce the variation in these steps which results in the occurrence of fewer defects and the production of higher quality goods and services. By controlling this variation, SS prevents defects from occurring rather than simply detecting and correcting them. SS intends to help companies to survive in a competitive environment by creating cost savings, improving customer satisfaction and improving organizational competence for innovation and continuous improvement.

3.3 Central Concepts of SS

Defect product is a common scenario of any manufacturing company but it’s a concerning matter that what the amount or volume of defect? Is that amount or volume is acceptable or not? With the help of SS rating these questions answer can be achieved. SS a defect is defined as any process output that does not meet customer specifications or that could lead to creating an output that does not meet customer specifications [50]. It is well known that ordinary businesses actually operate at between three and two sigma performance where the defect products are aligned approximately between 66,800 and 308,500 DPMO. A measurement of four sigma equates to approximately 6,200 DPMO or around 99.4% perfection. This range of perfection of production would arguably be an acceptable level of quality in certain types of business, for instance a roadside cafe, but a 99.4% success rate is obviously an unacceptable level of quality in other types of business, for example, passenger aircraft maintenance. A measurement of five sigma equates to just 233 DPMO equivalent to a 99.98% perfection rate and arguably acceptable to many businesses, although absolutely still not good enough for the aircraft industry and pharmaceutical industry. A measurement of SS equates to just 3.4 DPMO equivalents to a 99.98% perfection rate, which is widely accepted by whole manufacturing World including aircraft and pharmaceutical industry [50]. Here’s a simplified one-to-six sigma conversion scale:

Long term yield (basically the percentage of successful outputs or operations) %	DPMO	Sigma Level
99.99966	3.4	Six
99.98	233	Five
99.4	6210	Four
93.3	66807	Three
69.1	308537	Two
30.9	690000	One

It is very important to keep in mind that an 'operation' is not limited to the manufacturing processes - an operation can be any process critical to customer satisfaction, for example, the operation of correctly understanding a customer request or the operation of handling a customer complaint. SS is not restricted to engineering and production - it potentially covers all sorts of service-related activities. What matters is that the operation is identified as being strategically critical and relevant to strategy and customer satisfaction.

3.4 Tools and techniques of SS

Over the years, companies have developed a number of tools into the approach of SS to make them more effective and to eliminate possible gaps after its application. This tool sets includes the statistical and analytical tools both from industrial engineering and operations research fields [51]. Many tools and techniques that can be applied to SS projects are available both in the literature and public arena [52]. Tools of SS are also available in various forms such as models, analysis templates and procedures [53]. It is an important aspect to select the right tools or techniques of SS when embarking any SS project. Different tools and techniques of SS are used for different aspect so it is important to apply the right tool in the right situation in order to achieve successful results. The output of SS depends on the proper implementation of tools and techniques of SS. Sometimes it seems that simple tools are enough to reduce the defects of a complex manufacturing system [54]. Inspired by Deming's Plan-Do-Check-Act cycle SS projects follow two project methodologies. These methodologies composed of five phases each assume the acronyms DMAIC and DMADV. DMAIC is used for projects aimed at improving an existing business process while DMADV is used for projects aimed at creating new product or process designs [55].

3.5 DMAIC

The DMAIC project methodology has five phases:

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

production boards, visual workplaces and continuously monitor the process;

Some organizations add a recognize step at the beginning which is to recognize the right problem to work on thus yielding DMAIC methodology [55]. The DMADV project methodology known as DFSS features five phases [56]:

- **Define** design goals that are consistent with customer demands and the enterprise strategy.
- **Measure** and identify CTQs (characteristics that are Critical to Quality), product capabilities, production process capability and risks.
- **Analyze** to develop and design alternatives, create a high-level design and evaluate design capability to select the best design.
- **Design** details, optimize the design and plan for design verification. This phase may require simulations.
- **Verify** the design, set up pilot runs, implement the production process and hand it over to the process owner(s).

Within the individual phases of a DMAIC or DMADV project SS utilizes many established quality management tools that are also used outside SS. The following table shows an overview of the main methods used in different regarding research work.

- 5 Whys (five iterations of asking why is generally sufficient to get to a root cause)
- Analysis of variance
- ANOVA Gauge R&R
- Axiomatic design
- Business Process Mapping
- Cause & effects diagram (also known as fishbone or Ishikawa diagram)
- Check sheet
- Chi-squared test of independence and fits
- Correlation
- Cost-benefit analysis
- CTQ tree (critical-to-quality tree)
- Design of experiments
- Failure mode and effects analysis (FMEA)
- General linear model
- Histograms
- Pareto analysis
- Pareto chart
- Process capability
- Quality Function Deployment (QFD)
- Quantitative marketing research through use of Enterprise Feedback Management (EFM) systems
- Regression analysis
- Rolled throughput yield
- Root cause analysis
- Run charts
- Scatter diagram
- SIPOC analysis (Suppliers, Inputs, Process, Outputs, Customers)
- Stratification
- Taguchi methods
- Taguchi Loss Function

Many of the publications suggest the DMAIC and DFSS methods as the two most common methodologies to implement SS although the main objectives of the two techniques are quite different. They also stated that while DMAIC is a problem-solving method which aims at process improvement. DFSS is a process to define, design and deliver innovative products provides competitively attractive value to customers in a manner that achieves the critical-to-quality characteristics for all the significant functions [57]. It is therefore, clear from this definition that DFSS is used in the context of new product development that focuses on quality from the very beginning.

3.6 Benefits of SS

There are many benefits that can be derived from the adoption of Six Sigma. It could enhance product development cycles and process design, shorting product lead times by reducing the cycle time of the overall manufacturing process. The advantages of SS implementation that include are the increased market share and higher profit margins [58]. SS can be used to find and eliminate the root causes of the problem in the process in order to prevent defects. Reduced costs, reduced project time, improved results and improved data integrity are some of the benefits of SS suggested [54]. The methodologies of SS provide the guidelines which could help the managerial personnel as well as workers to understand how to carry out the job and train them to solve potential problems and consequently, they become more aware of the production process thereby improving their morale and reducing the human-related defects [59]. With respect to the role of SS in reducing the defects, it has been demonstrated in several studies that the defect rate per unit is reduced after its implementation in manufacturing systems [60]. The adoption of SS has improved both the efficiency of the line and the production capability including minimizing waste such as reduced need for inspection, removed useless components and excessive movements and decreased time for repair [61]. For this reason, SS can be used to build predictive models based on experiences gathered from earlier uncorrected measures to ensure a continuous improvement of the process [62]. In recent years, knowledge management has contributed to facilitate the implementation of SS and has emerged as a source of competitive advantage within the businesses [63]. SS is also recognized as a strategy that drives the cultural change to improve profitability of the company increasing the benefits from savings generated when the defect is detected at a very early stage [64]. The approach to SS varies between organizations because they integrate different techniques according to their needs, so there might be disagreement regarding the benefits as they depend on the industry and even the country where SS is applied [65]. SS also helps in improving the relationships between the outside and inside of the organization [60]. It can strengthen the customer loyalty by satisfying their needs and expectations and it works as a direct link to company's management which helps establish a common language from the board to the shop floor: SS has many benefits and unsurprisingly the most frequently cited are the reduction and prevention of defects which affect the quality of both products and processes.

CHAPTER 4
LEAN SIX SIGMA INVOLVEMENT IN INDUSTRIES

4.1 Lean Six Sigma (LSS) Model

LSS is a combination of two popular promising philosophies for industrial establishment Lean and SS. Typically Lean and SS concentrate on improving the production and transactional processes of an organization. Although each uses different tools and methodologies to stimulate the improvement both have complementary effects. Each of these methodologies has been individually popularized by successful implementations at companies such as Toyota, General Electric and Raytheon. Many companies are now recognizing the powerful synergy that is produced when these two methodologies are combined and have successfully implemented Lean or SS [66]. The principle of LSS is “the activities that cause the customer’s critical-to-quality issues and create the lowest time delays in any process offer the greatest opportunity for improvement in cost, quality, capital and lead time” [67]. This prim highlights is the strength of focusing on customer needs and shortening lead times. Although Lean and SS focus on different improvement goals, the reduction of waste and process variation a thorough analysis of each method shows that the methods complement each other. While the fundamental principle of SS is to take an organization to an improved level of sigma capability through the rigorous application of statistical tools and techniques, lean production has a role in eliminating waste and NVD activities across the entire supply chain [68]. The theories guiding Lean and SS methodologies are different but complementary. While Lean concentrates on the identification and elimination of waste, SS seeks to reduce process variation. Lean removes the NVD and SS adds value to the VD step of the process by reducing variation. Lean tools focus on removing the waste that will speed up the process thereby improving business performance while SS methodologies focus on reducing the variations of that process towards promising the business performance; ultimately both seek to improve the process. LSS can be involved at any employee’s desk as an individual contributor to a company. Without sacrificing or modifying policies of any company or enterprise, LSS can be implemented to the entire department. It is applied for faster, better and more cost-effective production of any product or service.

4.2 Involvement of LSS in Industries

With the flow of time and iridescent aptitude of consumer, today’s manufacturing industries are undergoing more and more competition in local and global marketing system to come up with the desired product or service within a limited period of time. The comedy in competitive marketing environment is “Timing”. Whatever the quality, price of the goods, the distance of origin of production, just important thing is “Be there by time with the product”. Otherwise someone will get the proof of the adages "What falls behind is left behind". To keep themselves competitive in global business environment different types of companies from different corners of the World have been involving with the lean thinking by making lean production. The methodologies of LSS have been successfully applied in many manufacturing organizations such as General Electric, Boeing, DuPont, Kodak, Honeywell, Texas Instruments, etc. From literature review, it is seen that along with the manufacturing LSS is also successfully applied in hospitals, pharmaceutical, housing and paper industry [68]. It is estimated that throughout the world by adopting LSS in pharmaceutical industry a cost could be saved up to $90 billion dollars per year [69]. In 1999, Motorola University (2008) calculated that LSS significantly brought the benefits of $20 billion to Motorola Inc. since 1986. The success story of Motorola inspired many companies in various industrial sectors to adopt LSS. In 1995, Jack Welch, the CEO of GE, further expanded the application of LSS by adopting the techniques in GE. During the first five years of the implementation, GE roughly gained a benefit of $10 billion (Six Sigma, 2011). Several hospitals in different country have started to work with LSS and savings obtained with these projects ranges from $57,000 to $229,000 annually [26, 52, 70]. In USA, Carlos, (2006) reported that a food manufacturing industry has gained the benefit of $2 million per year by adopting Lean tools [71].

From a literature it is seen that the programs of SS have been brought the promising financial impact in a number of companies over the World. For example, with the involvement of SS program, Volvo Cars in Sweden has been gained more than 55 million euro from its normal gain during the time between 2000 and 2002 [72, 73]. The Business Unit of Transmission & Transportation Networks at Ericsson located in Bora's, Sweden is the another company that has been successful in profit maximization with the successful involvement of SS program. With 1,100 employees the Ericsson in Bora's started their SS program in 1997. It was at Ericsson where SS was firstly defined towards solving the problems. Today, they consider SS as a business excellence model rather a methodology in order to reach at their business goals. Ericsson in Bora's has been executed approximately 50 Black Belt projects and 200 Yellow Belt projects which have been brought with a savings of approximately 200-300 million euros between 1997 and 2003 [73].

In 2008, Motorola University stated that between 1986 and 2007, Motorola Inc. has been saved over $20 billion dollars and the Return on Investment (ROI) has been between 10:1to50:1. It was showed a frozen fish industry would able to improve its PCE from 5.02% to 17.46% by adopting LSS model [74]. By this study the author was also tried to bring the economic benefit or improved production by using efficient lean tools and SS methodologies in one of the largest footwear industry of Bangladesh.

CHAPTER 5
RESEARCH METHODOLOGY

Throughout this study, it was endeavored to demonstrate the application of Lean tools SS methodology into the footwear sector of X footwear industry. Each tool and methodology of LSS was evaluated in terms of its impact on the performance of the project. The required data of the production process of the studied factory is simulated based on the information from personal production floor observation and document review. The required data were collected and designed based on purpose of the study.

5.1 Research field component

5.1.1 Population

In this study, X Footwear industry was the population where its different shoes production lines were the samples.

5.1.2 Primary data collection

The primary data was documented from personal observations of researcher from studied production floor at different processing steps. The primary data were collected and documented by the observation of set up time, change over time, machine function, material and labor flow at each and every processing stages of the production line. The regarding data collection tools were prepared by following the principles of different tools and strategies of LSS model.

5.1.3 Secondary data collection

The secondary data will be taken through the internet, books, journals, related studies and other sources of information.

5.2 Statistical analysis

Each type of data was collected for at least three times where mean and standard error of mean of these collected data were analyzed by using the statistical software tool of SPSS for windows (version, 17).

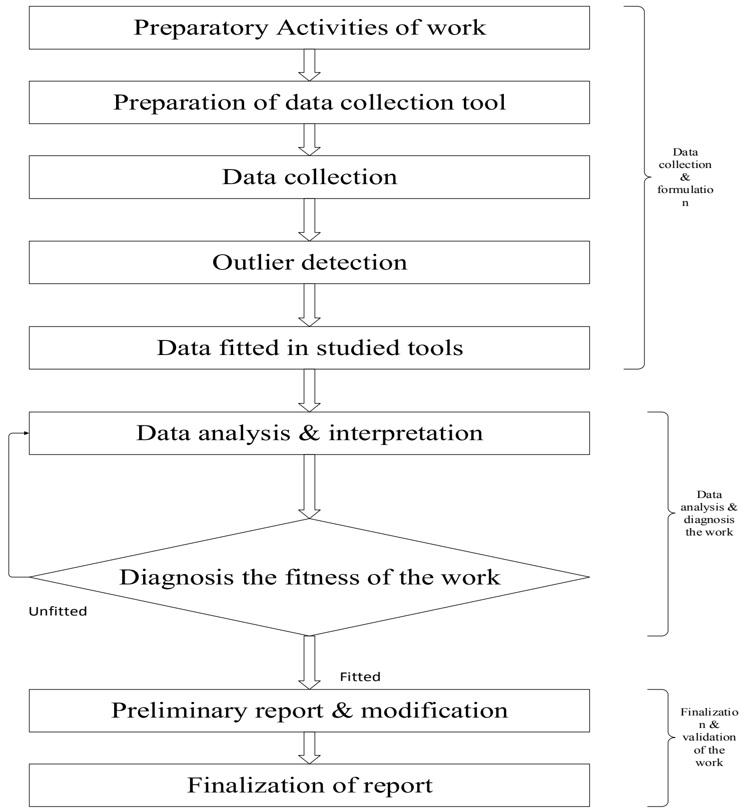


Fig 5.1: Complete Methodology for the study

5.3 Lean Tools and SS

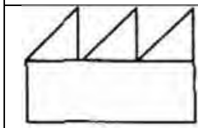
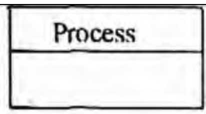
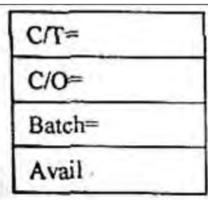
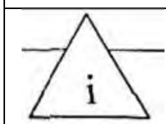
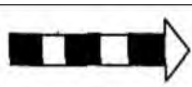
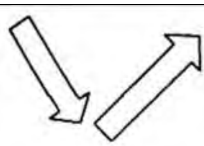
Lean tools like VSM, PCE and Kanban and two basic SS methodologies DMAIC and DMADV were applied to analyze the collected data. Within the SS methodologies a number of tools like Pareto Analysis, Pareto Chart, 5S, Poka-yoke and Cost-Benefit analysis were applied.

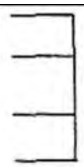
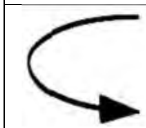
5.3.1 Value Stream Map (VSM)

VSM is a Lean manufacturing technique used to analyze and design the flow of materials and information required to bring a product or service to a consumer [34]. At Toyota, where the technique originated, it is known as "material and information flow mapping". The Lean Aerospace Initiative at MIT describes the objective of VSM as an important Lean practice to eliminate waste and make the VD steps 'flow' in meeting customer requirements [75]. The value stream is further described by Womack and Jones in Lean Thinking: "A VSM identifies every action required to design, order, and make a specific product. The actions are sorted into three categories: (1) those that actually create value as perceived by the customer; (2) those which create no value but are currently required by the product development, order filing or production systems and (3) those actions which don't create value as perceived by the customer and can be eliminated immediately" [8].

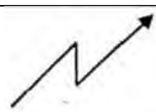
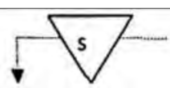
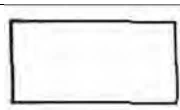
The symbols used in this thesis paper can be divided into three categories [34].

Material flow symbols

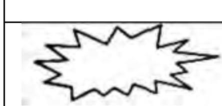
Symbol	Title	Definition
	Customer/Supplier	This symbol represents the supplier when in the upper left as well as the starting point for material flow. The customer is also represented by it when placed in the upper right meaning the usual end point for material flow.
	Dedicated process	This symbol denotes a process, operation, machine or department through which material flows.
	Data box	This symbol is used to summarize essential information for a process, machine or department, especially demand, batch sizes and frequency.
	Inventory	This symbol denotes raw material levels, the inventory build-up between process steps and finished product levels.
	External shipment	These symbols represent the shipments from suppliers or to customer using external transport.
	Push arrow	This symbol represents the pushing of material from one process to the next process. Here, push means that a process produces a product, goods or something regardless of the immediate needs of downstream processes.
	Shipment arrow (Receiving or shipping)	This symbol denotes movement of incoming raw materials, and movement of finished goods out of the plant.

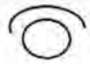
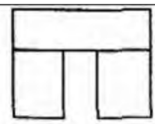
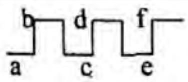
	Supermarket	Here this is an inventory "supermarket" (kanvan stock point). Like a supermarket a small inventory is available and one or more downstream customer comes to the supermarket to pick out what they need. The upstream work-center then replenishes stocks as required.
	Material pull	This symbol denotes the withdrawal (pull) of materials from a supermarket inventory for downstream processing.

Information flow symbols

Symbol	Title	Definition
	Manual information	This symbol denotes manual flow of information (hardcopies, memos, notes).
	Electronic information	This symbol denotes electronic flow of information (email, fax, phone, computerized data transmission).
	Signal Kanvan	This symbol denotes a material pull but when inventory levels have dropped to a minimum level
	Production control	This box represent a central production scheduling or control department, person or operation

General symbols

Symbol	Title	Definition
	Kaizen Burst	This symbol denotes a potential process change that can be used to improve the Current State.

	Human operator	This symbol denotes a human operator at a specific workstation. The number of operators should be noted.
	Work-cell	This symbol denotes a work-cell where several processes are integrated.
	Timeline	This symbol called the time line that shows VD times (cycle time) and NVD times (wait time) and used to calculate the lead time.

5.3.2 Process Cycle Efficiency (PCE)

It is the ratio of value added time and total time of a process.

Mathematically it is expressed as follows-

$$\text{PCE} = \frac{\text{VD time}}{\text{Total time of a process}} \text{x} 100$$

Here, Total time= VD time + NVD time [74]

5.3.3 Takt time

Takt time is defined as the time required producing one unit of daily salable quantity [76]. The purpose of takt time is to precisely match production with demand. It provides the heartbeat of a lean production system. Takt time first was used as a production management tool in the German aircraft industry in the 1930s. Takt time can be first determined with the formula:

$$T = \frac{Ta}{Td}$$

Where, T= Takt time, e.g. [work time between two consecutive units]

T_a= Net time available to work, e.g. [work time per period]

T_d= Time demand (customer demand), e.g. [units required per period]

Net available time is the amount of time available for work to be done. This excludes break times and any expected stoppage time (for example scheduled maintenance, team briefings, etc.).

5.3.4 Kanban

Kanban is a scheduling system for Lean and JIT production. It is one means through which JIT is achieved [29]. It is not an inventory control system rather a scheduling system that helps to determine what to produce, when to produce it and how much to produce. Kanban became an effective tool to support the running of the production system as a whole. In addition, it is proved to be an excellent way for promoting improvements [77].

5.3.5 Poka-yoke

Poka-yoke (poka joke) is a Japanese term that means "fail-saving" or "mistake-proofing". A poka-yoke is any mechanism in a Lean manufacturing process that helps an equipment operator avoid (yokeru) mistakes (poka). The purpose of Poka-yoke is to eliminate product defects by preventing, correcting or drawing attention to human errors as they occur [77]. It was originally described as baka-yoke but as this means "fool-proofing" (or "idiot-proofing") the name was changed to the milder poka-yoke. More broadly, the term can refer to any behavior-shaping constraint designed into a process to prevent incorrect operation by the user. Similarly, a constraint that is part of the product (or service) design is considered Design for Manufacturability or Design for X. A good example of a poka-yoke design is the shape of a cell phone SIM card which can only be inserted in the cell phone in the correct way.

5.3.6 5S

5S is the name of a workplace organization method that uses a list of five Japanese words: seiri, seiton, seiso, seiketsu and shitsuke. Transliterated or translated into English, they all start with the letter "S". The list describes how to organize a work space for efficiency and effectiveness by identifying and storing the items used, maintaining the area and items and sustaining the new order. There are five primary 5S phases: sorting, set in order, systematic cleaning, standardizing and sustaining [78].

i. **Sorting:** Eliminate all unnecessary tools, parts and instructions. Go through all tools, materials and so forth in the plant and work area. Keep only essential items and eliminate what is not required, prioritizing things per requirements and keeping them in easily-accessible places. Everything else is stored or discarded.
ii. **Straightening or Setting in Order:** Arranging tools, parts and instructions in such a way that the most frequently used items are the easiest and quickest to locate. The purpose of this step is to eliminate time wasted in obtaining the necessary items for an operation.
iii. **Sweeping or Shine:** Clean the workspace and all equipment and keep it clean, tidy and organized. At the end of each shift, clean the work area and be sure everything is restored to its place. This makes it easy to know what goes where and ensures that everything is where it belongs.
iv. **Standardizing:** All work stations for a particular job should be identical. All employees doing the same job should be able to work in any station with the same tools that are in the same location in every station. Everyone should know exactly what his or her responsibilities are for adhering to the first 3 S. Synonym : Systemize

v. **Sustaining the Practice:** Maintain and review standards. Once the previous 4 S have been established, they become the new way to operate. Maintain focus on this new way and do not allow a gradual decline back to the old ways. While thinking about the new way also is thinking about yet better ways. When an issue arises such as a suggested improvement, a new way of working, a new tool or a new output requirement, review the first 4 S and make changes as appropriate. It should be made as a habit and be continually improved.

5.3.7 Pareto analysis

It is a statistical technique in decision making that is used for selection of a limited number of tasks that produce significant overall effect. It uses the Pareto principle – the idea that by doing 20% of work, 80% of the advantage of doing the entire job can be generated. Or in terms of quality improvement, a large majority of problems (80%) are produced by a few key causes (20%). The Pareto Principle also known as the "80/20 Rule" which is the idea that 20% of causes generate 80% of results [78]. With this tool, we're trying to find the 20% of work that will generate 80% of the results that doing all of the work would deliver.

Pareto analysis is a formal technique useful where many possible courses of action are competing for attention. In essence, the problem-solver estimates the benefit delivered by each action then selects a number of the most effective actions that deliver a total benefit reasonably close to the maximal possible one. Pareto analysis is a creative way of looking at causes of problems because it helps stimulate thinking and organize thoughts. However, it can be limited by its exclusion of possibly important problems which may be small initially but which grow with time. It should be combined with other analytical tools such as failure mode and effects analysis and fault tree analysis for example. This technique helps to identify the top portion of causes that need to be addressed to resolve the majority of problems. Once the predominant causes are identified, then tools like the Ishikawa diagram or Fish-bone Analysis can be used to identify the root causes of the problems. While it common to refer to Pareto as "20/80", under the assumption that in all situations 20% of causes determine 80% of problems, this ratio is merely a convenient rule of thumb and is not nor should it be considered immutable law of nature. The application of the Pareto analysis in risk management allows management to focus on those risks that have the most impact on the project [77]. Steps to identify the important causes using simple rote (20/80) Pareto analysis [79]-

Step 1: Form an explicit table listing the causes and their frequency as a percentage.

Step 2: Arrange the rows in the decreasing order of importance of the causes (i.e., the most important cause first)

Step 3: Add a cumulative percentage column to the table

Step 4: Plot with causes on x-axis and cumulative percentage on y-axis

Step 5: Join the above points to form a curve

Step 6: Plot (on the same graph) a bar graph with causes on x-axis and percent frequency on y-axis

Step 7: Draw line at 80% on y-axis parallel to x-axis. Then drop the line at the point of intersection with the curve on x-axis. This point on the x-axis separates the important causes (on the left) and trivial causes (on the right)

Step 8: Explicitly review the chart to ensure that at least 80% of the causes are captured

5.3.8 Pareto Chart

A Pareto chart named after Vilfredo Pareto is a type of chart that contains both bars and a line graph where individual values are represented in descending order by bars and the cumulative total is represented by the line. These charts can be generated by simple spreadsheet programs such as OpenOffice.org, Calc and Microsoft Excel and specialized statistical software tools as well as online quality charts generators. The Pareto chart is one of the seven basic tools of quality control [80].

5.3.9 Cost–benefit analysis (CBA)

Sometimes it is called benefit–cost analysis (BCA) is a systematic process for calculating and comparing benefits and costs of a project, decision or government policy (hereafter, "project"). CBA has two purposes:

- To determine if it is a sound investment/decision (justification/feasibility)
- To provide a basis for comparing projects. It involves comparing the total expected cost of each option against the total expected benefits, to see whether the benefits outweigh the costs and by how much.

By this study the existing manufacturing wastes in the research process lines were identified, quantified and finally the quantified wastes were valued in terms of money and dollar in order to unveil the benefit of applied lean tools and SS methodologies.

5.3.10 Value Chain

According to "Cambridge University: Institute for Manufacturing ", the idea of the value chain is based on the process view of organizations, the idea of seeing a manufacturing or service organization as a system, made up of subsystems each with inputs, transformation processes and outputs. The value chain concept was introduced in the book of "Competitive Advantage: Creating and Sustaining Superior Performance" where it was mentioned that the value chain is a series of activities a product/service must pass through until it serves its final purpose of solving a customer need. In each phase of the value chain the product/service gains some value. If a phase is malfunctioning the chain will break down and the mission of generating value for the customer will not be accomplished [81]. A value chain is a chain of activities that a firm operating in a specific industry performs in order to deliver a valuable product or service for the market [82]. The value chain is a systematic approach to examining the development of competitive advantage [83].

Common Value chain of six shoes production lines

Inventory of raw materials	Cutting	Fitting and assembly	Sewing	Pre-Lasting	Post-Lasting	Finishing
In this stage all Required Raw Materials Were Gathered but there was no Value Added Towards The Finished goods. Although This stage was required for finished goods.	All regarding Raw materials Were cut in this stage in order to formulate Shoe Towards get the Finished Goods. In this Stage Value was added.	In this stage All Components Of respective Shoe are Fitting and Assembling Properly To complete The Upper.	In this stage the Title Given The Preparation Fitting Together And finishing Off of the Cut component To Produce An upper Ready for Lasting.	In this stage the Upper Leather Over the Last and Securing it To the Insole, With either Tacks or Adhesives.	In this Stage the Shoe Should be Subject to Inspection After Lasting To ensure Have been Lasted Properly & that all Proportion Are accurate.	In this Stage Quality inspection Are measures Aimed at Checking, Measuring Or testing Of one or More Product Features And to Relate the Result to The Requirements to Conform Compliance.

CHAPTER 6

OVERVIEW ON METHODOLOGY AND IMPLEMENTATION

This study was driven to find out and quantify the different types of manufacturing waste at different production stages of six shoes of X footwear industry in Bangladesh. The present Value Stream Map (VSM) of the studied production lines were prepared and analyzed in order to formulate the figure VSM with the improved PCE, takt time, reduced manufacturing wastes and reduced lead time by using lean tools and Six Sigma methodologies.

The required data were collected from Derby, Casual, Oxford, Boot, Court and Moccasin shoe production lines. Value Added (VD) time, Non Value Added (NVD) time and manufacturing wastes were deeply observed in the studied production lines. The expected result of this study can be deduced by data analysis from the different tables and graphs.

6.1 Derby Shoe Production Line

A footwear company has mainly four departments in which a progressive route is followed for producing finished shoes. These are Clicking or Cutting Department, Closing or Machining Department, Lasting & Making Department, Finishing Department and the Shoe Room. It was a Derby shoe production line. The basic stages of Derby shoe production line were as follows-

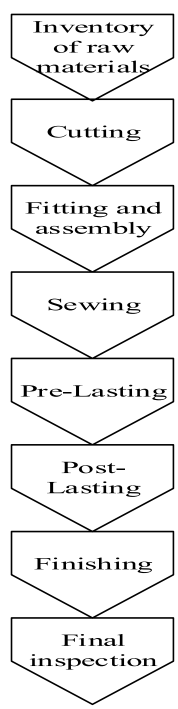


Fig 6.1.1 Basic stages of Derby shoe production line

6.1.1 Present VSM of Derby shoe production line

The present VSM of Derby shoe production line point out the different stages whose bring the different values. These values were brought by different stages which were points out in present VSM. All regarding data to build the present VSM were documented in Table 6.1.1 and Table 6.1.2. Other relevant data such as number of operators (O), assistant operator (AO) and worker (W) were shown in current VSM. To draw the completion of present VSM of Derby shoe production line, a timeline was added at the bottom of the map recording the VD and NVD time.

Table 6.1.1: Present state Down Time (D/T), Cycle Time (C/T) and Up Time (U/T) data of Derby shoe production line

Times	Sewing			Pre-lasting			Post-lasting			Finishing		
	D/T (Sec)	C/T (Sec)	U/T (%)	D/T (Sec)	C/T (Sec)	U/T (%)	D/T (Sec)	C/T (Sec)	U/T (%)	D/T (Sec)	C/T (Sec)	U/T (%)
1st	630	2880	78	1334	4680	71	1116	2880	76	816	2880	72
2nd	626	2880	78	1378	4680	70	1098	2880	77	833	2880	71
3rd	639	2880	77	1371	4680	71	1108	2880	76	817	2880	72

Note: Sewing speed: 245 RPM; Finishing speed: 245 RPM; Pre-lasting & Post-lasting machine speed: 25 case per min. Batch-2000 pair.

The D/T, C/T and U/T of Derby shoe production line were documented in table 6.1.1. In this production line the stage of sewing, lasting and finishing machine were mainly responsible for D/T. In the stage of sewing, average U/T was 78% and C/T was 2880 sec. In the stage of finishing average U/T was 72% and C/T was 2880 sec. In the stage of lasting, C/T of pre-lasting machine was 4680 sec and U/T was 71% and C/T of post-lasting machine was 2880 sec and U/T was 76%. The percentage of available time for machine work or processing of desire product was known as the U/T. By observing the U/T of different unit stage of production line, it can be assumed line efficiency of the whole production line. At present state, the U/T of Derby shoe production line varies from 71% (finishing stage) to 78% (sewing stage). By this study it was attempted to increase the U/T in the future state as well as to reduce the D/T and to reduce the ultimate lead time.

Table 6.1.2: Present state VD and NVD time for Derby shoe production line

Processing stages	Average VD time (Sec)	Average NVD time (Sec)
Receiving Inventory	00	27000
Cutting	600	1800
Fitting & assembly	1680	240
Sewing	2200	920
Pre-lasting	00	750
Post-lasting	1973	1207
Finishing	3371	1819
Shipping inventory	00	43200
Total	9824 (11.32%)	76936 (88.68%)

The VD and NVD time of different processing stages of Derby shoe production line were documented in table 6.1.2. At present state, there were no VD time except NVD lime in the stages of receiving inventory, pre-lasting and shipping inventory but in this process line, this NVD lime or these stages were required for the derby shoe production. In this Derby shoe production line, the total VD time were 9824 sec (11.32%) and the total NVD time were 76936 sec (88.68%). By this study, it was tried to increase the percentage of VD time by reducing the NVD time with the proper implementation of lean tools and SS methodologies.

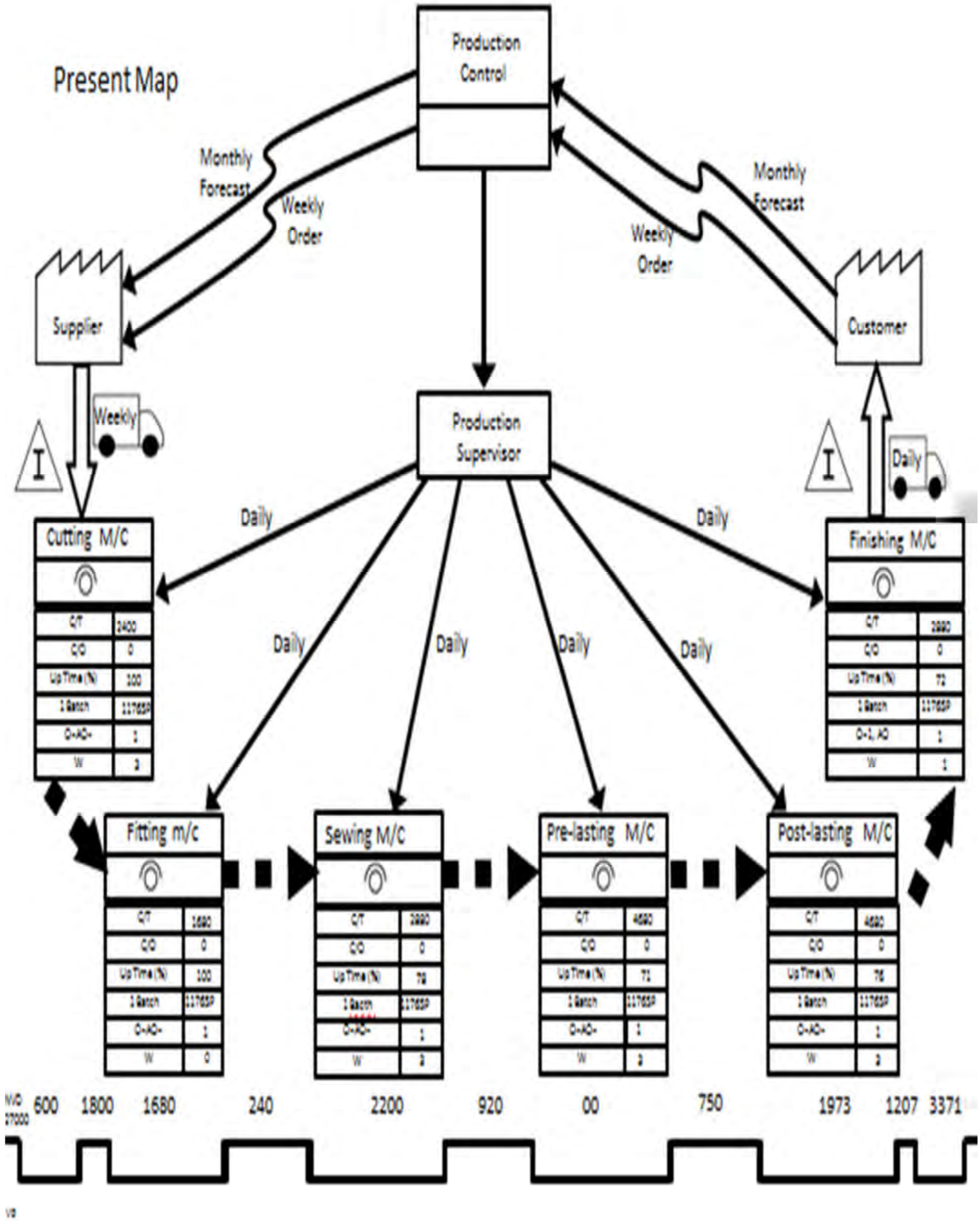


Fig 6.1.2 Present VSM of Derby shoe production line

Throughout the present VSM the whole processing system of Derby shoe production line were depicted with the flow of order, raw materials, labor, information, VD & NVD times. It helps to draw the required processing stage like cutting, fitting & assembly, sewing pre-lasting, post-lasting and finishing with mentioning required labor, C/T, U/T, C/O and batch size. By observing the present scenario of regarding processing line, it can be known like as what number of labor is needed at different processing unit? How much VD & NVD time is present? Where & what kind of improvement should be done? It helps to calculate the PCE, lead time and takt time. Fig 6.1.2 represents the present VSM of Derby shoe production line. At present VSM, the production of Derby shoe was controlled by production manager, assistant manager and supervisor. In this production line, the production starts by taking the order of production from the customers. In order to fulfill the customer demand the required raw materials were collected from the different regarding suppliers. These required raw materials were brought in the raw materials inventory which was the first stage of Derby shoe production that followed by cutting, fitting & assembly, sewing pre-lasting, post-lasting, finishing and shipment of finished goods. As observed from the present VSM of Derby shoe production line, different types of NVD activities were present in the flow of process line at different stages. The different types of bottlenecks at different processing stages were identified and quantified in terms of time as shown in the Fig 6.1.2. The Up time (U/T) of sewing, pre-lasting machine, post-lasting machine and finishing machine were consecutively 78%, 71 %, 70% and 72%. At present state of this processing line over the different stages total labor was 30. After the implementation of lean tools and SS methodologies it was expected that U/T could be improved and total labor could be reduced.

6.1.2 Present PCE of Derby shoe production line

In the Derby shoe production line,

Value Added time = 9824 Sec

Non Value Added time = 76936 Sec

Expected Lead time = Value Added time + Non Value Added time

= 9824 Sec + 76936 Sec = 86760 Sec

Process Cycle Efficiency (PCE) $= \frac{\text{Value Added time}}{\text{Lead time}} \times 100$

= 11.32%

It seems that the present PCE of Derby shoe production line was 11.32% which was the below of internationally competitive level 25% [74]. Throughout this study it was tried to improve the present PCE of Derby shoe production line with the proper implementation of lean tools and SS methodologies.

6.1.3 Present takt time calculation of Derby shoe production line

Net available time

Working shift/day	2 shifts
Hours/ shift	10 hours
Available time/ shift	600 minutes
Prepare time/ shift	40 minutes
Lunch time/ shift	0 minutes
Planned down time/ shift	0 minutes
Networking time/ shift	560 minutes
Networking time/ shift	33600 seconds
Net available time/ day	67200 seconds

Customer/production demand

Net available time/day	67200seconds/day
Customer demand/day	26781 cases/day
Takt time	2.51 seconds/case

The present Takt time of Derby shoe production line was 2.51 sec. i.e. it takes 2.51 sec to produce a single case of Derby shoe production. Each case produces 170 pairs Derby shoe. One of the basic objectives of this study was to reduce this present takt time after the proper implementation of lean tools and SS methodologies.

6.1.4 Manufacturing waste of Derby shoe production line

There are different types of manufacturing wastes like overproduction, defect, waiting, unnecessary processing, unnecessary inventory, unnecessary transportation between work sites and unnecessary motion of labor in the work place. Among these manufacturing wastes defect productions, wasted time due to different causes and unnecessary motion of labor were very common in the Derby shoe production line.

6.1.4.1 Down Time (D/T) calculation for Derby shoe production line

The down time at different machines and stages of this processing line were observed and documented in table 6.1.3.

Table 6.1.3: Down Time (D/T) of Derby shoe production line

Steps	Causes for D/T	D/T (sec)	Average D/T	C/T	%D/T
Sewing	Needle thread breakage	316		2880	
		312	316		9.09
		320			
	Bobbin or looped thread breakage	38			
		41	41		1.18
		45			
	Skipped stitches	75			
		71	75		2.15
		79			
	Seam pucker	67			
		60	62		1.78
		59			
	Variable stitch density	134			
		142	137		3.94
		136			
Finishing	Inefficient ironing	456		2880	
		446	447		12.86
		441			
	Improper polishing	142			
		150	146		4.20
		145			
	Inefficient spraying	132			
		145	138		3.97
		136			
	Bumps or hollows	86			
		92	91		2.62
		95			
Pre-Lasting	Improper setting during toe lasting	1022		4680	
		1050	1036		29.82
		1035			

	Improper setting during seat lasting	60			
		55	59		1.69
		63			
	Inappropriate scouring	201			
		215	209		6.01
		210			
	Side lasting problems due to feather edge stitching	51			
		58	57		1.06
		63			
Post-Lasting	Inefficient heat setting	767		4680	
		759	759		21.84
		751			
	Improper sole attaching	215			
		208	214		6.16
		220			
	Inappropriate sole press	68			
		75	68		1.95
		65			
	Improper chilling	66			
		60	66		1.89
		72			
Total			3921		

In Derby shoe production line, the most important production stages were sewing, pre-lasting, post-lasting and finishing where the most frequent D/T was observed due to different causes that were documented in table 6.1.3.

6.1.4.2 Wasted products calculation of Derby shoe production line

The amount of defect shoe was documented in table 6.1.4.

Table 6.1.4: Wasted products calculation of Derby shoe production line

Name of stages	No of observation	Rejected shoes per batch	Average rejected shoes per batch	Average rejected shoe per batch (per day 12 batch)	Rejected shoes per million opportunity	Gap at Six Sigma level	Remarks
Cutting	1	23					Contains at three sigma level
	2	25					
	3	21	22	264	1870	1867	
	4	20					
	5	20					
Sewing	1	37					
	2	40					
	3	43	38	456	3230	3227	
	4	39					
	5	33					
Pre-Lasting	1	10					
	2	9					
	3	11	11x6=66	792	5610	5607	
	4	11					
	5	13					
Post-Lasting	1	14					
	2	16					
	3	15	15x6=90	1080	7650	7647	
	4	14					
	5	16					
Finishing	1	103					
	2	99					
	3	94	95	1140	8075	8072	
	4	88					
	5	89					
Total			311	3732	26435		

Based on central SS concept it seems that if the amount of defect product was more than 6,210 but less than 66,807 per million product of production then it was considered as the three Sigma productions. From table 6.1.4, it seems that the total defect product of Derby shoe process line was 26435 per million products of production which was considered as the three Sigma productions. But the prime target of any manufacturing industry should be Six Sigma production where the amount of defect product should not be more than 3.4 per million products of production. Throughout this study it was expected that 80% of the present manufacturing waste could be reduced after the implementation of lean tools and SS methodologies.

6.1.4.3 Present and expected labor of Derby shoe production line

With the involvement of lean tools and Six Sigma methodology, it was expected that a number of labor could be eliminated from Derby shoe processing line. The unnecessary motion of labor in the processing line was also considered as the manufacturing waste. The expected numbers of eliminated labor were documented in the table 6.1.5.

Table 6.1.5: Present and expected Labor of Derby shoe production line

Name of stages	No of labor at present state			No of labor at future state		
	O	AO	W	O	AO	W
Cutting	1	1	3	1	1	3
Fitting & assembly	1	1	0	1	0	0
Sewing	1	1	3	1	1	1
Rework	0	0	5	0	0	2
Pre-lasting	1	1	3	1	1	1
Post-lasting	1	1	3	1	1	1
Finishing	1	1	3	1	1	1
Total	6	6	18	6	5	9

At present state, from table 6.1.5, it was seen that throughout the different processing stages of Derby shoe production line, total labor were 30 where operator (O), assistant operator (AO) and worker (W) were consecutively 6, 6 and 18. At future state, if the lean tools and SS methodologies will implement, it was expected that different types of bottlenecks and NVD activities will be reduced thus the present number of labor will also be reduced from 30 to 20 where operator (O), assistant operator (AO) and worker (W) were consecutively 6, 5 and 9. Because of a number of unwanted labors were engaged to manage the different types of bottlenecks and NVD activities. Fig. 6.1.6 Pareto analysis of Derby shoe processing line Pareto Analysis was performed by drawing the Pareto chart consisting of causes for delay along the X axis and percentage and cumulative percentage of down time along the Y axis. The highest frequency of down time was found for toe lasting problems at the Derby shoe processing line while bobbin thread breakage showed the lowest frequency. Different causes of down time with their frequency in terms of percentages and cumulative percentages were documented in table 6.1.5.

6.1.5 Pareto analysis of Derby shoe production line

Pareto analysis was performed by drawing the Pareto chart consisting of causes for delay along the X axis and cumulative percentage of down time along the Y axis. The highest frequency of NVD activities or down time was found for toe lasting problems at the Derby shoe production line while bobbin thread breakage of sewing machine showed the lowest frequency.

Table 6.1.6: Cumulative percentages D/T of Derby shoe production line for Pareto Analysis

Causes of delay times	Down Time(D/T)	Percentage of D/T	Cumulative of percentage
Toe lasting problems	1036	26.4218312	29.8215314
Inefficient heat setting	759	19.3573068	45.77913798
Inefficient ironing	447	11.400153	57.179291
Needle thread breakage	316	8.05916858	65.23845958
Improper sole attaching	214	5.45779138	70.69625096
Inappropriate scouring	209	5.33027289	76.02652385
Improper polishing	146	3.72353991	79.75006376
Inefficient spraying	138	3.51951033	83.26957409
Variable stitch density	137	3.49400663	86.76358072
Bumps or hollows	91	2.32083652	89.08441724
Skipped stiches	75	1.91277735	90.99719459
Inappropriate sole press	68	1.73425147	92.73144606
Insufficient Chilling	66	1.68324407	94.41469013
Seam pucker	62	1.58122928	95.99591941
Seat seating problems	59	1.50471818	97.50063759
Side lasting problems	57	1.45371079	98.95434838
Bobbin thread breakage	41	1.04565162	100

Different causes of NVD activities or down time at different processing stages of Derby shoe processing line with their frequency in terms of percentages and cumulative percentages were documented in table 6.1.6. The causes for NVD activities were arranged in downward movements in terms of their frequency.

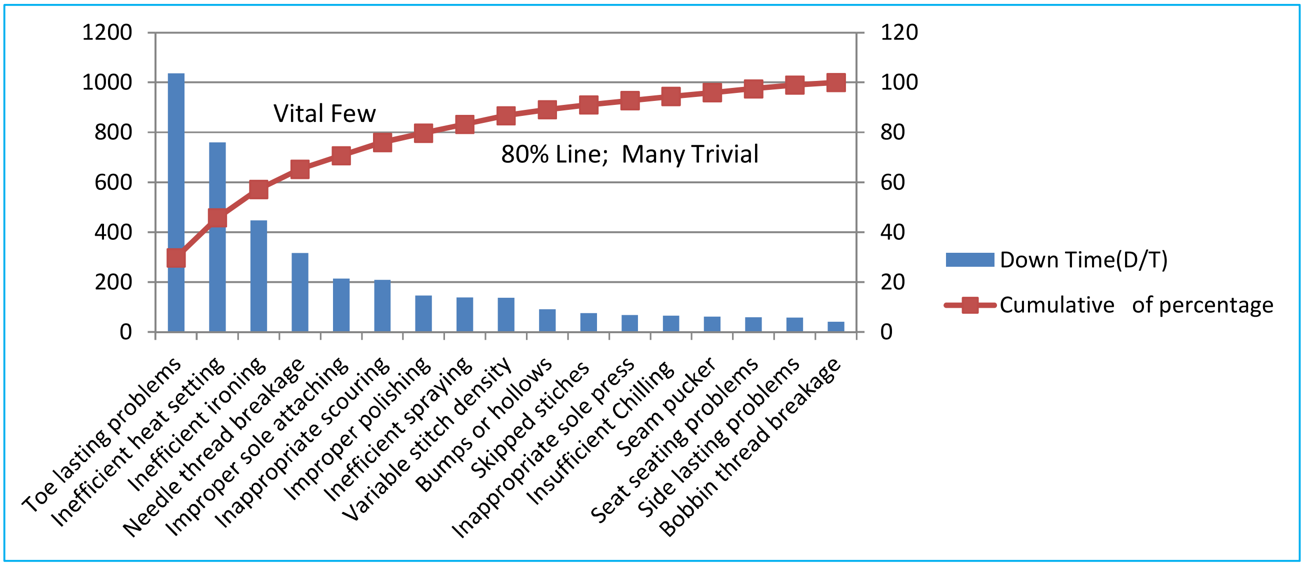


Fig 6.1.3 Pareto chart of Derby shoe production line

Pareto chart (Fig 6.1.3) was depicted from Pareto table (Table 6.1.6) by aligning the different causes along with X axis; percentage and cumulative percentage of these causes for NVD activities were aligned along with the Y axis. From Fig 6.1.3, it seems that the pioneer causes beyond the different types of bottlenecks and NVD activities were Toe lasting problems (26.42%), Inefficient heat setting (19.36%), Inefficient ironing (11.40%), Needle thread breakage (8.06%), Improper sole attaching (5.46%), Inappropriate scouring (5.33%), Improper polishing (3.72%), Inefficient spraying (3.52%), Variable stitch density (3.49%), Bumps or hollows (2.32%), Skipped stiches (1.91%), Inappropriate sole press (1.73%), Insufficient Chilling (1.68%), Seam pucker (1.58%), Seat seating problems (1.50%), Side lasting problems (1.45%) and Bobbin thread breakage (1.04%). From Pareto chart (Fig. 6.1.3) the most responsible causes were easily observed and the effective initiatives can be taken to remove these causes. It was expected that if the most frequent first three or 20% causes like as Toe lasting problems (26.42%), Inefficient heat setting (19.36%), Inefficient ironing (11.40%) could be removed, the 80% NVD activities or down times could be removed. 5S, JIT, TPM, DMAIC and other improving strategies could be effective initiatives to remove these most frequent causes.

6.1.6 Improvement points at present VSM of Derby shoe production line

Throughout the observation it was seen that there were some improvement points at different stages of Derby shoe production line. The nature of improving point differs from each and another stages.

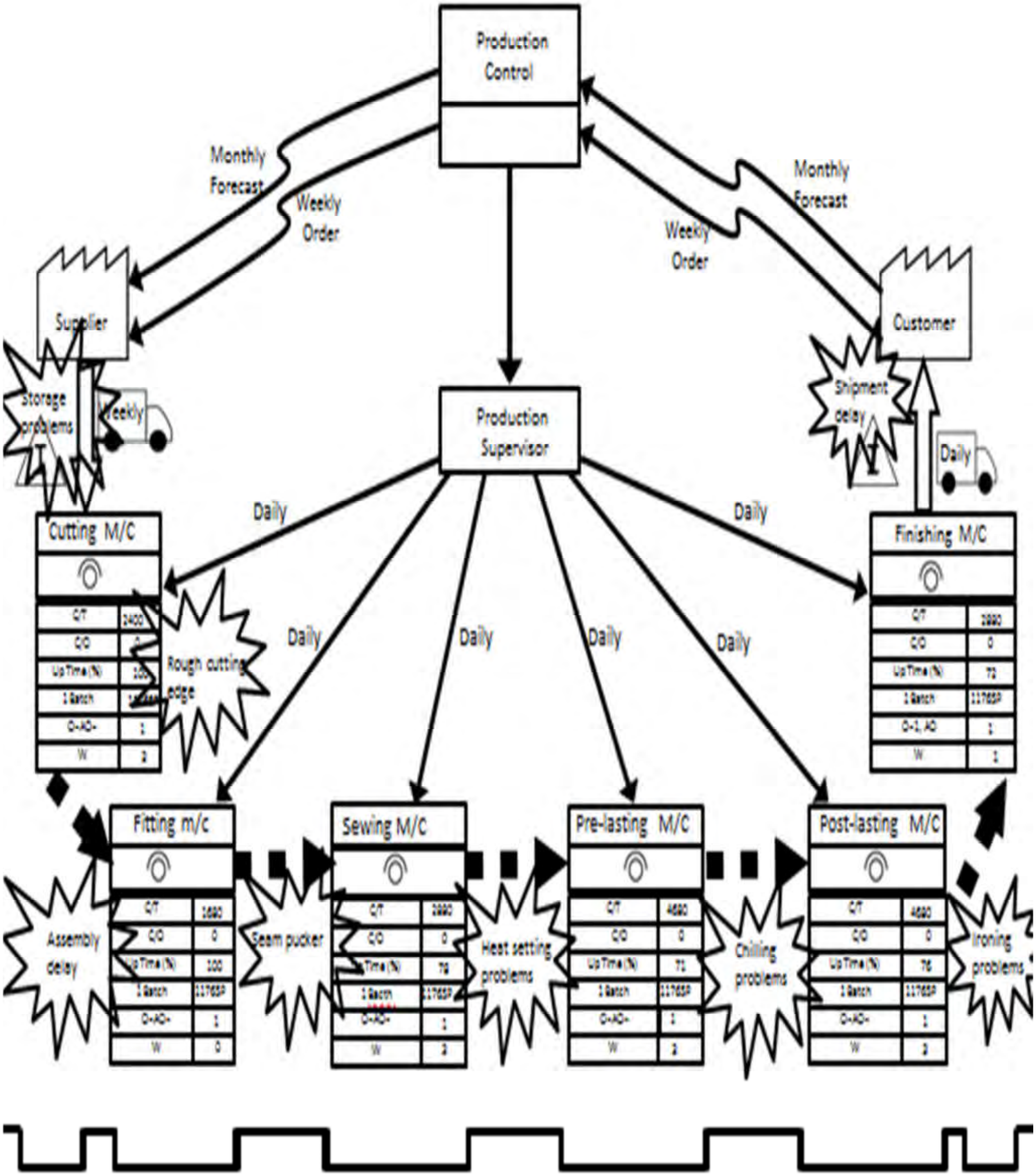


Fig 6.1.4 Present VSM of Derby shoe production line with improvement points

The crucial improvement points were pointed in Fig 6.1.4. In the stage of raw material or receiving inventory, delay handling of raw materials towards the next stage of shoe processing was observed as the prime point that should be removed in order to reduce the lead time as well as to improve the PCE. Besides these, conventional movement of raw materials like as carry of raw materials sack by labor instead of conveyor belt movement, inventory storage room was soaked and congested, crowd movement were most common. In the sewing stage, the delay of sewing was the main hindrance beyond the NVD activities and bottlenecks. No cause was identified that need to solve in the stage of fitting & assembly, because of it was difficult to detect any barrier beyond the bottleneck due to shoe production towards the next stage but it was observed that this stage was smoothly running and based on previous experience of regarding personnel it was also known that there was no mentionable barrier for bottlenecks. In the sewing stage the basic causes were needle thread breakage, seam pucker, skipped stitches and variable stitch density. In the stage of pre-lasting was improper setting during toe lasting, improper setting during seat lasting, inappropriate scouring. In the stage of post-lasting the main causes for bottlenecks or breakdown of machine were inappropriate sole press and improper chilling. In case of finishing stage the basic problems were pointed as insufficient ironing, spraying, polishing and many bumps or hollows. In the stage of shipment the basic barrier were irregular shipment and insufficient space for movement. In Fig 6.1.4 only the most relevant cause at different stages of Derby shoe production line were pointed. These pointed causes or barriers should be removed in order to reduce the manufacturing wastes and improve the PCE.

6.1.7 Future VSM of Derby shoe production line

In the future VSM, after a deep brainstorming and an intense observation in Derby shoe production line the VD and NVD time were calculated and documented in table 6.1.7.

Table 6.1.7: Future state VD and NVD time analysis of Derby shoe production line

Processing stages	VD time (Sec)	NVD time (Sec)
Receiving Inventory	00	13500 (50%)
Cutting	600	900 (50%)
Fitting & assembly	1680	240 (0%)
Sewing	2200	184 (80%)
Pre-lasting	00	150 (80%)
Post-lasting	1973	241 (80%)
Finishing	3371	364 (80%)
Shipping inventory	00	12960 (70%)
Total	9824 (25.61%)	28539 (74.39%)

It was expected, after the implementation of lean tools and SS methodologies the present state NVD activities or times could be reduced at least up to 80%. In this study, based on intense observation, brainstorming and previous regarding studies it was assumed that the NVD time of receiving stage of Derby shoe production line could be reduced at least 50% (13500 sec) and the NVD time of cutting stage could be also be reduced at least 50% (900 sec). The NVD time of sewing, pre-lasting, post-lasting and finishing could be reduced at least 80% from the present state and in the future state these NVD times could be consecutively 184 sec, 150 sec, 241 sec and 364 sec which could be seen in table 6.1.7. The Fig 6.1.5 was the future VSM of Derby shoe production line. The future VSM indicates the materials, information and labor flow of single batch production of Derby shoe production line. Each batch produce 11765 pairs of Derby shoe.

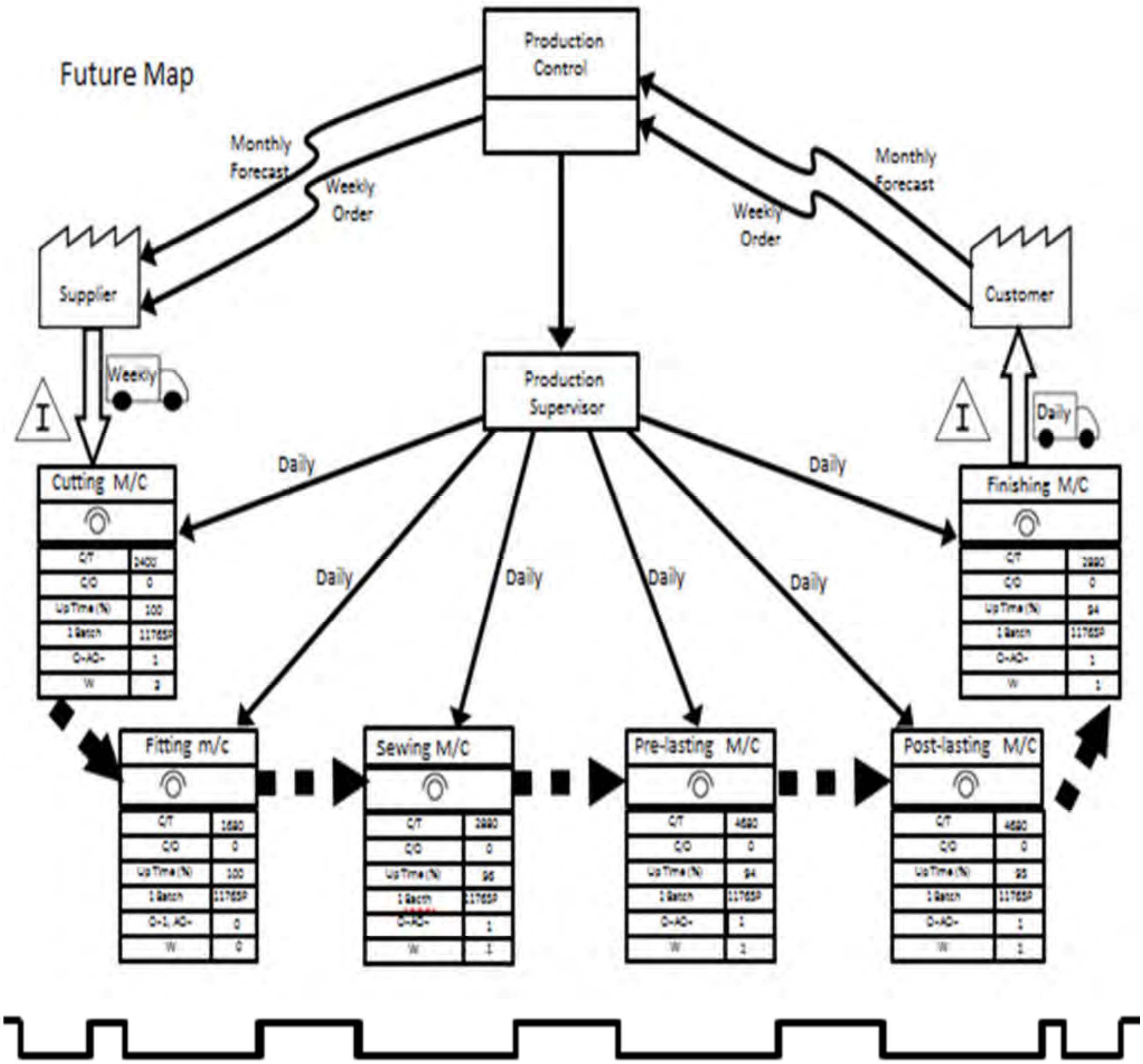


Fig 6.1.5 Future VSM of Derby shoe production line

The basic components of future VSM were customers, production control, production supervisor, suppliers, transportation, different stages of processing line like as receiving inventory, cutting, fitting& assembly, sewing, pre-lasting, post-lasting, finishing and shipment inventory and finally the VD and NVD times were depicted at the bottom of future VSM. Production control consists of one production manager and two assistant production managers and four supervisors. The production starts with taking the order from customer by electric signal like as over telephone or email. Later required raw materials were collected from the suppliers. Finally raw materials were transformed into finished Derby shoe throughout the receiving inventory stage to shipment stage. In this future VSM the basic promising changes were the reduction of total number of labor which was observed at every processing stage, reduction of NVD time which was indicated at the bottom level of future VSM, improved Up time (U/T) which was also seen at every processing stage of Derby shoe processing line. In future VSM the total labor including operator, assistant operator and worker could be 20 which was 30 at present VSM i.e. after the implementation of lean tools and SS methodologies it was expected at least 14 labors could be reduced. The U/T of sewing, pre-lasting machine, post-lasting machine and finishing could be consecutively 96%, 94%, 95% and 94% but at present state the U/T of sewing, pre-lasting machine, post-lasting machine and finishing were consecutively 78%, 71 %, 76% and 72%.

6.1.8 Expected PCE of Derby shoe production line

In the Derby shoe production line,

Value Added time	= 9824 Sec
Non Value Added time	= 28539 Sec
Expected Lead time	= Value Added time + Non Value Added time
	= 9824 Sec + 28539 Sec = 38363 Sec
Process Cycle Efficiency (PCE)	$= \frac{\text{Value Added time}}{\text{Lead time}} \times 100$
	= 25.60%

After the proper implementation of lean tools and SS methodologies it was expected the PCE of Derby shoe processing line could be 25.60 % while the present PCE was 11.32 %, the NVD time could be reduced from 76936 sec to 28539 sec and lead time could be reduced from 86728 sec to 38363 sec.

6.1.9 Expected takt Time calculation Derby shoe production line

Net available time

Working shift/day	2 shifts
Hours/ shift	10 hours
Available time/ shift	600 minutes
Prepare time/ shift	40 minutes
Lunch time/ shift	0 minutes
Planned down time/ shift	0 minutes
Networking time/ shift	560 minutes
Networking time/ shift	33600 seconds
Net available time/ day	67200 seconds

Customer/production demand

Net available time/day	67200seconds/day
Customer demand/day	27403 cases/day
Takt time	2.45seconds/case

The present takt time of Derby shoe production line was 2.51 sec per case production and it was expected that after the adoption of lean tools and SS methodologies this could be reduced to 2.45 sec per case production. So, it seems that the lean tools and SS methodologies could bring the revolution beyond the speed of production of any processing line.

6.2 Casual Shoe Production Line

It was a Casual shoe production line where the processed shoe contained many materials like Upper Leather 67.47%, Lining Leather 17.35%, Elastic 0.24%, Thread 0.24%, Toe puff and stiffener 0.96%, Insole (cellulose) 0.72%, Shank 1.45%, TPR unit sole 10.12% and Adhesive 1.45%. These materials came from different sources which were closing together that termed as complete shoe that was finally developed into Casual shoe through a number of production stages.

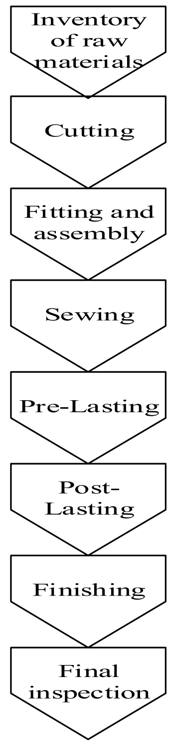


Fig 6.2.1: Basic stages of Casual shoe production line

6.2.1 Present Value Stream Mapping (VSM) of Casual Shoe Production Line

The present VSM of this process line was consisted with the sewing, lasting and finishing which were considered as the pivotal steps in the VSM. Throughout the VSM the Cycle Time (C/T), Change over Time (C/O), Uptime (U/T) and Batch size were drawn. The present required operator, assistant operator and worker were also mapped at present VSM. The Inventory (I) and Shipment were also the component of VSM where inventory was the initial stage and Shipment was the last stage. All required data regarding to build the current VSM were collected and documented in table 6.2.1 and table 6.2.2, summarized the overall activities associated with the production line along with their production time.

Table 6.2.1: Present State down Time (D/T), Cycle Time (C/T) and Up Time (U/T) data of Casual shoe production line

Times	Sewing			Lasting			Finishing		
	D/T (Sec)	C/T (Sec)	U/T (%)	D/T (Sec)	C/T (Sec)	U/T (%)	D/T (Sec)	C/T (Sec)	U/T (%)
1st	1116	6060	81	1416	6120	76	1368	4680	65
2nd	1105	6060	82	1415	6120	77	1349	4680	66
3rd	1105	6060	82	1399	6120	78	1341	4680	66
Average	1108	6069	82	1410	6120	77	1352	4680	66

Note: Sewing m/c speed: 276 RPM; Lasting m/c speed: 274 RPM; Finishing m/c speed: 50 pairs per hour, Batch production - 7000 pairs.

Table 6.2.1 reveals the D/T, C/T and U/T of Casual shoe production line. In this processing line the D/T due to different bottlenecks were observed in the stage of sewing, lasting and finishing machine which stages were mainly responsible for D/T. In the stage of sewing, average U/T was 82% and C/T was 6060 sec. In the stage of lasting average U/T was 77% and C/T was 6120 sec. In finishing machines stage, C/T was 4680 sec and U/T was 66%. The percentage of available time for machine work or processing of desire product is known as the U/T. By observing the U/T of different unit stage of production line, it can be assumed the efficiency of processing line. At present state, the U/T of Casual shoe process line varies from 66% (finishing stage) to 82% (sewing stage). By this study it was attempted to increase the U/T in the future state as well as to reduce the D/T and to reduce the ultimate lead time.

Table 6.2.2: Present State VD and NVD time of Casual shoe production line

Processing stages	Average VD time (Sec)	Average NVD time (Sec)
Receiving Inventory	00	32400
Cutting	600	1800
Fitting & assembly	1680	300
Sewing	4775	1525
Pre-Lasting	00	1770
Post-Lasting	4683	1857
Finishing	3532	1748
Shipping inventory	00	43200
Total	15270 (15.28%)	84600 (84.72%)

The VD and NVD time of different production stages of Casual shoe production line were documented in table 6.2.2. At present state, in the stages of receiving inventory, pre-lasting and shipping inventory there were no VD time rather than NVD time but in this process line, this NVD time or these stages were required for the casual shoe production.

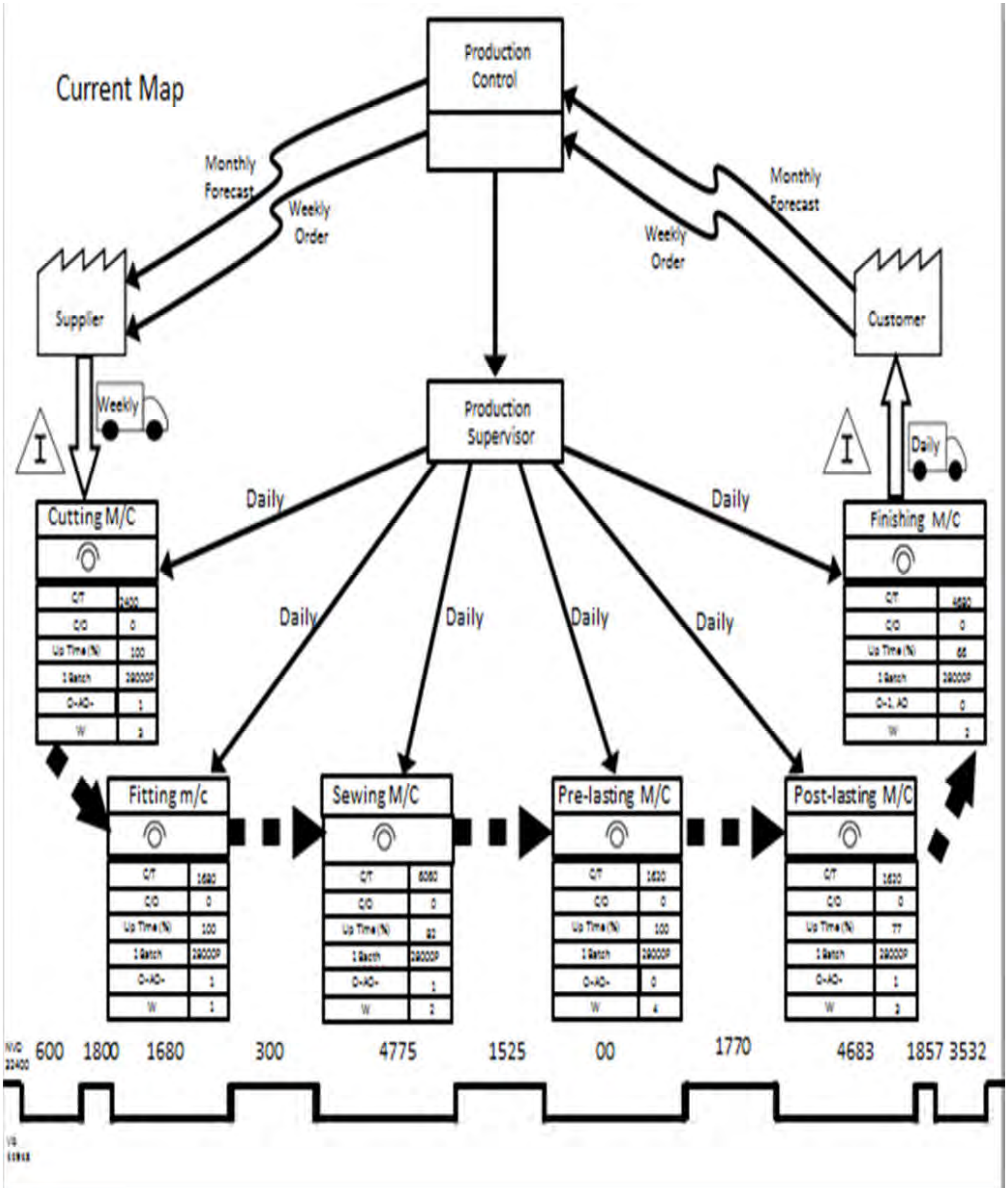


Fig 6.2.2: Present VSM of Casual Shoe Production Line

Fig 6.2.2 represents the present VSM of Casual shoe production line. At present VSM, it revealed that the production of casual shoe was controlled by production supervisor. The different types of bottlenecks at different processing stages were identified and quantified in terms of time as shown in the Fig 6.2.2. The VD and NVD times were shown at the bottom line of present VSM. It was found that in Casual shoe production line about 15270 sec out of 99870 sec or 15.28% were VD activities while 84600 sec or 84.72 % were NVD activities. The Up time (U/T) of sewing, lasting and finishing machine were consecutively 82%, 77% and 66%. At present state, total labor were 25 over the different stages of this production line. After the implementation of lean tools and SS methodologies it was expected that U/T could be improved and total labor and manufacturing waste could be reduced.

6.2.2 Present PCE of Casual shoe production line

In the Casual shoe production line,

Value Added time = 15270 sec

Non Value Added time = 84600 sec

Lead time = Value Added time + Non Value Added time

= 15270 sec + 84600 sec = 99870 sec

Process Cycle Efficiency (PCE) $= \frac{\text{Value Added time}}{\text{Lead time}} \times 100$

= 15.28%

It was seen that the present VSM of Casual shoe production line was 15.28% which was the below of internationally competitive level 25% [74].

6.2.3 Present takt time calculation of Casual shoe production line

Net available time

Working shift/day	2 shifts
Hours/ shift	10 hours
Available time/ shift	600 minutes
Prepare time/ shift	40 minutes
Lunch time/ shift	0 minutes
Planned down time/ shift	0 minutes
Networking time/ shift	560 minutes
Networking time/ shift	33600 seconds
Net available time/ day	67200 seconds

Customer/production scheduled demand

Net available time/day	67200seconds/day
Customer demand/day	5094 cases/day
Takt time	13.19 seconds/case

The present takt time of Casual shoe production line was 13.19 seconds i.e. it takes 13.19 seconds to produce a single case of casual shoe production. Each case contains 24 pair's shoes where a shoe size is Europe-42.

6.2.4 Manufacturing wastes of Casual shoe production line

Waste is a very common seen at every manufacturing industry especially to the industry of developing countries due to the lack of high technological and modern strategies involvement and the observed Casual shoe manufacturing floor was not beyond this.

6.2.4.1 Down Time (D/T) calculation for Casual shoe production line

Waiting time or down time was documented in table 6.2.3 which was observed at different production stages of the studied Casual shoe production line.

Table 6.2.3: Down time (D/T) of Casual shoe production line

Steps	Causes for D/T	D/T (sec)	Average D/T (sec)	C/T	% D/T
Sewing	Needle thread breakage	557			
		539	546	6060	14.11
		547			
	Bobbin or looped thread breakage	368			
		370	367		9.48
		363			
	Skipped stitches	138			
		146	141		3.64
		139			
	Seam pucker	53			
		50	53		1.39
		56			
Lasting	Improper setting during toe lasting	667			
		673	666	6120	17.21
		659			
	Improper setting during seat lasting	310			
		316	312		8.06
		309			

	Inappropriate scouring	269			
		262	263		6.79
		258			
	Side lasting problems due to feather edge stitching	170			
		164	169		4.36
		173			
Finishing	Inefficient ironing	823			
		815	819	3900	21.16
		820			
	Improper polishing	318			
		311	311		8.03
		305			
	Inefficient spraying	165			
		155	157		4.05
		151			
	Bumps or hollows	62			
		68	65		1.68
		65			
Total			3869		

In Casual shoe production line, the most important production stages were sewing, lasting and finishing where the most frequent D/T was observed due to different causes that were documented in table 6.2.3.

6.2.4.2 Waste or defect shoe calculation of Casual shoe production line

There are different types of manufacturing wastes like overproduction, defect, waiting, unnecessary processing, unnecessary inventory, unnecessary transportation between work sites and unnecessary motion in the work place. In a single processing line all types of wastes could not be seen. Base on the nature of production the manufacturing wastes were varied. Among these manufacturing wastes, defect production was very common in the Casual shoe production line. In this processing floor defect product was considered as the defect production. The amount of defect shoe was documented in table 6.2.4.

Table 6.2.4: Wasted products calculation of Casual shoe production line

Name of stages	No of observation	Rejected shoes per batch	Average rejected shoe per batch	Average rejected shoe per batch (per day 12 batch)	Rejected shoe per million opportunity	Gap at Six Sigma level	Remarks
Sewing	1	22					Contains at three sigma level
	2	20					
	3	18	20	120	714	711	
	4	21					
	5	17					
Pre-Lasting	1	195					
	2	187					
	3	120	170	1020	6071	6068	
	4	160					
	5	190					
Post-Lasting	1	208					
	2	210					
	3	215	206	1236	7357	7354	
	4	197					
	5	201					
Finishing	1	3					
	2	3					
	3	2	3x24=72	432	2571	2568	
	4	3					
	5	3					
Total			468	2808	16713		

From table 6.2.4, it seems that the total defect product of Casual shoe production line was 16713 per million products of production line which was considered as the three Sigma productions.

6.2.4.3 Labor waste of Casual shoe production line

The unnecessary motion of labor in the production floor was considered as one of the most common the manufacturing wastes which was also most common in the production floor of Casual shoe production line. After lean tools implementation it was expected that a number of labor could be eliminated from the processing line. The expected number of eliminated labor was documented in the table 6.2.5.

Table 6.2.5: Present and expected labor of Casual shoe production line

Name of stages	No of labor at present state			No of labor at future state		
	O	AO	W	O	AO	W
Cutting	1	1	3	1	0	3
Fitting & Assembly	1	1	1	1	0	1
Sewing	1	1	2	1	1	1
Pre-lasting	0	0	4	0	0	2
Post-lasting	1	1	3	1	1	1
Finishing	1	0	2	1	0	1
Total	6	4	15	5	2	10

At present state, from table 6.2.5, it was seen that throughout the different production stages of Casual shoe production line, total labor were 25 where operator (O), assistant operator (AO) and worker (W) were consecutively 6, 4 and 15. At future state, if the lean tools and SS methodologies will implement, it was expected that different types of bottlenecks and NVD activities will be reduced thus the present number of labor will also be reduced because of a number of unwanted labor were engaged to manage the different types of bottlenecks and NVD activities.

6.2.5 Pareto analysis of Casual shoe production line

The highest frequency of NVD activities or down time was found for inefficient ironing at the Casual shoe production line, while seam pucker of sewing machine showed the lowest frequency.

Table 6.2.6: Cumulative D/T of Casual shoe production line for Pareto analysis

Causes of delay times	Down Time(D/T)	Percentage of D/T	Cumulative of percentage
Inefficient ironing	819	21.1682605	21.1682605
Improper setting during toe lasting	666	17.2137503	38.38201086
Needle thread breakage	546	14.1121737	52.49418454
Bobbin thread breakage	367	9.48565521	61.97983975
Improper setting during seat lasting	312	8.06409925	70.043939
Improper polishing	311	8.03825278	78.08219178
Inappropriate scouring	263	6.79762212	84.87981391
Side lasting problems due to feather edge stitching	169	4.36805376	89.24786767
Inefficient spraying	157	4.0578961	93.30576376
Skipped stitches	141	3.64435255	96.95011631
Bumps or hollows	65	1.68002068	98.63013699
Seam pucker	53	1.36986301	100

The causes for NVD activities were arranged in downward movements in terms of their frequency.

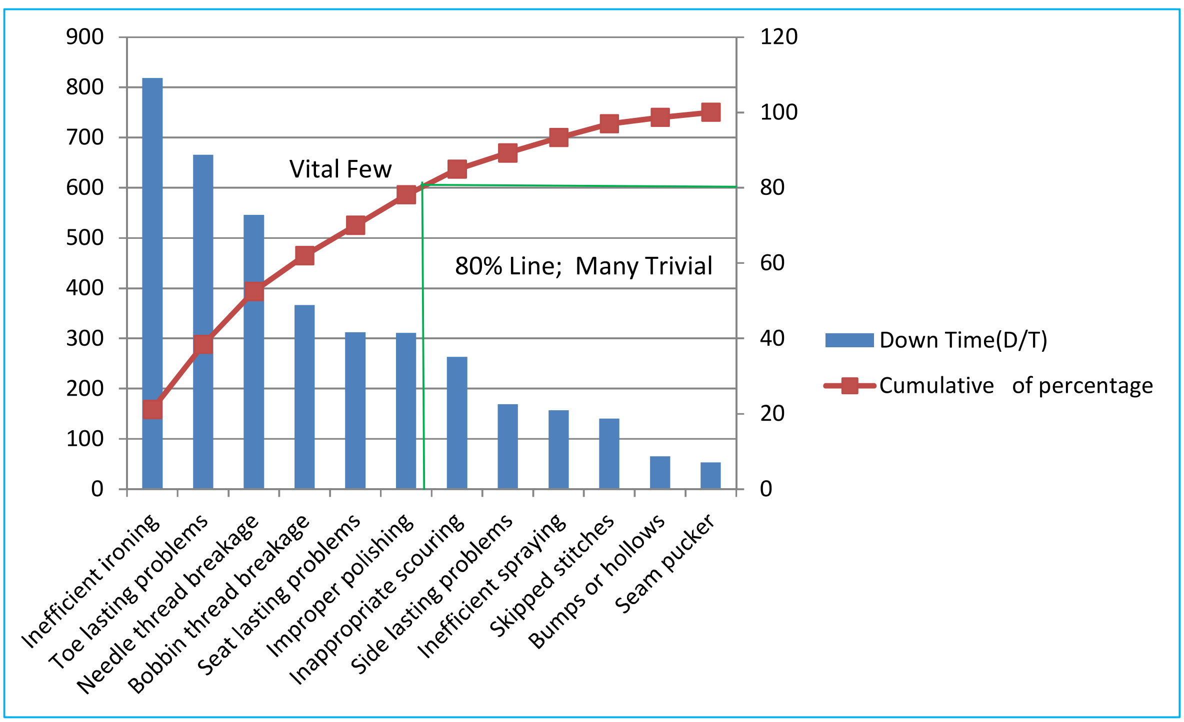


Fig 6.2.3 Pareto chart of Casual shoe production line

From Pareto table (Table 6.2.6); the Pareto chart (Fig 6.2.3) was depicted by aligning the different causes along with X axis; percentage and cumulative percentage of these causes for NVD activities were aligned along with the Y axis. From Fig 6.2.3, it seems that the pioneer causes beyond the different types of bottlenecks and NVD activities were inefficient ironing (21.17%), improper setting during toe lasting (16.21%), Needle thread breakage (14.11%), Bobbin or looped thread breakage (9.48%), Improper setting during seat lasting (8.06%), Improper polishing (8.03%), Inappropriate scouring (6.80%), Side lasting problems due to feather edge stitching (4.36%), Inefficient spraying (4.05%), Skipped stitches (3.64%), Bumps or hollows (1.70%) and Seam pucker (1.40%). From Pareto chart the most responsible causes were easily observed and the effective initiatives can be taken to remove these causes. From Pareto chart (Fig 6.2.3) it was expected that if the most frequent first three causes like as inefficient ironing (21.17%), improper setting during toe lasting (16.21%), Needle thread breakage (14.11%) could be removed, the 80% NVD activities or down times could be removed. Based on previous study, it was averred that 5S, JIT, TPM, DMAIC and other improving strategies could be effective initiatives to remove these most frequent causes.

6.2.6 Improvement points at present VSM of Casual shoe production line

Throughout the observation it was seen that there were some improvement points at different stages of Casual production line. The nature of improving point differs from each and another stages.

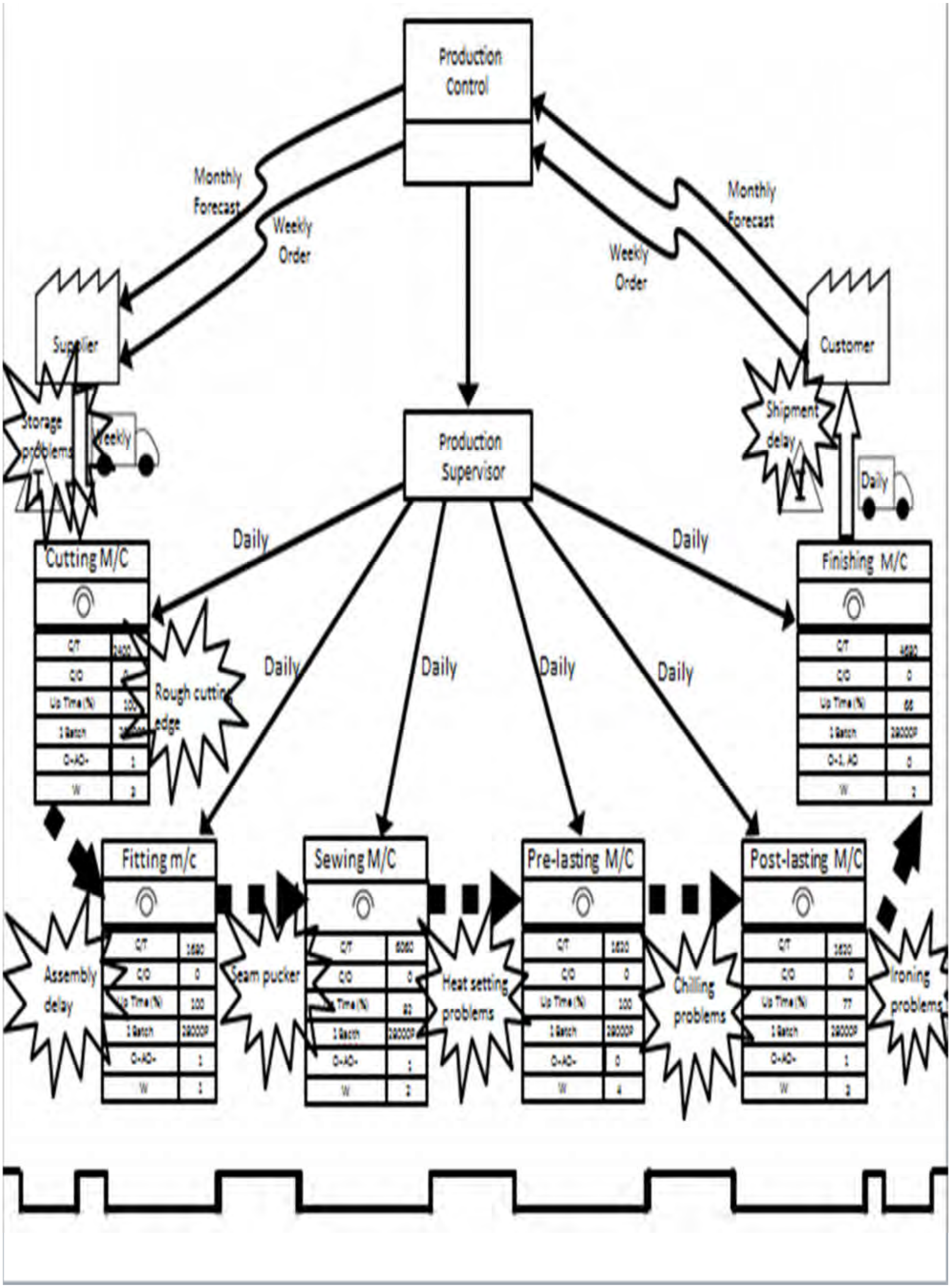


Fig 6.2.4: Present VSM of Casual shoe production line with improvement point

The crucial improvement points were pointed in Fig 6.2.4. In the stage of raw material inventory, delay handling of raw materials towards the next stage of shoe production was observed as the prime point that should be removed in order to reduce the lead time as well as to improve the PCE. In Fig 6.2.4 only the most frequent cause at different stages of Casual shoe production line were pointed. These pointed causes or barriers should be removed in order to reduce the manufacturing wastes and improve the PCE.

6.2.7 Future VSM of Casual shoe production line

In the future VSM, after an intense observation and brainstorming analysis on the Casual shoe production line, the VD and NVD time were calculated and documented in table 6.2.7.

Table 6.2.7: Future State VD and NVD time of Casual shoe production line

Production stages	VD time (sec)	NVD time (sec) (Expected reduction)
Receiving inventory	00	16200 (50%)
Cutting	600	900 (80%)
Fitting & assembly	1680	300 (80%)
Sewing	4775	305 (80%)
Pre-lasting	0	354 (80%)
Post-lasting	4683	371 (80%)
Finishing	3532	350 (80%)
Shipping inventory	00	10800 (60%)
Total	15270 (34.05%)	29580 (65.95%)

Fig 6.2.5 was the future VSM of Casual shoe production line. The future VSM indicated the materials, information and labor flow of single batch production of Casual shoe production line. Each batch produced 28000 pairs of casual shoes. The basic components of future VSM were customers, production control, production supervisor, suppliers, transportation and different stages of processing line like as receiving inventory, cutting, fitting & assembly, sewing, pre-lasting, post-lasting and shipment inventory. Production control was consisted by one manager and two assistant managers. The production started with taking the order from customers by electric signal like as over telephone or email. Later required raw materials were collected from the regarding suppliers. Finally, raw materials were transformed into finished casual shoe throughout the receiving inventory stage to shipment stage.

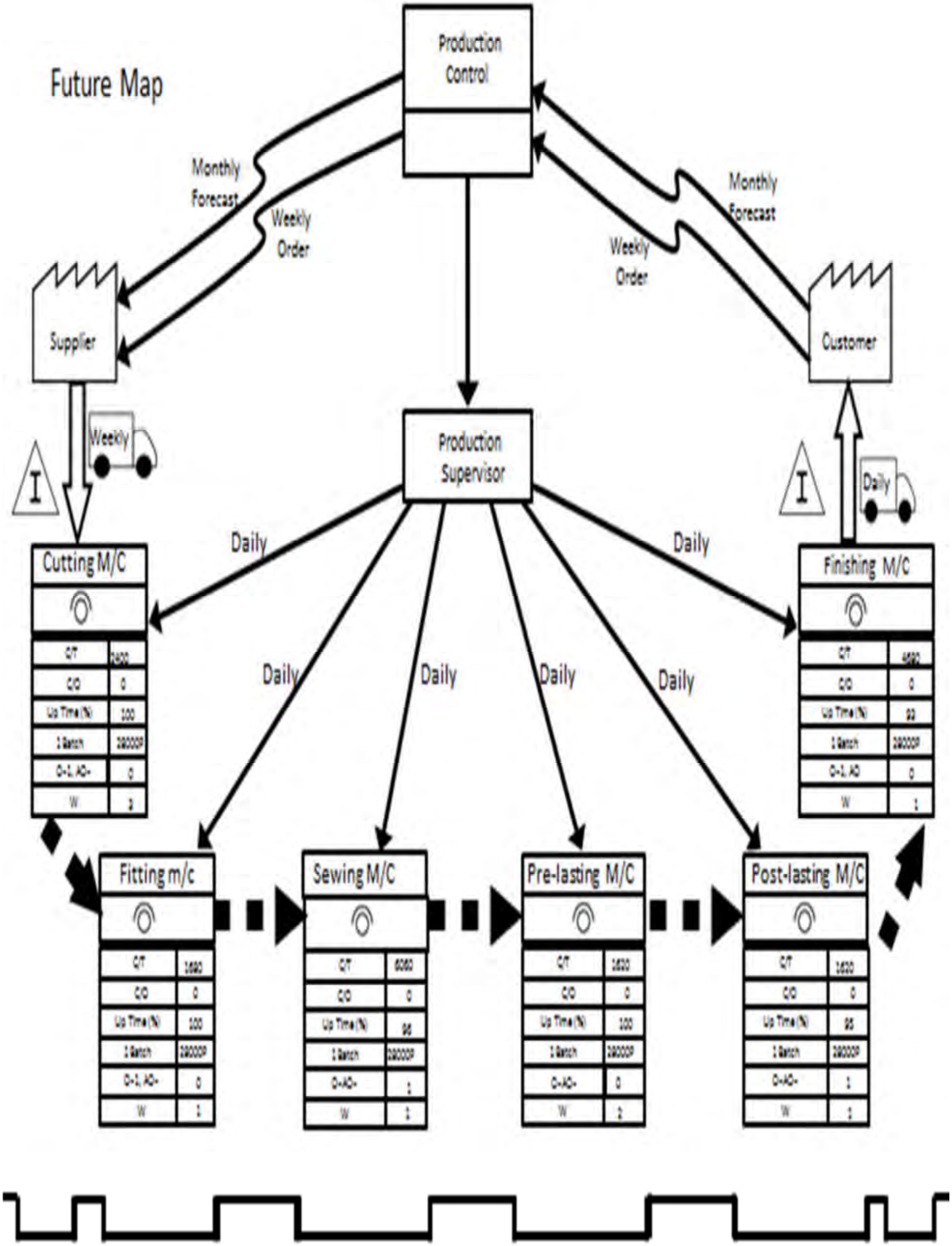


Fig 6.2.5: Future VSM of Casual shoe production line

In this study, based on intense observation, brainstorming and previous regarding studies it was assumed that the NVD time of receiving-stage of Casual shoe production line could be reduced at least 50% (16200 sec) and the NVD time of cutting could also be reduced at least 50% (900 sec). The NVD time of fitting & assembly, sewing and pre-lasting could be reduced at least 80% from the present state and in the future state these NVD times could be consecutively 305 sec, 354 sec, 371 sec and 350 sec which could be seen in table 6.2.7. In this future VSM, the pivotal promising changes were the reduction of total number of labor which were seen at every production stage, reduction of NVD time and improved up time (U/T). In future VSM, it was expected that the total labor including operator, assistant operator and worker could be 17 which was 25 at present VSM i.e. after the implementation of lean tools and SS methodologies at least 7 labor could be reduced. It was also anticipated that after the proper implementation of lean tools and SS methodologies, the U/T of sewing, lasting and finishing machine could be consecutively 96%, 95% and 93% while the U/T of that machines were found consecutively 82%, 77% and 66% at present state of the observed production line.

6.2.8 Expected PCE of Casual shoe production line

In the Casual shoe production line,

Value Added time	= 15270 Sec
Non Value Added time	= 29580 Sec
Expected Lead time	= Value Added time + Non Value Added time
	= 15270 Sec + 29580 Sec = 44850 Sec
Process Cycle Efficiency (PCE)	$= \frac{\text{Value Added time}}{\text{Lead time}} \times 100$
	= 34.05%

After the proper implementation of lean tools and SS methodologies it was expected the PCE of Casual shoe production line could be 34.05% while the present PCE was 15.28%, the NVD time could be reduced from 84600 sec to 29580 sec and lead time could be reduced from 99870 sec to 44850 sec.

6.2.9 Expected takt time of Casual shoe production line

Net available time

Working shift/day	2 shifts
Hours/ shift	10 hours
Available time/ shift	600 minutes
Prepare time/ shift	40 minutes
Lunch time/ shift	0 minutes
Planned down time/ shift	0 minutes
Networking time/ shift	560 minutes
Networking time/ shift	33600 seconds
Net available time/ day	67200 seconds

Customer/production demand

Net available time/day	67200seconds/day
Customer demand/day	5211 cases/day
Takt time	12.89 seconds/case

The present takt time of Casual shoe production line was 13.19 sec per case production and it was expected that after the adoption of lean tools and SS methodologies this could be reduced to 12.89 sec per case production.

The versatile promising advantages and outcomes that was drawn with the adoption of lean tools and SS methodologies were discussed in the discussion portion of this thesis paper where it was delineated the percentage of improvement of PCE, takt time, VD & NVD time, lead time and labor improvement at present state and future state of production.

6.3 Court Shoe Production Line

It was a Court shoe production line. The basic stages of court shoe production line were as follows-

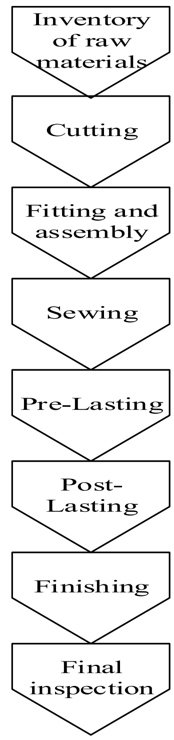


Fig 6.3.1 Basic stages of Court shoe production line

6.3.1 Present Value Steam Mapping (VSM) of court shoe production line

To draw the present VSM relevant data like as VD and NVD time, Cycle time, Change Over time, Uptime, Lot size, quantity to deliver, delivery time were observed and information related to assembly line such as processing time, inventory storages, inspections, rework loops, number of workers and operational hours per day were collected and documented in Table 6.3.1 and Table 6.3.2. To draw the completion of present VSM of Court shoe production, a timeline was added at the bottom of the map recording the VD and NVD time.

Table 6.3.1: Down Time, Cycle Time and Up Time data of court shoe production line

Times	Sewing			Lasting			Finishing		
	D/T (Sec)	C/T (Sec)	U/T (%)	D/T (Sec)	C/T (Sec)	U/T (%)	D/T (Sec)	C/T (Sec)	U/T (%)
1st	474	2760	83	862	2400	64	384	1620	76
2nd	487	2760	82	869	2400	64	385	1620	76
3rd	474	2760	83	849	2400	65	388	1620	76

Note: Sewing speed: 350 RPM; Lasting speed: 400 RPM; finishing machine speed: 25 case per min. Batch production-4000 pairs.

The D/T, C/T, and U/T of Court shoe production line were documented in Table 6.3.1. In this processing line the stage of sewing, lasting and finishing machine were mainly responsible for D/T. In the stage of sewing, average U/T was 83% and C/T was 2760 sec. In the stage of lasting average U/T was 64% and C/T was 2400 sec. In the stage of finishing C/T was 1620 sec and U/T was 76%. The percentage of available time for machine work or processing of desire product is known as the U/T. By observing the U/T of different unit stage of production line, it can be assumed the efficiency of the whole production line. At present state, the U/T of Court shoe production line varies from 64% (lasting stage) to 83% (sewing stage). By this study it was attempted to increase the U/T in the future state as well as to reduce the D/T and to reduce the ultimate lead time.

Table 6.3.2: VD and NVD time of Court shoe production line

Production stages	VD time (Sec)	NVD time (Sec)
Receiving inventory	00	28800
Cutting	600	1200
Fitting & assembly	1200	240
Sewing	2297	703
Pre-lasting	00	672
Post-lasting	1650	1372
Finishing	1231	702
Shipping inventory	00	43200
Total	6978 (8.32%)	76889 (91.68%)

The VD and NVD time of different processing stages of Court shoe production line was documented in Table 6.3.2. At present state, there were no VD time except NVD time in the stages of receiving inventory, pre-lasting and shipping inventory but in this process line, this NVD time or these stages were required for the court shoe production. In this court shoe production line, the total VD time were 6978 sec (8.32 %) and the total NVD time were 76889 sec (91.68 %). By this study, it was tried to increase the percentage of VD time by reducing the NVD time with the proper implementation of lean tools and SS methodologies.

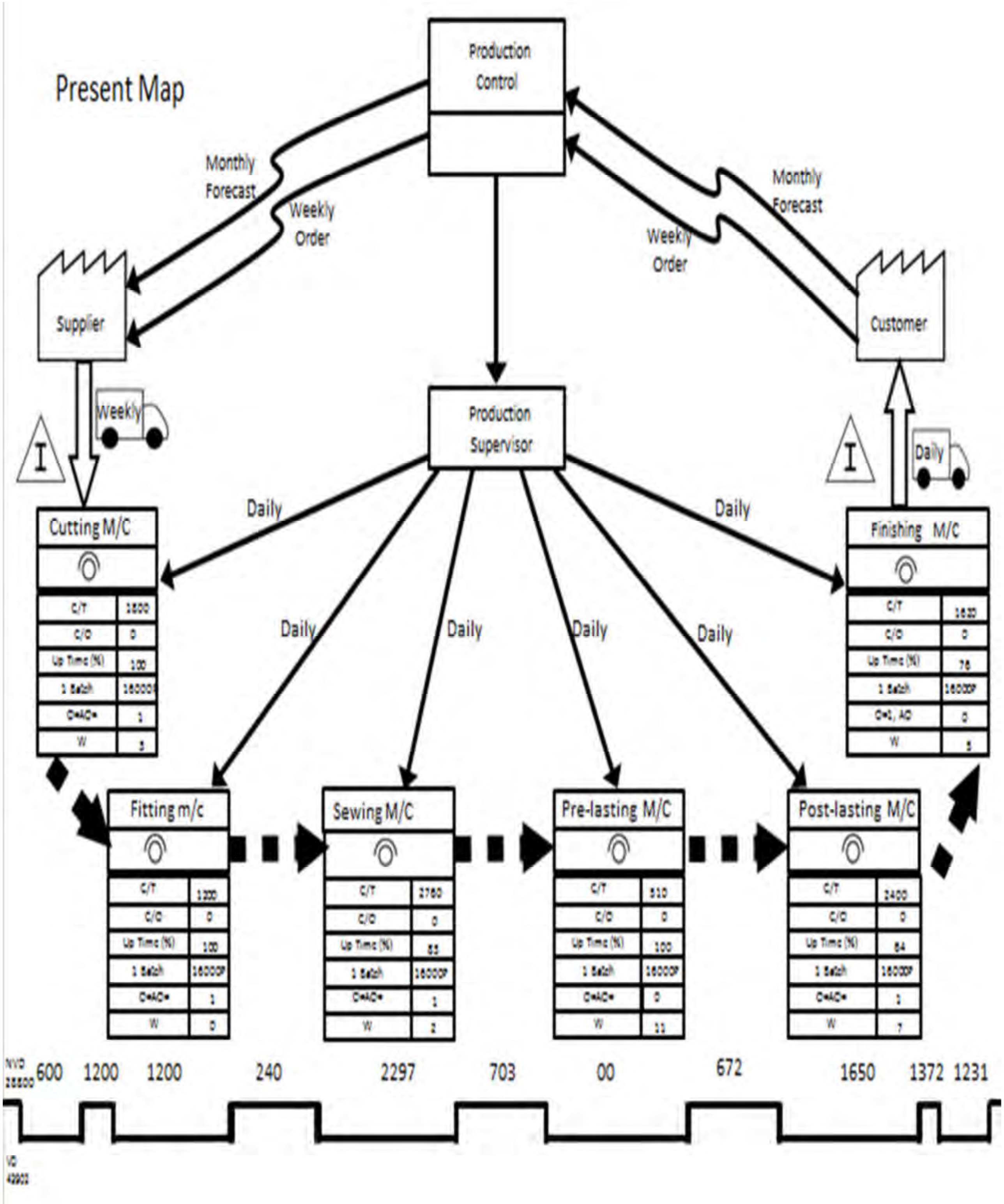


Fig 6.3.2 Present VSM of Court shoe production line

It helps to draw the required processing stage with mentioning required labor, C/T, U/T, C/O and batch size. By observing the present scenario of regarding processing line, it can be known like as what number of labor is needed at different processing unit? How much VD & NVD time is present? Where & what kind of improvement should be done? It helps to calculate the PCE, lead time and takt time. Fig 6.3.2 represents the present VSM of court shoe process line. At present VSM, the production of court shoe was controlled by production manager, assistant manager and supervisor. In this processing line, the production starts by taking the order of production from the customers. The different types of bottlenecks at different processing stages were identified and quantified in terms of time as shown in the Fig 6.3.2. The Up time (U/T) of sewing, lasting and finishing machine were consecutively 83%, 64% and 76%. At present state of this processing line over the different stages total labor were 36. After the implementation of lean tools and SS methodologies it was expected that U/T could be improved and total labor could also be reduced.

6.3.2 Present PCE of court shoe production Line

In the Court shoe production line,

Value Added time = 6978 Sec

Non Value Added time = 76889 Sec

Expected Lead time = Value Added time + Non Value Added time

= 6978 Sec + 76889 Sec = 83867 Sec

Process Cycle Efficiency (PCE) $= \frac{\text{Value Added time}}{\text{Lead time}} \times 100$

= 8.32%

It seems that the present VSM of court shoe processing line is 8.32 % which is the below of internationally competitive level 25% [74].

6.3.3 Present takt time of court shoe process line

Net available time

Working shift/day	2 shifts
Hours/ shift	10 hours
Available time/ shift	600 minutes
Prepare time/ shift	40 minutes
Lunch time/ shift	0 minutes
Planned down time/ shift	0 minutes
Networking time/ shift	560 minutes
Networking time/ shift	33600 seconds
Net available time/ day	67200 seconds

Customer/production demand

Net available time/day	67200seconds/day
Customer demand/day	9333 cases/day
Takt time	7.20 seconds/case

The present takt time of Court shoe production line was 7.20 sec i.e. it takes 7.20 sec to produce a single case of Court shoe production. Each case produced 250 pairs court shoe.

6.3.4 Manufacturing waste of court shoe production line

There are different types of manufacturing wastes like overproduction, defect, waiting, unnecessary processing, unnecessary inventory, unnecessary transportation between work sites and unnecessary motion in the work place. Among these defect productions, wasted time due to different causes and unnecessary motion of labor was very common in the Court shoe production line.

6.3.4.1 Down Time (D/T) calculation of court shoe production line

The down time for different causes in the court shoe production floor was documented in table 6.3.3.

Table 6.3.3: Down Time (D/T) of court shoe production line

Step	Causes for D/T	D/T (Sec)	Average D/T	C/T	% D/T
Sewing	Needle thread breakage	302		2760	
		308	303		17.55
		298			
	Bobbin or looped thread breakage	55			
		51	53		3.07
		48			
	Skipped stitches	34			
		32	35		2.02
		40			
	Seam pucker	83			
		96	89		5.15
		88			
Lasting	Improper setting during toe lasting	534		2400	
		524	526		5.96
		520			
	Improper setting during seat lasting	97			
		109	103		
		103			
	Inappropriate scouring	93			
		102	97		5.62
		96			
	Side lasting problems due to feather edge stitching	48			
		39	43		2.49
		41			

	Inappropriate chilling	90			
		95	91		5.27
		89			
Finishing	Inefficient ironing	176		1620	
		170	171		9.90
		167			
	Improper polishing	90			
		87	91		5.27
		95			
	Inefficient spraying	39			
		45	42		2.43
		42			
	Long mark defects	38			
		45	41		2.37
		41			
	Bumps or hollows	41			
		38	41		2.37
		43			
Total			1726		

In court shoe production line, the most important processing stages were sewing, lasting and finishing where the most frequent D/T was observed due to different causes that were documented in table 6.3.3.

6.3.4.2 Wasted products calculation of Court shoe production line

There are different types of manufacturing wastes like overproduction, defect, waiting, unnecessary processing, unnecessary inventory, unnecessary transportation between work sites and unnecessary motion in the work place. In a single processing line all types of wastes could not be seen. Base on the nature of production the manufacturing wastes are varied. Among these manufacturing wastes, defect production was very common in the Court shoe production line. In this processing line defect shoe was considered as the defect production. The amount of defect shoe was documented in table 6.3.4.

Table 6.3.4: Wasted product calculation of court shoe production line

Name of stages	No of observation	Rejected shoes per batch	Average rejected shoe per batch	Average rejected shoe per batch (per day 12 batch)	Rejected shoe per million opportunity	Gap at Six Sigma level	Remarks
Sewing	1	14					Contains at three sigma level
	2	11					
	3	10	11	132	688	685	
	4	13					
	5	9					
Pre-lasting	1	260					
	2	258					
	3	269	258	3096	16125	16122	
	4	253					
	5	248					
Post-lasting	1	193					
	2	180					
	3	199	186	2232	11625	11622	
	4	170					
	5	189					
Finishing	1	4					
	2	3					
	3	3	3x24=72	864	4500	4497	
	4	3					
	5	3					
Total			527	6324	32938		

From table 6.3.4, it seems that the total defect product of court shoe process line was 32938 per million product of production which was considered as the three Sigma productions. But the prime target of any manufacturing industry should be Six Sigma production where the amount of defect product should not be more than 3.4 per million product of production. Throughout this study it was expected that 80% of the present manufacturing waste could be reduced after the implementation of lean tools and SS methodologies.

6.3.4.3 Wasted labor of court shoe production line

After lean tools implementation it was expected that a number of labor could be eliminated from court shoe processing line. The unnecessary motion of labor in the processing line was also considered as the manufacturing waste. The expected number of eliminated labor was documented in the table 6.3.5.

Table 6.3.5: Present and expected Labor of court shoe production line

Name of stages	No of labor at present state			No of labor at future state		
	O	AO	W	O	AO	W
Cutting	1	1	3	1	1	3
Fitting & assembly	1	1	0	1	0	0
Sewing	1	1	1	1	0	1
Pre-lasting	0	0	11	0	0	4
Post-lasting	1	1	7	1	1	3
Finishing	1	0	5	1	0	2
Total	5	4	27	5	2	13

At present state, from table 6.3.5, it was seen that throughout the different processing stages of court shoe production line, total labor were 36 where operator (O), assistant operator (AO) and worker were consecutively 5, 4 and 27. At future state, if the lean tools and SS methodologies will implement, it was expected that different types of bottlenecks and NVD activities will be reduced thus the present number of labor will also be reduced from 36 to 20 where operator (O), assistant operator (AO) and worker were consecutively 5, 2 and 13. Because of a number of unwanted labors were engaged to manage the different types of bottlenecks and NVD activities.

6.3.5 Pareto analysis

Pareto analysis was performed by drawing the Pareto chart consisting of causes for delay along the X axis and percentage and cumulative percentage of down time along the Y axis. The highest frequency of down time was found as toe lasting problems at the court shoe production line while skipped stiches of sewing showed the lowest frequency.

Table 6.3.6: Cumulative D/T for Pareto analysis of court shoe production line

Causes of delay times	Down Time(D/T)	Percentage of D/T	Cumulative of percentage
Toe lasting problems	526	30.4750869	30.4750869
Needle thread breakage	303	17.5550406	48.03012746
Inefficient ironing	171	9.90730012	57.93742758
Seat lasting problems	103	5.96755504	63.90498262
Inappropriate scouring	97	5.61993048	69.52491309
Inappropriate chilling	91	5.27230591	74.797219
Improper polishing	91	5.27230591	80.06952491
Seam pucker	89	5.15643105	85.22595597
Bobbin thread breakage	53	3.07068366	88.29663963
Side lasting problems	43	2.49130939	90.78794902
Inefficient spraying	42	2.43337196	93.22132097
Long mark defects	41	2.37543453	95.5967555
Bumps or hollows	41	2.37543453	97.97219003
Skipped stiches	35	2.02780997	100

Different causes of NVD activities or down time at different processing stages of court shoe processing line with their frequency in terms of percentages and cumulative percentages were documented in table 6.3.6. The causes for NVD activities were arranged in downward movements in terms of their frequency.

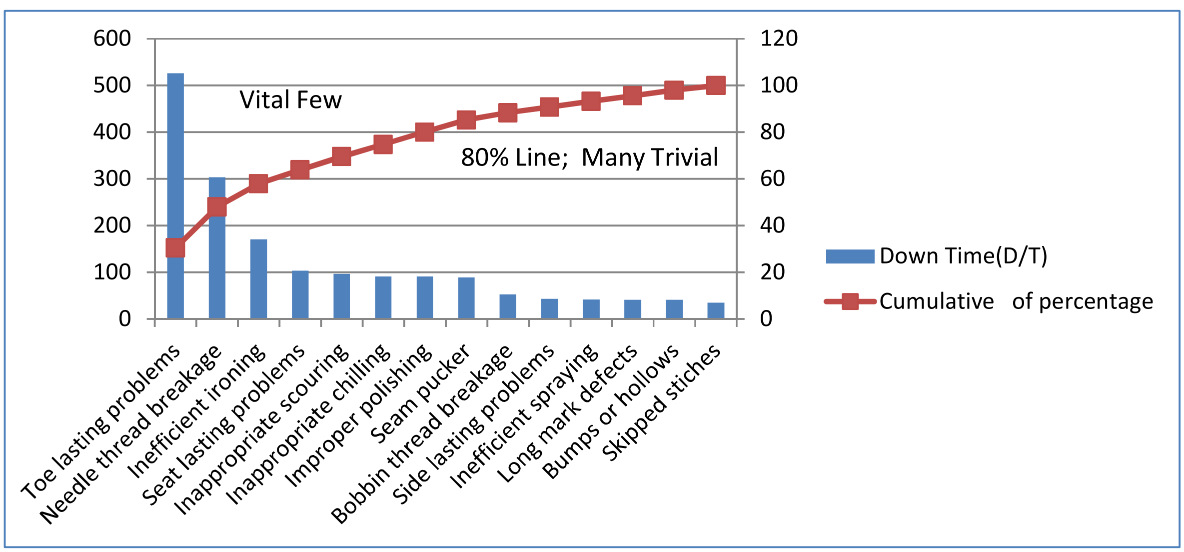


Fig.6.3.3. Pareto chart of Court shoe production line

Pareto chart (Fig 6.3.3) was depicted from Pareto table (Table 6.3.6) by aligning the different causes along with X axis; percentage and cumulative percentage of these causes for NVD activities were aligned along with the Y axis. From Fig 6.3.3, it seems that the pioneer causes beyond the different types of bottlenecks and NVD activities were Toe lasting problems (30.47%), Needle thread breakage (17.55%), Inefficient ironing (9.91%), Seat seating problems (5.97%), Inappropriate scouring (5.62%), Insufficient Chilling (5.27%), Improper polishing (5.27%), Seam pucker (5.16%), Bobbin thread breakage (3.07%), Inefficient heat setting (2.49%), Inefficient spraying (2.43%), Long mark defects (2.37%), Bumps or hollows (2.37%) and Skipped stiches (2.02%). From Pareto chart (Fig 6.3.3) the most responsible causes could be easily observed and the effective initiatives could also be taken to remove these causes. It was expected that if the most frequent first three or 20% causes like as Toe lasting problems (30.47%), Needle thread breakage (17.55%), Inefficient ironing (9.91%) could be removed, the 80% NVD activities or down times could be removed. 5S, JIT, TPM, DMAIC and other improving strategies could be effective initiatives to remove these most frequent causes.

6.3.6 Improvement points at present VSM of Court shoe production line

Throughout the observation it was seen that there were some improvement points at different stages of Court shoe production line. The nature of improving point differs from each and another stages.

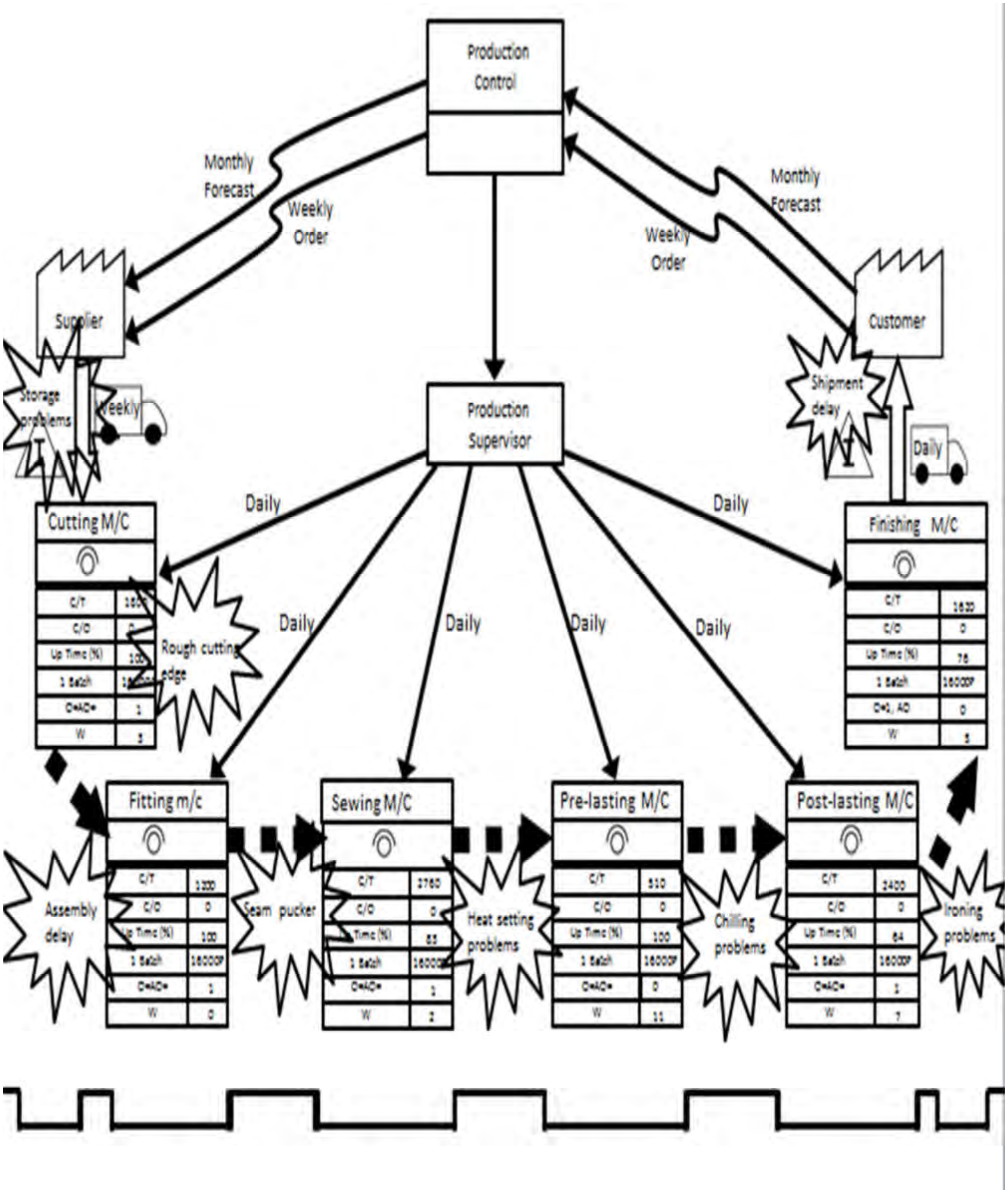


Fig 6.3.4 Present VSM of Court shoe production line with improvement point

The crucial improvement points were pointed in Fig 6.3.4. Besides these, conventional movement of raw materials like as carry of raw materials sack by labor instead of conveyor belt movement, inventory storage room was soaked and congested, crowd movement were most common. In the stage of shipment the basic barrier were irregular shipment and insufficient space for movement in fig 6.3.4 only the most frequent cause at different stages of court shoe processing line were pointed. These pointed causes or barriers should be removed in order to reduce the manufacturing wastes and improve the PCE. The fig 6.3.5 is the future VSM of court shoe production line. The future VSM indicates the materials, information and labor flow of single batch production of court production line. Each batch processed 16000 pair of court shoe.

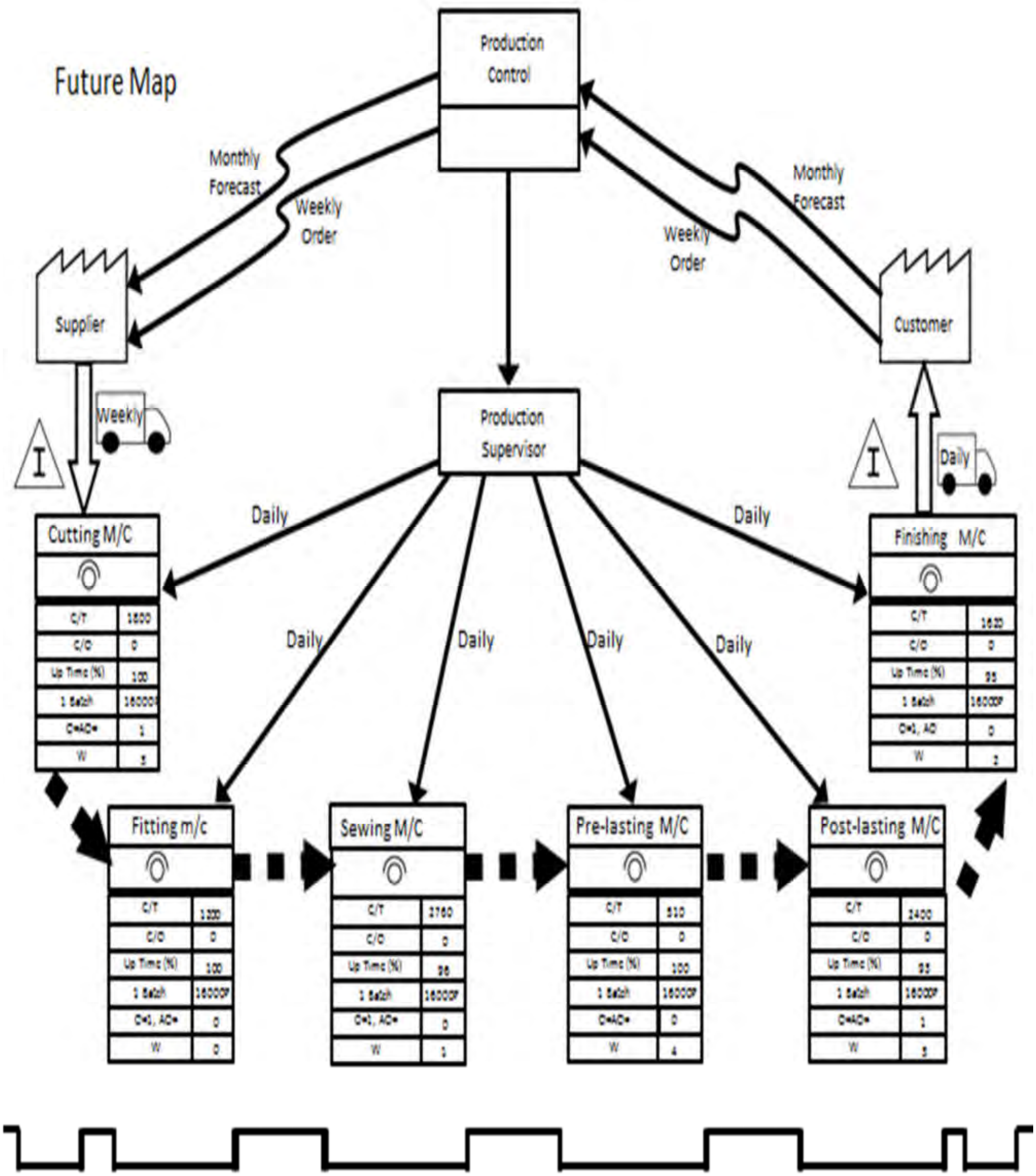


Fig. 6.3.5 Future VSM of court shoe production line

6.3.7 Future VSM of court shoe production line

In the future VSM after a deep brainstorming and an intense observation on the court shoe processing line the VD and NVD time were calculated and documented in table 6.3.7.

Table 6.3.7: Future State VD and NVD time analysis of court shoe production line

Processing stage	Value Added Time (Sec)	Non Value Added Time (Sec)
Receiving Inventory	00	14400 (50%)
Cutting	600	600 (50%)
Fitting & assembly	1200	240 (0%)
Sewing	2297	140(80%)
Pre-lasting	00	134(80%)
Post-lasting	1650	274 (80%)
Finishing	1231	140(80%)
Shipping Inventory	00	12960 (70%)
Total	6978 (19.46 %)	28888 (80.54%)

In this study, based on intense observation, brainstorming and previous regarding studies, it was assumed that the NVD time of receiving stage of court shoe processing line could be reduced at least 50% (14400 sec) and the NVD time of shoe production could be also be reduced at least 50% (600 sec). The NVD time of sewing, pre-lasting, post-lasting and finishing could be reduced at least 80% from the present state and in the future state these NVD times could be consecutively 140 sec, 134 sec, 274 sec and 140 sec which were seen in table 6.3.7.

In this future VSM the basic promising changes were the reduction of total number of labor which was observed at every processing stage, reduction of NVD time which was indicated at the bottom level of future VSM, improved Up time (U/T) which was also seen at every processing stage of court shoe processing line. In future VSM the total labor including operator, assistant operator and worker could be 20 which was 36 at present VSM i.e. after the implementation of lean tools and SS methodologies it was expected at least 16 labors could be reduced. The U/T of sewing, lasting and finishing machine could be consecutively 96%, 93% and 95% but at present state the U/T of sewing, lasting and finishing machine were consecutively 83%, 64% and 76%.

6.3.8 Expected PCE of court shoe production line

In the court shoe production line,

Value Added time	= 6978 Sec
Non Value Added time	= 28888 Sec
Expected Lead time	= Value Added time + Non Value Added time
	= 6978 Sec + 28888 Sec = 35866 Sec
Process Cycle Efficiency (PCE)	$= \frac{\text{Value Added time}}{\text{Lead time}} \times 100$
	= 19.46%

After the proper implementation of lean tools and SS methodologies it was expected the PCE of court shoe processing line could be 19.46 % while the present PCE was 8.32 %, the NVD time could be reduced from 76889 sec to 28,888 sec and lead time could be reduced from 83867 sec to 35866 sec.

6.3.9 Expected takt time of court shoe production line

Net available time

Working shift/day	2 shifts
Hours/ shift	10 hours
Available time/ shift	600 minutes
Prepare time/ shift	40 minutes
Lunch time/ shift	0 minutes
Planned down time/ shift	0 minutes
Networking time/ shift	560 minutes
Networking time/ shift	33600 seconds
Net available time/ day	67200 seconds

Customer/production demand

Net available time/day	67200seconds/day
Customer demand/day	9597 cases/day
Takt time	7.002 seconds/case

The present takt time of court shoe production line was 7.20 sec per case production and it was expected that after the adoption of lean tools and SS methodologies this could be reduced to 7.002 sec per case production. So, it seems that the lean tools and SS methodologies could bring the revolution beyond the speed of production of any production line.

6.4 Oxford shoe production Line

It was an oxford shoe production line. The basic stages of oxford shoe production line were as follows-

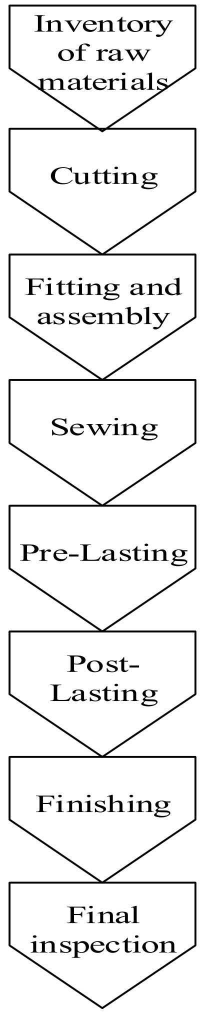


Fig 6.4.1 Basic stages of oxford shoe production line

6.4.1 Present VSM of oxford shoe production line

To draw the present VSM relevant data like as VD and NVD time, Cycle time, Change Over time, Uptime, Lot size, quantity to deliver, delivery time were observed and information related to assembly line such as processing time, inventory storages, inspections, rework loops, number of workers and operational hours per day were collected and documented in table 6.4.1 and table 6.4.2. Other relevant data such as number of operators (O), assistant operator (AO) and worker (W) were shown in current VSM. To draw the completion of present VSM of oxford shoe processing line, a timeline was added at the bottom of the map recording the VD and NVD time.

Table 6.4.1: Present state Down Time (D/T), Cycle Time (C/T) and Up Time (U/T) data of oxford shoe production line

Times	Sewing			Lasting			Finishing		
	D/T (Sec)	C/T (Sec)	U/T (%)	D/T (Sec)	C/T (Sec)	U/T (%)	D/T (Sec)	C/T (Sec)	U/T (%)
1^{st}	503	2700	82	651	2400	73	501	1620	69
2^{nd}	512	2700	81	646	2400	73	462	1620	71
3^{rd}	515	2700	81	621	2400	74	492	1620	70

Note: Cutting speed: 350 RPM; Sewing speed: 400 RPM; Lasting machine speed: 27 case per min. Batch production- 4000 pairs.

The D/T, C/T and U/T of oxford shoe processing line were documented in table 6.4.1. In this production line the stage of sewing, lasting and finishing machine were mainly responsible for D/T. In the stage of sewing, average U/T was 81% and C/T was 2760 sec. In the stage of lasting average U/T was 73% and C/T was 2400 sec. In the stage of finishing C/T was 1620 sec and U/T was 70%. The percentage of available time for machine work or processing of desire product was known as the U/T. By observing the U/T of different unit stage of production line, it can be assumed the efficiency of the whole production line. At present state, the U/T of oxford shoe process line varies from 70% (finishing stage) to 81% (sewing stage). By this study it was attempted to increase the U/T in the future state as well as to reduce the D/T and to reduce the ultimate lead time.

Table 6.4.2: Present state VD and Non NVD time for oxford shoe production line

Processing stages	VD time (Sec)	NVD time (Sec)
Receiving Inventory	00	28800
Cutting	600	1200
Fitting & assembly	1200	240
Sewing	2035	905
Pre-lasting	00	648
Post-lasting	1745	1205
Finishing	1132	790
Shipping inventory	00	43200
Total	6712 (8.01%)	76988 (91.99%)

The VD and NVD time of different processing stages of oxford shoe production line were documented in table 6.4.2. At present state, there were no VD time except NVD time in the stages of receiving inventory, pre-lasting and shipping inventory but in this process line, this NVD time or these stages were required for the oxford shoe processing. In this production line, the total VD time were 6712 sec (8.01%) and the total NVD time were 76988 sec (91.99 %). By this study, it was tried to increase the percentage of VD time by reducing the NVD time with the proper implementation of lean tools and SS methodologies.

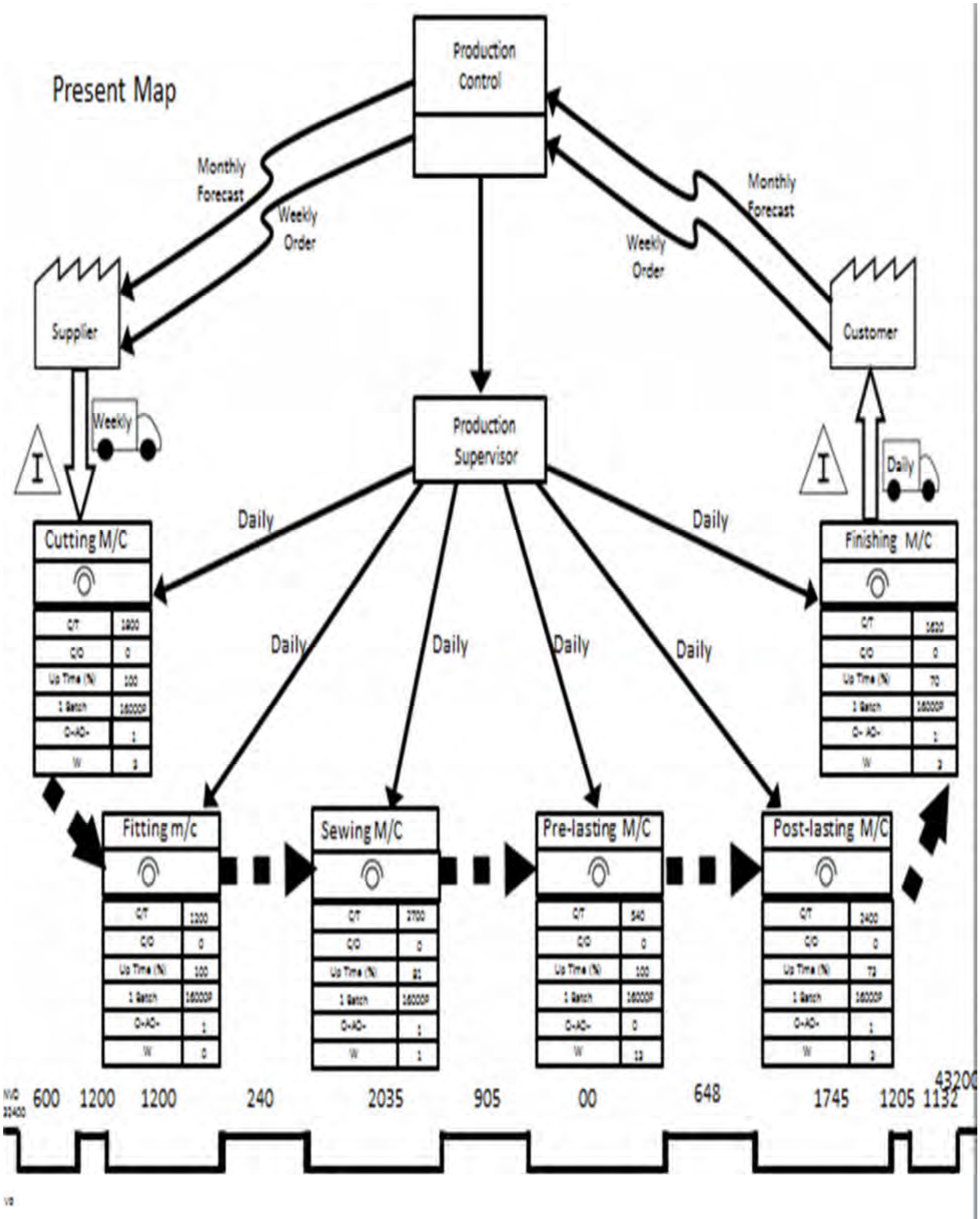


Fig-6.4.2 Present VSM of oxford shoe production line

It helps to draw the required processing stage with mentioning required labor, C/T, U/T, C/O and batch size. By observing the present scenario of regarding processing line, it can be known like as what number of labor is needed at different processing unit? How much VD & NVD time is present? Where & what kind of improvement should be done? It helps to calculate the PCE, lead time and takt time. Fig 6.4.2 represents the present VSM of oxford shoe process line. At present VSM, the production of oxford shoe was controlled by production manager, assistant manager and supervisor. The different types of bottlenecks at different processing stages were identified and quantified in terms of time as shown in the Fig 6.4.2. The Up time (U/T) of sewing, lasting and finishing machine were consecutively 81%, 73% and 70%. At present state of this processing line over the different stages total labor was 33. After the implementation of lean tools and SS methodologies it was expected that U/T could be improved and total labor could be reduced.

6.4.2 Present PCE of oxford shoe production line

In the oxford shoe production line,

Value Added time = 6712 Sec

Non Value Added time = 76988 Sec

Expected Lead time = Value Added time + Non Value Added time

= 6712 Sec + 76988 Sec = 83700 Sec

Process Cycle Efficiency (PCE) $= \frac{\text{Value Added time}}{\text{Lead time}} \times 100$

= 8.01%

It seems that the present VSM of oxford shoe production line is 8.01 % which is the below of internationally competitive level 25% [74].

6.4.3 Present Takt time of oxford shoe production line

Net available time

Working shift/day	2 shifts
Hours/ shift	10 hours
Available time/ shift	600 minutes
Prepare time/ shift	40 minutes
Lunch time/ shift	0 minutes
Planned down time/ shift	0 minutes
Networking time/ shift	560 minutes
Networking time/ shift	33600 seconds
Net available time/ day	67200 seconds

Customer/production demand

Net available time/day	67200seconds/day
Customer demand/day	9566 cases/day
Takt time	7.03 seconds/case

The present takt time of oxford shoe production line was 7.03 sec. i.e. it takes 7.03 sec to produce a single case of oxford shoe production. Each case produced 250 pairs oxford shoe.

6.4.4 Manufacturing waste of oxford shoe production line

Manufacturing wastes like overproduction, defect, waiting, unnecessary processing, inventory & transportation between work sites and unnecessary motion of labor in the work place were very common in the oxford shoe production line.

6.4.4.1 Down time (D/T) calculation for oxford shoe production line

The down time of different machines of the processing line were observed and documented in table 6.4.3.

Table 6.4.3: Down time (D/T) of oxford shoe production line

Steps	Causes for D/T	D/T (sec)	Average D/T	C/T	%D/T
Sewing	Needle thread breakage	314		2760	
		310	311		19.09
		308			
	Bobbin or looped breakage	73			
		82	78		4.78
		80			
	Seam pucker	29			
		31	32		1.96
		37			
	Skipped stitches	87			
		89	87		5.34
		90			
Lasting	Improper setting during toe lasting	312		2400	
		318	313		19.12
		310			
	Improper setting during seat lasting	112			
		104	103		6.32
		93			
	Inappropriate scouring	93			
		96	92		5.64
		88			

	Side lasting problems due to feather edge stitching	84			
		81	81		4.97
		78			
	Inefficient chilling	50			
		47	49		3.01
		52			
Finishing	Inefficient ironing	293		1620	
		281	286		17.55
		284			
	Improper polishing	83			
		78	83		5.09
		87			
	Inefficient spraying	46			
		41	41		2.51
		37			
	Long mark defects	41			
		32	37		2.27
		43			
	Bumps or hollows	38			
		30	36		2.20
		41			
Total			1629		

In oxford shoe production line, the most important processing stages were sewing, lasting and finishing where the most frequent D/T was observed due to different causes that were documented in table 6.4.3.

6.4.4.2 Wasted products calculation of oxford shoe production line

The amount of defect product was documented in table 6.4.4.

Table 6.4.4: Wasted products of oxford shoe production line

Name of stages	No of observation	Rejected shoes per batch	Average rejected shoe per batch	Average rejected shoe per batch (per day 12 batch)	Rejected shoe per million opportunity	Gap at Six Sigma level	Remarks
Sewing	1	10					Contains at three sigma level
	2	11					
	3	9	11	132	688	685	
	4	13					
	5	12					
Pre-lasting	1	266					
	2	253					
	3	260	257	3084	16063	16060	
	4	254					
	5	250					
Post-lasting	1	186					
	2	180					
	3	192	185	2220	11563	11560	
	4	176					
	5	189					
Finishing	1	3					
	2	3					
	3	2	3x24=72	864	4500	4497	
	4	3					
	5	3					
Total			525	6300	32814		

From table 6.4.4, it seems that the total defect product of oxford shoe process line was 32814 per million product of production which was considered as the three Sigma productions. But the prime target of any manufacturing industry should be Six Sigma production where the amount of defect product should not be more than 3.4 per million product of production. Throughout this study it was expected that 80% of the present manufacturing waste could be reduced after the implementation of lean tools and SS methodologies.

6.4.4.3 Wasted labor of oxford shoe production line

After lean tools implementation it was expected that a number of labor could be eliminated from oxford shoe processing line. The unnecessary motion of labor in the processing line was also considered as the manufacturing waste. The expected number of eliminated labor was documented in the table 6.4.5.

Table 6.4.5: Present and expected Labor of oxford shoe production line

Name of stages	No of labor at present state			No of labor at future state		
	O	AO	W	O	AO	W
Cutting	1	1	3	1	1	3
Fitting & assembly	1	1	0	1	0	0
Sewing	1	1	1	1	0	1
Pre-lasting	0	0	13	0	0	5
Post-lasting	1	1	3	1	1	1
Finishing	1	1	3	1	0	2
Total	5	5	23	5	2	12

At present state, from table 6.4.5, it was seen that throughout the different processing stages of oxford shoe processing line, total labor were 33 where operator (O), assistant operator (AO) and worker (W) were consecutively 5, 5 and 23. At future state, if the lean tools and SS methodologies could be implemented, it was expected that different types of bottlenecks and NVD activities could be reduced thus the present number of labor will also be reduced from 33 to 19 where operator (O), assistant operator (AO) and worker were (W) consecutively 5, 2 and 12. Because of a number of unwanted labors were engaged to manage the different types of bottlenecks and NVD activities.

6.4.5 Pareto analysis for oxford shoe production line

Pareto Analysis was performed by drawing the Pareto chart consisting of causes for delay along the X axis and percentage and cumulative percentage of down time along the Y axis. The highest frequency of down time was found for Toe lasting problems at the oxford shoe processing line while seam pucker of sewing machine showed the lowest frequency. Different causes of down time with their frequency in terms of percentages and cumulative percentages were documented in table 6.4.5.

Table 6.4.6: Cumulative percentage of D/T for Pareto analysis of oxford shoe production line

Causes of delay times	Down Time(D/T)	Percentage of D/T	Cumulative of percentage
Toe lasting problems	313	19.2142419	19.2142419
Needle thread breakage	311	19.0914672	38.305709
Inefficient ironing	286	17.5567833	55.8624923
Seat lasting problems	103	6.32289748	62.1853898
Inappropriate scouring	92	5.64763659	67.8330264
Skipped stiches	87	5.34069982	73.1737262
Improper polishing	83	5.0951504	78.2688766
Side lasting problems	81	4.97237569	83.2412523
Bobbin breakage	78	4.78821363	88.0294659
Inefficient chilling	49	3.00798036	91.0374463
Inefficient spraying	41	2.51688152	93.5543278
Long mark defects	37	2.27133211	95.8256599
Bumps or hollows	36	2.20994475	98.0356047
Seam pucker	32	1.96439533	100

Different causes of NVD activities or down time at different processing stages of oxford shoe production line with their frequency in terms of percentages and cumulative percentages were documented in table 6.4.6. The causes for NVD activities were arranged in downward movements in terms of their frequency.

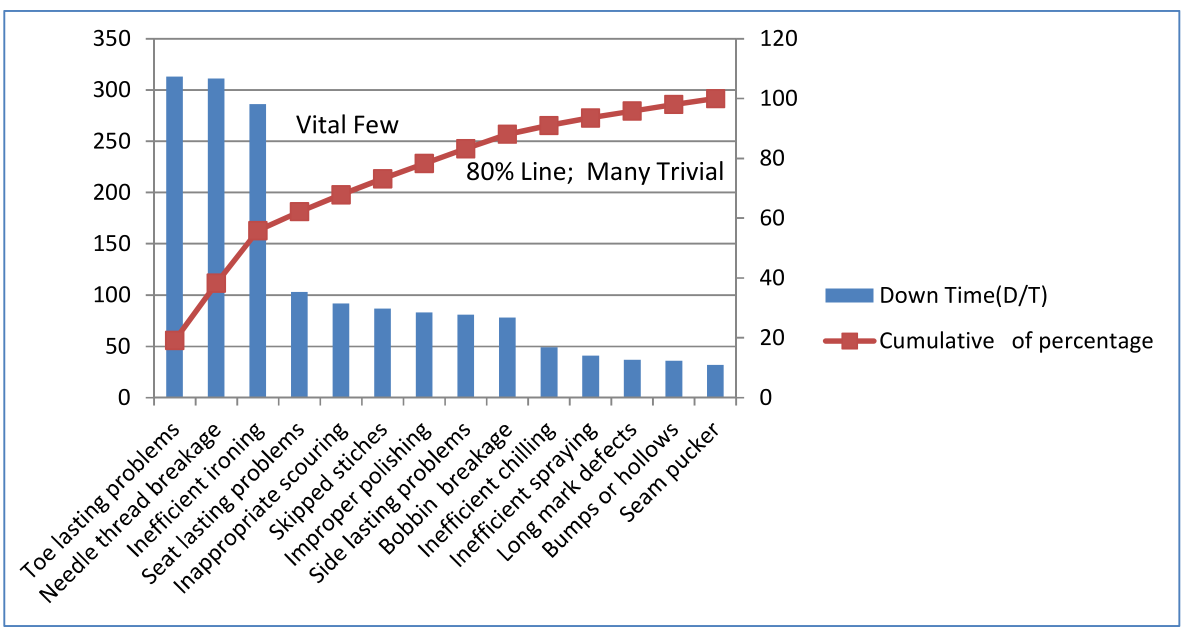


Fig 6.4.3 Pareto chart of Oxford shoe production line

Pareto chart (Fig 6.4.3) was depicted from Pareto table (Table 6.4.6) by aligning the different causes along with X axis; percentage and cumulative percentage of these causes for NVD activities were aligned along with the Y axis. From Fig 6.4.3, it seems that the pioneer causes beyond the different types of bottlenecks and NVD activities were toe lasting problems (19.21%), needle thread breakage (19.09%), inefficient ironing (17.55%), seat lasting problems (6.32%), improper scouring (5.64%), Skipped stiches (5.34%), improper polishing (5.09%), Side lasting problems (4.97%), bobbin breakage (4.79%), improper chilling (3.0%), inefficient spraying (2.51%), long mark defects (2.27%), bumps or hollows (2.20%) and seam pucker (1.96%). From Pareto chart (Fig 6.4.3) the most responsible causes were easily observed and the effective initiatives can be taken to remove these causes. It was expected that if the most frequent first three or 20% causes like as toe lasting problems (19.21%), needle thread breakage (19.09%), inefficient ironing (17.55%) could be removed, the 80% NVD activities or down times could be removed. 5S, JIT, TPM, DMAIC and other improving strategies could be effective initiatives to remove these most frequent causes.

6.4.6 Improvement points at present VSM of oxford shoe production line

Throughout the observation it was seen that there were some improvement points at different stages of oxford shoe production line. The nature of improving point differs from each and another stages.

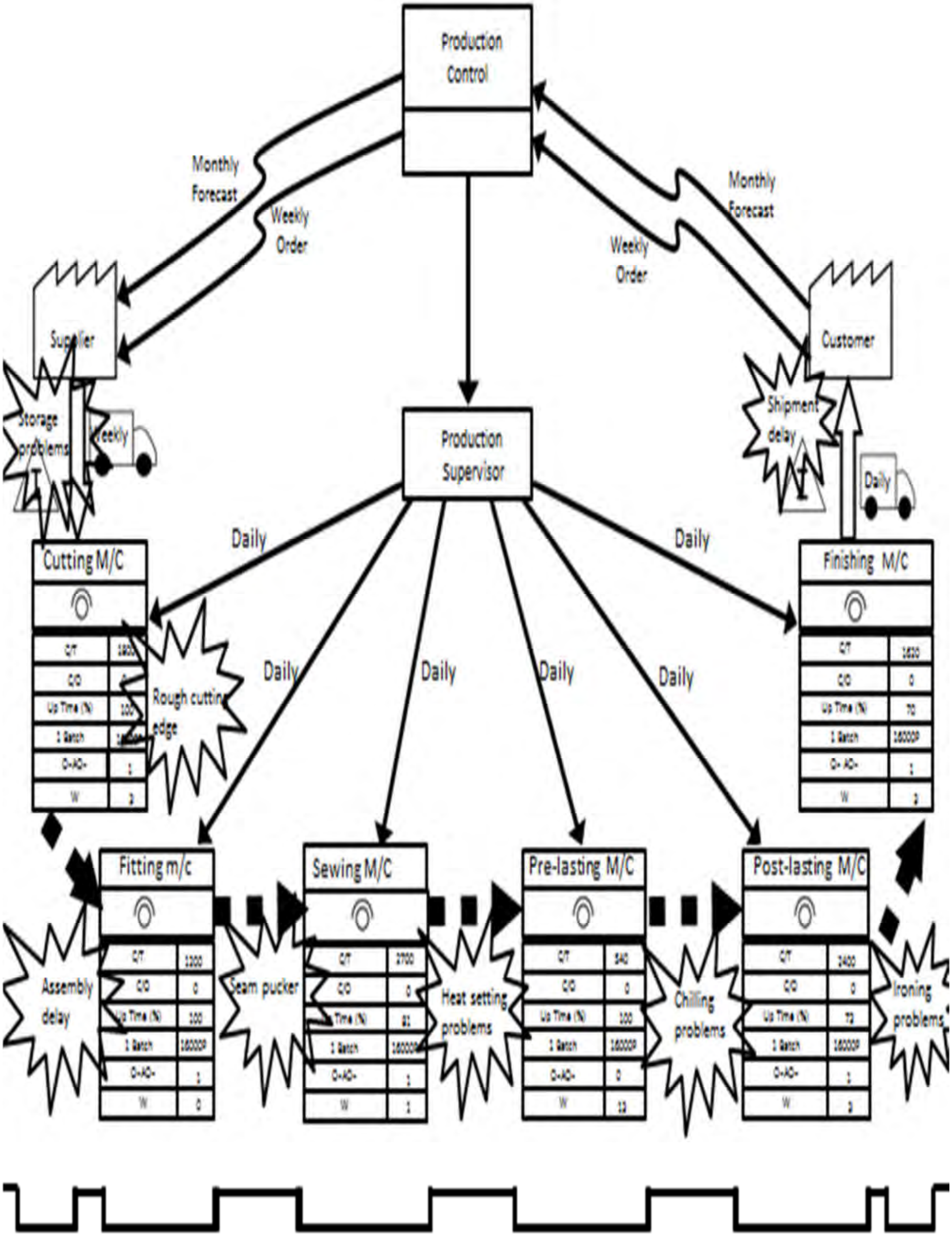


Fig 6.4.4 Present VSM of oxford shoe production line with improvement points

The crucial improvement points were pointed in Fig 6.4.4. These pointed causes or barriers should be removed in order to reduce the manufacturing wastes and improve the PCE. Based on previous study it was expected that 80% of pointed causes could be removed by reducing 20% most frequently occurring barriers.

6.4.7 Expected future VSM of oxford shoe production line

In the future VSM after a deep brainstorming and an intense observation in oxford shoe production line the VD and NVD time were calculated and documented in table 6.4.7.

Table 6.4.7: Future state VD and Non NVD time analysis for oxford shoe production line

Processing stages	VD time (Sec)	NVD time (Sec)
Receiving Inventory	00	14400 (50%)
Cutting	600	600 (50%)
Fitting & assembly	1200	240 (50%)
Sewing	2035	181 (80%)
Pre-lasting	00	130 (80%)
Post-lasting	1745	241 (80%)
Finishing	1132	158 (80%)
Shipping inventory	00	12960 (70%)
Total	6712 (18.84%)	28910 (81.16%)

It was expected, after the implementation of lean tools and SS methodologies the present state NVD activities or times could be reduced at least up to 80%. In this study, based on intense observation, brainstorming and previous regarding studies it was assumed that the NVD time of receiving stage of oxford shoe processing line could be reduced at least 50% (14400 sec) and the NVD time of cutting could be also be reduced at least 50% (600 sec). The NVD time of sewing, pre-lasting, post-lasting and finishing could be reduced at least 80% from the present state and in the future state these NVD times could be consecutively 181 sec, 130 sec, 241 sec and 158 sec which could be seen in table 6.4.7. The Fig 6.4.5 was the future VSM of oxford shoe processing line. The future VSM indicates the materials, information and labor flow of single batch production of oxford shoe processing line. Each batch produces 16000 pairs of oxford shoe.

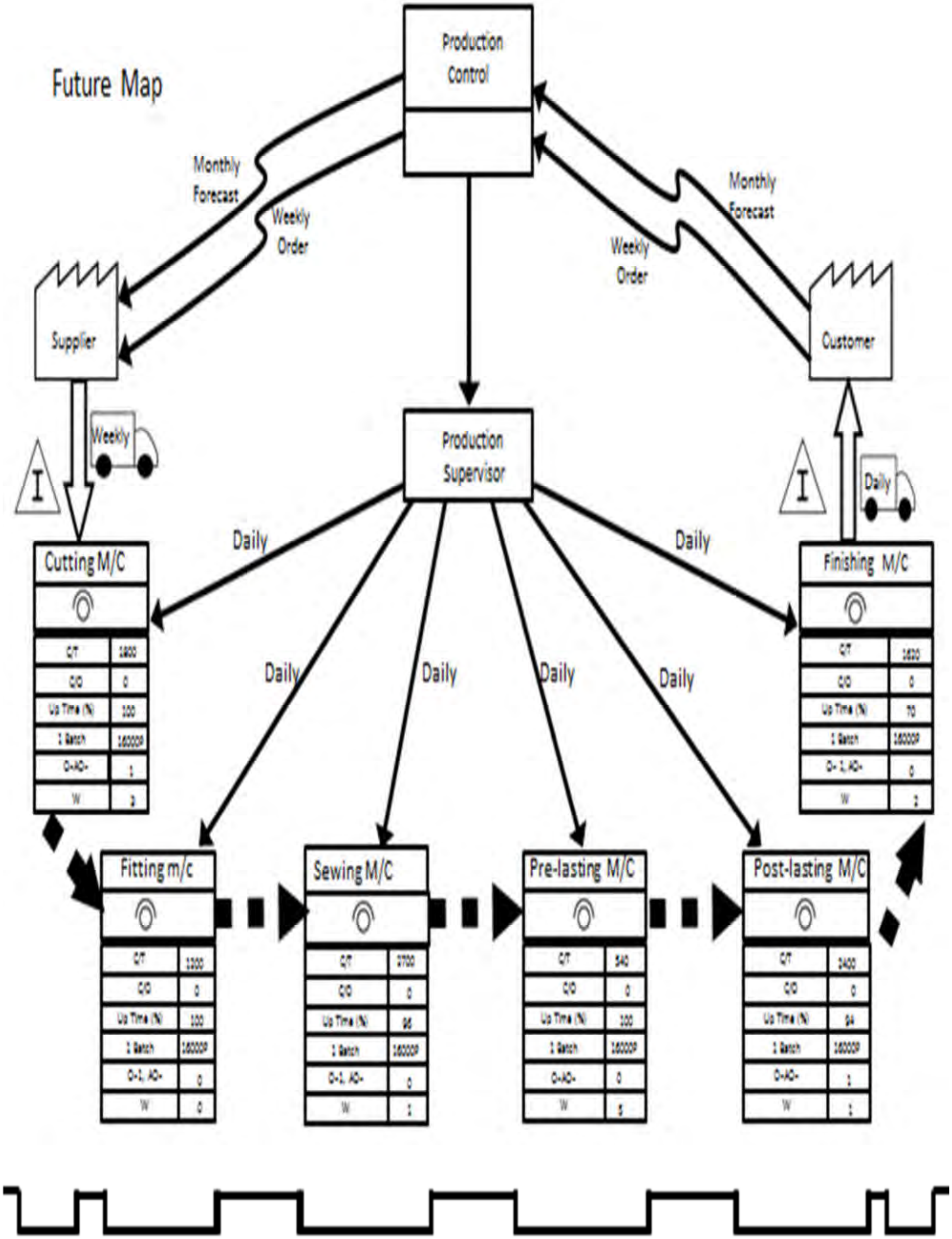


Fig 6.4.5 Future VSM of Oxford shoe production line

In this future VSM the basic promising changes were the reduction of total number of labor, reduction of NVD time & improved Up time (U/T) of oxford shoe production line. In future VSM the total labor including operator, assistant operator and worker could be 19 which was 33 at present VSM i.e. after the implementation of lean tools and SS methodologies it was expected at least 14 labors could be reduced. The U/T of sewing, lasting and finishing machine could be consecutively 96%, 94% and 94% but at present state the U/T of sewing, lasting and finishing machine were consecutively 81%, 73% and 70%.

6.4.8 Expected PCE of oxford shoe production line

In the oxford shoe production line,

Value Added time = 6712 Sec

Non Value Added time = 28910 Sec

Expected Lead time = Value Added time + Non Value Added time

= 6712 Sec + 28910 Sec = 35622 Sec

Process Cycle Efficiency (PCE) $= \frac{\text{Value Added time}}{\text{Lead time}} \times 100$

= 18.84%

After the proper implementation of lean tools and SS methodologies it was expected the PCE of oxford shoe processing line could be 18.84 % while the present PCE was 8.01 %, the NVD time could be reduced from 76988 sec to 28910 sec and lead time could be reduced from 83700 sec to 35622 sec.

6.4.9 Takt time of oxford shoe production line

Net available time

Working shift/day	2 shifts
Hours/ shift	10 hours
Available time/ shift	600 minutes
Prepare time/ shift	40 minutes
Lunch time/ shift	0 minutes
Planned down time/ shift	0 minutes
Networking time/ shift	560 minutes
Networking time/ shift	33600 seconds
Net available time/ day	67200 seconds

Customer/production demand

Net available time/day	67200seconds/day
Customer demand/day	9829 cases/day
Takt time	6.84 seconds/case

The present takt time of oxford shoe processing line was 7.03 sec per case production and it was expected that after the adoption of lean tools and SS methodologies this could be reduced to 6.84 sec per case production.

6.5 Boot production Line

It was a Boot production line. The basic stages of Boot production line were as follows-

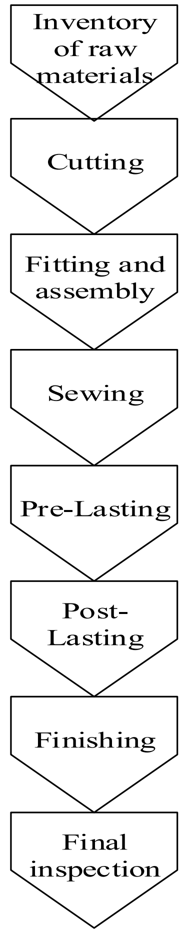


Fig 6.5.1 Basic stages of Boot production line

6.5.1 Present VSM of Boot production line

To draw the present VSM relevant data like as VD and NVD time, Cycle time, Change Over time, Uptime, Lot size, quantity to deliver, delivery time were observed and information related to assembly line such as processing time, inventory storages, inspections, rework loops, number of workers and operational hours per day were collected and documented in table 6.5.1 and table 6.5.2. Other relevant data such as number of operators (O), assistant operator (AO) and worker (W) were shown in current VSM. To draw the completion of present VSM of oxford shoe processing line, a timeline was added at the bottom of the map recording the VD and NVD time.

Table 6.5.1: Present state Down Time (D/T), Cycle Time (C/T) and Up Time (U/T) data of Boot production line

Times	Sewing			Lasting			Finishing		
	D/T (Sec)	C/T (Sec)	U/T (%)	D/T (Sec)	C/T (Sec)	U/T (%)	D/T (Sec)	C/T (Sec)	U/T (%)
1st	642	2880	78	649	2940	78	1058	3900	73
2nd	661	2880	77	672	2940	77	1083	3900	72
3rd	668	2880	77	675	2940	77	1083	3900	74

Note: Sewing speed: 245 RPM; lasting speed: 240 RPM; finishing machine speed: 30 case per min. Batch production- 2000 pairs.

The D/T, C/T, and U/T of Boot production line were documented in table 6.5.1. In this production line the stage of sewing, lasting and finishing machine were mainly responsible for D/T. In the stage of sewing, average U/T was 77% and C/T was 2880 sec. In the stage of lasting average U/T was 77% and C/T was 2940 sec. In the stage of finishing C/T was 3900 sec and U/T was 73%. The percentage of available time for machine work or processing of desire product was known as the U/T. By observing the U/T of different unit stage of production line, it can be assumed the efficiency of the whole production line. At present state, the U/T of Boot process line varies from 73% (finishing stage) to 77% (sewing stage). By this study it was attempted to increase the U/T in the future state as well as to reduce the D/T and to reduce the ultimate lead time.

Table 6.5.2: Present state VD and Non NVD time for Boot production line

Processing stages	VD time (Sec)	NVD time (Sec)
Receiving Inventory	00	27000
Cutting	600	1800
Fitting & assembly	1680	240
Sewing	2113	1007
Pre-lasting	00	1046
Post-lasting	2028	1362
Finishing	2849	1803
Shipping inventory	00	43200
Total	9270 (10.68%)	77458 (89.32%)

The VD and NVD time of different processing stages of Boot production line were documented in table 6.5.2. At present state, there were no VD time except NVD time in the stages of receiving inventory, pre-lasting and shipping inventory but in this process line, this NVD time or these stages were required for the Boot processing. In this processing line, the total VD time were 9270 sec (10.68%) and the total NVD time were 77458 sec (89.32%). By this study, it was tried to increase the percentage of VD time by reducing the NVD time with the proper implementation of lean tools and SS methodologies.

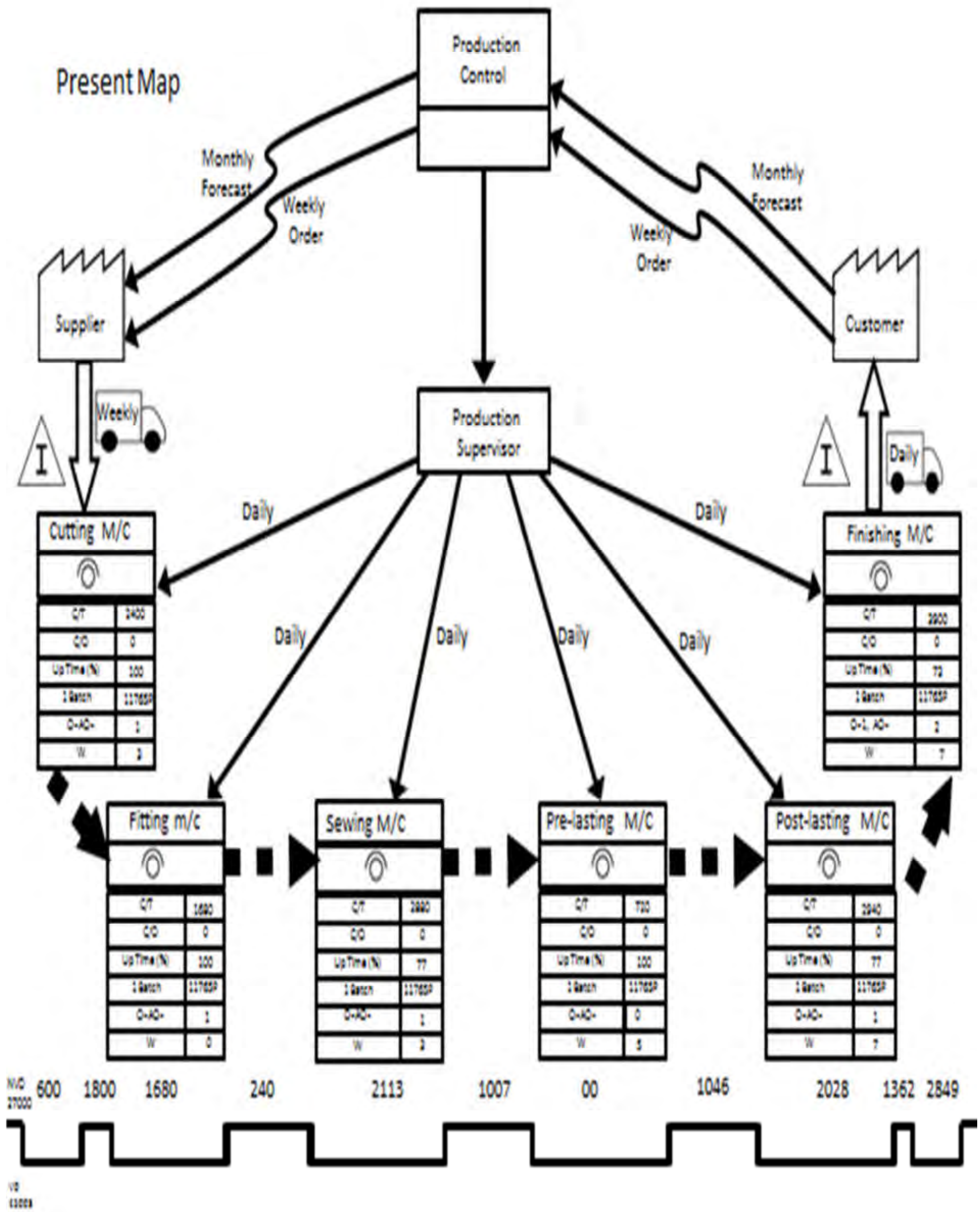


Fig 6.5.2 Present VSM of Boot production line

It helps to draw the required processing stage with mentioning required labor, C/T, U/T, C/O and batch size. As observed from the present VSM of Boot production line, different types of NVD activities were present in the flow of process line at different stages. The different types of bottlenecks at different processing stages were identified and quantified in terms of time as shown in the Fig 6.5.2. The Up time (U/T) of sewing, lasting and finishing machine were consecutively 77%, 77% and 73%. At present state of this processing line over the different stages total labor was 36. After the implementation of lean tools and SS methodologies it was expected that U/T could be improved and total labor could be reduced.

6.5.2 Present PCE of Boot production line

In the Boot production line,

Value Added time = 9270 Sec

Non Value Added time = 77458 Sec

Expected Lead time = Value Added time + Non Value Added time

= 9270 Sec + 77458 Sec = 86728 Sec

Process Cycle Efficiency (PCE) $= \frac{\text{Value Added time}}{\text{Lead time}} \times 100$

= 10.68%

It seems that the present VSM of Boot production line is 10.68 % which is the below of internationally competitive level 25% [74].

6.5.3 Present takt time of Boot production line

Net available time

Working shift/day	2 shifts
Hours/ shift	10 hours
Available time/ shift	600 minutes
Prepare time/ shift	40 minutes
Lunch time/ shift	0 minutes
Planned down time/ shift	0 minutes
Networking time/ shift	560 minutes
Networking time/ shift	33600 seconds
Net available time/ day	67200 seconds

Customer/production demand

Net available time/day	67200seconds/day
Customer demand/day	27450 cases/day
Takt time	2.45 seconds/case

The present takt time of Boot production line was 2.45 sec. i.e. it takes 2.45 sec to produce a single case of Boot production. Each case produced 170 pairs Boot.

6.5.4 Manufacturing waste of Boot production line

6.5.4.1 Down time (D/T) calculation for Boot production line

The down time of different machines of the production line were observed and documented in table 6.5.3.

Table 6.5.3: Down time (D/T) of Boot production line

Steps	Causes for D/T	D/T (sec)	Average D/T	C/T	%D/T
Sewing	Needle thread breakage	310		2880	
		305	312		13.11
		320			
	Bobbin or looped thread breakage	99			
		105	105		4.41
		112			
	Skipped stitches	63			
		71	67		2.82
		68			
	Seam pucker	170			
		180	173		7.27
		168			
Lasting	Improper setting during toe lasting	351		2940	
		360	353		14.83
		347			
	Improper setting during seat lasting	103			
		113	112		4.70
		120			
	Inappropriate scouring	72			
		69	72		3.23
		76			
	Side lasting problems due to feather edge stitching	81			
		78	77		3.02
		73			
	Improper chilling	42			
		52	51		2.14
		59			

Finishing	Long mark defects	287		3900	
		290	282		11.85
		269			
	Upper damage during rubbing by emery paper	40			
		50	46		1.93
		47			
	Inefficient ironing	33			
		41	34		1.42
		29			
	Improper polishing	110			
		116	109		4.58
		103			
	Inefficient spraying	480			
		473	478		20.09
		482			
	Bumps or hollows	108			
		113	108		4.53
		103			
Total			2379		

6.5.4.2 Wasted products calculation of Boot production line

Table 6.5.4: Wasted products of Boot production line

Name of stages	No of observation	Rejected shoes per batch	Average rejected shoe per batch	Average rejected shoe per batch (per day 12 batch)	Rejected shoe per million opportunity	Gap at Six Sigma level	Remarks
Sewing	1	26					Contains at three sigma level
	2	24					
	3	29	24	288	2040	2037	
	4	20					
	5	19					

Pre-lasting	1	33					
	2	29					
	3	31	32	384	2720	2717	
	4	34					
	5	33					
Post-lasting	1	114					
	2	104					
	3	94	98	1176	8330	8327	
	4	90					
	5	88					
Finishing	1	22					
	2	23					
	3	26	21x6=126	1512	1785	1782	
	4	19					
	5	17					
Total			280	3360	14875		

From table 6.5.4, it seems that the total defect product of Boot production line was 14875 per million product of production which was considered as the three Sigma productions.

6.5.4.3 Wasted labor of Boot production line

After lean tools implementation it was expected that a number of labor could be eliminated from Boot processing line. The unnecessary motion of labor in the processing line was also considered as the manufacturing waste. The expected number of eliminated labor was documented in the Table 6.5.5.

Table 6.5.5: Present and expected Labor of Boot production line

Name of stages	**No of labor at present state**			**No of labor at future state**		
	O	AO	W	O	AO	W
Cutting	1	1	3	1	1	3
Fitting & assembly	1	1	0	1	1	0
Sewing	1	1	3	1	1	1
Pre-lasting	0	0	5	0	0	2
Post-lasting	1	1	7	1	1	3
Finishing	1	2	7	1	1	3
Total	5	6	25	5	5	12

At present state, from table 6.5.5, it was seen that throughout the different processing stages of Boot processing line, total labor were 36 where operator (O), assistant operator (AO) and worker (W) were consecutively 5, 6 and 25. At future state, if the lean tools and SS methodologies could be implemented, it was expected that different types of bottlenecks and NVD activities could be reduced thus the present number of labor will also be reduced from 36 to 22 where operator (O), assistant operator (AO) and worker were (W) consecutively 5, 5 and 12. Because of a number of unwanted labors were engaged to manage the different types of bottlenecks and NVD activities.

6.5.5 Pareto analysis for Boot production line

Table 6.5.6: Cumulative percentage of D/T for Pareto analysis of Boot production line

Causes of delay times	Down Time(D/T)	Percentage of D/T	Cumulative of percentage
Inefficient spraying	478	20.09247583	20.09247583
Toe lasting problems	353	14.8381673	34.9306431
Needle thread breakage	312	13.1147541	48.0453972
Long mark defects	282	11.85372005	59.8991173
Seam pucker	173	7.27196301	67.1710803
Seat lasting problems	112	4.707860446	71.8789407
Improper polishing	109	4.581757041	76.4606978
Bumps or hollows	108	4.539722573	81.0004203
Bobbin thread breakage	105	4.413619168	85.4140395
Side lasting problems	77	3.236654056	88.6506936
Inappropriate scouring	72	3.026481715	91.6771753
Skipped stiches	67	2.816309374	94.4934847
Improper chilling	51	2.143757881	96.6372425
Upper damage	46	1.93358554	98.5708281
Inefficient ironing	34	1.429171921	100

Different causes of NVD activities or down time at different processing stages of Boot production line with their frequency in terms of percentages and cumulative percentages were documented in table 6.5.6. The causes for NVD activities were arranged in downward movements in terms of their frequency.

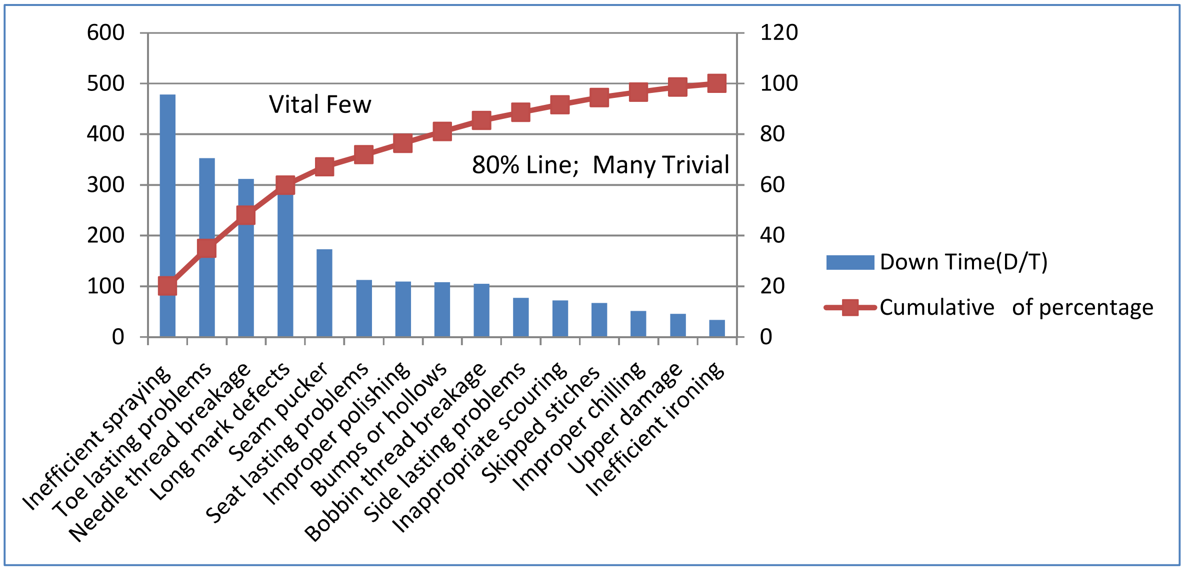


Fig 6.5.3 Pareto chart of Boot production line

From Fig 6.5.3, it seems that the pioneer causes beyond the different types of bottlenecks and NVD activities were inefficient spraying (20.09%), toe lasting problems (14.84%), needle thread breakage (13.11%), long mark defects (11.85%), seam pucker (7.27%), seat lasting problems (4.70%), improper polishing (4.58%), bumps or hollows (4.53%), bobbin thread breakage (4.41%), side lasting problems (3.23%), inappropriate scouring (3.02%), skipped stiches (2.81%), improper chilling (2.14%), upper damage (1.93%) and inefficient ironing (1.45%). From Pareto chart (Fig 6.5.3) the most responsible causes were easily observed and the effective initiatives can be taken to remove these causes. It was expected that if the most frequent first three or 20% causes like as inefficient spraying (20.09%), toe lasting problems (14.84%), needle thread breakage (13.11%) could be removed, the 80% NVD activities or down times could be removed. 5S, JIT, TPM, DMAIC and other improving strategies could be effective initiatives to remove these most frequent causes.

6.5.6 Improvement points at present VSM of Boot production line

Throughout the observation it was seen that there were some improvement points at different stages of Boot processing line. The nature of improving point differs from each and another stages.

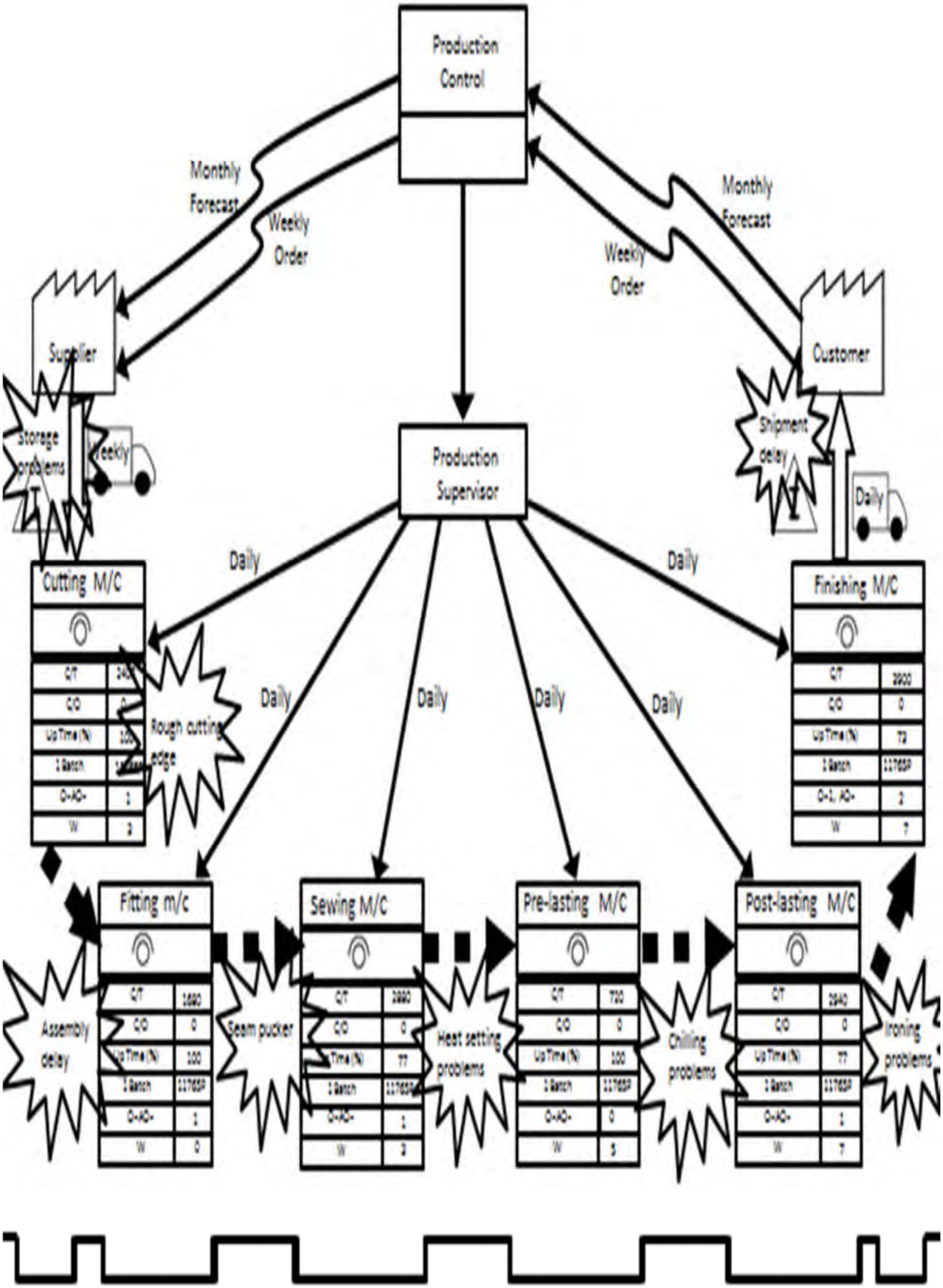


Fig 6.5.4 Present VSM of Boot production line with improvement points

The crucial improvement points were pointed in Fig 6.5.4. These pointed causes or barriers should be removed in order to reduce the manufacturing wastes and improve the PCE. Based on previous study it was expected that 80% of pointed causes could be removed by reducing 20% most frequently occurring barriers.

6.5.7 Expected future VSM of Boot production line

In the future VSM after a deep brainstorming and an intense observation in Boot production line the VD and NVD time were calculated and documented in table 6.5.7.

Table 6.5.7: Future state VD and Non NVD time analysis for Boot production line

Processing stages	VD time (Sec)	NVD time (Sec)
Receiving Inventory	00	13500 (50%)
Cutting	600	900 (50%)
Fitting & assembly	1680	240 (0%)
Sewing	2113	201 (80%)
Pre-lasting	00	87 (80%)
Post-lasting	2028	272 (80%)
Finishing	2849	360 (80%)
Shipping inventory	00	12960 (70%)
Total	9270 (24.45%)	28642 (75.55%)

In this study, based on intense observation, brainstorming and previous regarding studies it was assumed that the NVD time of receiving stage of Boot production line could be reduced at least 50% (13500 sec) and the NVD time of cutting could be also be reduced at least 50% (900 sec). The NVD time of sewing, pre-lasting, post-lasting and finishing could be reduced at least 80% from the present state and in the future state these NVD times could be consecutively 201 sec, 87 sec, 272 sec and 360 sec which could be seen in table 6.5.7. The fig 6.5.5 was the future VSM of Boot processing line. The future VSM indicates the materials, information and labor flow of single batch production of Boot processing line. Each batch produces 11765 pairs of Boot.

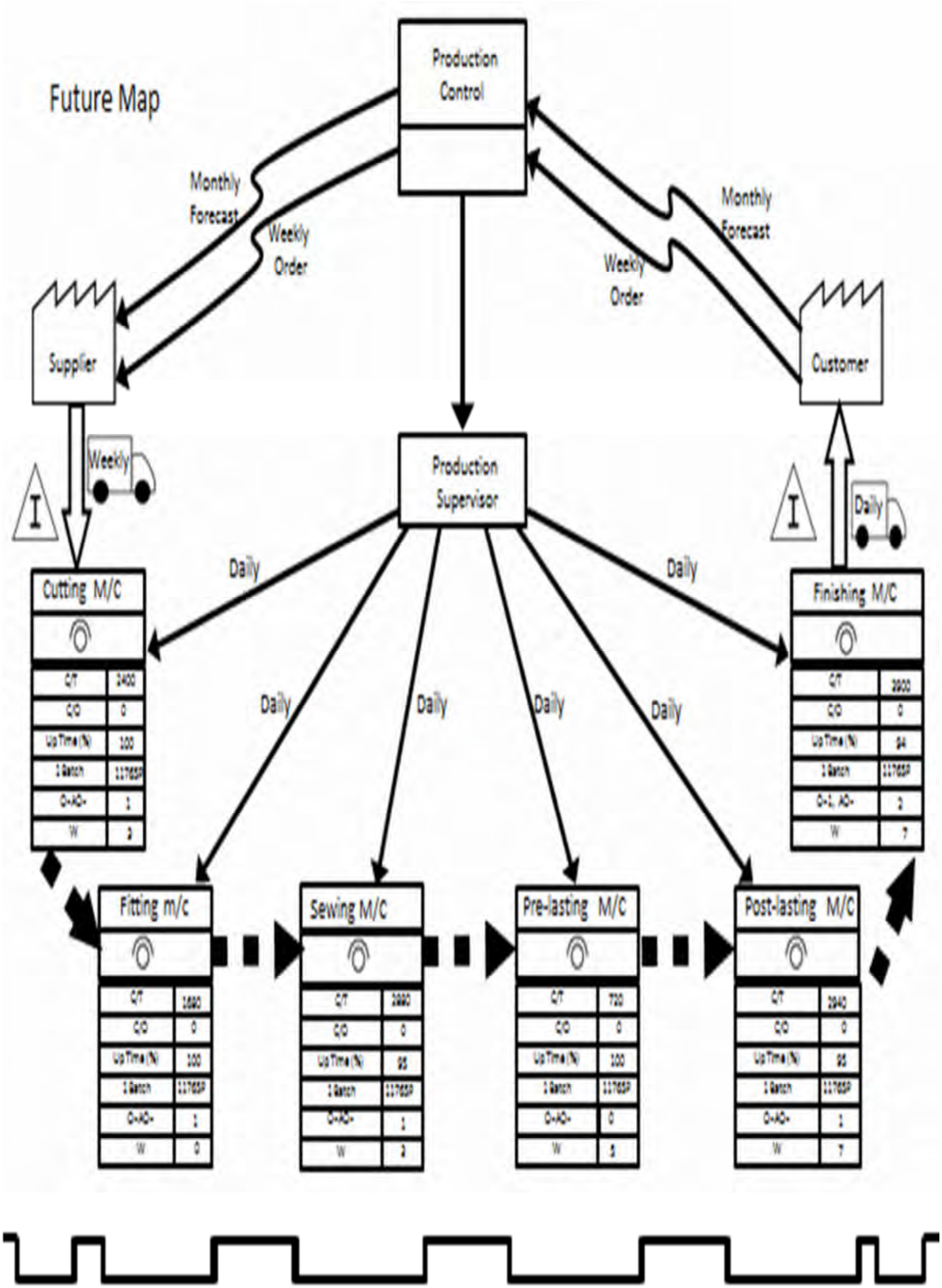


Fig 6.5.5 Future VSM of Boot production line

In this future VSM the basic promising changes were the reduction of total number of labor, reduction of NVD time & improved Up time (U/T) of Boot processing line. In future VSM the total labor including operator, assistant operator and worker could be 22 which was 36 at present VSM i.e. after the implementation of lean tools and SS methodologies it was expected at least 14 labors could be reduced. The U/T of sewing, lasting and finishing machine could be consecutively 96%, 95% and 94% but at present state the U/T of sewing, lasting and finishing machine were consecutively 77%, 77% and 73%.

6.5.8 Expected PCE of Boot production line

In the Boot production line,

Value Added time = 9270 Sec

Non Value Added time = 28642 Sec

Expected Lead time = Value Added time + Non Value Added time

= 9270 Sec + 28642 Sec = 37912 Sec

Process Cycle Efficiency (PCE) $= \frac{\text{Value Added time}}{\text{Lead time}} \times 100$

= 24.45%

After the proper implementation of lean tools and SS methodologies it was expected the PCE of Boot production line could be 24.45 % while the present PCE was 10.68%, the NVD time could be reduced from 77458 sec to 28642 sec and lead time could be reduced from 86760 sec to 37912 sec.

6.5.9 Takt time of Boot production line

Net available time

Working shift/day	2 shifts
Hours/ shift	10 hours
Available time/ shift	600 minutes
Prepare time/ shift	40 minutes
Lunch time/ shift	0 minutes
Planned down time/ shift	0 minutes
Networking time/ shift	560 minutes
Networking time/ shift	33600 seconds
Net available time/ day	67200 seconds

Customer/production demand

Net available time/day	67200seconds/day
Customer demand/day	28010cases/day
Takt time	2.39 seconds/case

The present takt time of Boot processing line was 2.44 sec per case production and it was expected that after the adoption of lean tools and SS methodologies this could be reduced to 2.39 sec per case production.

6.6 Moccasin shoe Production Line

It was a Moccasin shoe production line. The basic stages of Moccasin shoe production line were as follows-

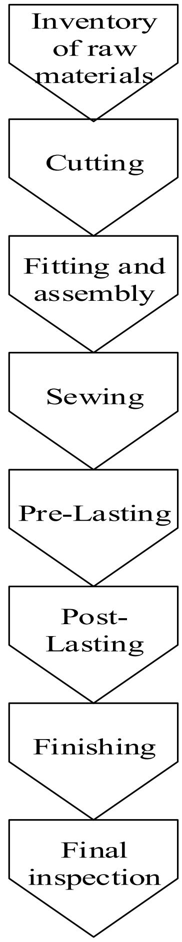


Fig 6.6.1 Basic stages of Moccasin shoe production line

6.6.1 Present VSM of Moccasin shoe production line

The present VSM of Moccasin shoe production line point out the different stages whose bring the different values. These values were brought by different stages which were points out in present VSM. All regarding data to build the present VSM were documented in Table 6.6.1 and Table 6.6.2. Other relevant data such as number of operators (O), assistant operator (AO) and worker (W) were shown in current VSM. To draw the completion of present VSM of Moccasin shoe processing line, a timeline was added at the bottom of the map recording the VD and NVD time.

Table 6.6.1: Present state Down Time (D/T), Cycle Time (C/T) and Up Time (U/T) data of Moccasin shoe production line

Times	Sewing			Lasting			Finishing		
	D/T (Sec)	C/T (Sec)	U/T (%)	D/T (Sec)	C/T (Sec)	U/T (%)	D/T (Sec)	C/T (Sec)	U/T (%)
1st	1068	3960	73	888	4200	79	525	3900	87
2nd	1064	3960	73	884	4200	79	528	3900	86
3rd	1077	3960	72	886	4200	79	526	3900	87

Note: Sewing speed: 420 RPM; lasting speed: 400 RPM; finishing machine speed: 18 case per min. Batch production-7000 pairs.

The D/T, C/T, and U/T of Moccasin shoe processing line were documented in table 6.6.1. In this processing line the stage of sewing, lasting and finishing machine were mainly responsible for D/T. In the stage of sewing, average U/T was 73% and C/T was 3960 sec. In the stage of lasting average U/T was 79% and C/T was 4200 sec. In the stage of Finishing, C/T of pre-lasting machine was 3900 sec and U/T was 87%. The percentage of available time for machine work or processing of desire product was known as the U/T. By observing the U/T of different unit stage of production line, it can be assumed line efficiency of the whole production line. At present state, the U/T of Moccasin shoe line varies from 73% (sewing stage) to 87% finishing stage). By this study it was attempted to increase the U/T in the future state as well as to reduce the D/T and to reduce the ultimate lead time.

Table 6.6.2: Present state VD and NVD time for Moccasin shoe production line

Processing stages	Average VD time (Sec)	Average NVD time (Sec)
Receiving Inventory	00	32400
Cutting	600	1800
Fitting & assembly	1680	300
Sewing	3144	1056
Pre-lasting	00	1620
Post-lasting	3415	1265
Finishing	2764	1796
Shipping inventory	00	43200
Total	11603 (12.21%)	83437 (87.79%)

In this Moccasin shoe processing line, the total VD time were 11603 sec (12.21%) and the total NVD time were 83437 sec (87.79%). By this study, it was tried to increase the percentage of VD time by reducing the NVD time with the proper implementation of lean tools and SS methodologies.

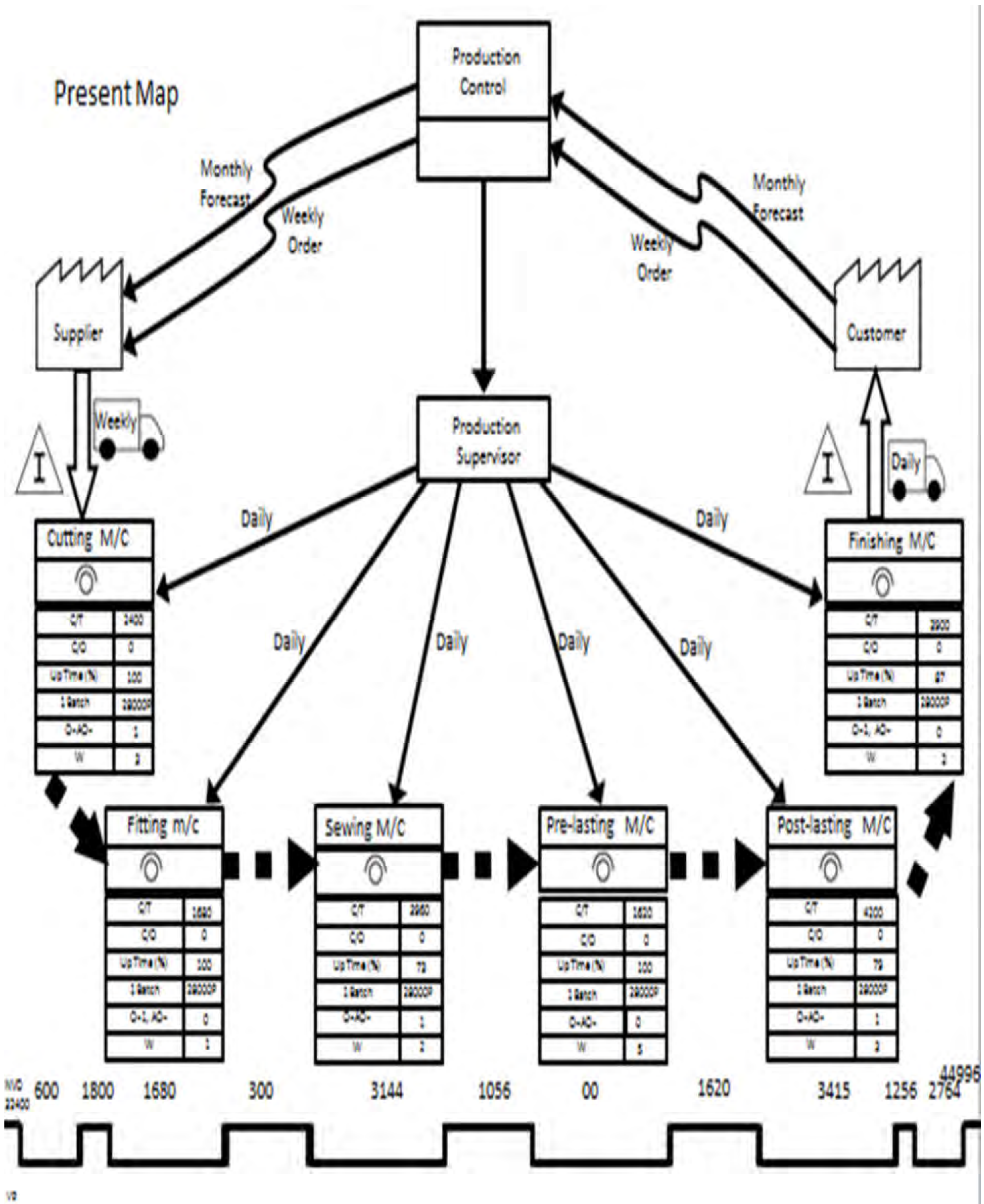


Fig 6.6.2 Present VSM of Moccasin shoe production line

Fig 6.6.2 represents the present VSM of Moccasin shoe production line. The VD and NVD times were shown at the bottom line of present VSM. It was found that in Moccasin shoe production line about 11603 sec out of 95040 sec or 12.21% were VD activities while 83437 sec or 87.79 % were NVD added activities. By this study it was endeavored to increase the percentage of VD activities and time by reducing the NVD activities and time. The Up time (U/T) of sewing, lasting and finishing machine were consecutively 73%, 79% and 87%. At present state of this processing line over the different stages total labor were 24. After the implementation of lean tools and SS methodologies it was expected that U/T could be improved and total labor could be reduced.

6.6.2 Present PCE of Moccasin shoe production line

In the Moccasin shoe production line,

Value Added time = 11603 sec

Non Value Added time = 83437 sec

Lead time = Value Added time + Non Value Added time

= 11603 sec + 83437 sec = 95040 sec

PCE $= \frac{\text{Value Added time}}{\text{Lead time}} \text{ x } 100$

= 12.20%

It was observed that the present VSM of Moccasin shoe production line was 12.20% which was the below of internationally competitive level 25% [74].

6.6.3 Present takt Time of Moccasin shoe production line

Net available time

Working shift/day	2 shifts
Hours/ shift	10 hours
Available time/ shift	600 minutes
Prepare time/ shift	40 minutes
Lunch time/ shift	0 minutes
Planned down time/ shift	0 minutes
Networking time/ shift	560 minutes
Networking time/ shift	33600 seconds
Net available time/ day	67200 seconds

Customer/production scheduled demand

Net available time/day	67200seconds/day
Customer demand/day	8167 cases/day
Tact time	8.22 seconds/case

The present takt time of Moccasin shoe production line was 8.22 sec. i.e. it takes 8.22 sec to produce a single case of Moccasin shoe production. Each case 250 pair Moccasin shoes.

6.6.4 Manufacturing waste of Moccasin shoe production line

6.6.4.1 Down Time (D/T) calculation for Moccasin shoe production line

The down time for different causes in the processing floor of Moccasin shoe production line were documented in table 6.6.3

Table 6.6.3: Down time (D/T) of Moccasin shoe production line

Steps	Causes for D/T	D/T (sec)	Average D/T (sec)	C/T	% D/T
Sewing	Needle thread breakage	672			
		675	675	3960	27.19
		679			
	Bobbin or looped thread breakage	210			
		205	209		8.42
		211			
	Skipped stitches	106			
		99	103		4.15
		104			
	Seam pucker	80			
		85	83		3.34
		83			
Lasting	Improper setting during toe lasting	214			
		207	211		8.50
		212			
	Improper setting during seat lasting	240			
		248	244		9.83
		244			
	Inappropriate scouring	115			
		111	113		4.55
		113			
	Side lasting problems due to feather edge stitching	214			
		210	213		8.58
		216			
	Improper chilling	105			
		108	105		4.23
		101			

Finishing	Inefficient ironing	210			
		208	207		8.34
		203			
	Improper polishing	194			
		197	197		7.93
		200			
	Inefficient spraying	56			
		53	57		2.29
		61			
	Long mark defects	55			
		59	55		2.21
		52			
	Bumps or hollows	10			
		11	10		0.40
		10			
Total			2482		

In Moccasin shoe production line, the most important processing stages were sewing, lasting and finishing where the most frequent D/T was observed due to different causes that were documented in table 6.6.3.

6.6.4.2 Wasted products calculation of Moccasin shoe production line

There are different types of manufacturing wastes like overproduction, defect, waiting, unnecessary processing, unnecessary inventory, unnecessary transportation between work sites and unnecessary motion in the work place. In a single processing line all types of wastes could not be seen. Based on the nature of production the manufacturing wastes are varied. Among these manufacturing wastes, defect production was very common in the Moccasin shoe production line. In this processing line defect shoe was considered as the defect production. The amount of defect shoe was documented in table 6.6.4.

Table 6.6.4: Wasted products calculation of Moccasin shoe production line

Name of stages	No of observation	Rejected shoes per batch	Average rejected shoe per batch	Average rejected shoe per batch (per day 12 batch)	Rejected shoe per million opportunity	Gap at Six Sigma level	Remarks
Sewing	1	12					Contains at three sigma level
	2	14					
	3	9	12	108	429	426	
	4	13					
	5	10					
Pre-Lasting	1	270					
	2	265					
	3	276	264	2376	9429	9426	
	4	259					
	5	251					
Post-Lasting	1	190					
	2	181					
	3	200	186	1674	6643	6640	
	4	172					
	5	187					
Finishing	1	3					
	2	3					
	3	4	3x24=72	648	2571	2568	
	4	4					
	5	5					
Total			534	4806	19072		

From table 6.6.4, it seems that the total defect product of Moccasin shoe production line was 19072 per million product of production since it was considered as the three Sigma productions. But the prime target of any manufacturing industry should be Six Sigma production where the amount of defect product should not be more than 3.4 per million product of production. Throughout this study it was expected that 80% of the present manufacturing waste could be reduced after the implementation of lean tools and SS methodologies.

6.6.4.3 Wasted labors of Moccasin shoe production line

After lean tools implementation it was expected that a number of labor could be eliminated from Moccasin shoe production line. The unnecessary motion of labor in the processing line was also considered as the manufacturing waste. The expected number of eliminated labor were documented in the table 6.6.5

Table 6.6.5: Present and expected labor of Moccasin shoe production line

Name of stages	No of labor at present state			No of labor at future state		
	O	AO	W	O	AO	W
Cutting	1	1	3	1	1	1
Fitting & Assembly	1	0	1	1	0	0
Sewing	1	1	2	1	0	1
Pre-lasting	0	0	5	0	0	2
Post-lasting	1	1	3	1	1	1
Finishing	1	0	2	1	0	1
Total	5	3	16	5	2	6

At present state, from table 6.6.5, it was seen that throughout the different processing stages of Moccasin shoe production line, total labor were 24 where operator (O), assistant operator (AO) and worker (W) were consecutively 5, 3 and 16. At future state, if the lean tools and SS methodologies will implement, it was expected that different types of bottlenecks and NVD activities will be reduced thus the present number of labor will also be reduced from 24 to 13 where operator (O), assistant operator (AO) and worker (W) were consecutively 5, 2 and 6. Because of a number of unwanted labors were engaged to manage the different types of bottlenecks and NVD activities.

6.6.5 Pareto analysis for Moccasin shoe production line

Pareto analysis was performed by drawing the Pareto chart consisting of causes for delay along the X axis and percentage and cumulative percentage of down time along the Y axis. The highest frequency of NVD activities or down time was found for needle thread breakage of sewing at Moccasin shoe production line while bumps or hollows of finishing showed the lowest frequency.

Table 6.6.6: Cumulative D/T of Moccasin shoe production line for Pareto analysis

Causes of delay times	Down Time(D/T)	Percentage of D/T	Cumulative of percentage
Needle thread breakage	675	27.1958098	27.1958098
Seat lasting problems	244	9.83078163	37.0265915
Side lasting problems	213	8.58178888	45.6083803
Toe lasting problems	211	8.5012087	54.109589
Bobbin thread breakage	209	8.42062853	62.5302176
Inefficient ironing	207	8.34004835	70.8702659
Improper polishing	197	7.93714746	78.8074134
Inappropriate scouring	113	4.55278002	83.3601934
Improper chilling	105	4.23045931	87.5906527
Skipped stiches	103	4.14987913	91.7405318
Seam pucker	83	3.34407736	95.0846092
Inefficient spraying	57	2.29653505	97.3811442
Long mark defects	55	2.21595488	99.5970991
Bumps or hollows	10	0.40290089	100

The causes for NVD activities were arranged in downward movements in terms of their frequency.

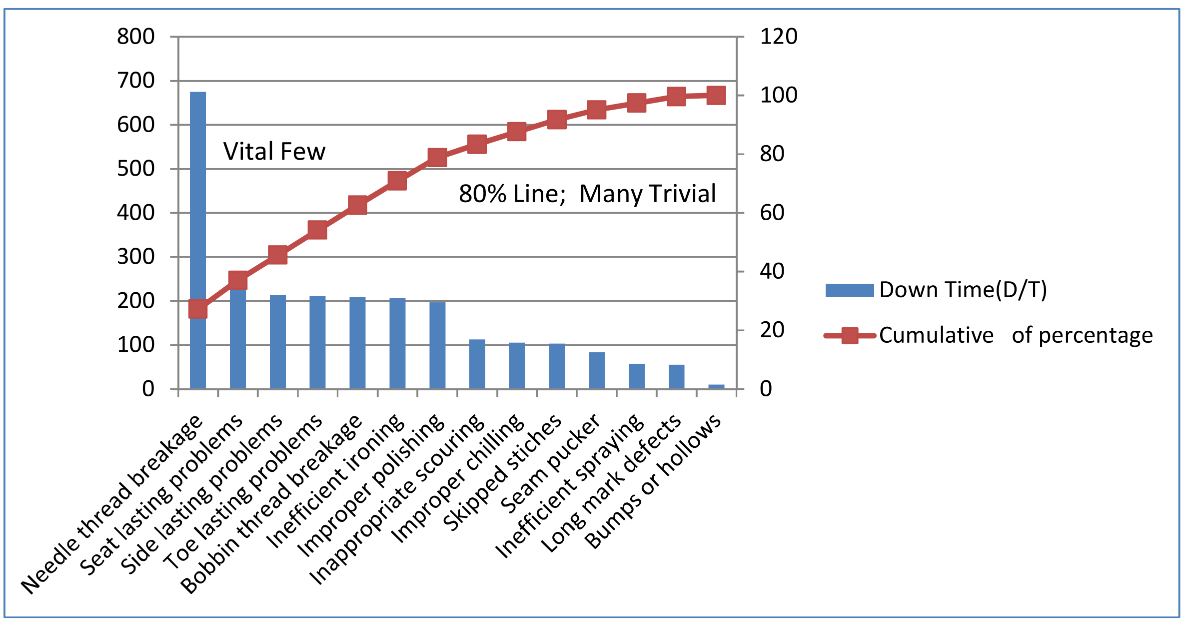


Fig 6.6.3 Pareto chart of Moccasin shoe production line

From Fig 6.6.3, it seems that the pioneer causes beyond the different types of bottlenecks and NVD activities were needle thread breakage (27.19%), seat lasting problems (9.83%), side lasting problems (8.58%), toe lasting problems (8.50%), bobbin thread breakage (8.42%), inefficient ironing (8.34%), improper polishing (7.93%), inappropriate scouring (4.55%), improper chilling (4.23%), skipped stiches (4.14%), seam pucker (3.34%), inefficient spraying (2.29%), long mark defects (2.21%) and bumps or hollows (0.4%). From Pareto chart the most responsible causes were easily observed and the effective initiatives can be taken to remove these causes. From Pareto chart (Fig 6.6.3) it was expected that if the most frequent first three causes like as needle thread breakage (27.19%), seat lasting problems (9.83%), side lasting problems (8.58%) could be reduced, the 80% NVD activities or down times could be removed. 5S, JIT, TPM, DMAIC and other improving strategies could be effective initiatives to remove these most frequent causes.

6.6.6 Improvement points at present VSM of Moccasin shoe production line

Throughout the observation it was seen that there were some improvement points at different stages of Moccasin shoe production line. The nature of improving point differs from each and another stages.

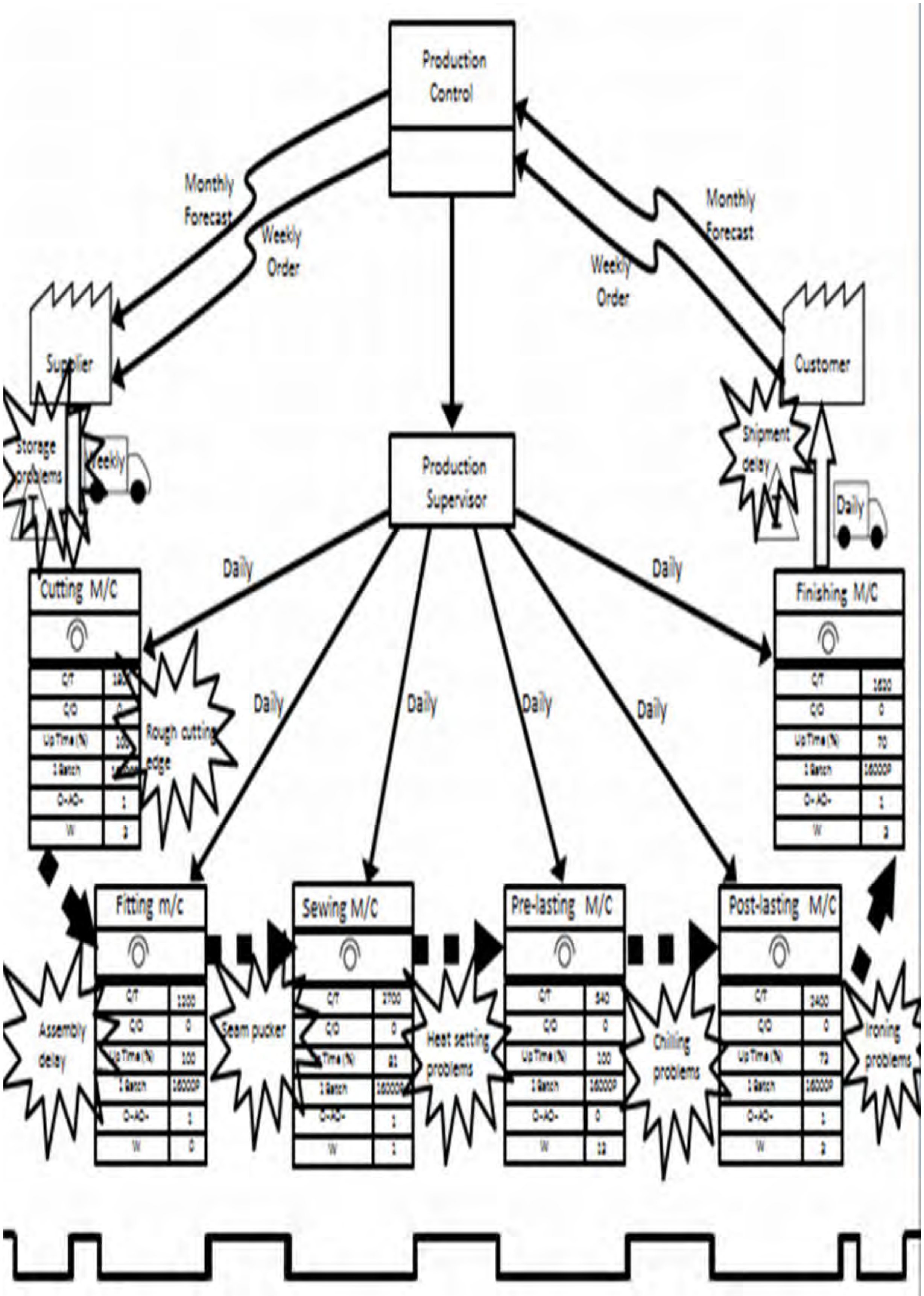


Fig 6.6.4 Present VSM of Moccasin shoe production line with improvement points

The crucial improvement points were pointed in Fig 6.6.4. These pointed causes or barriers should be removed in order to reduce the manufacturing wastes and improve the PCE.

6.6.7 Expected future VSM of Moccasin shoe production line

In the future VSM after an intense observation on the Moccasin shoe production line and brainstorming analysis the VD and NVD time were calculated and documented in table 6.6.7.

Table 6.6.7: Future State VD and NVD time of Moccasin shoe production line

Production stages	VD time (sec)	NVD time (sec) (Expected reduction)
Receiving inventory	00	16200 (50%)
Cutting	600	900 (50%)
Fitting & assembly	1680	300 (0%)
Sewing	3144	211 (80%)
Pre-lasting	00	324 (80%)
Post-lasting	3415	252 (80%)
Finishing	2764	359 (80%)
Shipping inventory	00	12960 (70%)
Total	11603 (25.18%)	31506 (74.82%)

In this study, based on intense observation, brainstorming and previous regarding studies it was assumed that the NVD time of receiving stage of Moccasin shoe production line could be reduced at least 50% (16200 sec) and the NVD time of cutting could be also be reduced at least 50% (900 sec). The NVD time of sewing, pre-lasting, post-lasting and finishing could be reduced at least 80% from the present state and in the future state these NVD times could be consecutively 211 sec, 324 sec, 252 sec and 359 sec which could be seen in table 6.6.7. The fig 6.6.5 was the future VSM of Moccasin shoe production line. The future VSM indicates the materials, information and labor flow of single batch production of Moccasin shoe production line. Each batch processed 28000 pairs of Moccasin shoe. The basic components of future VSM were customers, production control, production supervisor, suppliers, transportation, different stages of processing line like as receiving inventory, fitting & assembly, sewing, pre-lasting, post-lasting, finishing and shipment inventory and finally the VD and NVD times that were depicted at the bottom of future VSM.

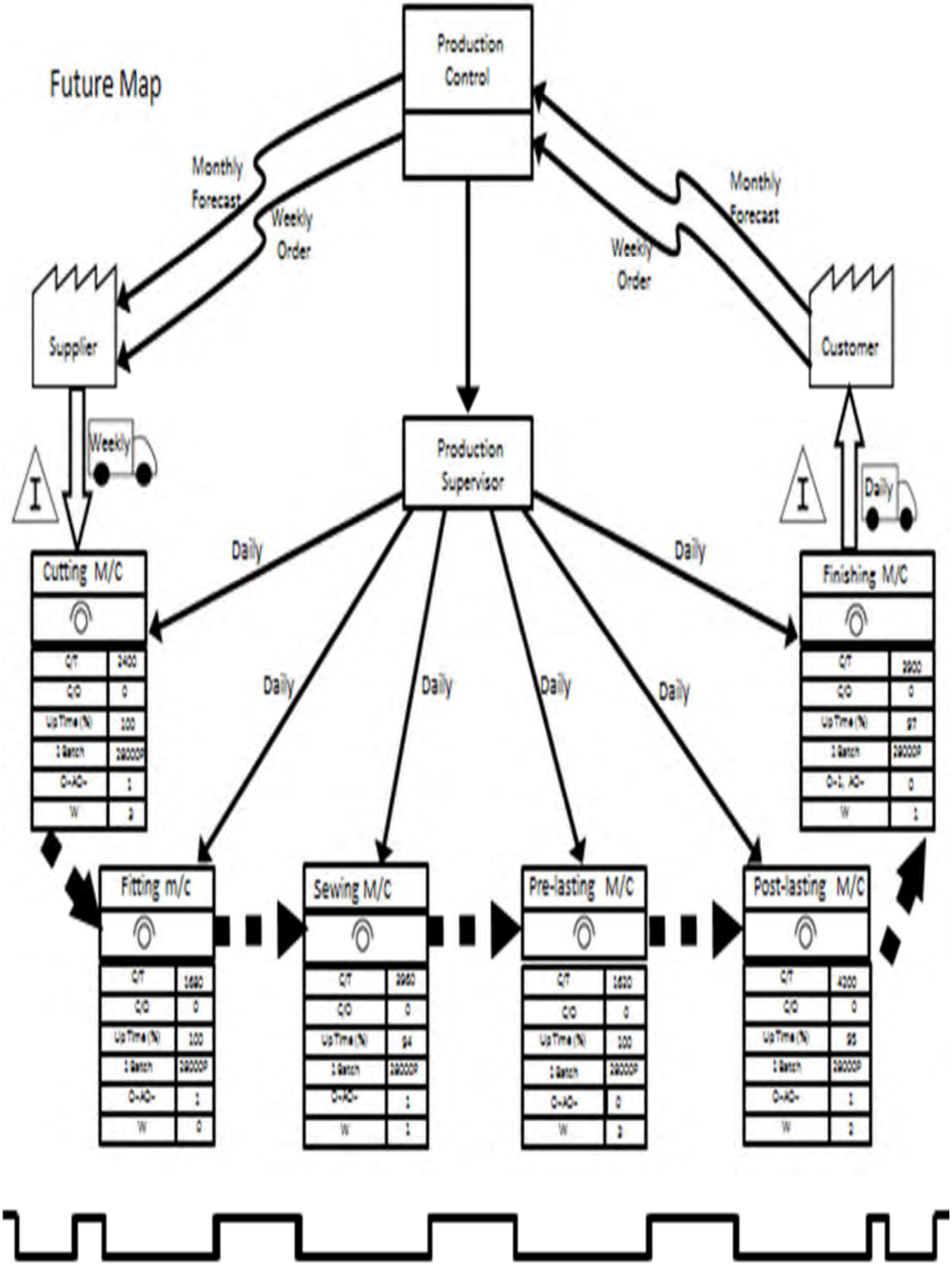


Fig 6.6.5 Future VSM of Moccasin shoe production line

In this future VSM, the basic promising changes were the reduction of total number of labor, reduction of NVD time and improved Up time (U/T) at every processing stage of Moccasin shoe production line. In future VSM the total labor including operator, assistant operator and worker could be 13 which was 24 at present VSM i.e. after the implementation of lean tools and SS methodologies it was expected at least 11 labors could be reduced. The U/T of sewing, lasting and finishing machine could be consecutively 94%, 95% and 97% but at present state the U/T of sewing, lasting and finishing machine were consecutively 73%, 79% and 87%.

6.6.8 Expected PCE of Moccasin shoe production line

In the Moccasin shoe production line,

Value Added time = 11603 Sec

Non Value Added time = 31506 Sec

Expected Lead time = Value Added time + Non Value Added time

= 11603 Sec + 31506 Sec = 43109 Sec

Process Cycle Efficiency (PCE) $= \frac{\text{Value Added time}}{\text{Lead time}} \times 100$

= 26.91%

After the proper implementation of lean tools and SS methodologies, it was expected the PCE of Moccasin shoe production line could be 26.91% while the present PCE was 12.20%, the NVD time could be reduced from 83437 sec to 31506 sec and lead time could be reduced from 95040 sec to 43109 sec.

6.6.9 Expected future Takt time of Moccasin shoe production line

Net available time

Working shift/day	2 shifts
Hours/ shift	10 hours
Available time/ shift	600 minutes
Prepare time/ shift	40 minutes
Lunch time/ shift	0 minutes
Planned down time/ shift	0 minutes
Networking time/ shift	560 minutes
Networking time/ shift	33600 seconds
Net available time/ day	67200 seconds

Customer/production demand

Net available time/day	67200seconds/day
Customer demand/day	5211 cases/day
Takt time	12.89 seconds/case

The present takt time of Moccasin shoe production line was 8.22 sec per case production and it was expected that after the adoption of lean tools and SS methodologies this could be reduced to 8.03 sec per case production.

CHAPTER 7

RESULT AND DISCUSSION

7.1 Gap analysis of footwear industry

- Lack of cost effective project
- Costly raw materials in comparison to synthetic material
- Tendency of the industry as being export oriented
- Lack of market research
- Lack of season based survey for demand
- Local fashion trends integration inability
- Lack of customer based marketing
- Lack of appropriate technology
- Lack of skilled manpower
- Lack of global market reputation
- Lack of branding
- Political instability
- Shortage of power and utilities
- Lack of R&D facilities
- Lack of laboratories for physical and chemical testing
- Lack of product design and development capability
- Uncertainties in government strategies, bureaucratic delays and disposal of effluent [110]

7.2 Visionary plan of footwear sector in Bangladesh

7.2.1 Mission and vision

- **Data Bank:** Establishment of Data Bank for raw Leather, Leather goods and Footwear industries.
- **Exhibitions:** Arrangement of periodic/permanent exhibition of locally produced Footwear in the country.
- **Entrepreneurial culture:** Entrepreneurial culture environment creation so that there capability can be upgraded from the average level to excellent level.
- **Professional training:** Professional training courses should be organized for capacity building of the footwear sector.
- **Technology:** Up gradation of Technological status of product/ production technology from conventional to modern level as per market demand

- **Quality and Testing:** Creation of awareness campaign on standardization and quality of the products.
- **Processing:** To enhance capability of the Footwear industries with respect to material processing by introducing appropriate technology [119].

7.2.2 Road Map for Footwear Sector Development

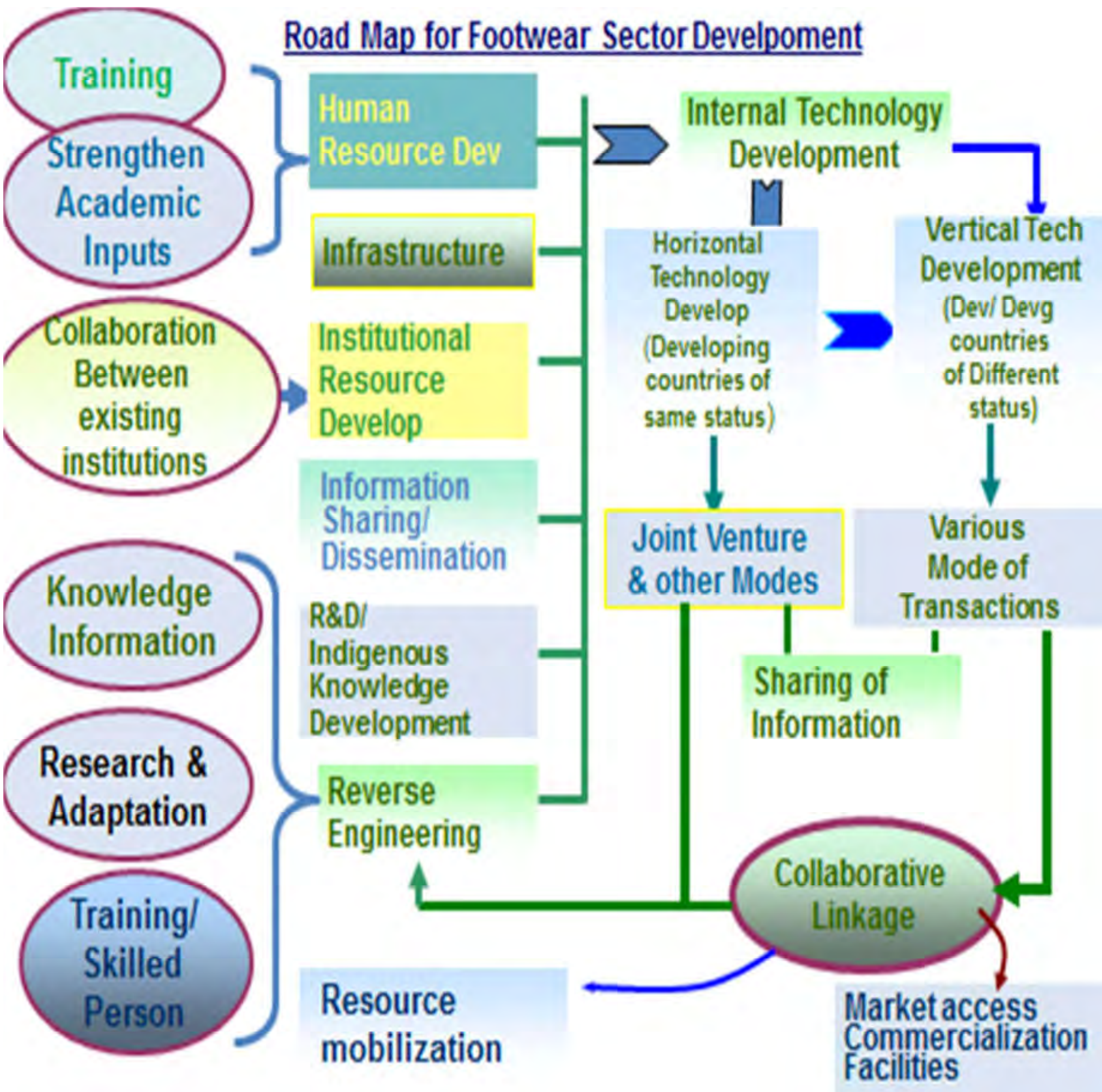


Fig. 7.2.1 Road map for footwear sector development

7.3 Improvement Strategic Model for Footwear Sector Development

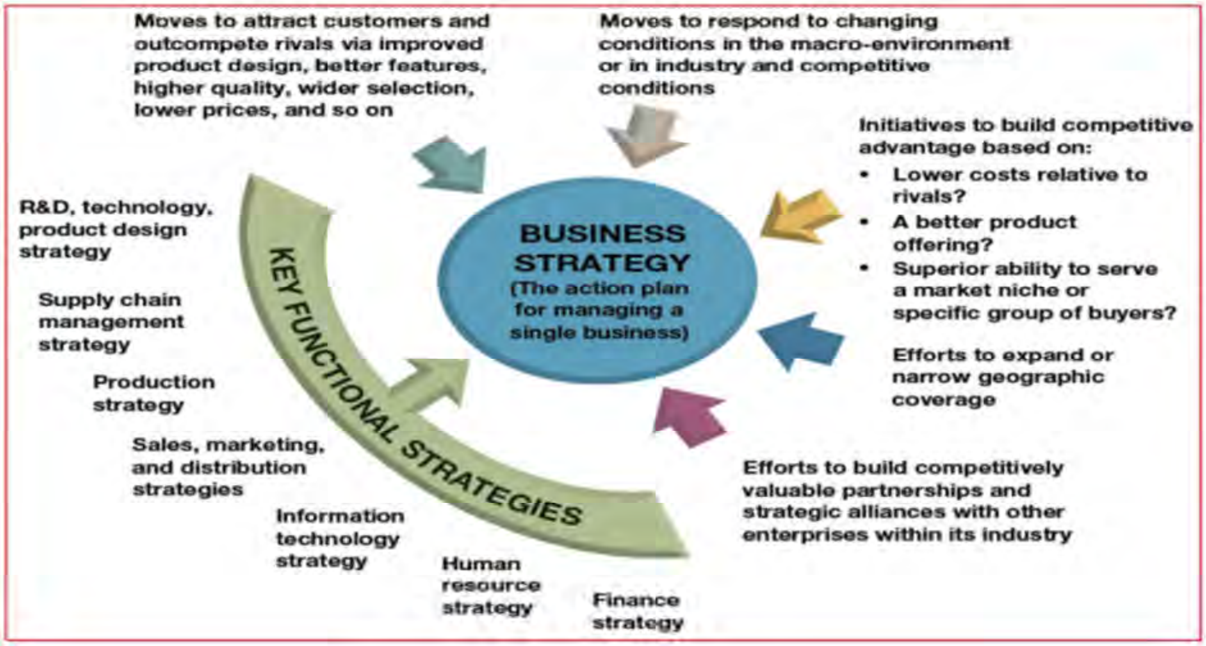


Fig. 7.3.1 Improvement strategic model for footwear sector development

To formulate the improvement strategies [122], it is needed to find out basic causes for NVD activities at different stages of different studied production lines. After intense brainstorming and a thorough study of the observed processing floors, it was observed that the activities of processing floors contain various forms of NVD activities which could be deduced from the Pareto Analysis. In order to reduce these NVD activities a number of strategic steps have to be taken for improved PCE, takt time and reduced lead time of regarding production lines.

7.3.1 Introducing Total Productive Maintenance (TPM)

TPM is a widely using tool in the manufacturing companies over the World. It is a unique Japanese philosophy, which has been developed based on the Productive Maintenance concepts and methodologies. In 1971, this concept was first introduced by M/s Nippon Denso Co. Ltd. of Japan, a supplier of M/s Toyota Motor Company. Total Productive Maintenance is an innovative approach to maintenance that optimizes equipment effectiveness, eliminates breakdowns and promotes autonomous maintenance by operators through day-to-day activities involving total workforce [82].

Machine break down is one of the most important issues that concern the people on the processing floor. The reliability of the equipment on the processing floor is very important since one machine breaks down the entire production line could go down. An important tool that is necessary to account for sudden machine breakdowns is TPM. In almost any lean environment setting a TPM program is very important. TPM focuses on the equipment used. It is a holistic approach to equip the maintenance that strives to achieve perfect production with no breakdowns; no small stops or slow running and no defects. There are three components of a TPM: preventive maintenance, corrective maintenance and maintenance prevention. Preventive maintenance has to do with regular planned maintenance on all equipment rather than random checkups. Workers have to carry out regular equipment maintenance to detect any anomalies as they occur. By doing so sudden breakdown can be prevented which leads toward improvement in the throughput of each machine [83]. Corrective maintenance deals with decision such as whether to fix or buy new equipment. If a machine is always down and its components are always breaking down then it is better to replace those parts with newer ones. As a result the maintenance will last longer and its uptime will be higher. Maintenance prevention has to do with buying the right machine. If a machine is hard to maintain (e.g. hard to lubricate or bolts are hard to tighten) then workers will be reluctant to maintain the machine on a regular basis, which was frequently observed in the studied processing floors that will results in a huge amount of lost money invested in that machine. Though in recent years, many companies have attempted to implement TPM programs, less than 10 per cent of companies succeed in implementing TPM [84]. Implementing TPM requires the change of the organizational culture and change of existing behaviors of all employees, operators, engineers, maintenance technicians and managers. By this study during the observation sudden downs of different machines, especially the cutting, sewing and lasting machine were observed at different processing stages of production fines which were quantified in Table 6.1.3, Table 6.2.3, Table 6.3.3, Table 6.4.3, 6.5.3, and Table 6.6.3. During the down time, sometimes machines were stopped for maintenance or the machines were producing defect product that were accounted as manufacturing waste. To maintain and to prevent the defect production a number of operators, assistant operators and workers were engaged which was also considered as manufacturing waste in term of unwanted motion of labor so it seems that if it is possible to implement the TPM, then the manufacturing waste could be eliminated at expected level. The TPM is measured by the Overall Equipment Effectiveness (OEE). For successful implementation of TPM, it is necessary to evaluate the present OEE. The following Tables were contained the present OEE of all observing processing lines.

Table 7.3.1: OEE of Derby shoe production line

- **Availability rate (A)** = (Net Down time ÷ Total good time) x 100

  = (3921 ÷ 10440) x 100

  = 37.55%

Here, Net Down time = 3921 sec, Total good time = 10440 sec

➢ **Percentage of quality (Q)** = [(Total produced –Defected produced) ÷ Total Produced] x 100

= [11765-311) ÷ 11765] x 100

= 97.35%

Here, Total produced= 11765 pair, Defected produced= 311 pair

➢ **Performance rate (P)** = [Net Down time – (Management Down time + Startup Down time)] ÷ Net Down time

= [3921-(267+240)] ÷ 3921

= 87.07%

Here, Net Down time=3921 sec, D/T for management loss= 267sec, startup loss= 240sec

➢ **Overall Equipment Effectiveness** = Availability rate (A) x Percentage of quality (Q) x Performance rate (P)

= 0.3755 x 0.9735 x 0.8707

= 31.82%

Table 7.3.2: OEE of Casual shoe production line

➢ **Availability rate (A)** = (Net Down time ÷ Total good time) x 100

= (3869 ÷ 16080) x 100

= 24.06%

Here, Net Down time = 3869 sec, Total good time = 16080 sec

➢ **Percentage of quality (Q)** = [(Total produced –Defected produced) ÷ Total Produced] x 100

= [928000-468) ÷ 28000] x 100

= 98.32%

Here, Total produced= 28000 pair, Defected produced= 468 pair

➢ **Performance rate (P)** = [Net Down time – (Management Down time + Startup Down time)] ÷ Net Down time

= [3869-(574+240)] ÷ 3869

= 78.96%

Here, Net Down time=3869 sec, D/T for management loss= 574sec, startup loss= 240sec

- **Overall Equipment Effectiveness** = Availability rate (A) x Percentage of quality (Q) x Performance rate (P)
  = 0.2406 x 0.9832 x 0.7896
  = 18.67%

Table 7.3.3: OEE of Court shoe production line

- **Availability rate (A)** = (Net Down time ÷ Total good time) x 100
  = (1726 ÷ 6780) x 100
  = 25.46%

  Here, Net Down time = 1726 sec, Total good time = 6780 sec

- **Percentage of quality (Q)** = [(Total produced –Defected produced) ÷ Total Produced] x 100
  = [16000-527) ÷ 16000] x 100
  = 96.70%

  Here, Total produced= 16000 pair, Defected produced= 527 pair

- **Performance rate (P)** = [Net Down time – (Management Down time + Startup Down time)] ÷ Net Down time
  = [1721-(266+240)] ÷ 1721
  = 70.68%

  Here, Net Down time=1721 sec, D/T for management loss= 266 sec, startup loss= 240sec

- **Overall Equipment Effectiveness** = Availability rate (A) x Percentage of quality (Q) x Performance rate (P)
  = 0.2546 x 0.9670 x 0.7068
  = 17.40%

Table 7.3.4: OEE of Oxford shoe production line

- **Availability rate (A)** = (Net Down time ÷ Total good time) x 100
  = (1629 ÷ 6780) x 100
  = 24.02%

  Here, Net Down time = 1629 sec, Total good time = 6780 sec

- **Percentage of quality (Q)** = [(Total produced –Defected produced) ÷ Total Produced] x 100
  = [16000-525) ÷ 16000] x 100
  = 96.72%

  Here, Total produced= 16000 pair, Defected produced= 525 pair

- **Performance rate (P)** = [Net Down time – (Management Down time + Startup Down time)] ÷ Net Down time
  = [1629-(207+240)] ÷ 1629
  = 72.56%

  Here, Net Down time=1629 sec, D/T for management loss= 207sec, startup loss= 240sec

- **Overall Equipment Effectiveness** = Availability rate (A) x Percentage of quality (Q) x Performance rate (P)
  = 0.2402 x 0.9672 x 0.7256
  = 16.86%

Table 7.3.5: OEE of Boot production line

- **Availability rate (A)** = (Net Down time ÷ Total good time) x 100
  = (2379 ÷ 9720) x 100
  = 24.47%

  Here, Net Down time = 2379 sec, Total good time = 9720 sec

- **Percentage of quality (Q)** = [(Total produced –Defected produced) ÷ Total Produced] x 100
  = [11765-280) ÷ 11765] x 100
  = 97.62%

  Here, Total produced= 11765 pair, Defected produced= 280 pair

- **Performance rate (P)** = [Net Down time – (Management Down time + Startup Down time)] ÷ Net Down time
  = [2379-(185+240)] ÷ 2379
  = 82.13%

  Here, Net Down time=2379 sec, D/T for management loss= 185sec, startup loss= 240sec

➢ **Overall Equipment Effectiveness** = Availability rate (A) x Percentage of quality (Q) x Performance rate (P)

= 0.2447 x 0.9762 x 0.8213

= 19.62%

Table 7.3.6: OEE of Moccasin shoe production line

➢ **Availability rate (A)** = (Net Down time ÷ Total good time) x 100

= (2482 ÷ 12060) x 100

= 20.58%

Here, Net Down time = 2482 sec, Total good time = 12060 sec

➢ **Percentage of quality (Q)** = [(Total produced –Defected produced) ÷ Total Produced] x 100

= [28000-534) ÷ 28000] x 100

= 98.09%

Here, Total produced= 28000 pair, Defected produced= 534 pair

➢ **Performance rate (P)** = [Net Down time – (Management Down time + Startup Down time)] ÷ Net Down time

= [2482-(226+240)] ÷ 2482

= 93.31%

Here, Net Down time=2482 sec, D/T for management loss= 226sec, startup loss= 240sec

➢ **Overall Equipment Effectiveness** = Availability rate (A) x Percentage of quality (Q) x Performance rate (P)

= 0.2058 x 0.9809 x 0.9331

= 18.83%

Table 7.3.7: Overall Equipment Efficiency (OEE) of observing production lines

Production line	**Present OEE**	**Comments**
Derby shoe production line	31.82%	In order to attain the world class manufacturing performance the OEE should be at least 85% [83].
Casual shoe production line	18.67%	
Court shoe production line	17.40%	
Oxford shoe production line	16.86%	
Boot production line	19.62%	
Moccasin shoe production line	18.83%	

It seems that the lowest OEE was 16.86% of Oxford shoe production line and the highest TPM was 31.82% of Derby shoe production line. But the existing OEE could be improved up to 85%. It was expected throughout the implementation of TPM, it could be obtained at least up to 90% OEE. The machine should be operated in a manner so that there will be no customer complaints. By implementing TPM it could be possible to reduce the manufacturing cost by 30%, to achieve 100% success in delivering the goods as required by the customer, to maintain an accident free environment, to increase productivity and OPE (Overall Plant Efficiency) by 1.5 or 2 times [85]. Equipment maintenance represents a significant component of the operating cost in transportation, utilities, mining, and manufacturing industries. The potential impact of maintenance on the manufacturing performance is substantial. Maintenance is responsible for controlling the cost of manpower, material, tools and overhead [86, 87], Manufacturers are beginning to realize that maintenance organization and management and design for maintainability and reliability are strategic factors for success in 1990s 186J. Thus the effectiveness of maintenance function significantly contributes towards the performance of equipment, production and products [88, 89]. Some years ago 100-year-old steel foundry employed most of the principles, tools and techniques of TPM. The results were excellent the average downtime on overhead cranes went from about 17% to 2.5%. Other major equipment showed comparable results. Here are some other results reported by industry.

- MRC Bearings reduced unplanned downtime by 98% in one cell and 99% in another all within one year.
- Monsanto runs their three-year old TPM start-up plant at 97% on-stream time while most other units run between 85% and 90%.
- 3M reduced their maintenance cost by 60% within three years.
- DuPont reduced off-quality by 69% and improved capacity by 29% in three years.
- Harley-Davidson estimates that the ROI from TPM has been ten-fold to the cost of implementation.
- Kodak reported a $5 million investment in TPM that resulted in a $16 million increase in profits [90].

For the reduction of machine failure it is suggested to implement TPM. It is recommended to follow the following some steps to the machine operator daily. These are:

- Checking the lubrication regularly if needed lubricant the machine
- Reporting oil leakages
- Being alert and recognize unusual noise, vibrations and temperature which signify impending failure
- Checking bolts for tightness
- Reporting any deterioration in product quality before the issue goes out-of-control

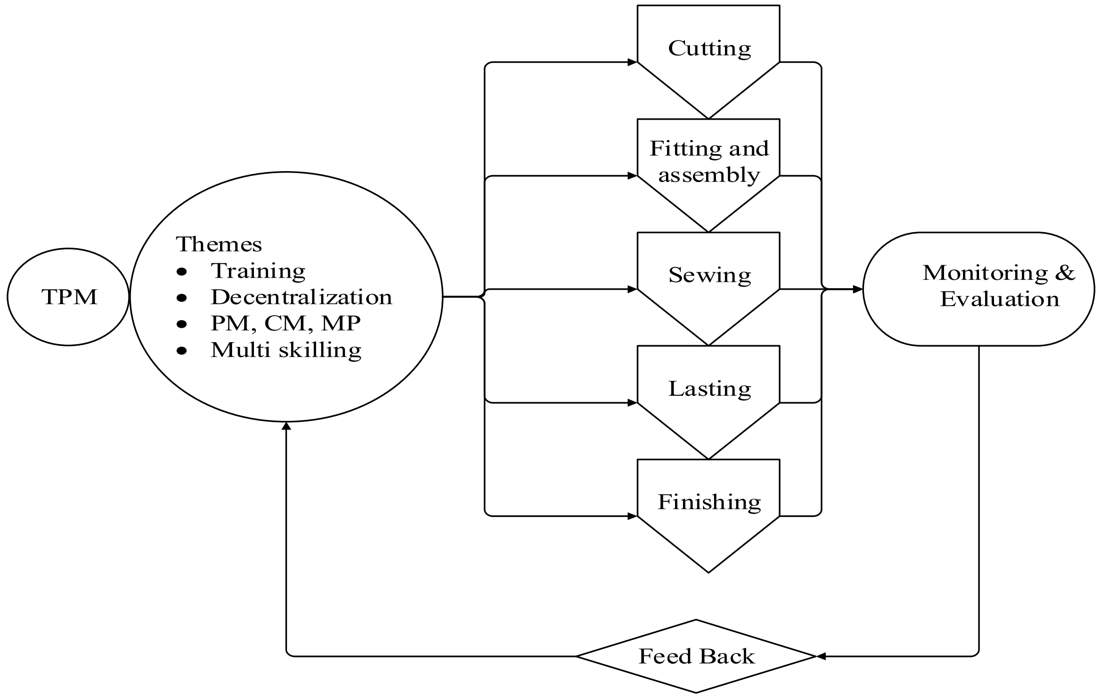


Fig. 7.3.2 Strategic frame work for TPM implementation

A strategic frame work is formulated by author in order to implement the TPM in studied shoe production lines. The basic theme of TPM is formulated by the components of training of regarding operators and labors, decentralization of responsibility instead of central, different types of TPM measurement like as preventive maintenance (PM), corrective maintenance (CM) and maintenance prevention (MP). These components of TPM should be implemented into the basic stages where the machining problems are occurred most frequently like cutting, sewing and lasting. A strong expert team should be established for proper monitoring and evaluation in order to generate a fruitful feedback. The whole system should be operated as a circular system. So, it is suggested to involve TPM with production management system of shoe production sector of X Footwear industry.

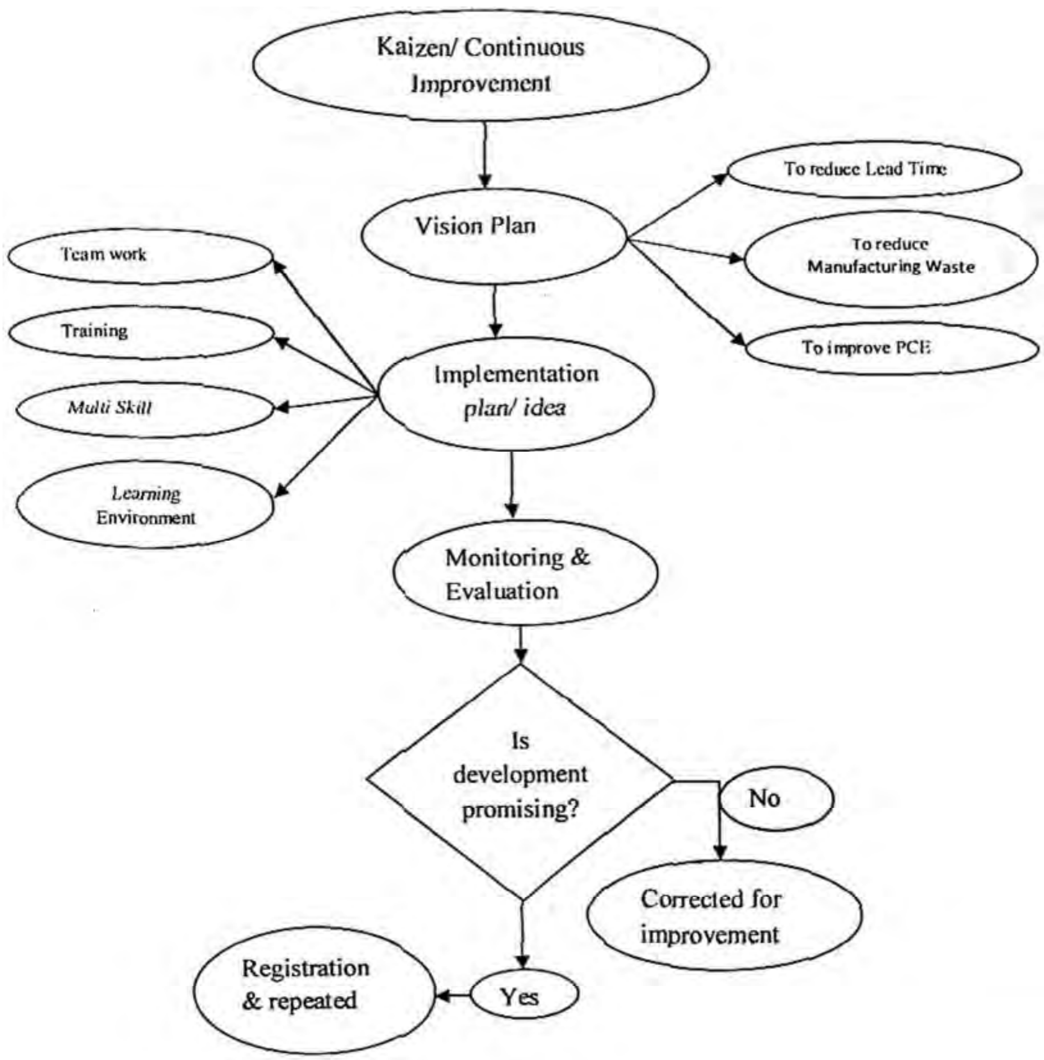
7.3.2 Increase Skill Manpower

In the studied processing floors it was observed that there was no skill helper for any operators. But for this reason the change over time and maintenance time was observed due to a limited number of skilled labors were engaged beyond the machine operation and maintenance. The transportation time was also high due to unskilled worker between two stages towards maintenance the products flow. So, it is suggested to hire some skill manpower as assistant operator or as operator especially for cutting, sewing and lasting machine.

7.3.3 Continuous Improvement

Kaizen also known as continuous improvement is a long-term approach to work that systematically seeks to achieve small, incremental changes in processes in order to improve efficiency and quality. Kaizen can be applied to any kind of work but it is perhaps best known for being used in lean manufacturing. Kaizen can be roughly translated from Japanese to mean "good change". The philosophy behind kaizen is often credited to Dr. W. Edwards Deming. Dr. Deming was invited by Japanese industrial leaders and engineers to help rebuild Japan after World War II. He was honored for his contributions by Emperor Hirohito and the Japanese Union of Scientists and Engineers. Continuous improvement is one of the most basic tools of lean production. Kaizen is a Japanese word which indicates the continuous endeavor for bringing the perfection in the production with considering the quality and quantity. Kaizen is a systematic approach to gradual, orderly and continuous improvement. In a production processing line the improvement can be achieved by many ways such as reduction of inventory, reduction of production time, reduction of defective parts. From a number of continuous improvement tools, 5S is one of the most popular tools for effective continuous improvement tools. Towards the serious waste reduction 5S is the first, modular step. 5S consists of Japanese words Seiri (Sort), Seiton (Straighten), Seiso (Sweep and Clean), Seiketsu (Systemize) and Shitsuke (Standardize). The basic and underlying concept of 5S is look for waste and then tries to eliminate it. The first S, Seiri (Sort), deals with moving those items that are not currently being used on a continuous basis (e.g., that will not be used for next month or so) away from those that are. If every area has people assigned to it then every people has responsibility to maintain a high standard of housekeeping and cleaning [84]. The second S, Seiton (Straighten), has to do with having the right items in the right area. Items that do not belong to a given area must not be that area. For a given work place area tools must be marked and arranged as belonging in that area. This will make it easier to move those items that are not labeled from that area. Arranging items in the right place will make tools, jigs, fixtures and resource noticeable, detectable and easy to use [84]. The third S, Seiso (Sweep and Clean), deals with cleaning and sweeping the work place methodologically. The work place should look neat and clean and ready to use for the next shift. The work place should be maintained on a regular basis. All tools and items should be in the right place and nothing should be missing. A well maintained work place creates a healthy environment to work with. The fourth S, Seiketsu (Systemize), deals with maintaining a high standard of housekeeping and work place arrangement. A regular audit should be run and scores should be assigned for areas of responsibilities. If every area has people assigned to it then everyone has responsibility to maintain a high standard of housekeeping and cleaning [81]. The fifth S, Shitsuke (Standardize), deals with the management accountability to train people to follow housekeeping rules. Management should implement the housekeeping rules in a practiced fashion so that their shop floor, explain what they want from people, reward those who follow and instruct those who do not [81].

Taken together, 5S means good housekeeping and better workplace organization. Kaizen tools such as 5S are not only a means to increase profitability of a firm but also allow companies to reveal potential strengths and capabilities [91, 92]. Key Performance Indicators (KPI) showed that the Scunthorpe mill is achieving its targets for rolling steel in planned weeks and is delivering almost 100% of customers' orders complete on time. Scunthorpe Plate Mill aims to have all orders complete and on time by March 2009, while at the same time reducing lead time [93]. By implementing the 5S taking the delivery of product has increased from 70% of plates on time to 92% on time [94]. So, with the proper implementation of 5S it is expected that the recognized manufacturing waste of studied floors could be reduced as to the desired level.



Strategic plan for kaizen Implementation

A strategic plan for kaizen implementation is developed by author in order to implement the Kaizen in the studied shoe production lines. 5S was considered as the basic concept of kaizen improvement for this study. In order to implement the 5S it could be needed a proper plan or vision which could be formulated by the management of shoe production sector. The vision plan could be incorporated with the theme of reducing lead time, reducing manufacturing waste and improving PCE. The plan could be implemented by consisting of team work, training, multi skill and learning environment. To implement a new idea a team work will be effective wheel to bring the idea into practical. In order to adopt with new idea training is very important since, in order to kaizen implementation training is very emergence and thus way regarding managerial personnel as well as operator and labor could be belonged of multi skill. It is rational that only multi skilled manpower could be able to monitoring and evaluating whether adopted plans could be promising or not, if it could be promising it should be legislated and if not, the draw backs should be find out in order to promising implementation towards the improved PCE, reduced takt time, NVD time and lead time.

7.3.4 Standardization of Work

The standardization of worker's action is the prim principle of waste elimination. Basically the standardized work ensures that each job is organized and is carried out in the most effective manner. In this case it is not the matter that who is doing the job rather than achieving the same level of quality. At Toyota every worker follows the same processing steps all the time. This includes the time needed to finish a job, the order of steps to follow for each job and the parts on hand. By doing this one ensures that line balancing is achieved, unwarranted work in process inventory is minimized and non-value added activities are reduced. A tool that is used to standardize work is called takt time. Takt (German for rhythm or beat) refers to how often a part should be reduced in a product family based on the actual customer demand. The target is to produce at a pace not higher than the takt time [95]. By this study it was suggested to the managerial personnel of the studied processing line to standardize the responsibility of each and every employed worker on the process line towards achieving the same level of quality at the highest level.

7.3.5 Just in Time (JIT)

JIT is a Japanese management philosophy which has been applied in practice since the early 1970s in many Japanese manufacturing organizations. It was first developed and perfected within the Toyota manufacturing plants by Taiichi Ohno as a means of meeting consumer demands with the minimum delays [96]. For this reason, Taiichi Ohno is frequently referred to as the father of JIT. At present, the nature of production technologies has changed tremendously because of the implementation of lean tools and advanced manufacturing technologies. The first element of lean production is the focus on what is most commonly thought of as 'just in time' management. Just in Time Manufacturing (JIT) is one of the main principles of lean manufacturing, it is the idea of producing exactly what the customer wants, in the quantities they want, where they want it, when the customer wants it without it being delayed or held up in inventory [97]. Some general guidelines for JIT implementation have been suggested and these form a basis for finding the appropriate way for implementing JIT. Key obstacles such as long change over time; unleveled production schedules; highly variable production processes; large container sizes; severe bottlenecks and long lead times should be removed before implementing the JIT [97]. That means to implement the JIT the regarding organization has to remove these mentioning obstacles. Broadly speaking, one can think about JIT implementation from different angles, the most common being people and the engineering angles. However, JIT experts mentioned that it is essential to begin JIT implementation with a good deal of attention first being paid to the people aspects [98, 99]. There are two stages of JIT implementation [95]: One, prepare the plant and its people for flexibility, low costs, short lead-times and high quality by concentrating on design; maintenance; quality; layout; set-up time; and people. Two, strive to produce zero lead-time with no waste by focusing on: total people involvement; visibility; process data collection; enforced improvement; flow scheduling; inventory control; buffer and lot size reduction and supplier and customer relationship. These two stages, however, don't specify a general sequence of steps for the implementation of JIT. Moreover, the ability of the different techniques in both stages depends highly on a specific manufacturing environment. The JIT techniques are grouped into two stages [100]. The first stage of JIT implementation is composed of areas that are necessary for full JIT to work. They focus on four main elements of JIT that can be achieved in the short term. These are simplicity, flow, quality and fast set-up and lay the foundation for moving on to the more difficult techniques like kanban and JIT purchasing, which are a part of stage two. However, benefits from these programs have often been limited because of unreliable or inflexible equipment [101]. The production process of all the studied processing lines start from raw material inventory and draw the completion of production by the finished goods inventory, although throughout the entire processing system internal inventory were also present at different stages of processing floor that was created by overproduction. Inventory is probably the biggest waste of lean Manufacturing. By implementing the philosophy of JIT this kind of waste of overproduction could be eliminated. It was reported that after the implementation of JIT the efficiency could be gained 30-60%, lead time could be reduced 50-90%, capital expenditures could be reduced 25-30%; and a significant inventory costs could also be reduced [102].

7.3.6 Lead time reduction

The reduction of lead time of production of any product is a continuous improvement process. The lead time of studied different processing lines were first calculated. The various elements that are associated with the lead time were first identified separately and different practical strategies are adopted for lead time reduction or improvement. In general the various components associated with the lead time of any process are waiting time before process set up time, process time, waiting time after process and transfer time [103]. In this study it was found that queue time, insufficient sole supply at different stages of production, sewing, lasting and unsmooth conveyor belt were the basic hindrance beyond the long lead time. After an intense observation of studied processing floors with a sharp brain storming, it is proposed that with the proper implementation of continuous improvement, 5S and JIT philosophies the lead time could be reduced by 60-80%.

7.3.7 Inventory management

Inventory management has often meant too much inventory and too little management or too little inventory too much management. By all sectors of economy it is experience that inventory management is a vital problem. Inventories are stockpiles of raw materials suppliers, components, work in process and finished goods that appear at numerous points, throughout a firm's production and logistics channel. Inventory is the stock of any item or resource used in an organization. Inventory management is a set of policies and controls that monitor levels of inventory and determine what levels should be maintained when stock should be replenished and how large order should be received [104].

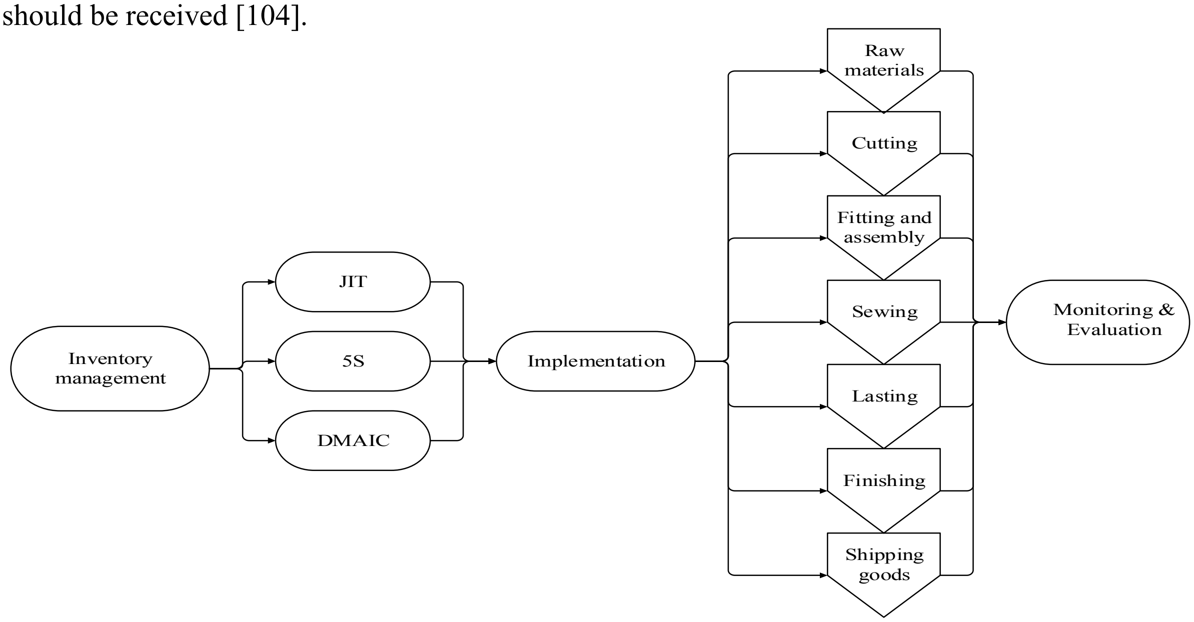


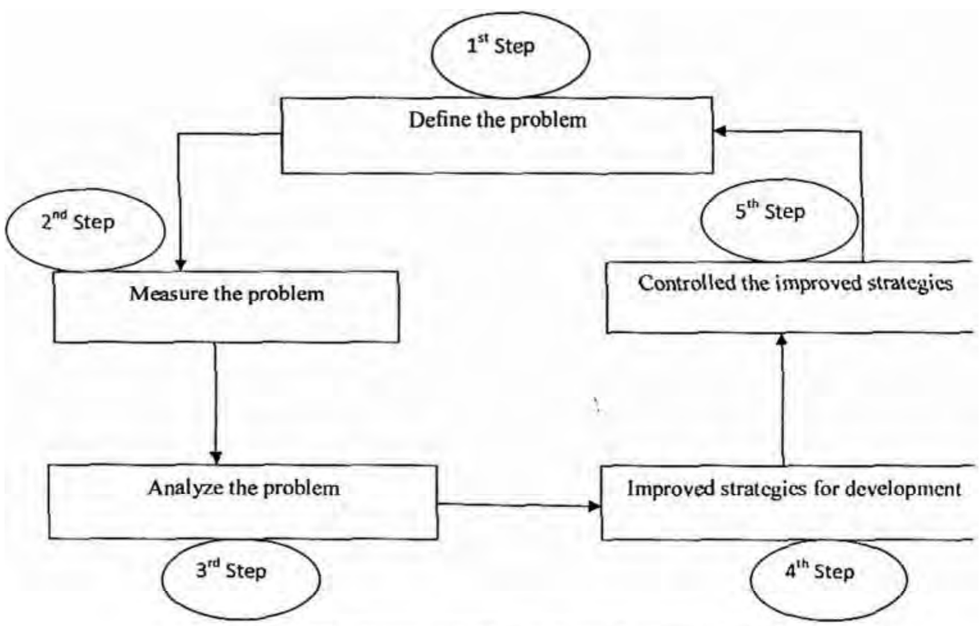
Fig. 7.3.3 Strategic plan for inventory management

From the strategic plan it seems that inventory of each stage should be managed with the proper implementation of JIT, 5S and DMAIC methodologies. Throughout this study it was expected that proper inventory management could be the consequence of successful implementation of JIT, 5S and DMAIC methodologies. From the strategic plan it also seems that between every two stages there is an inventory, so it is emergence to ensure the proper adoption of JIT, 5S and DMAIC methodologies at every processing stage of studied shoe production lines. After the proper implementation JIT, 5S and DMAIC methodologies 80/20 Pareto principle could be easily achieved and thus 80% existing manufacturing waste could be reduce as well as lead time could be reduced with the improved PCE.

7.3.8 DMAIC methodology

The DMAIC project methodology has five phases [105]:

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

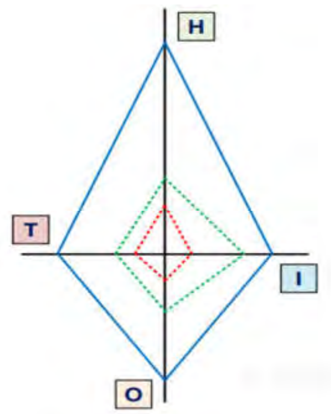


A strategic plan for DMAIC implementation

A strategic plan was formulated in order to implement the DMAIC methodology for the sake of manufacturing waste reduction. For the first time the problem beyond the manufacturing wastes should be defined. During the study at different production lines machines problems, unnecessary motions of labor, unwanted downtimes and others most frequently occurred problems were defined. Secondly, the defined problems should be measured in terms of quantitative manner for example the downtimes were calculated in seconds, unnecessary motion of labor were measured in number. Thirdly, these measure problems were analyzed in terms of frequency for example there were different causes for down times where these causes were identified in terms of frequency of occurrence. Fourthly, an improved strategy were developed to remove these causes beyond the defined problems for example JIT, 5S, Kaizen and DMAIC strategies were formulated and suggested to adopt within the managerial system of studied production lines in order to removes theses identified causes at different stages of production lines. Finally, monitoring and controlling of these strategies should be done properly in order to attain the ultimate goal of this study.

7.3.9 Assessment of technology system components sophistication range and innovation scope of footwear industry

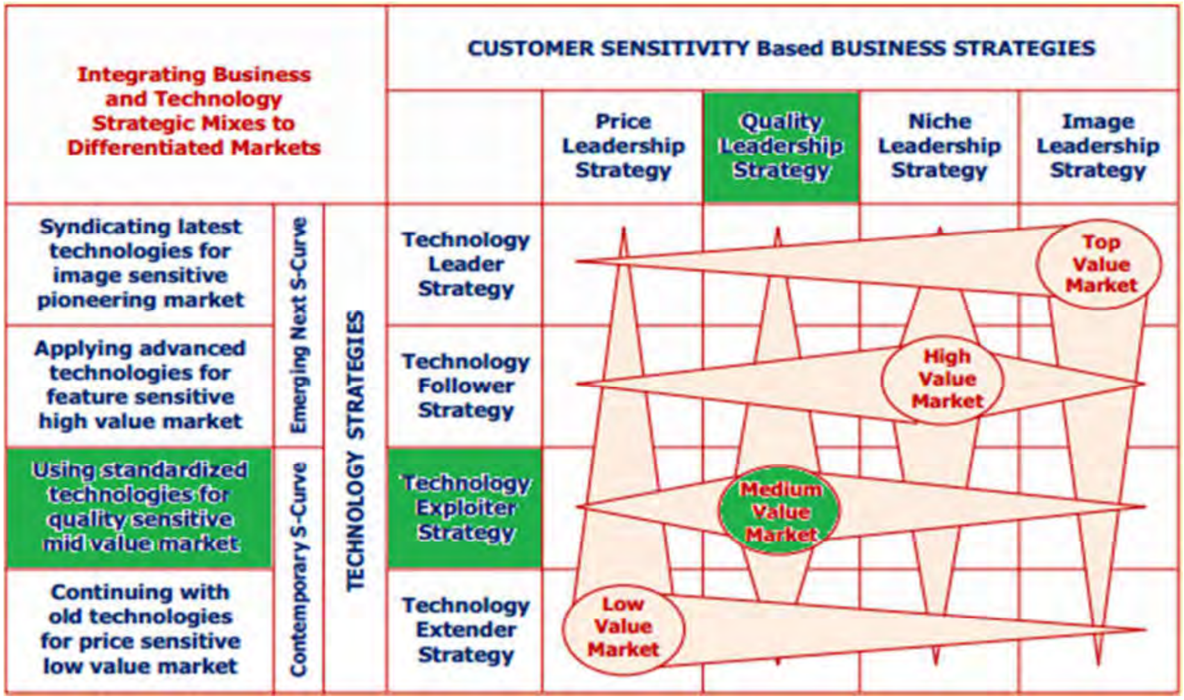
Ideal (Best) profile : Outer shape (blue)
Current profile : Middle shape (green)
Minimum profile : Inner shape (red)



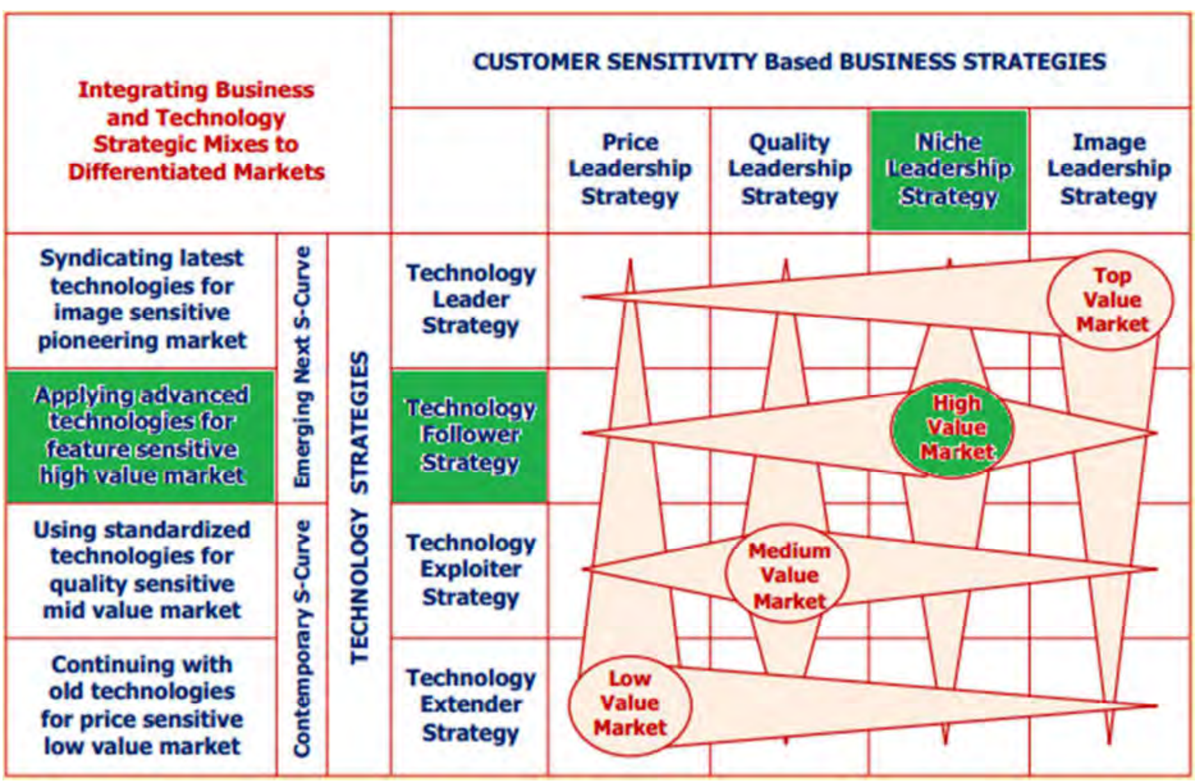
Revised the scoring table for assessing degree of sophistication of THIOs using a 9-point overlapping scoring scale with 10 for ideal best [122]-

Technology Components	LOW Primitive Score: 1-2-3	MEDIUM Traditional Score: 3-4-5	HIGH Modern Score: 5-6-7	TOP Emerging Score: 7-8-9	IDEAL Best Score: 10
Technoware	Manual	**Powered**	Automatic	Programmable	Zero Deviation
Humanware	Basic	Superior	**Advanced**	Extra-ordinary	Zero Error
Infoware	General	Special	**Unique**	Frontier	Zero unknown
Orgaware	Adhoc	**Orderly**	Managed	Optimized	Zero tolerance

7.3.10 Assessment of product market value using integrated business and technology strategies of "X" footwear industry



Use this framework to determine the strategic status and pathway for innovation for a "Product Line" of "X" footwear industry-



7.4 Discussion

Since, 1990s lean tools are implementing at different automobiles and manufacturing industries over the World but implementation of lean in footwear industry is very new and this study was for the first time in a footwear industry of Bangladesh. Throughout this study it was endeavored to implement lean and SS in the shoe production sector of X footwear industry. To conduct this study, author was inspired by the previous outcomes with the implementation of lean and SS at different manufacturing and service industry that were illustrated by reducing the lead time, improving PCE and eliminating the NVD activities from the production floor. This study was conducted in Casual shoe production line, Derby shoe production line, Court shoe production line, Oxford shoe production line, Boot production line and Moccasin shoe production line. These production floors were evaluated in three steps: firstly, the production lines were assessed at the present state in order to find out the present lead time, PCE, takt time by using VSM. An attempt was conducted to find out the different kinds of manufacturing wastes at different processing stages of production floor. It was also tried to quantify these manufacturing wastes. Secondly, an improvement strategy was developed by involving lean tools and SS methodologies to improve the PCE, to reduce the lead time, takt time and NVD activities. Thirdly, after the implementation of lean tools and SS methodology an improved PCE, reduced lead time and takt time were expected.

7.4.1 Process Cycle Efficiency (PCE)

The present PCE of Casual, Derby, Court, Oxford, Boot and Moccasin shoe production lines were found consequently as 15.28%, 11.32%, 8.32%, 8.01%, 10.68% and 12.20% that could be 34.05%, 25.60%, 19.46%, 18.84%, 24.45% and 26.91% after the implementation of lean tools and SS methodologies within present production system. To be an internationally competitive company its PCE could be at least 25% [74] but in this study it was seen that all observing production floor's PCE was far away than 25% PCE. By this study it was a hopeful finding that after the implementation of lean tools in the X footwear industry could be an internationally competitive. It seems that with the proper involvement of lean, the PCE of Casual, Derby, Court, Oxford, Boot and Moccasin shoe production lines could be improved consequently by 123%, 126%, 134%, 145%, 129%, and 121%.

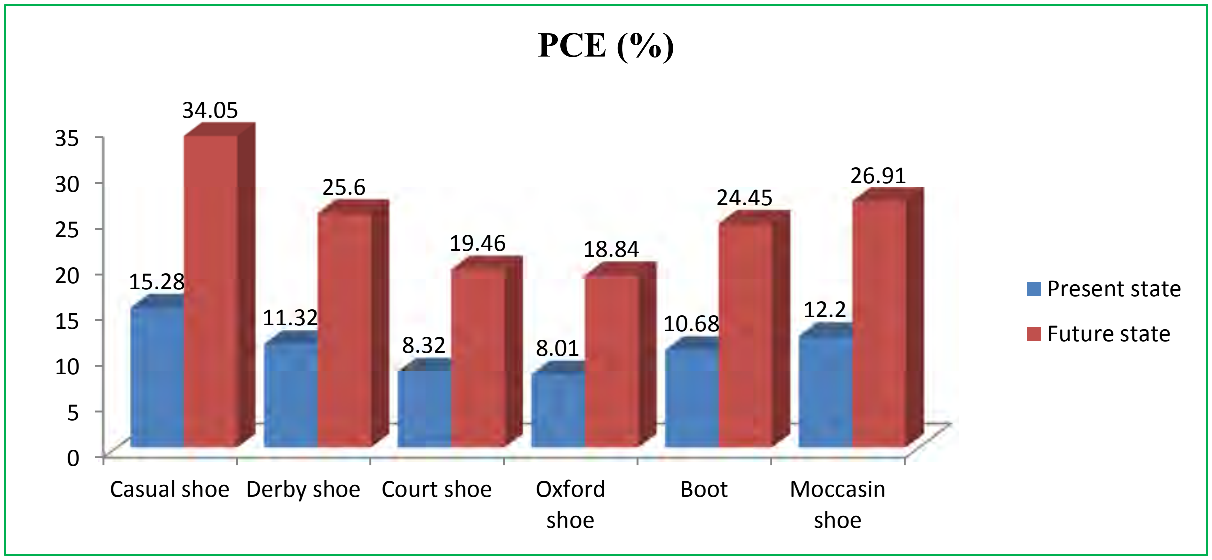


Fig. 7.4.1 Comparison of PCE between present state and future state

7.4.2 Lead time reduction

The existing lead time of Casual, Derby, Court, Oxford, Boot and Moccasin shoe production lines were found consequently as 99870 sec, 86760 sec, 83867 sec, 83700 sec, 86728 sec and 95040 sec but it was expected that after the implementation of lean tools and Six Sigma methodologies within present production system the lead time of these observing production lines could be consequently 44850 sec, 38363 sec, 35866 sec, 35622 sec, 37912 sec and 43109 sec with the promising reduction of lead time consequently by 55.09%, 55.78%, 57.23%, 57.44%, 56.28% and 54.64% (Fig 6.10.2).

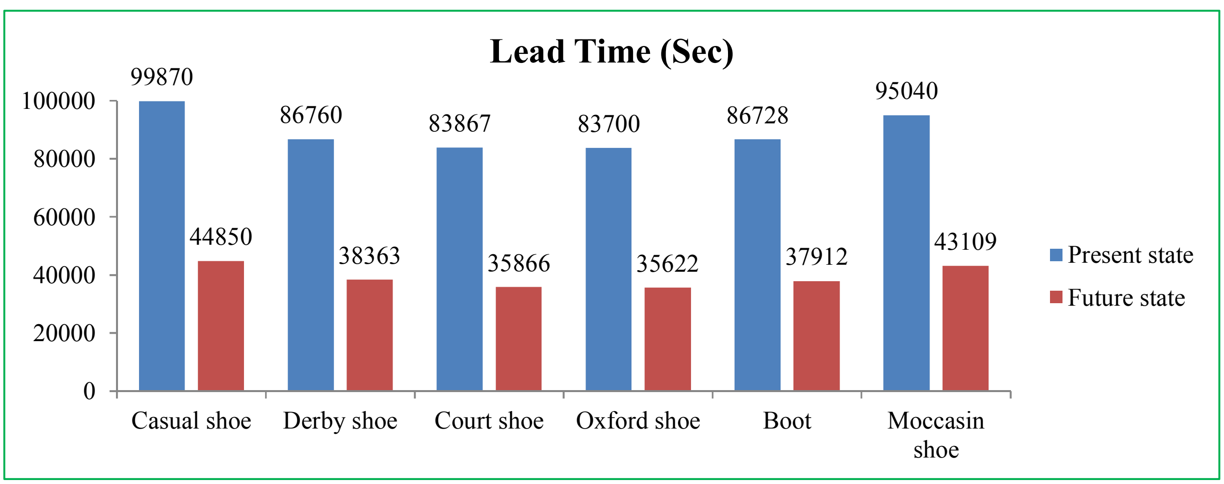


Fig 7.4.2 Comparison of lead time between present state and future state

7.4.3 Takt time reduction

Takt time is considered as the heartbeat of any productive industry. As lowest the takt time of a production floor, it is considered as the highest rate of productivity. By this study, the present takt time of Casual, Derby, Court, Oxford, Boot and Moccasin shoe production lines were found consequently as 13.19 sec, 2.51 sec, 7.20 sec, 7.03sec, 2.44 sec and 8.22 sec where it was expected that after the proper implementation of lean and smooth adoption of SS methodologies the improved or reduced takt time of these production floor would be consequently as 12.89 sec, 2.45 sec, 7.002 sec, 6.84 sec, 2.39 sec and 8.03 sec.

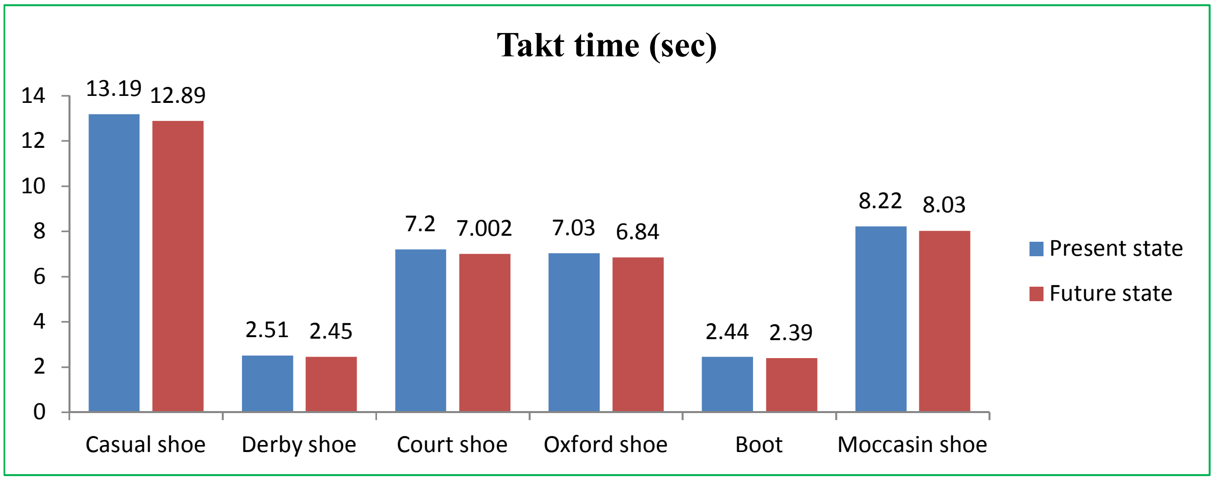


Fig 7.4.3 Comparison of takt time between present state and future state

7.4.4 Reduction of Non Value Added (NVD) activities

In this study the NVD activities were quantified in terms of time. At present the NVD time of Casual, Derby, Court, Oxford, Boot and Moccasin shoe production lines were found consequently as 84600 sec, 76936 sec, 76889 sec, 76988 sec, 77458 sec and 83437 sec while it was hoped that after the intense involvement of lean the NVD activities and time of these observed processing lines could be reduced consequently by 65.03%, 62.91%, 62.42%, 62.45%, 63.02% and 62.23%.

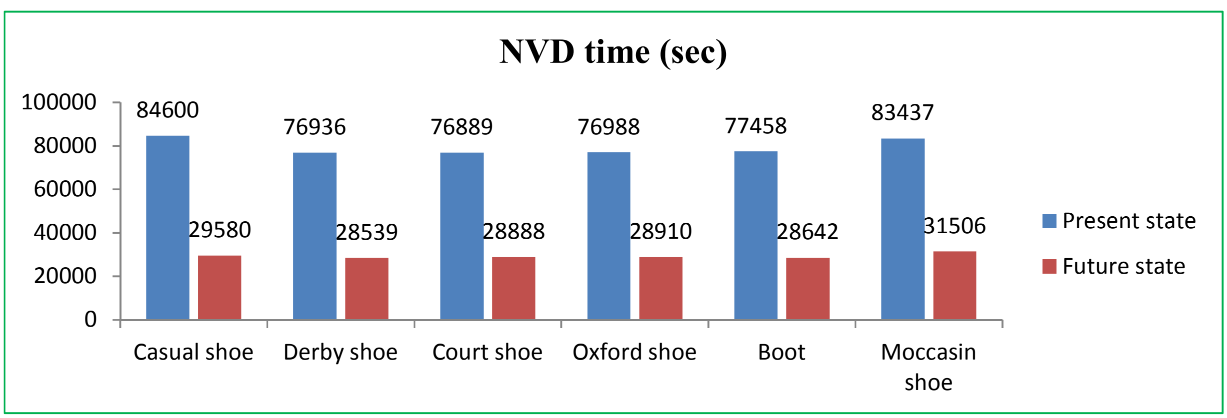


Fig 7.4.4 Comparison of NVD time between present state and future state

7.4.5 Economic benefit with the lean implementation

An economic benefit was calculated by this study which was showed in Table 6.10.1. It was expected that after the proper implementation of lean tools and SS methodology an economic benefit would be 1196576160 TK. or 15147214.34 USD (exchange rate 79 Tk. /l USD) per year by removing the wasted products from the observed different shoe production lines.

Table 7.4.1: Economic benefit from reduction of waste product loss

Production lines	Wasted shoe per batch	Wasted shoe per day	Wasted shoe per week	Marketable value of wasted shoe per year
Casual shoe production line	468	468x2=936	936x6=5616	5616x52x700=204422400Tk.
Derby shoe production line	311	311x2=622	622x6=3732	3732x52x720=139726080Tk.
Court shoe production line	527	527x2=1054	1054x6=6324	6324x52x660=217039680Tk.
Oxford shoe production line	525	525x2=1050	1050x6=6300	6300x52x750=245700000Tk.
Boot production line	280	280x2=560	560x6=3360	3360x52x800=139776000Tk.
Moccasin shoe production line	534	534x2=1068	1068x6=6408	6408x52x750=249912000Tk.
Total				1196576160Tk.

By reducing the wasted shoe it could be a milestone to achieve the SS production, thus it would also be effective to reduce the NVD time and activities as well as lead time. But alas! At present the production floors remain at a gulf gap towards the SS rating production which was evinced from the Fig 7.4.5.

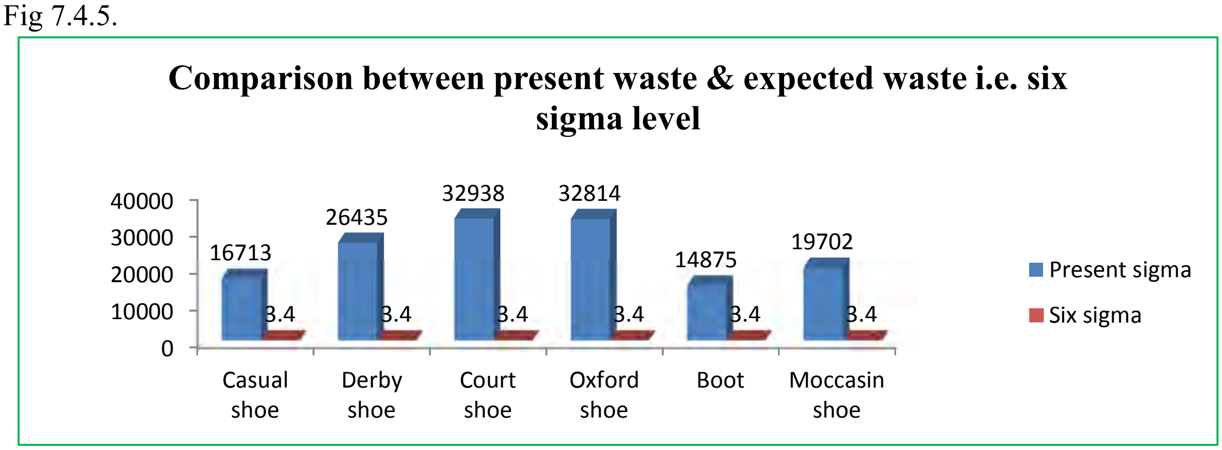


Fig 7.4.5 Comparison of SS rating production between present state and future state

Table 7.4.2: Labor reduction from present state to future state

	Present state (per shift)				Future state (per shift)			
Production lines	O	AO	W	Total	O	AO	W	Total
Casual shoe production line	6	4	15	25	5	2	10	17
Derby shoe production line	6	6	18	30	6	5	9	20
Court shoe production line	5	4	27	36	5	2	13	20
Oxford shoe production line	5	5	23	33	5	2	12	19
Boot production line	5	6	25	36	5	5	12	22
Moccasin shoe production line	5	3	16	24	5	2	6	13
Total	32	28	124	184	31	18	62	111

The graphical presentation of labor benefit after the implementation of Lean tools and SS can be seen from the Fig 7.4.6.

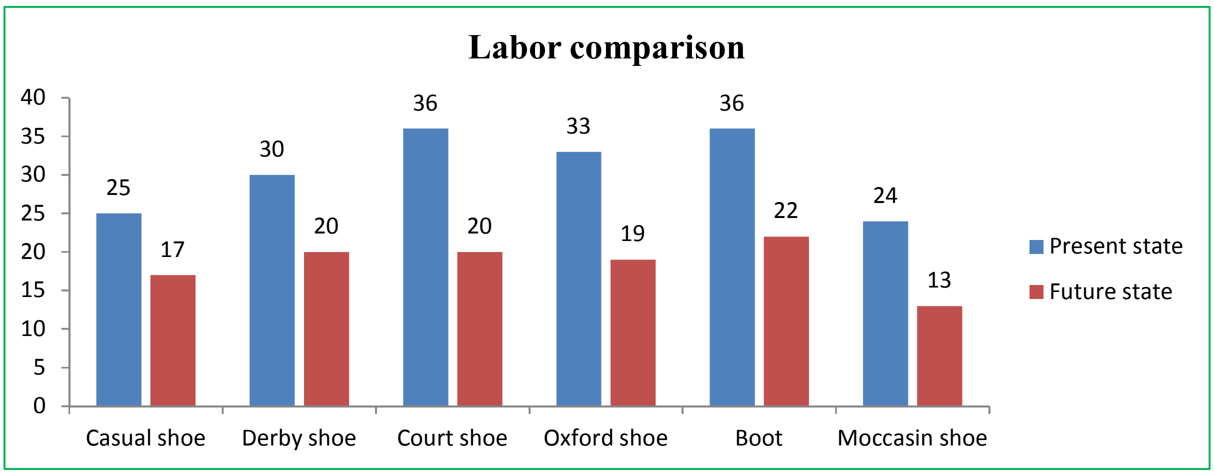


Fig 7.4.6 Comparison of labor benefit between present state and future state

7.4.6 Comparison of Footwear industries various parameters in different countries (Bangladesh, Vietnam & China)

Cost structure:

Cost structure encompasses all the expenses that a firm must take into account when manufacturing & selling a product. Various types of costs that are benchmarked in this section are: Raw material costs, labor costs (including wages), Energy costs, and Interest charges. Margins can only be improved by increasing sales prices or reducing costs. As prices in real terms for many of the industry's staple products have eroded over many years, the focus has long been on reducing costs. Cost reduction is one of the important parameters to achieve first stage of competence i.e. targeting basic inconveniences and cleaning up of operations. Most of the countries have not been able to achieve absolute competitiveness with respect to cost structure [98, 99, 100].

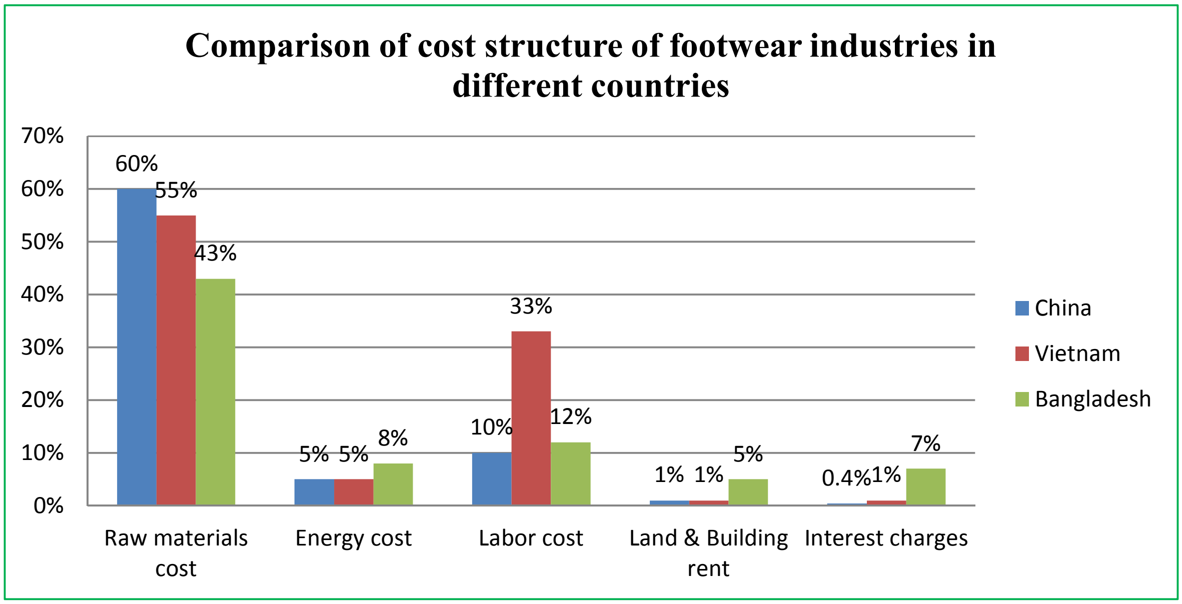


Fig 7.4.7 Comparison of cost structure of footwear industries in different countries

Quality Accreditation

Quality accreditation is an important parameter for competitive advantage as it would enable a firm to increase its market reach. Most of the buyers use quality accreditation as a parameter to evaluate a supplier and in some cases they have a mandate to buy only from firms with desired accreditation [98, 99, 100]. Further, quality accreditation has direct impact on productivity as it would require tightening up of processes and giving away inefficiencies.

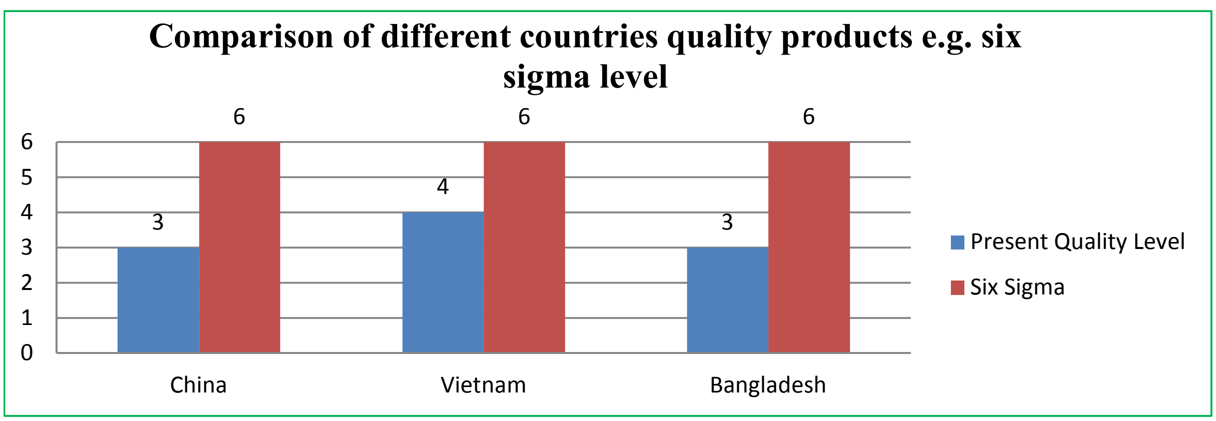


Fig 7.4.8 Comparison of different countries quality products

Working Environment

The work environment has huge effect on the performance of employees which in turn impacts the overall productivity of the firm. The type of work environment in which employees operate determines the way in which such enterprises prosper [113, 115].

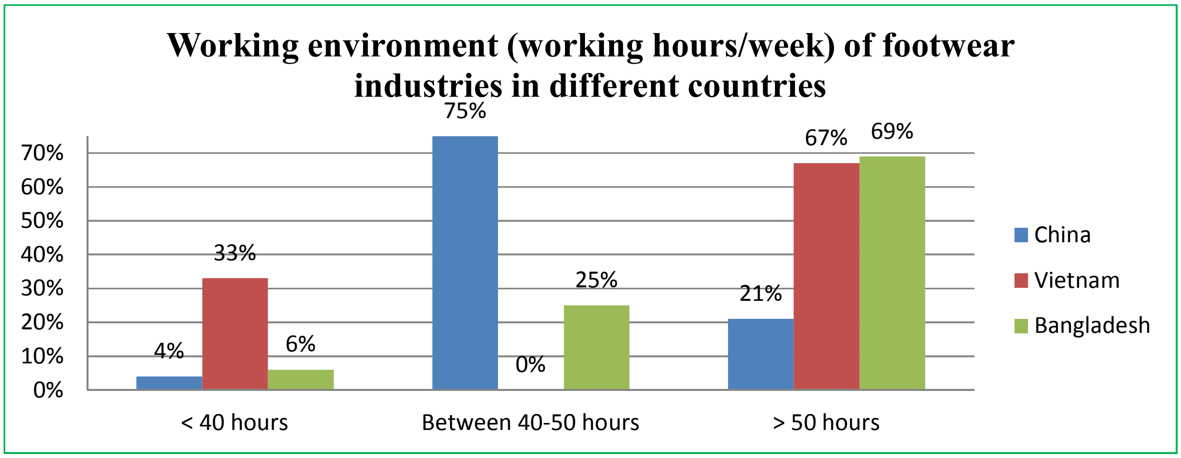


Fig 7.4.9 Working environment of footwear industries in different countries

System Improvement

This section examines the extent of technology and innovation being employed by the firms which would lead to overall improvement in production systems and have direct impact on productivity and ensure sustainability of the same in long run that has been compared training & development of employees [98, 99, 100].

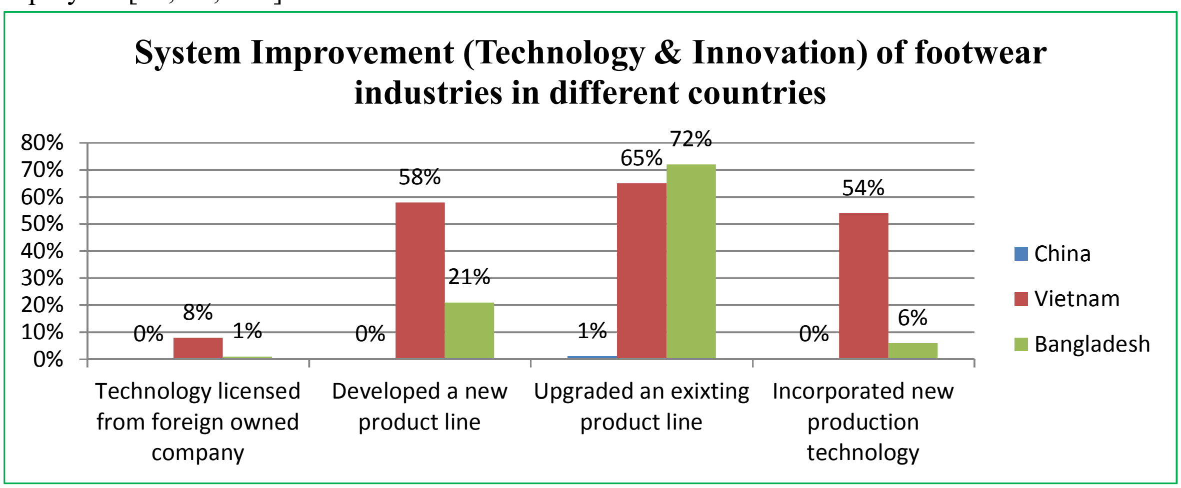


Fig 7.4.10 System improvement of footwear industries in different countries

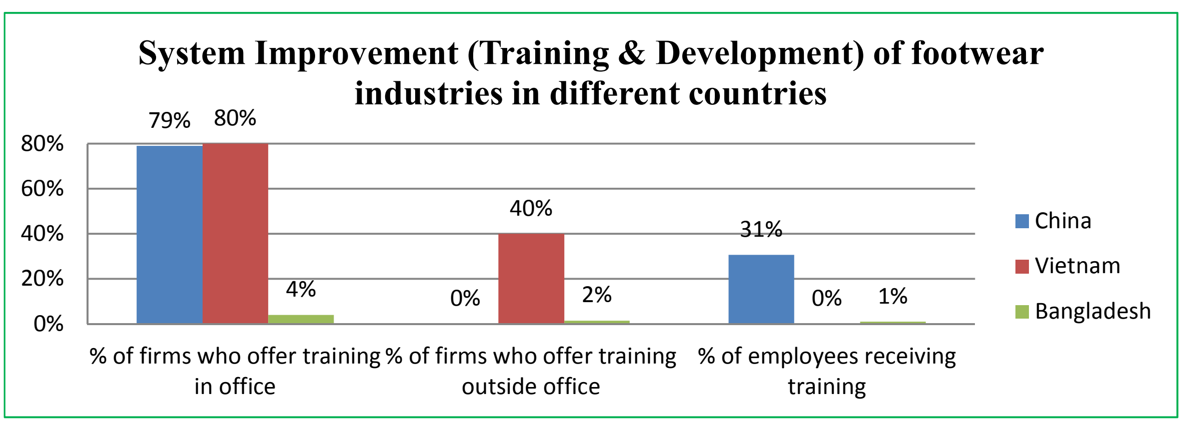


Fig 7.4.11 System improvement of footwear industries in different countries

Table 7.4.3: Economic benefit at future state by labor reduced

Labor (per shift)	Present state (per shift)	Future state (per shift)	Improved or reduced labor at future state (per shift)	Improved or reduced labor at future state (per day)	Economic benefit at future state (per month)	Economic benefit at future state (per year)
Operator	32	31	1	2	2@12000Tk=24000	288000Tk.
Assistant operator	28	18	10	20	20@8000Tk=160000	1920000Tk.
Worker	124	62	62	124	124@5000Tk=620000	7440000Tk.
Total	184	111	73	146	804000Tk.	9648000Tk.

After the reduction of unwanted motion of labor from the observed different shoe production lines it was expected an economic benefit of 9,648,000 Tk. or 122132.07 USD (exchange rate 79 Tk. /1 USD) could be attained per year (Table 7.4.3).

It was reported that lean production management is the most frequently associated with elimination of seven wastes [105]. It was stated that the purpose of implementation was to increase productivity, reduce lead time and cost and improve quality [106, 107]. Quality of production management is a major focus in lean manufacturing because poor quality management should result in huge waste and scraps. The right quality management at right time will help to control the manufacturing process [108, 109]. It is mentioned that companies such as Toyota, Pratt and Whitney, Sikorsky, Delphi, Ford and many other companies have achieved large savings by implementation of lean principles in their manufacturing activities [110, 111]. It was reported that the companies that adopt lean manufacturing as a working philosophy within their organizations can make significant improvement in terms of their operational performance even if it is in a modified format that best suits their particular business culture [112, 113, 114]. The organizations intending to implement the lean tools should first understand the need to use that tools and its application, prepare for its adaption and then identify the ways and measures required for its successful implementation [115, 116]. It was stated that to implement lean thinking in any organization the first step is to identify the VSM. The VSM has been applied in variety of manufacturing industries. It was also described an application of VSM in order to identify the various forms of waste in shoe production floor [117, 118]. The work in process lines across the value stream should be performed with the minimum NVD activities in order to reduce waiting time, queue time, moving time, setup time and other delays [120, 121]. In this research, the author has successfully applied VSM. So, it could be expected as with other researchers lean tools and SS methodologies implementation will bring the promising outcomes with improved PCE, NVD time reduction, reduced lead time and after all desired economic benefit.

7.5 Policy for Footwear sector development

Industrialization is an essential pre-requisite for rapid and sustained economic development and social progress.

- The Government will pursue the creation of special economic zones (SEZs) in Bangladesh for both export and local market oriented footwear industries based on the cluster principle of collections of industries, brought together geographically for the purpose of promoting economic development.
- The Ministry of Industries and the National Productivity Organization (NPO) will develop in consultation with the footwear sector a programme for improving national productivity which will provide an institutional framework for managing productivity improvements, building awareness of productivity improvement in enterprises and human resource development.
- The Ministry of Industries and NPO will actively promote the adoption of ISO standards of certification particularly ISO 9000 family of standards for quality management.
- Necessary steps will be taken to provide women entrepreneurs with pre-investment advice and assistance in drawing up and implementing projects.
- Export-oriented footwear industries will be prioritized and all-out government assistance will be provided for their promotion in line with the provisions of the next Export Policy.
- Foreign direct investment will be encouraged in high-tech, innovative and first-of-its kind footwear industries that have potential for skill and technology transfer.
- One of the foremost objectives of the Industrial Policy 2016 is to improve competitive efficiency of Bangladeshi footwear industries by building technological capacity, which will be cost-effective and environment friendly.
- Environmental protection and preservation of aquatic and terrestrial resources are of utmost priority in a nation which has a rapidly rising population and very limited land resources.
- The government takes into cognizance that program of industrialisation, poverty reduction and economic growth requires a knowledge society driven by advanced knowledge, technology and manufacturing processes and practices.
- Implementation of industrial policy 2016 requires a combining effort of public and private sector organisations with proper plan of action for short, medium and to some extent long term.

- All public sector agencies will follow the Industrial Policy 2016. This policy will be implemented properly and monitored annually and necessary changes will be brought about consistent with the needs of economic development.
- Selection of technologies to be imported for footwear industries from foreign countries should be determined by a correlation between national needs and usable resources available in the country.
- Imported technologies need to be applied after adapting them in such a way that they fit local surroundings in footwear industries.
- Repair, imitation and improvements in introduced technology should be done by local trained manpower.
- Hired foreigners (not foreign experts associated with aid or assistance programs) can give effective training for manpower development.

7.5.1 Benefit of policy

- Modernization and structural transformation of the economy and diversification of the economic base
- Increasing returns and economies of scale, technological progress and productivity & competitiveness increase
- Accelerated economic growth and employment creation, reduction of poverty, hunger & unemployment
- Increase in incomes and standard of living of the people

CHAPTER 8
CONCLUSION AND RECOMMENDATION

8.1 Conclusion

- This study was incarnated as a case analysis of six shoe production lines of X footwear industry in order to improve the PCE by reducing NVD activities with the proper implementation of LSS model
- By this study, the observed shoe production lines were analyzed by the VSM, Pareto Analysis, PCE and Takt time
- With the proper implementation of LSS model, the PCE of the studied six shoe production lines have improved from 121% to 145%, the lead time have reduced by 54.04-57.44%, NVD time have reduced by 62.42-65.03% and total labor have reduced from 184 to 111
- Find out the statistical data analysis of X footwear industry and calculate different parameters
- Shown comparison of footwear industries various parameters in different countries e.g. China, Vietnam and Bangladesh
- Develop a strategic visionary plan for footwear sector
- Formulate a set of policies for footwear sector development
- Finally an economic benefit of 1.2 Billion USD will be gained per year
- Lean Six Sigma (LSS) model could never help a company to achieve the goals without the support of management
- For long term success, a company needs to establish a detailed LSS plan and incorporate this plan into the company's strategies
- After all, it was endeavored up to the best to draw the successful implementation strategy of LSS model within the studied shoe production lines of X footwear industry

8.2 Recommendations

Each and every task or success has to face some obstacles. Throughout this study it had to face a number of obstacles to draw the completion of this study which could also be considered as the limitation.

- Expected improved PCE is evaluated without changing the present layout of production lines. Because of the company's personnel were not flexible to permit in taking different required scale of measurement to draw an improved design in order to improve PCE due to their unexpected disruption or hamper in production.
- The required most of data were collected for three times and some of data were collected for five times, if these data were collected for further more times it would be more accurate.

- It was not possible to take data for the continuous time or entire shifting time of production rather than periodic data collection.
- The proposed tools and strategies should be introduced within the studied processing lines
- The tools of VSM, takt time, PCE should be immediately considered for implementation in the regarding production lines
- LSS model should be adopted within the company's management system
- Managerial body should be flexible to innovative thinking
- Beneficial teamwork should be practiced prior to proper implementation of LSS model within the regarding shoe production lines
- The required machines and equipment's should be arranged properly so that the speed of machines like cutting, sewing, lasting machine etc. could be controlled in balance way.
- To conduct project in different footwear industries as well as other manufacturing industries in order to reduce the Lead time, NVD activities, Manufacturing wastes and to improve the PCE by using Lean Tools & SS methodologies.
- To provide the consultancy services in footwear industries and other manufacturing sectors.

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