LEAN MANUFACTURING THROUGH VSM FOR ETHIOPIAN LEATHER INDUSTRY

Ph.D. THESIS

by

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STUDENT'S DECLARATION

I hereby certify that the work presented in the thesis entitled **"LEAN MANUFACTURING THROUGH VSM FOR ETHIOPIAN LEATHER INDUSTRY**" is my own work carried out during a period from July, 2018 to April, 2022 under the supervision of Dr. Akshay Dvivedi, Professor, Department of Mechanical and Industrial Engineering, Indian Institute of Technology Roorkee, Roorkee.

The matter presented in the thesis has not been submitted for the award of any other degree of this or any other Institute.

Dated: ____________ **(HILUF REDA)**

SUPERVISOR'S DECLARATION

This is to certify that the above mentioned work is carried out under my supervision.

Dated: ____________ **(AKSHAY DVIVEDI)**

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ABSTRACT

Globalization has created numerous problems for industries worldwide. Its influence has grown over the last few decades, affecting manufacturing industries' competitiveness and rendering them highly vulnerable. In such times any business's survival depends on its capability of competitiveness. For this reason, they require adopting modern management philosophies to improve their competitiveness.

Several researchers claimed that one of the comprehensive management philosophies for achieving competitiveness is the realization of lean manufacturing (LM). The Toyota Production System (TPS) is the foundation of LM. It is a philosophy that emphasizes eliminating production wastes to maximize customer value and increase productivity. Manufacturing industries strive to adopt lean concepts to maximize their resources like staff, facilities, materials, and schedules to be economically effective. To achieve the goal of LM, it uses various tools and techniques. Scholars mention value stream mapping (VSM), 5S, total productive maintenance (TPM), just in time, kaizen, total quality management (TQM), cellular manufacturing, etc. However, most previous scholars' focus was on manufacturing industries with well-developed manufacturing systems in developed nations. Integrating LM to not-well developed manufacturing systems in developing countries is not addressed. And also, managers face difficulty in selecting the appropriate lean tools out of the many available LM tools for successful lean implementation.

The research described in this thesis aims to examine and generate knowledge on how manufacturing industries integrate LM into their manufacturing systems for their competitive advantages. Accordingly, the purpose was to contribute to understanding how manufacturing industries use LM to enhance their competitiveness. This research focused on the leather products manufacturing industry (LPMI) of Ethiopia. It is struggling with low performance. One way to facilitate the sector's performance is by studying how much the organizations are using their resources effectively and efficiently. It helps organizations identify their critical resources, wastes that consume these resources and identify potential improvement areas. This, in turn, contributes to improving organizational performances and meeting the challenges of global competition.

To achieve the research objective, the research analysis was conducted in four phases. In phase I, the materials and information flow were studied to identify the wastes which consumes

the critical resources of the organizations. Mainly VSM was used as a tool, and parameters like cycle time, lead time, & takt time were used. As a result, waiting, transportation and inventory are identified as the top three most critical waste that consumes the organizations' resource without adding value. The finding revealed that reduction in cycle time& lead time were obtained, confirming its application in low-level technology organizations to improve their performance and productivity.

In phase II, a performance analysis of the organization was conducted. Mainly its focus was on the dynamics performance of the manufacturing assembly line. Data were gathered from the actual manufacturing assembly line using a stopwatch, observation, and interview. A discrete event simulation model is used to analyze precisely the manufacturing system's actual performance without disturbing the real system. Arena Simulation software were used for the analysis. And different alternative solutions have been experimented. The finding revealed that the combination of all options is the best alternative solution that improves output and line balance efficiency.

In phase III, an integrated approach was applied in a multi-criteria decision-making process, i.e., selecting suitable lean tools to maximize the critical resources in a manufacturing organization. VSM and plant layout were used to identify the wastes. A systematic fuzzy QFD procedure was used to establish the priority of technical solutions to improve critical resources. Fuzzy process FMEA is used to select suitable lean tools for critical resources' prioritized lean failure modes. To illustrate its application, the model was demonstrated with data obtained from the manufacturing organization. The findings revealed that improvement of total cycle time, lead-time, materials transportation distance & transportation activities and manpower productivity were quantified.

In phase IV, the relationship between QM practices and OP of manufacturing organizations were studied. A set of QM practices were taken into consideration that defines the characteristics of QM. These practices are the commitment of top management (TMC), continuous improvement (CI), employees' participation (EP), teamwork (TW), and customer focus (CF). Data was gathered from the shop floor workers using a structured survey questionnaire and face-to-face interviews. Exploratory and confirmatory factor analysis was used to validate the survey instrument. Then, to test the proposed structural model, a structural equation modeling method was used, which shows the link between QM practices and OP. The findings revealed that TMC, EP, and CI have the strongest impact on OP. While CF and TW were found to have an insignificant effect on OP.

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ACRONYMS/ABBREVIATIONS

ACRONYMS/ABBREVIATIONS	DESCRIPTION
LM	Lean Manufacturing
TPS	Toyota Production System
TPM	Total Productive Maintenance
LPMI	Leather Products Manufacturing Industry
UNIDO	United Nations Industrial Development Organization
FAO	Food and Agriculture Organization
UNCTAD	United Nations Conference on Trade and Development
MOI	Ministry of Industry
GTP	Growth and Transformation Plan
GDP	Gross Domestic Product
AGP-LMD	Agricultural Growth Project- Livestock Market Development
FDRE	Federal Democratic Republic of Ethiopia
VSM	Value Stream Mapping
SM	Simulation modeling
VA	Value Adding
NVA	Non-Value Adding
WIP	Work in progress
TQM	Total Quality Management
JIT	Just-in-Time
QFD	Quality Function Deployment
CSM	Current State Map
FSM	Future State Map
QM	Quality Management
FMEA	Failure Mode Effect Analysis
FFMEA	Fuzzy Failure Mode Effect Analysis
SPC	Statistical Process Control
FQFD	Fuzzy quality function deployment
OP	Operational Performance

RQ	Research Question
CSVSM	Current State Value Stream Mapping
FSVSM	Future State Value Stream Mapping
ALBP	Assembly Line Balancing Problem
FIFO	First in First Out
VOC	Voice of the Customer
TFN	Triangular fuzzy Number
FMEA	Failure Mode & Effect Analysis
RPN	Risk Priority Number
FRPN	Fuzzy Risk Priority Number
RI	Relative Importance
FWGM	Fuzzy weighted Geometric Mean
LP	Linear Programming
HOQ	House of Quality
QM	Quality management
OP	Operational Performance
LIDI	Leather Industry Development Institute
SEM	Structural Equation Modeling
EFA	Exploratory Factor Analysis
CFA	Confirmatory Factor Analysis
CDA	Centroid Defuzzification Approach
MCDM	Multi-Criteria Decision Making
DES	Discrete-Event Simulation
AL	Assembly Line

CHAPTER 1

INTRODUCTION

1.0 Preamble

Globalization has created numerous problems for industries worldwide (Jastia & Kodali, 2015). Its influence has grown over the last few decades, affecting manufacturing industries' competitiveness and rendering them highly vulnerable (Jain & Garg, 2007). In such times any business's survival depends on its capability of competitiveness (Jilcha & Kitaw, 2015).

Manufacturing industries are primarily confronted with two types of issues. This is due to the emerging advanced manufacturing philosophies, which make the existing methods obsolete & the nature of customer thinking has shifted. Customers are increasingly seeking innovative products and services provided at low cost and within a short time (Ho et al., 2005; Lau, Jiang, Chan, & Ip, 2002). Increased productivity is required to raise people's living standards and maintain competitiveness (Altenburg, 2010). Notably, low- and middle-income countries need to emphasize productivity growth to contribute to economic development. Indeed, the shift from low-productivity to higher-productive societies is a contentious issue, particularly in developing countries (Altenburg, 2010). Concerning Ethiopia, the government has demonstrated a remarkable commitment to laying the groundwork for a socially comprehensive industrial transformation. After that, several concrete institutional reforms were made. These includes the development of new specialized capacity-building and technological institutes for sub-sectors, as well as the strengthening of existing ones. For example, sugar industry, leather & leather products, textile and apparel etc.). According to Scott (2006), one of the essential characteristics of the modern economy is the emergence of low-technology labor-intensive businesses as a source of growth and development in both low and middle-income countries. Agro-processing industries (e.g., leather tanning, edible oil production, sugar, grain milling) and basic consumer goods producers (e.g. footwear, textiles, and garments) are particularly important industries (Addis, 2018).This is because of their proclivity to reduce the high levels of unemployment in developing countries caused by the fast-growing population. The leather industry is regarded as the world's largest industrial sector. Leather is an intermediate industrial product with a wide range of downstream applications. It may be cut and assembled to make shoes, clothing, leather goods, furniture, and various other daily use items (Joseph & Nithya, 2009). Leather is one of the world's most commonly traded commodities. With an estimated global trade value of around US$100 billion each year, it plays a significant role in the global economy (Alubel Abtew, 2015; UNIDO, 2010). It is compared very well with any internationally traded commodity. According to the report of the Food and Agriculture Organization (FAO) (FAO, 2016), When compared to other commodities, this value chain's trade exceeds the combined trade of tea, cotton, rubber, rice, coffee, sugar and meat (see Figure 1.1). And according to UNCTAD (2018), the total value of annual trade is estimated at more than eight times that of rice, more than five times that of coffee, and 1.5 times that of the meat trade.

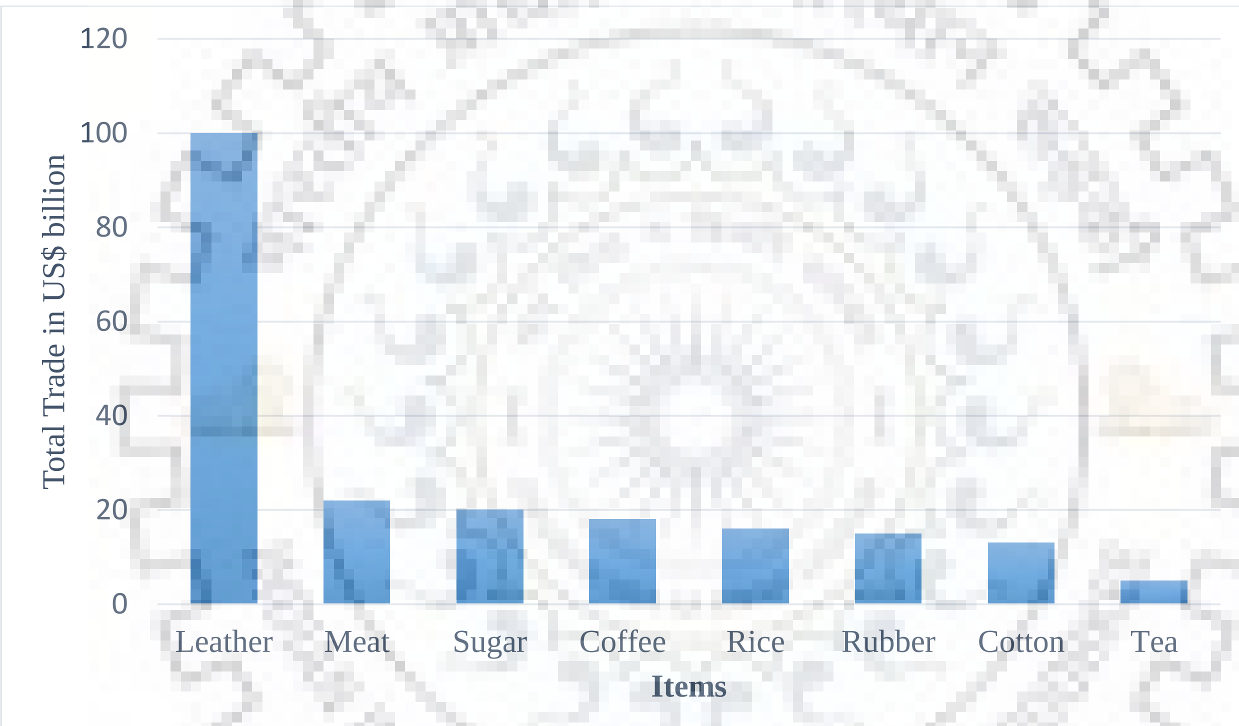

Figure 1.1 Global importance of the leather value chain (source: (MOI, 2016).

1.1 Global Review of Leather Industry

Tanning is one of the world's oldest industries, and leather has been used since prehistoric times. The tannery process involves transforming raw skin into leather. The leather industry is a global manufacturing sector that produces raw, processed and finished materials for the production of leather goods. Leather is used to make a wide range of products, including footwear, leather clothing, general goods, etc. According to FAO, the top five leather producing countries in the world in 2013 are China (4 billion sq. feet), Brazil (1.7 billion sq. feet), Italy (1.5 billion sq. feet), Russia (1.4 billion sq. feet), and India (1.4 billion sq. feet) (FAO, 2015). Developing countries produce 78.3 % of all hides and skins in the global market, with Africa accounting for only 11 % (AGP-LMD, 2013). The total global export of leather is expected to be worth US$17 billion per year. Developed countries account for 51.2 % of overall leather exports, with Europe accounting for 40 %. Developing countries account for 48.8 % of overall leather exports, whereas Africa accounts for only 1.9 percent of total export value (Addis, 2018). Global performance in the sector indicates that the entire revenue from the sale of leather products is expected to be $100 billion per year, with Africa earning only $4 billion (Mwinyihija & Quisenberry, 2013). The global trade value and export share from the leather trade in 2015 are presented in Table 1.1. The world's top three exporters of leather and leather products which accounted for nearly 55% of global exports are China, Italy, and Hong Kong, China. China, the world's largest exporter, exported 37.35 % to the world. Then followed by Italy 10.47 %, Hong Kong (China) 6.87%, Viet Nam 4.87%, France 4.76%, Germany 3.80%, Belgium 3.30%, India 2.32%, Spain 2.28%, Netherlands 2.20%, Ethiopia 0.01% (UNCTAD, 2018). China is the largest importer of raw hides and skins, which it then converts into leather and leather products and exports it. As a result, China is the leading player in the leather industry. According to UNIDO (2010), despite having 21% of the world's livestock population, Africa's contribution of the global leather trade has remained low throughout the last twenty-five years of the 21th century. Ethiopia is 1st Africa's and 10th world's livestock producer (UNCTAD, 2018). Though Ethiopia is one of the leading leather processing countries in Africa, the export share in the world is negligible. The export share of Ethiopia was, on average, only 0.00023% over 2001-2003 (Bekele & Ayele, 2008), 0.000597% in 2010 (Ashebre, 2014), and 0.01% in 2015 (UNCTAD, 2018). Hence, the production of leather footwear contributes significantly to the growth of both emerging and industrialized nations (Ulutas & Islier, 2015). In the world, leather footwear export accounts for around $47 billion. China is the largest footwear exporter, accounting for 22% of the total market, followed by Italy, which accounts for 15% of the value—and followed by footwear export shares of Vietnam (8%), Hong Kong (7.8%), Germany (4.4%), and Belgium (3.9%). But, the share of Africa's footwear export is only 1.3% (Addis, 2018). According to data from the last ten years, the entire Sub-Saharan Africa (SSA) region's footwear export revenues have remained one tenth or less than those of China, India, or even Vietnam. As a result, SSA and Ethiopia still have a long way to go to catch up to their Asian benchmark in terms of global market share for footwear products (Assefa & Gebreeyesus, 2018).

In general, despite the availability of a huge amount of raw material resources, exploiting global market prospects has remained a major concern. The performance gaps indicated above show that the leather sector has a lot of potential for growth. For the development of Africa's leather-processing countries, reducing the gap between the available resources and production is particularly important. Ethiopia's leather industry is at the forefront of the African leather sector, owing to its current competitive advantage in terms of raw material requirements. It is ranked at first place in Africa and tenth in the world in livestock population (UNIDO, 2010). Based on its large promising resource comparative advantages, Ethiopia's leather sector is a suitable contender to boost production and achieve global competitiveness.

Table 1.1 Global exporter of leather products average share, 2006–2015 (UNCTAD, 2018).

Exporters	Average share (%)	Average export (thousands of $)
World	100.00	165, 095, 251
China	37.35	61, 665, 280
Italy	10.47	17, 280, 204
Hong Kong (China)	6.87	11, 349, 733
Viet Nam	4.87	8, 042, 795
France	4.76	7, 858, 938
Germany	3.80	6, 267, 013
Belgium	3.30	5, 450, 820
India	2.32	3, 831, 242
Spain	2.28	3, 763, 236
Netherlands	2.20	3, 632, 688
Ethiopia	***0.01***	***17, 909***

1.2 Ethiopian Leather Industry

Ethiopia is one of the oldest countries in the world, with more than 3,000 years of recorded History (Beshah, 2011). Ethiopia's population is around 100 million, making it Sub-Saharan Africa's second most populated country after Nigeria (MOI, 2016). Ethiopia's economy is mainly based on agriculture, which accounts for 41.5% of the country's GDP (Altenburg, 2010). Even by the standards of many least developed countries, Ethiopia's manufacturing sector has been characterized by a low-level of development (Cherkos, 2011). Over the last 20 years, its current share of GDP remained stagnated at 5% (Altenburg, 2010). Currently, the government of Ethiopian has shown remarkable commitment in laying the groundwork for a market-driven, socially inclusive industrial revolution (Altenburg, 2010). The plan focuses on labor-intensive and export-oriented manufacturing sectors that use agricultural products as input. Policymakers acknowledge this method, as seen by second Ethiopia's Growth and Transformation Plan (GTP II) for the period (2015/16-2019/20) (FDRE, 2016). Manufacturing employment are expected to grow by 15% yearly on average as a result of the significant emphasis placed on the expansion of the manufacturing industry. Over the next ten years, it is planned to raising the total number of job opportunities created by the sector to 1.5 million (FDRE, 2016).

Ethiopia's Industrial Development Strategic Plan 2013-2025 aims to build an industrial sector with Africa's highest manufacturing capabilities that is globally competitive. The Vision of Ethiopia Industrial Development Strategic Plan of 2013-2025 is to build an industrial sector with the highest manufacturing capability in Africa which is globally competitive. To attain this goal, rapid industrial development is required (MOI, 2016). The Leather & Leather Products sector is one of the strategic industrial sectors included in this plan (MOI, 2013). To eradicate poverty, rapid and broad-based growth has to be sustained mainly by accelerating the agriculture and manufacturing sectors (FDRE, 2016). The government is now implementing the second phase of the GTP-II, which intends to transform the country into a manufacturing hub by 2025, to help boost the manufacturing industry (UNCTAD, 2018).

According to the GTP, the leather industry is one of the priority sectors capable of driving economic development by generating revenue, providing investment opportunities, and creating more jobs (MOI, 2016). Ethiopia’s comparative advantage for the growth of the leather sector is availability of a vast amount of livestock population. Ethiopia boasts the largest livestock production in Africa and the 10th largest in the world (UNCTAD, 2018). Ethiopia has over 90 years of experience in processing leather and leather products. It is well known in livestock population which is one of the largest world’s livestock population of which 57,829,953 cattle, 28,892,380 sheep and 29,704,958 goats (LIDI, 2019). Ethiopia's leather sector has plenty of opportunities to grow because of its massive livestock population. And this qualifies the leather industry as a good option for a concerted effort to increase production and achieve global competitiveness. Also, the availability of numerous labor forces in the country provides an opportunity to develop the Ethiopian leather industry. Accordingly, the importance of developing this industry is not only its economic impact, but also it reduces unemployment rate. It has many promises for poverty reduction because of its strong backward links to rural economy. So far, it has created around 10,000 jobs in the formal industry (Altenburg, 2010). Hence, by utilizing Ethiopia's cheap labor costs, manufacturing footwear is a promising option for enhancing the leather industry's value-added.

To summarize, the leather industry in Ethiopian is identified as one of the potential sectors. By raising the country's foreign currency earnings, expanding employment possibilities, and attracting foreign direct investments, it might play a critical role in accomplishing long-term policy objectives. It also plays a great role in moving the country's development status to a higher level.

Despite the aforementioned availability of indigenous resource potentials, Ethiopia's leather industry is yet to utilize them to an appreciable extent. In terms of accelerating the country's economic development, its resource potential remains very limited (UNCTAD, 2018). Even it significantly lags behind many less abundantly endowed countries (Addis, 2018). Both in the raw materials' production and during the manufacturing phases, the industry is plagued by major issues. Previous studies show that the leather industry is operating below its capacity. For example, in 2009/10, the tanning and dressing of leather, luggage, and handbag sectors were operating at 56% of capacity, and the capacity utilization for shoe firms was 48% (UNIDO, 2013).

In contrast, the daily installed capacity of leather goods and garment producers ranges from 20-150 pieces/day. But the actual output ranges from 10-60 pieces of garment/day (Gebeyehu, 2014). The export performance of the industry is also stagnated below average. From 2014 to 2018, the average performance of footwear producers was only 35.9% of the anticipated export value. (see Table 1.2). Similarly, the tannery's export value was quite below the projected plan for the same period. In 2017/18, the footwear industry employed 11,145 people and produced approximately 5 million pairs of leather shoes. The capacity utilization rate is only around 47% (Grumiller & Raza, 2019). In general, the Ethiopian leather sector remains uncompetitive (Beshah, 2011). It demonstrates that a country's wealth does not only depend on its available resources. Unless otherwise, it is utilized effectively and efficiently.

Furthermore, the industry's actual average output falls significantly below the global standard benchmarks. For example, in 2009, footwear manufacturers produced four pairs of shoes per day per person. This indicates low operational performance and manufacturing efficiency when compared to best standards (i.e. 16 pairs of shoe/day/person) (Cherkos, 2011). Hence, the country's massive resource potential unable to provide the intended economic returns. In recent years, the loss to Ethiopia's economy has been estimated at $14 million per year (Gebeyehu, 2014).

Table 1.2 Export performance of footwear manufacturers in Ethiopia (‘000’ USD) (LIDI, 2019)

Years	Shoe factories total	
	Plan	Actual
2014	95,698.1	30,543.73
2015	11,5476.2	34,577.57
2016	67,994.56	34,917.51
2017	115,419.2	38,566.53
2018	128,091.5	49,039.05
Average 5 years	104,535.9047	37,528.87923
%	35.9	

Source: LIDI, 2019

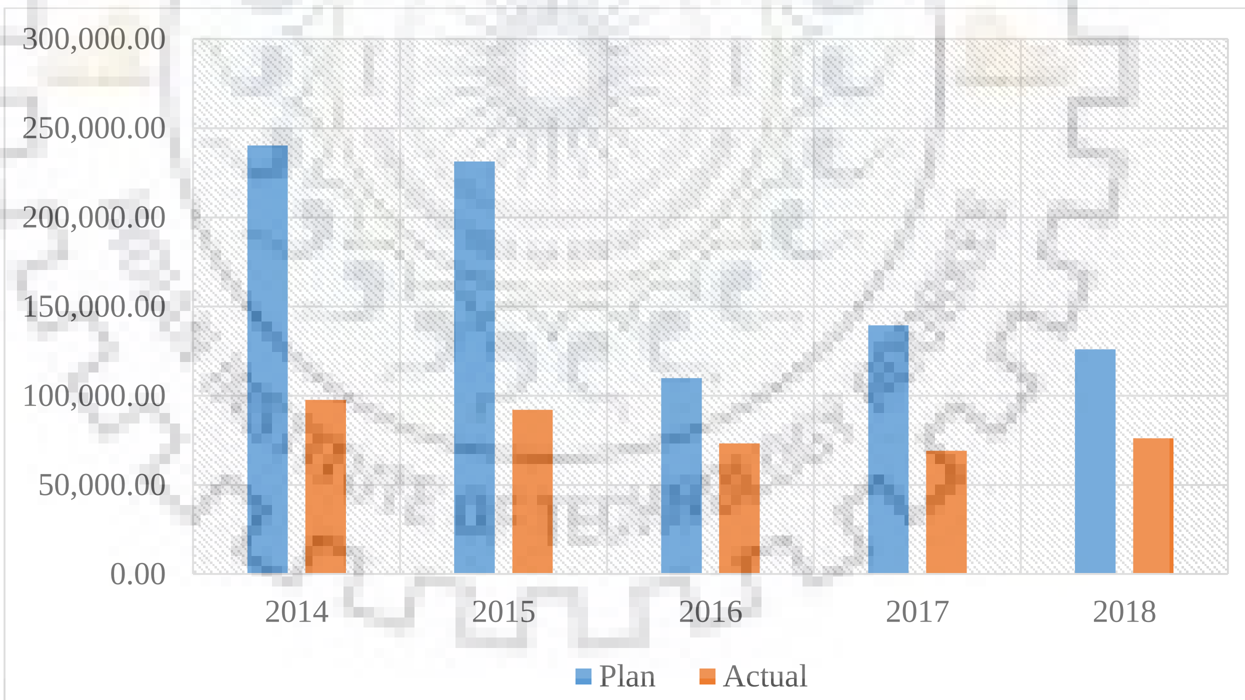

Figure 1.2 Export performance of the leather industry of Ethiopia (000’ USD) (2014-2018)

Source: Export performance report from LIDI in 2019

Previous researches have demonstrated that the nature of problems, for the industry's underperformance, are multifaceted. Some of the problems are low capacity utilization, less productivity, long lead times, less quality products, low competitiveness, low labor productivity, shortage of raw materials (e.g. processed leather for footwear manufacturers), production delays, the bottleneck at workstations, lack of an efficient market structure, financial constraints, lack of latest technologies and lack of human resource management…etc. (Bekele & Ayele, 2008; UNCTAD, 2018; MOI, 2016; Solomon, Jilcha, & Berhan, 2015; Addis, 2018). Ethiopia needs to address the various challenges in the leather industry's value chain to exploit its available potential resources fully. It's critical to address restrictions downstream to the manufacturing phase. Because high level of production activity allows firms to attain higher levels of operational performance and meet the challenge of global competition (Filketu, Dvivedi, & Beshah, 2017). Manufacturing industries, in general, are in need of adopting & practicing modern management philosophy to increase their productivity, reduce waste and enhance their global competitiveness (Reda & Dvivedi, 2021). One way to increase the productivity and performance of manufacturing industries is by fighting against the hidden enemy of the manufacturing industries, i.e., waste. Several researchers claimed that one of the comprehensive management philosophies for achieving competitiveness is the realization of lean manufacturing (LM) (Chauhan & Singh, 2012). Value stream mapping (VSM) is one of the LM techniques used for identifying and reducing waste, which improves the organizations' performance and productivity, leading to enhance competitiveness (Andrade, Pereira, & Del Conte, 2016).

1.3 The Present Research

LM is one of the modern management philosophies that help manufacturing industries enhance their productivity by reducing waste. The concepts of LM can make it possible to use their resources effectively and increase their competitiveness. Wastes are the hidden enemies of the manufacturing industries. Most of the manufacturing industries are struggling with excess lead times, excess inventory, as well as defects in the final product (Jastia & Kodali, 2015), which are some of the wastes. LM is one of the weapons to fight against these wastes. To achieve the goal of lean, LM uses various tools and techniques. VSM is one of the important LM elements to achieve excellence in manufacturing activities (Jastia & Kodali, 2015). It is a powerful tool that helps in visualization, understanding, and documentation of the materials and information flow through the value chain. This enables the easy identification of wastes and their levels. It includes all the VA and NVA activities. It allows systematic waste identification in a series of production processes and detects improvement potentials (Lacerda, Xambre, & Alvelos, 2016). As LM is a continuous improvement approach, all lean concepts couldn't be implemented once. Previous research does not investigate the way to approach the successful LM concept implementation at the operational level, especially for manufacturing industries with a lack of resources and undeveloped manufacturing systems.

The purpose of the research reported in this thesis is to examine how the lean concept can be used to improve manufacturing industries' operational performance and competitiveness. Also, look at what aspects of quality management have an impact on operational performance. Hence, it also aims to contribute empirical evidence in the understanding of decision making on the selection of lean tools and the relationship between operational performance & quality management practices. Therefore, the problem for the present research work has been defined as follows: "**Lean Manufacturing through VSM for Ethiopian Leather Industry**."

1.4 Organization of the Thesis

This study comprises the following seven chapters:

Chapter 1: Introduction

This chapter describes the background of the research. It gives a broad overview of the global leather industry, with a specific focus on Ethiopia's leather industry. The motivation of the study is also covered in this chapter.

Chapter 2: Literature Review and Problem Formulation

This chapter provides an understanding of the study topic as well as a theoretical foundation for the thesis. Theory on lean manufacturing concepts and VSM are provided. And also, theories on quality management and Operational performance are provided. Their relationships are reviewed and discussed. This chapter also discusses how the problem was defined and the methodological choices taken during the research process. An overall research algorithm is also depicted, which provides a general perspective of the research process.

Chapter 3: Application of value stream mapping (VSM) in low-level technology organizations (Phase I)

This chapter presents the application of VSM in low-level technology organizations of Ethiopian leather industry in order to reduce the cycle and lead times using time study and line balancing.

Chapter 4: Performance analysis of the footwear manufacturing assembly line using value stream mapping-simulation modeling (VSM-SM) (Phase II)

In this chapter, the integration of VSM with discrete event simulation modeling is presented. Proposed alternative solutions are identified and experimented with using Arena simulation software in the footwear manufacturing industry to analyze the current performance and identify 'what-if' alternative improvement options.

Chapter 5: Decision-making on the selection of lean tools using fuzzy QFD and FMEA approach in the manufacturing industry (Phase III)

This chapter presents the approaches to how practitioners can make decision on selection of appropriate lean tools from the many LM tools available for successful implementation of lean. It provides knowledge on how different tools are integrated to achieve one successful objective. It used the integrated approach of VSM, plant layout, fuzzy QFD, and FMEA.

Chapter 6: The impact of quality management practices on the operational performance of low-level technology organizations: the case of Ethiopia (Phase IV)

This chapter presents the transferability of quality management (QM) practices by validating the direct relations between quality management practices and operational performance using structural equation modeling technique. This chapter contributes to understanding the mechanics of the link between QM and operational performance by demonstrating how one is constituted inside the corpus of the other.

Chapter 7: Conclusions and Scope for Future Work

In this chapter, the research findings are described in relation to the research questions, followed by contribution & scope for future research.

CHAPTER 2

LITERATURE REVIEW AND PROBLEM FORMULATION

2.0 Overview

In today's globally competitive market, organizations must adopt modern management philosophies improve performance and productivity. Lean manufacturing is one of the modern and comprehensive management philosophies for achieving manufacturing industries' competitiveness. This chapter aims to lay down relevant theoretical framework to the research presented in this thesis and review related literature in the area. The theoretical explanations of LM, VSM, and quality management & operational performance are briefly described in this part. Section 2.1 presents an explanation about the concept of LM. Section 2.2 presents detail descriptions about LM tools and techniques by means of definitions and practices. Section 2.3 presents the concept of quality management in terms of definitions, theories and consequences on organizational operational performance outcomes. Section 2.4 provides discussions about operational performance in terms of definition and its key measures. Section 2.5 presents the relationships of quality management and operational performance, followed by lean practice in Ethiopia in Section 2.6. In Section 2.7, research gaps and opportunities are presented. Section 2.8 describes the problem formulation and scope for the research work. Section 2.9 presents the methodological choices made along the research journey. Finally, section 2.10 presents a summary of the chapter.

2.1 Lean Manufacturing - clarification of the basic concept

Increasing competition in today's global marketplace has driven many manufacturing companies to implement innovative manufacturing management practices in order to improve their efficiency and competitiveness. Customer satisfaction is the key to achieving global competitiveness through higher quality, lower costs, shorter delivery lead times, and effective communication. Getting the right product, at the right time to the consumer is not only essential for competitive success, but also the key to survival (Shankar, Agarwal, & Tiwari, 2006). The goal of choosing an appropriate manufacturing system is to use the available resources optimally in order to produce high-quality products that enhances customer satisfaction (Upadhye, Deshmukh, & Garg, 2010). Manufacturing companies have embraced the LM system as a valuable management tool. And many of them have implemented lean concepts in various forms and names (Nordin, Deros, & Wahab, 2010). Its goal is to attain a smooth production flow through waste reduction and improving the value of activities. However, becoming lean is not as simple as it seems. Personnel commitment, strong leadership, careful planning, and enough knowledge of LM philosophy, tools & practices are all required (Pavnaskar, Gershenson, & Jambekar, 2003).

2.1.1 Introduction

According to the history of the industrial revolution, process-oriented and mass production methods were popular before World War II. They were eventually replaced by production systems i.e. result-oriented & output-focused. Now it controls the majority of manufacturing organizations (Goshime, Kitaw, & Jilcha, 2018). Indeed, industrial development plays an essential part in emerging economies' economic growth. Developing nations were anticipated to take the lead in transforming their economies to an industrial basis to reduce poverty (UNIDO, 2016). Decades ago, the groundwork for a comprehensive strategy that transcends the constraints of production, organization, and management around the world was laid. It all began with Toyota Motor Company's Taiichi Ohno's invention of the Toyota Production System (TPS) in 1950s (Ohno, 1988). Contrary to Henry Ford's mass production, TPS laid great emphasis on product quality and variety (Lacerda et al., 2016).

However, Wommack, Jones, and Roos established and explained LM's modern framework, which has been broadly implemented by many industries over the past decades, in the pioneering book "*The machine that changed the world*" (Womack, Jones, & Roos, 1990). The TPS principles are the foundation of LM. LM philosophy focuses on increasing customer values by identifying and eliminating production waste (Lacerda et al., 2016; Womack & Jones, 2003). A value-adding (VA) activity is defined by the customer, and it is one for which the customer is willing to pay for it (R. Kumar & Kumar, 2016; Goshime et al., 2018). Operations like inspection, sorting, warehousing, handling, etc., demand additional time, handling, and workforce, yet they add no value to the product (Sudarshan & Rao, 2013).

LM continually identifies and eliminates the waste from the system. Anything else than the bare minimum of materials, equipment, parts, and employees required for production is considered waste (Pavnaskar et al., 2003). Similarly, waste is any activity that doesn't add value to a product but consumes resources (Singh and Sharma, 2011). It makes the product more expensive by consuming both time and resources (Jilcha & Kitaw, 2015; Lacerda et al., 2016; Womack and Jones, 2003).

Scholars have pointed out that for the majority of production operations (Melton, 2005; Ohno, 1988; Womack & Jones, 2003; Gupta & Jain, 2013) the activities about:

• 5 % add value;
• 35 % necessary non-value; and
• 60 % add no value at all.

The following are the core principles of lean:

1) specifying value using product family from customer's perspective
2) breaking each phase into value-adding steps
3) maximizing the flow of product to customers and reducing waste
4) attempting to produce at a customer's pull rate
5) repeating the process in a continuous improvement cycle. In short, they are value, value stream, flow, pull, and perfection (Lacerda et al., 2016; Womack & Jones, 2003; Goshime et al., 2018).

In order to eliminate waste & reduce lead time, the time between customer order & delivery of products should be investigated (Ohno,1988). The original seven common wastes in an industrial environment that were initially identified by Ohno (1988), in which many researchers also reported are abbreviated as TIM-WOOD. These are motion, inventory, transportation, over-processing, waiting time, defects, overproduction (Liker, 2004; Okpala, 2012; Lacerda et al., 2016; Womack and Daniel, 2003; Goshime et al., 2018; Langstrand, 2016; Behnam et al., 2018). They are briefly described as follows:

- Transportation - Movement of products and materials within a plant necessitates the use of transportation systems, which can be costly, require maintenance, extend lead times, and even damage parts.
- Inventory – inventory surpluses are typically caused by production bottlenecks, lengthy changeovers, or imbalanced processes. As a result, more handling procedures and greater inventory storage rooms are required.
- Motion - worker movement which does not add value to the product is referred to as motion. This is frequently linked to the placement of tools and components within the station and ergonomic factors that require more effort from the workers than they should.

- Waiting - the amount of time spent waiting for people, goods, or equipment. It might happen as a result of flow obstacles, station layout issues, component delivery delays, or a lack of balanced manufacturing procedures.
- Over-processing - Any activity or process that does not bring value to the organization is regarded as a waste of resources. It might potentially increase the number of product defects.
- Overproduction - refers to the production of more things than the customer requires. As a result, resources are expended without generating a profit, stock and warehouse space requirements rise, and less flexibility in production planning occurs.
- Defects – are quality issues that can result in customer complaints or be recognized earlier by inspection or maintenance teams. These issues are usually caused by a lack of standard procedures & quality control systems, as well as human error, and they have a detrimental influence on production costs and productivity.

A new type of waste, i.e. talent, has just been identified as important (Like & Meier, 2006).

• Talent - Wasting human potential can lead to missed possibilities for improvements, especially as lean philosophy supports that everyone is a thinker who can contribute to beneficial outcomes.

Many successes concerning the successful implementation of LM methods in the automotive industry promote the adoption of the philosophy and its use in firms from different sectors and industries. To mention some of them: in healthcare organizations (Halwachs-Baumann, 2010; Simon & Canacari, 2012; Teichgräber & De Bucourt, 2012), public sector (Bateman, Hines, & Davidson, 2014), hotel industry (Vlachos & Bogdanovic, 2013), forest products industry (Lyon, Quesada-Pineda, & Crawford, 2014), military organizations (Kasava et al., 2015), and information technology firm (Staats et al., 2011). Naylor et al. (1999) introduced the idea of leagility by merging the lean and agile production paradigms in the complete supply chain of PC manufacturers. Shah and Ward (2003) empirically investigated the effects of plant size on lean implementation. The impacts of plant size on the implementation of lean were studied empirically by Shah & Ward, 2003. Abdulmalek & Rajgopal (2007) conducted a case study in which VSM and other lean principles were implemented. They used a simulation technique to demonstrate the benefits of lean manufacturing and VSM in a process industry. For the selection of manufacturing automation technologies, Almannai et al. (2008) provided a decision support system model based on QFD and FMEA. However, none of them addresses the concept of LM and how to integrate LM to the existing manufacturing system in developing country's low-level technology organizations like Ethiopia with lack of resources. The details of each of the tools used in this thesis are presented in their respective chapters of this thesis.

2.1.2 Definition of lean manufacturing- What is lean manufacturing?

LM definitions have been investigated and commented on by a number of researchers and practitioners around the world. There is currently no consensus among the authors on the definition of LM (Pettersen, 2004). LM is a universally accepted philosophy that one can implement and practice in any industry to a certain extent (Shah & Ward, 2003). In short, it can be characterized as "doing more with less" (Deif & Elmaraghy, 2014). Its main objective is enhancing the operational performance of the organizations, i.e., high quality, less cost, and less time delivery by eliminating waste (Gupta & Jain, 2013). It's a never-ending process aimed at reducing waste and improving procedures by reducing lot sizes, queue lengths, and setup times (Chen, Cheng, & Huang, 2013). Many researchers have defined lean in various ways. Table 2.1 shows some of the scholars who defined LM from their respective scientific perspectives.

Table 2.1 Definition of LM

Scholars	Definition of LM
Krafick (1988)	In comparison of mass production, LM uses less of everything to produce the required output – less in space, human effort, investment in tools, to develop a new product.
Womack et al. (1990)	A dynamic transformation process guided by a set of principles and best practices that aim for continuous improvement.
Shah & Ward (2007)	A management philosophy that focuses on waste identification and elimination throughout a product's entire value stream, both within the organization and along its entire supply chain network (*The author selected this definition for this study*)
Naylor, Naim, & Berry (1999)	Leanness entails creating a value stream that eliminates all waste, including time, and ensuring level schedule
Howell (1999)	A new way of designing and making things that differ from mass and craft production forms to optimize production system performance
Taj & Morosan, (2011)	A multidimensional approach that consists of Cellular Layout (continuous flow), JIT (minimum amount of waste), TQM (established quality system), TPM (maintained equipment), and HRM (empowered and trained labor force) that has a positive impact on operations/competitive performance
Liker (2004)	A philosophy that, when put into practice, reduces the time taken from customer order to delivery by eliminating the sources for waste in the manufacturing process

Alukal (2003)	A philosophy that reduces the lead time between customer order and products delivery. It helps the organizations in reducing cycle time, non-value-added activities, and cost, which results in a more competitive firm.
Holweg (2007)	Extends the scope of the philosophy of Toyota Production to product development process, supplier management process, customer management process and policy focusing process.
Simpson & Power, (2005)	A practice for creating an efficient and well-organized system that is committed to continual improvement and waste elimination.
Cooper (1996) and Shah & Ward (2007)	A system built to compete on the idea that long-term product advantage is rare; hence, it is met head-on rather than avoiding it.
Hopp & Spearman (2004)	A system which is integrated to accomplish the production of goods/services with minimal buffering costs
Hallgren & Olhager (2009)	A program that focuses on improving operational efficiency
Rothstein (2004)	A manufacturing paradigm containing various lean practices (tools)
Seth & Gupta (2005)	A manufacturing paradigm centered on the core goal of continuously reducing waste while increasing the flow
Alves, Dinis-Carvalho, & Sousa (2012)	A model in which people take on the role of thinkers and are actively involved in the process encourages continuous improvement and gives businesses the flexibility they need to meet today's and tomorrow's market needs
Papadopoulou & Özbayrak (2005)	A manufacturing philosophy that, if adopted and correctly followed, may surely lead to global manufacturing excellence.
Slack, Brandon-Jones, & Johnston (2013)	Lean is a set of tools that improve operations performance

It is evident from the preceding definitions that lean may be a process (Womack et al., 1990), a concept (Naylor et al., 1999), a set of tools and techniques (Bicheno, 2004), a way (Howell, 1999), a philosophy (Liker, 2004), a set of principles (Womack et al., 1990), an approach (Holweg, 2007; Taj & Morosan, 2011; Alukal, 2003; Shah & Ward, 2007), a practice (Simpson & Power, 2005), a system (Shah & Ward, 2007; Hopp & Spearman, 2004; Cooper, 1996), a manufacturing paradigm (Seth & Gupta, 2005; Rothstein, 2004), a program (Hallgren & Olhager, 2009) or a model (Alves et al., 2012). For this research, the author selected the definition of LM given by (Shah & Ward, 2007), i.e., “an integrated socio-technical system which aims to eliminate waste by simultaneously reducing supplier, manufacturer, and customer variability..”

2.1.3 Benefits of lean manufacturing

The benefits of LM are evident in organizations all around the world. Firms report enhanced productivity, cycle time reduction, reduced costs, better utilization of machinery, reduction in inventories, improved product quality, improved space utilization, reduced lead time, eliminating bottlenecks, reduced WIP, increased flexibility, improved utilization of labor, better skills enhancement, improved net income, quicker return on inventory investment, and reduction in tool investment (Pavnaskar et al., 2003; Goshime et al., 2018). The benefits that can be gained from LM implementation can be divided into two categories: qualitative (improvement in job satisfaction, employee morale, standardized housekeeping, teamwork, and effective communication) and quantitative (enhancement in processing time, setup time, lead time, cycle time, inventory and defects), etc. (Bhamu & Sangwan, 2014). Overall, a related research study shows that implementing lean principles is typically linked to improved operational performance metrics. Improvements in worker efficiency and quality and reductions in customer cycle & lead times and production costs are the most typically mentioned benefits associated with lean approaches (Shah & Ward, 2003).

The benefits of LM reported in the research papers are summarized as follows:

Reduction in: defects, reduction, cycle time, set-up time, lead time, in floor space and improvement in: productivity, return on assets, labor utilization, facility utilization, machine availability, quality, & increase in employee morale (Pavnaskar et al., 2003; Upadhye et al., 2010)

2.1.4 Barriers to lean implementation

Implementation of LM is not an easy task. It needs a compressive understanding of the various tools and techniques. Despite the fact that LM implementation can yield significant benefits, many businesses fail to adopt lean practices (Papadopoulou & Özbayrak, 2005; Ballé, 2005). As a philosophy, LM cannot be practiced immediately. It will take some time for employees to grasp its concepts in the firm (Goshime et al., 2018). Several researchers have proposed reasons for the LM implementation's failure. The inability to adopt LM is due to a misunderstanding of the major system’s aim and concept (Schonberger, 2007). According to Zahraee (2016), Iran's manufacturing organizations are facing several challenges. Some of them are lack of: finance, input resources (like water & electricity, adequate markets, skilled labor), outdated manufacturing systems, obsolete technology, surplus manpower, frequent economic fluctuations, and high raw materials cost. Although there are many lean tools available, there are some barriers to practice it. Some of them mentioned by scholars are: lack of standardization, inadequate knowledge, lack of predicting the benefits etc.(Tezel, Koskela, & Aziz, 2018; Bhamu and Sangwan, 2014). Cultural differences that arise during the implementation of LM are a major source of misunderstanding when it comes to achieving the organizational goal (Achanga, Shehab, Roy, & Nelder, 2006; James, 2006). Firms having a clear understanding of lean have begun to execute it. However, those view lean as a costly improvement strategy are opposed to implementing it (Melton, 2005). According to Zahraee (2016), employees who are afraid about organizational change, time & cost in implementing LM, and lack of training & knowledge on lean philosophy are some reasons for not implementing LM as intended. On the other hand, lack of: top management's commitment, employee's involvement & training, dedicated suppliers, inventory control system, infrastructure etc. are some of the barriers for LM implementation (Upadhye, Deshmukh, & Garg, 2016). Furthermore, implementing LM is not a one-time event rather it is a continuous process (Bhamu & Sangwan, 2014) that requires continued support (Gupta & Jain, 2013).

Some of the driving and resisting forces are shown in Figure 2.1. The changes will occur when the driving forces for an organization exceed the opposing forces.

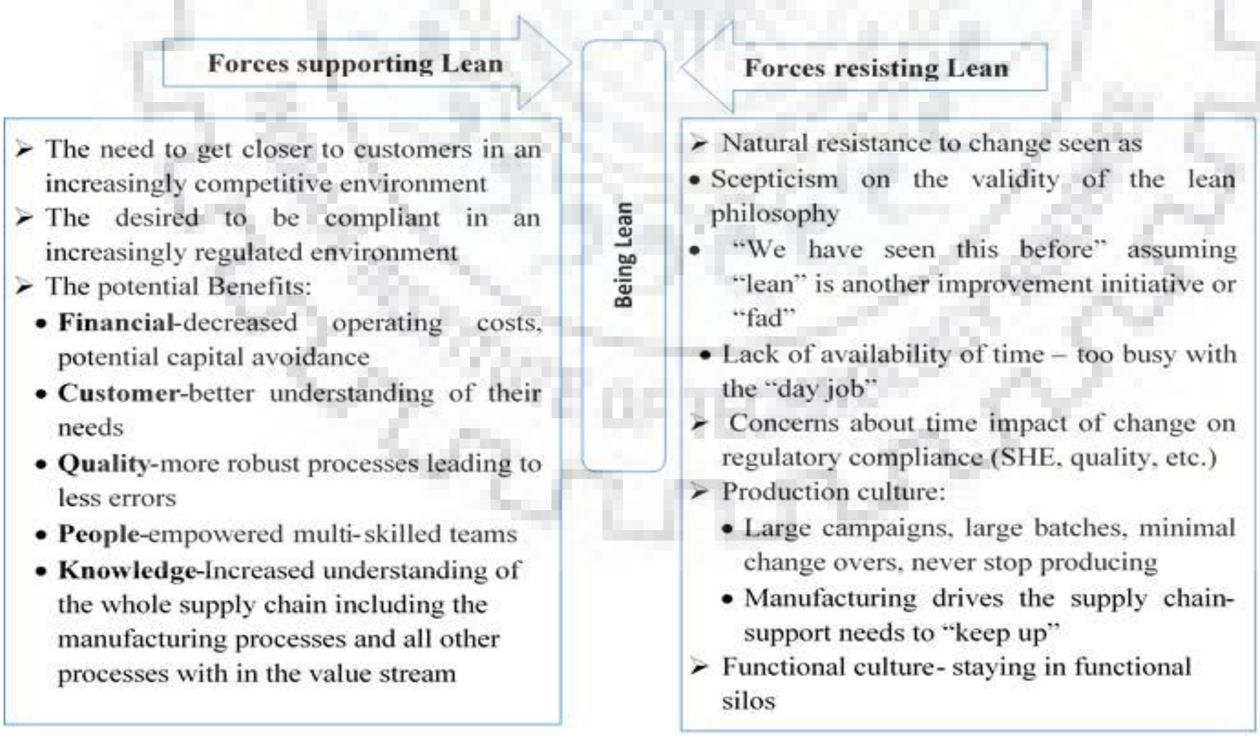

Figure 2.1 'Lean' driving & opposing forces (Melton, 2005).

Hence, for the successful implementation of LM, researchers should develop various practice models suitable for different products & industries. Organizations should understand the benefits of LM, and top managers of the manufacturing industries should take the initiative. To summarize, these barriers are divided into ten categories based on their characteristics: financial, knowledge, resource, conflict, technology, management, culture, customer, employee, and prior experience (Zhang, Narkhede, & Chaple, 2017)

2.2 Lean Manufacturing (LM) tools and techniques

Adopting a lean concept is an essential step in the journey of becoming a global competitor. LM is comprised of a variety of waste-reduction philosophies and tools (Gershenson & Pavnaskar, 2003). There are many LM tools and techniques (Nordin et al., 2010). Shah & Ward (2003) identified twenty-two LM practices that are widely cited in literature. They classified them into four bundles. These are (TQM) Total Quality Management, Human Resource, (JIT) Just-in-Time, and (TPM) Total Productive Maintenance. Other researchers divided the lean tools and approach into categories based on how they were implemented, such as internal or external focused lean practices (Panizzolo, 1998; Shah & Ward, 2003; Olsen, 2004). For example, Panizzolo (1998) categorized lean practices into six areas. These are human resources; process & equipment; planning, manufacturing; and product design which are internal oriented lean practices, while customer and supplier relationships are external focused lean practices. Jastia & Kodali (2015) has also revealed twenty-five LM tools of which value stream mapping (VSM) and quality management practice are among them. Similarly, other researchers mention many specific LM tools and techniques to achieve the goal of lean. Many studies revealed that *VSM*, 5S, TPM, JIT, Kaizen, *TQM*, cellular manufacturing, etc. are some of the tools used to practice lean (Jastia and Kodali, 2015; Bhamu and Sangwan, 2014; Singh and Sharma, 2009; Vamsi and Sharma, 2014). Mohanraj & Sakthivel, M. and Vinodh (2011) have used integrated approach of Quality Function Deployment (QFD) with VSM. Behrouzi & Wong (2011) suggested a fuzzy membership function as a unique technique to measuring the lean performance of manufacturing systems.

Following a brief review of LM tools and techniques, the case study's specific tools are described in the subsections that follow.

2.2.1 Value stream mapping (VSM)

Initially VSM was presented in 1999 for the first time (Rother & Shook, 1999). Subsequently, there have been more reviews (Forno et al., 2014). A value stream is a collection of operations (both value-added (VA) and non-value added (NVA)) that are currently necessary to move a product through the main flows that every product must pass through from raw materials to customers (Rother & Shook, 1999). The major purpose of VSM is to locate various sorts of wastes and attempt to eliminate them. Hence, developing the process map and analyzing the level of waste in the system using a VSM is a very useful initial step in getting started with lean after identifying the product families (Shou et al. 2017). The VSM records the time spent on each process step and analyzes the amount of time spent on VA and NVA (waste) activities. VSM can be used as a tool for communication, business planning, and managing process change. There are four steps in applying VSM in organizations for waste and value analysis (Shou et al., 2017; Rother & Shook, 1999):

(i). Product family selection - is the first step in developing the CSM.

(ii). Drawing the current-state map (CSM)- Information from the shop floor is collected to show the value & non-value adding activities of the CSM.

(iii). Drawing the future-state map (FSM)- Analyzing the CSM in detail provides to observe the potential improvement areas and proposed improvement scenarios. The proposed FSM is developed by implementing the proposed solutions and modifications.

(iv). Attaining the future-state – preparing some guidelines and plans are developed for the successful achievement of the future-state. By following these four steps, several studies have been conducted to examine VSM deployment in a specific sector.

2.2.2 Application of VSM

Several studies have looked into how lean thinking and practices have been implemented successfully in various manufacturing companies. The application of VSM was successfully implemented in a complicated manufacturing environment & gains a considerable reduction in cycle time (Seth, Seth, & Dhariwal, 2017). The successful application of VSM in different areas and firms were reported by researchers. To mention some of them: in the automotive industry (Lacerda et al., 2016), in the supply chain of agri-food (De Steur et al., 2016), in textile industry (Behnam et al., 2018), and so on. Other researchers discovered the extended use of VSM. VSM, with the integration of life cycle assessment in an automotive component manufacturing industry, was studied to ensure its sustainability (Vinodh, Ruben, and Asokan, 2016). Similarly, Faulkner & Badurdeen (2014) uses the extended VSM in identifying lean metrics for the performance sustainability of manufacturing firms. Based on lean ideas and practices, (Kuhlang, Edtmayr, & Sihn (2011) used VSM to reduce lead time and increase productivity. Álvarez, Calvo, Peña, & Domingo, (2009) explored the use of VSM on the assembly line. They constructed CSM and FSM of the VSM to optimize the manufacturing line by identifying waste & NVA operations. Singh, Garg, & Sharma (2011) has conducted a case study in Indian small manufacturing industries using VSM. Finally, they obtained performance improvements in terms of inventory, WIP, cycle time, takt time, change over time, labor productivity, and lead time. Sahoo et al. (2008) provided a systematic way to implement lean techniques.

2.2.3 Summary of LM

LM is a modern management philosophy comprised of a variety of waste-reduction tools and techniques. Scholars define LM differently based on their scientific perspectives. It may be defined as a process, a concept, a set of tools and techniques, a way, a philosophy, a set of principles, an approach, a practice, a system, a manufacturing paradigm, a program, or a model. It uses several tools and techniques for its successful implementation, of which VSM and quality management practice are among them. The successful implementation of LM has benefits in productivity improvement, reducing the cycle & lead time…etc. by eliminating the production waste. Scholars report many reasons for not to implement LM successfully. They are summarized and categorized as: financial, knowledge, resource, conflict, technology, management, culture, customer, employee, and prior experience. However, less attention is given in terms of LM implementation, its benefits and approaches in low-level technology organizations with undeveloped manufacturing systems. VSM only shows the static nature of the production system. Hence, there is a need to see the dynamic nature of the production system to tackle the bottleneck and increase the organization's productivity.

In this thesis, LM is defined as a management philosophy that identifies and eliminates waste throughout a product's entire value stream.

2.3 Quality Management (QM)

2.3.1 Introduction

Quality is a critical issue in today's competitive business world (Dahlgaard, Kristensen, & Kanji, 1998). The business environment has undergone major transformations and quality enhancements. It's also become one of the most significant strategies that any company may employ to acquire a competitive advantage. Additionally, as the global market continues to grow, businesses must enhance the quality of their products and services in order to compete (Al-Qahtani, Alshehri, & Aziz, 2015). Latent potential for performance enhancement is always abundant in a world of imperfect understanding & information. QM approaches offer some unique means of transforming some of the latent potential into recognized opportunities, then into actual improvements (Thakkar, Deshmukh, & Shastree, 2006). Firms that have applied QM gained many advantages in various aspects of organizational performances (Talib, Rahman, & Qureshi, 2013). Some of the benefits of QM reported by scholars are: established knowledge management (Ooi, 2009), enhanced labor productivity (Belay et al., 2014), improved financial performance (Bou & Beltrán, 2005), improved job satisfaction (Addis, Dvivedi, & Beshah, 2019), increased market shares and profitability (Evans & Lindsay, 2002), etc.

Hence, QM can be viewed as a means of gaining a competitive advantage in the global market.

2.3.2 Definition of quality

The concept of quality is an integral part of human activity (Beshah, 2011). It is an integrative management philosophy focused on continuously improving the quality of products and processes to satisfy customers (Ahire, Landeros, & Golhar, 1995). It requires the participation of many people in doing their activities appropriately in the business process. QM is a multi-dimensional concept (Kaynak, 2003). The idea of quality has started as early as human existence. It is, however, one of the most misunderstood topics, despite the fact that it is critical to the survival of even the world's most successful organizations (Goh, 2000). In the past, quality was defined by firms for their customers. Then organizations began to establish actual customer requirements and produce what they wanted within the specified timeframe and at the minimum possible cost (Ramessur, Hurreeram, & Maistry, 2015). Soon post-war, quality started to be defined by customers (Bergman & Klefsjö, 2010).

Quality is a multifaceted term (Hallgren, 2007). Quality is sometimes described as a relative concept and can be different things to different people (Dahlgaard et al., 1998). Quality has been defined in many ways by various gurus, consultants, and scholars. For instance, Juran (1988) defines quality as “fitness for use”. This definition is more customer-oriented. Crosby (Crosby, 1980) defines it as “conformance to requirements”. Crosby's concept looks to be a more restricted definition because it only takes into consideration the producers' point of view (Bäckström, 2009). This definition has a similarity with Slack et al. (2013), who defines quality as ‘consistent conformance to customers’ expectations’. According to Morrow (1997), quality is defined as consistently meeting and improving on agreed-upon requirements in order to delight customers. Because customers judge quality, initiatives aimed at enhancing the quality within firms must begin by identifying customers (Bäckström, 2009). According to Flood (1993), as cited by Addis (2018), quality implies meeting agreed-upon customer needs, both informal and formal, at a lower cost, the first time, every time. Deming (1986) defined it as “quality should be aimed at the needs of the customer, present and future”. Quality, according to Feigenbaum, (1983), is multifaceted and so requires a comprehensive definition. In a more widely concept, ‘quality’ is defined as value, conforming to specifications & standards, excellence and meeting and/or exceeding expectations of customers (Reeves & Bednar, 1994). To sum up, the definition of quality is summarized as “doing things properly for profitability and competitiveness” (Dahlgaar, Kristensen, & Kanji, 2002).

However, the definition of quality should be expanded further compared to those presented above. According to Bergman & Klefsjö (2010), they suggested as “*the quality of a product is its ability to satisfy, and preferably exceed, the needs and expectations of the customers*”.

2.3.3 Definition of QM and its development

The concept of QM has been recognized in Japan since ancient times, particularly following World War II in the late 1930s (Al-Qahtani et al., 2015). Since there are various definitions for quality, QM has been also defined in a variety of ways. The definition of QM has remained arguable issue in the literature (Bäckström, 2009). The QM concept is changeable and flexible to the spirit of the times. This could be the reason why researchers couldn’t reach a consensus on the common definition of QM. Dahlgaard et al. (1998) defined QM as "a business culture characterized by improved customers satisfaction through continuous improvements in which all employees actively participates”. QM is defined as "a single integrated approach to the organizational functions, and a process trying to achieve harmony and consistency" (Morrow, 1997). In a more broad way, Hellsten & Klefsjö (2000) defined QM as "a continuously changing management system comprised of values, techniques, and tools".

Similarly, Shiba et al. (1993) defined it as "a dynamic system, comprised of behaviors, tools, and training techniques for leading firms in a rapidly changing environment". This is similar to Hellsten & Klefsjö, (2000) definitions. QM is a quality-centered organization's management approach upon the participation of all employees, aiming its ultimate successes at customer satisfaction and benefits to all organizations members & society (Dale, 2003). QM is a management philosophy that emphasizes employee participation in obtaining the highest levels of customer satisfaction (Kitaw & Bete, 2003). QM is a corporate culture characterized by increased customer satisfaction through continuous improvements, in which all employees actively participate (Forza & Filippini, 1998).

The Industrial Revolution, which fundamentally changed how people worked, accelerated the development of QM at the turn of the century (Bäckström, 2009). In the 1950s, Japan started the quality management (QM) movement. Then, as the result of the success of Japanese organizations in the global market, it became increasingly popular in the 1980s in the United States and Europe. Since the 1990s, QM has been widely accepted as one of the most important issues in many firms. However, these organizations categorize the development of QM into four stages: (Beshah, 2011; Addis, 2018).

- Quality inspection (1920s-1960s) - after production
- Quality control (1960s-1970s) - during production
- Quality assurance (1970s-1980s) - before production
- Quality management – continuous improvements before, during, and after production.

The highest level of QM is the application of QM principles to all areas of the business (Beshah, 2011). The development of QM began with the introduction of quality inspection at the Ford Motor Company in 1910 (Dahlgaard et al., 1998). Bergman & Klefsjö (2010) described the next stage as quality control, and Walter A. Shewhart developed it. The third phase which is quality assurance considers the entire production system from design to market (Dahlgaard et al., 1998). The current phase, QM, is the fourth phase and involves understanding & applying concepts and principles in all aspects of the business with a clear system approach (Bergman & Klefsjö, 2010).

2.3.4 QM practices

Due to fierce competition in a dynamic business environment, today's corporate leaders and managers are challenged (George & Weimerskrch, 1998). In this dynamic global market environment, companies can no longer thrive and compete with their bureaucratic procedures and inefficient management systems (Dahlgaard et al., 1998). Globalization has posed many challenges to organizations around the world. These are demanding for enhanced process standards, higher quality, and greater responsiveness to customers (Farazmand, 2004). Many scholars argue that one of the inclusive management philosophy for achieving these outcomes and improving business performance is the realization of QM practices (Belay et al., 2014). In support of this idea in the recent two decades, there has been a significant increase in interest in QM practices (Al-Qahtani et al., 2015). Organizations that use quality as a competitive strategy have found lower costs, enhanced productivity, and increased customer satisfaction (Harrington, 1991).

Generally, QM comprises both the 'hard' and 'soft' aspects. The 'hard' aspect entails a variety of tools and techniques for improving production processes, including FMEA, SPC, QFD, seven tools, Pareto analysis, etc. (Prajogo & Cooper, 2010a). While the 'soft' aspect is mainly concerned with customer awareness & human aspects, i.e., teamwork, commitment, empowerment, culture, leadership, involvement, etc. Hence, this study focuses on the 'soft' aspect or people factor of QM practices (Maistry, Hurreeram, & Ramessur, 2017). For various reasons, several experts have advocated that businesses should focus on understanding the soft side to achieve successful QM adoption (Prajogo & Cooper, 2010a). Because "soft" QM aspects are long-term concerns, they must be emphasized and addressed in a company's QM implementation strategy (Thiagaragan, Zairi, & Dale, 2001). It creates a suitable situation in which the 'hard' aspect of QM practices can be implemented. Researchers reported that soft practices in addition to their direct influence on organizational performance, have an indirect effect on hard practices (Addis et al., 2019). The effective exploitation of the "soft" practice must be supported by the "hard" practice in order to be effective and obtain the "social mixed" of practices (Fotopoulos & Psomas, 2009; Escrig-Tena et al., 2018). Hence based on the above justifications, this study focuses on the 'soft' aspect of QM practices.

According to Talib, Rahman, & Qureshi (2011), the benefit of QM can be realized by identifying sets of common QM practices. Given the major advantages of QM implementation, several studies recommend set soft QM practices (Kaynak, 2003; Arunachalam & Palanichamy, 2017). According to the study presented in this thesis, QM is based on the five sets of soft QM dimensions. These are top management leadership commitment, everybody's participation, customer focus, teamwork, and continuous improvement. These sets of QM practices have been frequently used as essential success factors of QM in many QM studies (Sadikoglu & Olcay, 2014; Aquilani et al., 2017; Sabella et al., 2014).

2.4 Operational performance (OP)

Operations management can either 'make or break' any business (Slack et al., 2013). The quality, cost, delivery and productivity outcomes of an organization are referred to as OP (Kaynak, 2003). Similarly, Saleh et al. (2018) has defined OP as the performance of organizations' internal operations like product quality, productivity & customers satisfaction. QM's performance aspect is concerned with quality, operational, and business performance metrics (Samson & Terziovski, 1999). Previous research revealed that OP is very important for manufacturing industries as it leads to better production efficiency, increased profit, better products quality, delighted customers, and increased sales volume (Truong et al., 2014; Kaynak, 2003; Ou et al., 2010). OP is regarded as the most important factor which determines a company's competitive advantage (Phan et al., 2019). Manufacturing industries' capabilities are frequently regarded as a business unit's desired competitive performance and are thus evaluated using OP indicators, commonly comprising quality, delivery, flexibility, and cost measures (Hallgren, 2007).

Performance measurement is considered a necessary component in all managerial approaches. Concerning the measuring metrics, using a single measure does not index organizational OP (Bayraktar et al., 2009). Thus, several researchers suggested various indicators and dimensions for operational performance. For instance, Ataseven, Prajogo, & Nair (2014) used cost, quality, & delivery time. Jabbour et al. (2013) used delivery, flexibility, quality, cost, development of a new product, & time to market. Whereas productivity, quality, cost, inventory reduction, & delivery were used by Nawanir et al. (2013). According to Slack, Brandon-Jones, & Johnston (2013), the core elements of OP include quality, cost, speed, flexibility, and dependability. Recent researchers use cost, speed, dependability, quality, and flexibility to measure the organizations' OP (Belekoukias et al., 2014; Abdallah et al., 2016). In particular, Hallgren & Olhager (2009) have suggested using delivery time, quality, flexibility, and cost to measure OP of manufacturing industries. These metrics are the basis of production capabilities which results in enhanced competitiveness. Hence, delivery time (speed), flexibility, quality, cost, and dependability are the most commonly and frequently used OP measures (Truong et al., 2014; Nawanir et al., 2013; Nabass & Abdallah, 2018; Leite & Braz, 2016). And these measures are also used in this study.

2.5 QM practices and Operational performance

The impact of particular practices on firm performance is a topic that scholars' interest is increasing in the field of business management. The implementation of any practices incurs a cost to the organization in terms of both material and human resources. Hence, organizations need to investigate the effects of implementing these practices over the intended results. If the efforts put into implementing and maintaining these practices will pay off, then results must improve. According to Parast, Adams, & Jones (2011), QM has developed as a management model for improving firms' efficiency and competitiveness. Several studies have attempted to link QM practices to various operational outcomes, including quality outcomes (De Cerio, 2003). Previous empirical studies have claimed that QM practice enables organizations to improve OP in terms of flexibility, delivery, time productivity, quality, and cost (Sadikoglu & Zehir, 2010; Tan, 2013; Kibe & Wanjau, 2014; Sadikoglu & Olcay, 2014; Truong et al., 2014). These previous studies revealed mixed results on the impact of QM practices on OP. This is because of the following reasons. First, due to the substantial differences in construct development and research methodology (Ittner & Larcker, 1997). Second, operationalizing QM as single or multiple constructs, measuring performance in one or multiple levels, and differences in the techniques used for data analysis (Molina et al., 2007; Kaynak, 2003). Third, utilization of different theoretical frameworks (Parast et al., 2011) etc.

The relationships between QM and OP have only been studied in a few countries; most of them are in developed nations. The conventional QM system was designed based on the findings of companies in developed countries. Thus, its applicability and generalizability should be restricted to such nations (Jun et al., 2006). Furthermore, according to Sila & Ebrahimpour (2003) suggestion more industry-specific & cross-cultural QM investigation is required to evaluate the impact of QM on a company's performance. Industry-specific research helps researchers and practitioners to have a better understanding of the determinants of performance (Garvin, 1988).

Hence, the objective of this study is to investigate whether implementing QM practices has an impact on improvement in OP and to determine the most influential elements of QM practices.

2.6 Summary of QM and OP

Quality is a multifaceted term. Many scholars agree that the survival of an organization is in the hand of customers. Globalization has posed many challenges to organizations around the world. These are demanding for enhanced process standards, higher quality, and greater responsiveness to customers. Many scholars argue that one of the inclusive management philosophy for achieving these outcomes and improving business performance is the realization of QM practices. Since there are many distinct definitions for quality, QM has been defined in a variety of ways. Some of the benefits of QM reported by scholars are improved labor productivity, financial performance, job satisfaction, increased market shares, profitability, etc. Generally, QM comprises both the 'hard' and 'soft' aspects. The ‘hard’ aspect entails a variety of techniques and tools for the enhancement of manufacturing processes. These includes FMEA, SPC, QFD, seven tools, Pareto analysis, etc. While the ‘soft’ aspect is mainly concerned with customer awareness & human elements, i.e., teamwork, commitment, empowerment, culture, leadership, involvement, etc.

QM's performance aspect is concerned with quality, operational, and business performance metrics. OP is vital for manufacturing industries as it leads to better production efficiency, increased profit, better products quality, delighted customers, and increased sales volume. Previous researchers agree that the core elements of OP include quality, cost, speed, flexibility, and dependability.

2.7 Gaps and Opportunities

The literature review revealed that there is no work carried out in labor-intensive and complex manufacturing processes such as the leather sector using value stream mapping (VSM) as a tool. In developed countries, the manufacturing system is well developed. They have enough materials, methods, machines, and skilled manpower (4M’s). But developing countries, especially the low-level technology organizations, do not have sufficient 4M’s and well-developed manufacturing systems. No work has been done to integrate the LM system to undeveloped manufacturing systems and low-level technology. Many researchers agreed with the availability of many LM tools and techniques. However, for successful lean deployment, appropriate lean tools selection from the numerous available LM tools, which maximizes the essential resources, is an issue yet not addressed in the literature. None of the researchers have conducted a research on leather manufacturing industries addressing the issue of VSM. This shows a need to study the topics related to lean through VSM in manufacturing industries taking leather industries as a case study. Based on the reviewed literature, a number of gaps and opportunities have been identified, which are presented in Table 2.2.

Table 2.2 Gaps and opportunities

S.No.	Gaps	Opportunity
1.	The literature review revealed that there is no work carried out in the area of lean through VSM in labor-intensive and complex manufacturing processes such as the leather sector, especially in developing countries like Ethiopia.	Manufacturing industries in Ethiopia are considered a promising option for the country's economic development. At the same time, this industry struggles to increase its productivity and quality of the products in order to compute or increase competitiveness in the local as well as global market. One way to improve productivity and increase competitiveness is by studying the manufacturing process to identify waste, bottleneck, and potential improvement areas. This helps to improve the performance of the organizations.
2	Despite the increase of studies on lean/VSM, it seems research has solely focused on the static nature of the VSM. Understanding of the proposed solution before implementation using modeling and simulation is not addressed especially for complex manufacturing processes such as the leather industry.	Wastes are more when the manufacturing process of organizations is labor-intensive. Some of the hidden wastes can be seen by studying the manufacturing process to analyze the dynamic nature of the manufacturing process using the modeling and simulating the system.
3	No work has been done on how to integrate lean to not well-developed manufacturing systems like Ethiopian footwear manufacturing industries.	Since lean manufacturing is new to developing countries, it is better to study what should be its approach to integrate lean to not well developed manufacturing systems.
4.	Very less work has been done on the relationship between QM and OP especially in low-level technology organizations, While QM is likely to have an impact on various elements of an organization.	Recognizing the relationships between QM and OP have a wide area of importance for the effectiveness of organizations' performance. More empirical investigations are required to understand how QM is affecting the OP.

2.8 Problem Formulation and Research Scope

2.8.1 Problem definition

The present research is mainly focusing on the LM through VSM. It empirically investigates the application of VSM in low-level technology organizations and an innovative method to make a decision in choosing appropriate lean tools to maximize the critical resources. The research was conducted in the Ethiopian leather industry to increase the sector's competitiveness.

2.8.2 Research questions (RQ)

The present research formulated four research questions. The research questions are slightly progressive in nature since new knowledge during the research journey has generated new questions. Knowledge from seeking an answer to the first Research Question (RQ1) created a new question (i.e., RQ2) and a base for further research. The research questions are described in the following.

The leather industry of Ethiopia needs to be transformed to a fully-fledged manufacturing stage. This is so because an increased level of organizational performance is achieved with a higher stage of processing/manufacturing activity. However, it has been revealed that the industry's performance is found at a low level; because of widespread constraints downstream to the manufacturing stage. One way to facilitate improvement is to identify the wastes that largely inhibit the industry's performance. Then, the industry could improve performances tremendously and live up to the challenge of international competition. The first research question is:

RQ 1. What is the possible way to reduce the lead times of the Ethiopian leather industry?

Many organizations are suffering from long lead times, which brings customer dissatisfaction and less competitiveness. In Ethiopia, a number of organizations, including the leather industry, struggle with low productivity and performance. Organizations need to understand how much they are successful in achieving their customer needs on delivering the products at the intended time. This directly helps the organizations understand how successful they are in utilizing their available resources by minimizing the waste to increase the productivity & performance of the organizations. In relation to this manufacturing process is dynamic by its nature. Hence, the second research question is:

RQ 2. How is it possible to analyze the dynamics performance of the manufacturing processes?

The work done in search of a solution to RQ1&2 resulted in new questions that need to be addressed. Previous scholars revealed that manufacturing industries are attempting to implement lean techniques to maximize their resources. But out of many lean tools & techniques, how to select the suitable one for a particular organization is a question to be answered (i.e., RQ3). In today's competitive global market, firms seek to adopt modern management philosophies and techniques. One of their common goals is to increase the organizations' operational performance. Currently, Ethiopian leather industry firms are adopting some QM practices. The impact of these practices on the operational performance of the Ethiopian leather industry is another question that should be addressed (RQ4). Hence, the third and fourth research questions are:

RQ 3. How can LM be integrated into not well-developed manufacturing systems?

RQ4. What is the impact of QM practices on the OP of the Ethiopian leather industry?

2.8.3 Objectives of the research

This study has the following general and specific objectives derived from the research questions. Figure 2.2 depicts the main relationship between the research questions and objectives.

General objectives

The main objective of this thesis is to generate knowledge about how to enhance the competitiveness of manufacturing industries. Notably, the research reported in this thesis aims to investigate how LM can be practiced in order to improve the performance of manufacturing organizations.

Specific objectives

1. To investigate the application of VSM in low-level technology organizations.

2. To analyze the dynamics performance of the manufacturing processes.

3. To investigate methods to integrate lean to not well-developed manufacturing systems.

4. To investigate the impact of QM practices on OP.

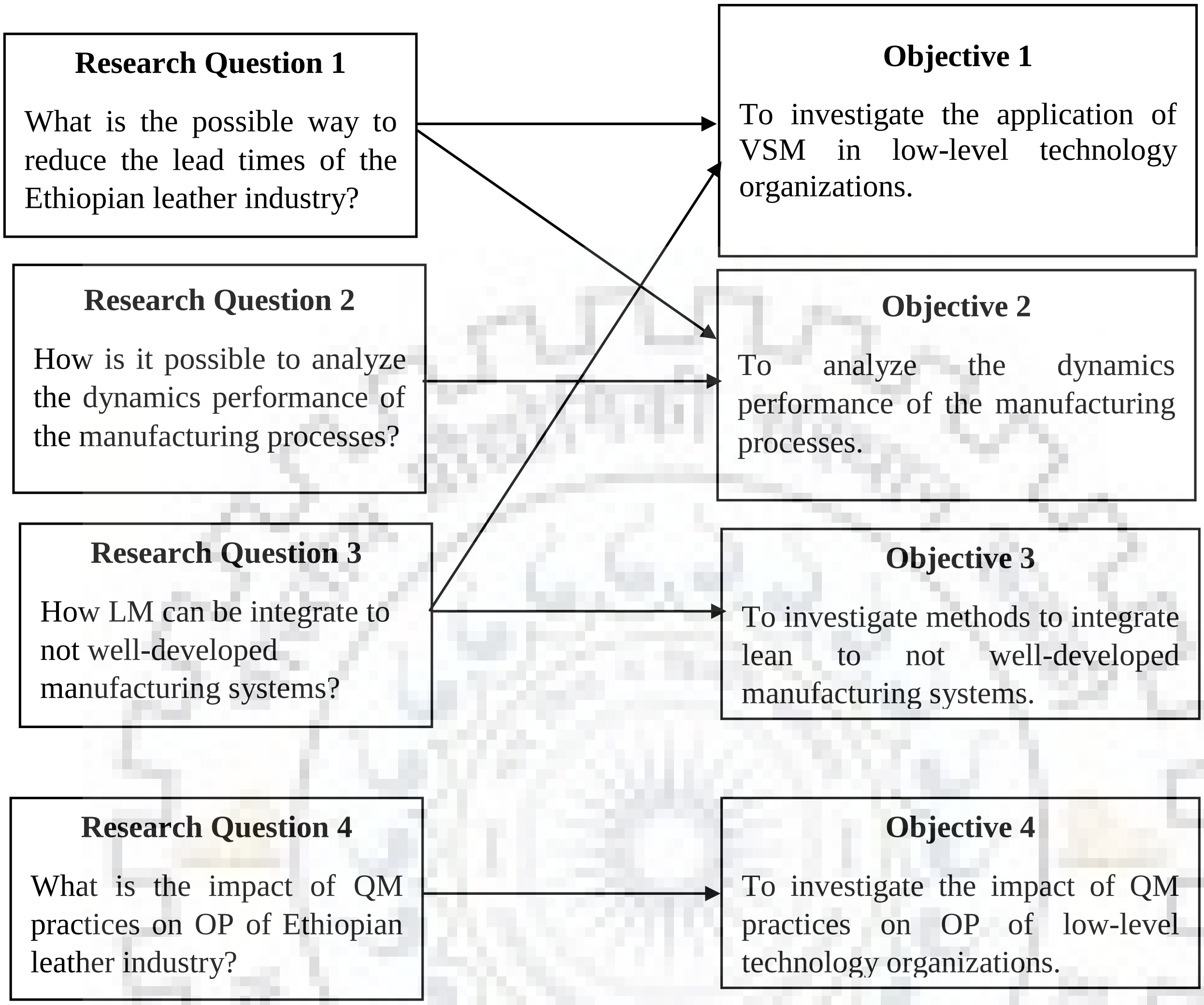

Figure 2.2 The links between the RQs and objectives

2.8.4 Scope of the research

The research described in this thesis focused on a systematic analysis of the leather products manufacturing industry of Ethiopia in order (1) to investigate the applicability of VSM in low-level technology organizations, (2) to develop alternative models which will enhance the productivity of the organizations (3), to develop a method to integrate LM into not-well developed manufacturing systems in order to utilize the available critical resources effectively and (4) to investigate the interconnection between the OP with QM. This study is confined to analyzing operational-related issues within the assembly lines of the manufacturing systems of shop floor workers. The study does not look at supply chain issues, weak national infrastructure, raw material quality issues, or business and financial regulation barriers, which are amongst the key reasons of industry underperformance. The focus here is on how a modern measurement approach can be developed and implemented to tackle manufacturing industries' hidden enemies (waste).

2.9 Research Methodology

2.9.1 Introduction

As research is the systematic and organized form of continuous attention applied to the field of knowledge, undertaken to establish facts and relations, research methodology is the study of conducting a research activity. This part of the thesis describes the research method used in the study. Mainly it discusses the methodological choices made during the research process. The methodological decisions are discussed in relation to the research's purpose and research questions. An overall research methodology is also presented, which provides a general overview of the research process.

2.9.2 Research types and purposes

In any study, there are two major categories of research problems – state problems and process problems (Addis, 2018). State problems are concerned with the current state of phenomena, whereas process problems are concerned with the evolution of a phenomenon over time. Hence, based on these two research problems, the literature provides three types of research approaches or purposes. These are exploratory, descriptive, and explanatory (Marshall & Rossman, 2016). The three types of research purposes are presented in Table 2.3. Each research purpose has its own logical method for gathering and interpreting empirical evidence. According to Zikmund (2000), exploratory research is utilized in investigative investigations and studies to resolve ambiguous issues.

The main purpose of the present research is *to examine how LM can be practiced in order to enhance the performance and competitiveness, particularly the OP, of the manufacturing organizations and what approaches to follow in order to utilize the available resources effectively and efficiently in order to promote successful implementation of LM.*

Hence, its purpose is to gather empirical evidence that helps in understanding & investigating the issues related to LM and OP. The primary task starts with studying the applicability of LM tools and techniques focusing on waste elimination. Therefore, the purpose of the research is mainly exploratory as it intends to investigate the applicability of lean through VSM

(Table 2.3). The RQs deal with 'what' and 'how' questions, which are typical for explanatory research. Explanatory research, according to Yin (1994), is probably the best strategy when the research questions deal with 'what' and 'how'. In addition, the study is descriptive in nature. Most of the issues in relation to LM, as revealed from the literature, focus on well-developed manufacturing systems or countries. In developing countries like Ethiopia, the successful implementation of advanced management tools and techniques is not common such as LM. The methodology used in this study examines and describes the regarded issue related to LM and its approaches for its successful implementation. Another rationale for the research being descriptive is its aim to investigate and describe how LM can be practiced. The research is also exploratory by nature. Additionally, it explores how QM affects the OP of the manufacturing industries.

Table 2.3 The three types of research purposes. Source:(Marshall & Rossman, 2016)

Exploratory	**Descriptive**	**Explanatory**
• To investigate little-understood phenomena	• To document and describe the phenomenon of interest	• To explain the pattern related to the phenomenon in question
• To identify/discover important categories of meaning		• To identify plausible relationships shaping the phenomenon
• To generate hypotheses for further research		

2.9.3 Research strategies

In order to best answer the research question, a decision on research strategies must be taken during the research process. The three most frequent strategies for conducting research are case study, correlational and experimental methods (Bäckström, 2009; Addis, 2018). Each technique can be used to conduct descriptive, explanatory, or exploratory research. According to Addis (2018), the *case study method* entails acquiring information about a topic under investigation by observing the phenomenon in the real world. When 'how' questions are being posed, a case study is the preferred research strategy (Yin, 1994). However, the case study approach is often criticized for being subjective in nature and unscientific. The *experimental/scientific method* gathers collects data through well controlled experiments. It is formal & objective and helps in determining whether or not two variables have a cause-and-effect relationship. But, critics claimed that it has poor external validity. This refers to the extent to which its findings can be extrapolated outside the context in which study was carried out. The *correlational method* is used to discover if two or more variables are statistically connected. If two variables are statistically connected, the correlational approach helps predict a score on one variable by using the score on the second variable. Correlational approach provides a blend of both relevance and precision. However, it lacks the degree of precision connected with the experimental approach, as well as the degree of relevance associated with the case study method.

The current study used a mixed strategy of case study and correlational methods, similar to prior research that focused on the relationship between two units (Addis, 2018). Additionally, it uses the experimental method as it uses simulation software to experiment with different alternative proposed solutions. As the research questions are ‘how’ and ‘what’, the case study method is an obvious first choice for the current study. This is because it contains a ‘how’ question to contribute to understanding the relationship between LM implementation & its consequences and QM & OP. The case study method is used to gather data of the study variables from the case industry. And these data are used for experimental/analytical analysis.

As previously stated, the case study was the primary research strategy used in this thesis. Depending on the stated 'unit of analysis', a fundamental contrast when constructing case studies is between holistic and embedded designs (Yin, 1994).

Whether the case studies analyze one or more subunits determines whether *holistic* or *embedded* examination is used (Bäckström, 2009). When only one unit of analysis (e.g., the global nature of an organization) is studied, the case study is regarded as holistic. The design is called an embedded case study design if it involves more than one unit of analysis, implying that multiple sub-units are also given attention (Yin, 1994). Both variants have their weaknesses. In holistic design, the study's overall nature may change as it progresses. In contrast, embedded design can have difficulties if the sub-unit level study fails to return to bigger unit of analysis (Bäckström, 2009). As mentioned earlier, the study described in this thesis focused only on issues related the manufacturing processes within the assembly line, i.e., the research has chosen a holistic case study design, with careful consideration for its drawbacks.

2.9.4 Research approach

After deciding the research purpose, the next step is to decide on the research approach to use. The choice of research approach & design is determined by the specific problem, the research purpose, and the questions that the problem raises (Yin 1994; Zikmund 2000).

2.9.4.1 Induction and deduction approaches

There is often a distinction between deduction and induction research approaches (Schön, 2007; Bäckström, 2009). The term 'induction' refers to a researcher's ability to draw general inferences from empirical data. The researcher provides theoretical interpretations based on empirical data from a variety of scenarios. While in the 'deduction' research, a specific case is explained, which is departed from a general conclusion (Bäckström, 2009). Abduction is the combination of both induction and deduction (Patton, 2002). It is often used in case studies.

The RQ1 & RQ2 were performed using an inductive approach. In order to answer these questions, empirical data were gathered from the case company to make analytical generalizations on the applicability of VSM in low-level technology organizations context like in Ethiopia (RQ1) and to analyze the dynamics performance of the manufacturing processes (RQ2). Hence, the research in relation to RQ1 and RQ2 can be classified as induction as they arose from empirical material. RQ3 explored how LM can be implemented systematically within organizations that have not well-developed manufacturing systems. Hence, in the RQ3, a deductive approach was used. And also, RQ3 can be classified as partly inductive since it starts by collecting empirical data regarding the LM practices. Regarding RQ4, with the existing theory, hypotheses were developed. In RQ4, it was hypothesized that QM might positively affect OP. And followed by collecting empirical data regarding the QM practices. Hence, in RQ4, the deductive approach was used. Figure 2.3 depicts an overview summary of the current research's approach. The study used both inductive and deductive research methods, as illustrated in Figure 2.3. The RQ1 and RQ2 used induction type of research. The RQ3 consists of both inductive and deductive types, and RQ4 used deductive type of research.

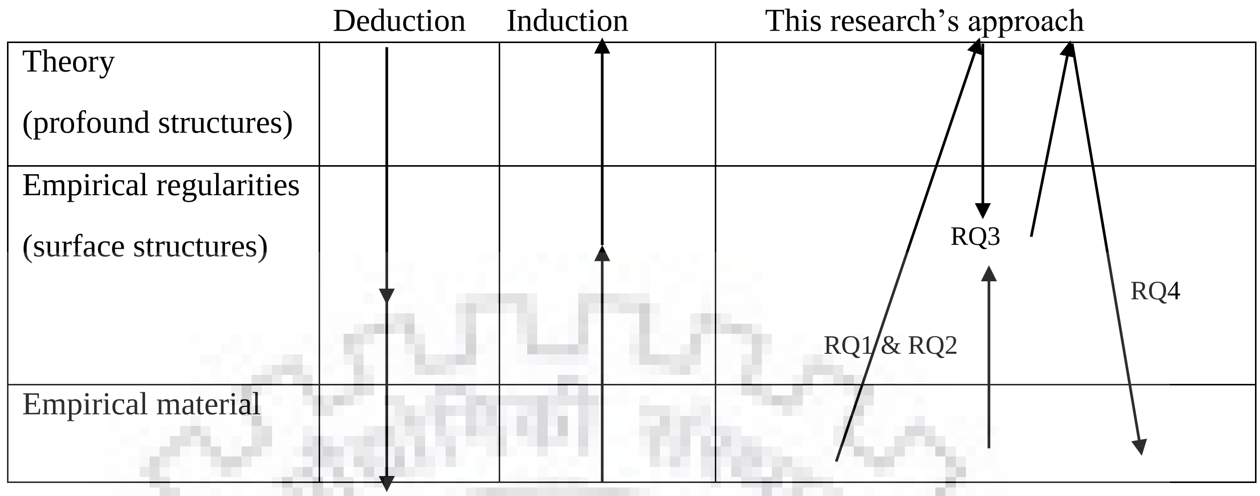

Figure 2.3 Types of research approaches (Bäckström, 2009).

2.9.4.2 Qualitative, quantitative, or mixed approaches

The two most common research approaches are qualitative and quantitative approaches (Creswell, 2014). Qualitative is information that is conveyed through words, while quantitative is information that is conveyed by numbers. Qualitative data is made up of extensive descriptions of sceneries, people, & observable actions, attitudes, and events that cannot be tested or evaluated empirically (Merriam & Tisdell, 2016). Quantitative research, on the other hand, focuses on the measurement and analysis of causal relationships between variables (Denzin & Lincoln, 2005). Because they are examining the same issue in different ways, these two research traditions can be integrated and contribute to a richer picture of the phenomenon (Bryman, 2012). Researchers can be more confident in their conclusions when they use the combination of these two methods (mixed approach) since their findings have been confirmed in two different ways (Merriam & Tisdell, 2016). This kind of procedure, sequential procedure, is one that involves elaborating the findings of one approach with the findings of another method (Schön, 2007).

The current study was conducted using a combination of quantitative and qualitative approaches. As previously stated, this thesis employed a hybrid technique combining case studies and correlational methods. According to Bäckström (2009), case studies can include any combination of quantitative and qualitative evidence. To answer RQ1 & RQ2 data were gathered from the case industry, using observation and interview. This is performed to investigate the application of VSM (RQ1) and to analyze the performance of the manufacturing systems assembly line (RQ2). RQ3 was aimed to explore the LM implementation approach into not well-developed manufacturing systems. Data were gathered using questionnaires, interviews, and observations from the case company. Experts, managers, and supervisors were asked to prioritize the wastes evaluate the relationship between waste & resources. And also, the occurrence, severity & detection of these wastes were rated. Then, their feedback was quantitatively analyzed using fuzzy QFD and FMEA. Hence a mixed approach was used to answer RQ3. RQ4, on the other hand, is aimed at finding the mechanics of the relationships between OP and QM. To answer RQ4 in a reliable way data were gathered from case companies using questionnaires and observations. Their feedback was empirically analyzed to reach at a certain conclusion. It was beneficial to use a quantitative and qualitative approach to acquire reliable material and obtain a detailed representation of the phenomenon under investigation.

A more detailed description of the methodological choices such as data collection methods, sampling, etc., used in the whole research endeavor is presented in the subsequent chapters and the performed analysis.

2.9.5 Plan of the present thesis

The study was conducted sequentially in four phases. The first phase (Phase I) involved identifying the product family and developing the current & future state of VSM. In performing these, the material and information flow were studied in depth for the leather shoe manufacturing process. The aim of Phase II was to analyze the performance of the footwear manufacturing assembly line. Mainly its focus was on the dynamics of the manufacturing system. Data were gathered mainly from the assembly line during the actual production process, and Arena simulation software was used for the analysis. The third phase (Phase III) was to develop innovative approach decision-making on selecting lean tools. A systematic fuzzy QFD procedure was used to establish the priority of technical solutions for the improvement of critical resources. The centroid defuzzification approach (CDA) is used to prioritize the failure modes. After examining the FMEA in-depth, significant lean projects are chosen.

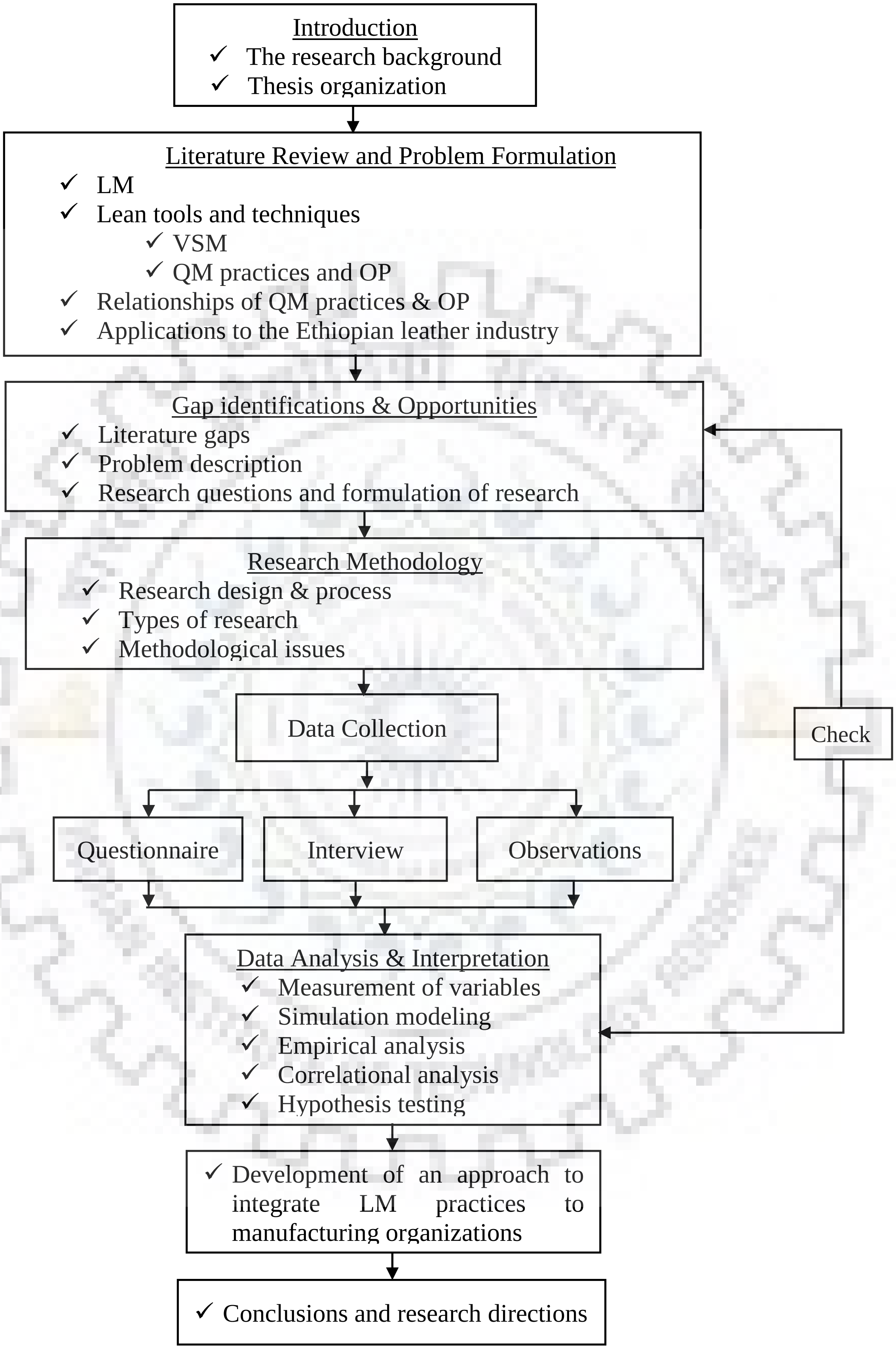

Figure 2.4 Flowchart of the research

The fourth phase (Phase IV) details on the understanding of the relationship between QM and OP. A standardized survey questionnaire and face-to-face interviews with shop floor personnel were used to obtain data. The survey instrument was validated using exploratory and confirmatory factor analysis. A structural equation modeling technique was used for the analysis. Moreover, the mechanics of the relationships between OP and QM was studied in phase IV. It augments the understanding of how one is constituted in the corpus of the other.

The flowchart of the present research work is shown in Figure 2.4. The figure shows the detailed flow of the work to achieve the research objectives.

2.10 Summary

LM is a modern management philosophy comprised of a variety of waste-reduction tools and techniques. Scholars define LM differently based on their scientific perspectives. It may be defined as a process, a concept, a set of tools and techniques, a way, a philosophy, a set of principles, an approach, a practice, a system, a manufacturing paradigm, a program, or a model. It uses several tools and techniques for its successful implementation, of which VSM and QM practice are among them. Though scholars agree that LM implementation has many benefits, the approach to integrating LM practices to manufacturing organizations to gain the intended benefits is not addressed by researchers. And also, the impact of implementing QM practices on the OP of the organizations needs to be investigated. More empirical research is required to recognize the relationships between QM and OP clearly. Hence, this research mainly aims *to create an understanding of the mechanism of how LM practices can be integrated into manufacturing organizations.* This chapter describes the methodological decisions used during the research process. The study was designed to be carried out sequentially in four stages.

As stated in Chapter 1, the research is focused on Ethiopia's leather industry. It has been discovered that the industry's performance is found at low level. The nature of the issues is diverse, which appears to explain the industry's underperformance. The initial phase of the research is presented in the following chapter. Phase I involved the investigation of the applicability of VSM in low-level technology organizations.

CHAPTER 3

INVESTIGATING THE APPLICATION OF VALUE STREAM MAPPING (VSM) IN LOW-LEVEL TECHNOLOGY ORGANIZATIONS (PHASE I)

3.0 Overview

In this chapter, the first phase of the research was presented. Phase I involved the investigation of the applicability of VSM in low-level technology organizations[1]. A literature review was conducted to identify the lean tools & techniques, and metrics. Related data were gathered from the actual production process. For each activity, time study and line balancing were performed to develop standard time and balanced assembly lines. Then, the current and future state VSM were then developed, followed by results and discussions. Finally, a summary of the chapter is presented.

3.1 Introduction

Organizations need to adopt modern management philosophy to improve their performance and productivity in today's global competitive market. Several researchers claimed that one of the comprehensive management philosophies for achieving competitiveness is the realization of lean manufacturing (LM) (Chauhan & Singh, 2012). The Toyota Production System is the foundation of LM. It is a philosophy that emphasizes eliminating production wastes to maximize customer value and increase productivity (Belekoukias et al., 2014). To achieve the goal of lean, LM uses various tools and techniques. Some of them mentioned by (Jastia and Kodali, 2015; Bhamu and Sangwan, 2014; Singh and Sharma, 2009; Vamsi and Sharma, 2014) are value stream mapping (VSM), 5S, total productive maintenance (TPM), just in time, kaizen, total quality management, cellular manufacturing, etc. Therefore, as aforementioned, VSM is one of the LM tools used for analyzing information and material flows within the manufacturing process. It helps to identify the different types of waste and their levels.

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[1]***Parts of the contents of this chapter have been published in International Journal of Productivity and Performance Management, Vol. 71 No. 6, pp. 2393-2409, 2021.***

As Andrade et al. (2016), mentioned, VSM is one of the LM techniques used for identifying and reducing waste, which improves the performance and productivity of the organizations. VSM is used primarily to minimize the time between order's placement and delivery time. Ethiopia has more than 90 years of experience in processing leather and leather products. And in livestock population, it is the leading in Africa and 10th in the world (LIDI, 2019).

Ethiopian leather industries have vast resources, but their export performance contribution is negligible compared to their resource availability (Ashebre, Gebremeskel, and Hadush, 2013; Mekonnen Bekele, 2008). This indicates that the sector lacks competitiveness in the global market and needs performance & productivity improvement. As Scott (2006) revealed, low-level technology organizations are labor-intensive. And footwear, clothing, and furniture industries are mentioned as low-level technology organizations. A labor-intensive nature mainly characterizes organizations in Ethiopia, or it does not require very sophisticated technology (Addis, Dvivedi, & Beshah, 2018). Hence, Ethiopia's leather footwear manufacturing organization is selected for the case study to improve the sector's competitiveness. In section 2 of this study, the literature review indicates that no work is done in applying lean tools like VSM in low-level technology organizations, especially in developing countries like Ethiopia; therefore, a research gap exists. Hence, the study aims to investigate the applicability of VSM in low-level technology organizations to improve the performance and productivity of low-level technology organizations.

Firstly, lean manufacturing tools, mainly VSM, were selected and considered to achieve the proposed objectives. Then, related to the VSM, both from documented and actual production processes, production data were collected and analyzed. Subsequently, mapping the current production process, identifying the wastes, identifying proposed solutions, and mapping the future production process is followed.

3.2 Lean manufacturing (LM)

At the end of World War II, Taiichi Ohno Toyota’s executive has developed the automotive industry's Toyota Production System (TPS). Unlike mass production of Henry Ford’s single model, the system focused on the quality and variety of products (António and Ana, 2016). According to Goshime, Kitaw, and Jilcha (2018), lean principle is described as “doing more with fewer resources.” On the other hand, productivity can be improved by identifying the VA and NVA activities, differentiating the types of wastes, minimizing the wastes/ NVA activities, by making continuous improvement, and enhancing the flow of the production system (Gunaki and Teli, 2015; Seth, Seth, and Dhariwal, 2017).

Toyota has identified the “seven deadly wastes.” Waste is any activity that doesn’t add value to a product but consumes resources (Singh and Sharma, 2011). It makes the product more expensive by consuming both time and resources (Kassu and Daniel, 2015; Lacerda, Xambre, and Alvelos, 2016; Womack and Jones, 2003). The three types of activities in any production process are i) the VA that adds value to the final product as set by the customer; ii) the NVA currently required by the production system but unavoidable - type one Muda/ necessary NVA activities) and; iii) the NVA - avoidable (type two Muda) (Lacerda, Xambre and Alvelos, 2016; Wenchi, Jun and Peng, 2017; Womack and Jones, 2003). There is no clear boundary between the NVA and necessary NVA activities in the literature. The “seven deadly wastes” identified by Taiichi Ohno, abbreviated as TIM-WOOD, in an industrial environment are motion, inventory, transportation, over-processing, waiting time, defects, overproduction (Liker, 2004; Okpala, 2012; Lacerda, Xambre and Alvelos, 2016; Womack and Daniel, 2003; Modi and Thakkar, 2014; Goshime, Kitaw and Jilch, 2018; Langstrand, 2016; Behnam, Ayough and Mighaderi, 2018). In addition to the wastes mentioned above, talent is also reported as waste by Liker (2004), Locher (2008), and António (2016). Following a brief review of lean philosophy, the case study's specific tools are described in the subsections that follow.

3.2.1 Value stream mapping (VSM)

VSM is a crucial lean tool in identifying opportunities for improvement and elimination of wastes. Mainly it is used for analyzing, implementing, and maintaining lean approaches. The overall aim is to observe the flow of materials and information from the beginning of raw materials to the finished end product (Dal Forno et al., 2014; Matt, 2014).

Lacerda, Xambre, and Alvelos (2016) and Rother and Shook (1999) have also described VSM as a powerful tool that helps in visualization, understanding, and documentation of the materials and information flow through the value chain. This enables the easy identification of wastes. It includes all the VA and NVA activities. It allows the systematic way of waste identification in a series of production processes and detects improvement potentials. VSM can be applied by any business activity and extended upstream or downstream (Meudt, Metternich, and Abel, 2017). It is a powerful tool in highlighting process transactional, inefficiencies &

communication mismatches, and guides about the improvement (Rother and Shook, 1999; Meudt, Metternich and Abel 2017; Singh and Sharma, 2009). Though VSM was appeared first in 1999 and introduced through learning-to-see Rother and Shook (1999), some recent reviews are also reported (Dal Forno et al., 2014).

Seth et al. (2017) successfully applied VSM in a complex production environment and obtained a significant cycle time reduction. VSM was applied by Lacerda et al. (2016) in automotive sector and gains financial benefits by reducing cycle time and workforce level. And Behnam et al. (2018) used VSM in the textile industry to improve processing & waiting times. Based on a systematic review, De Steur et al. (2016) study the applicability of VSM in the agri-food industry supply chain. Similarly, Ciarapica, Bevilacqua, & Mazzuto (2016) have used VSM to improve the performance of a project in product development. Jing et al. (2020) have used VSM to improve the manufacturing industry's procurement process, and Alowad et al. (2020) study the application of VSM in healthcare to improve patient flow in the emergency department. Concerning environmental aspects, Muñoz-Villamizar et al. (2019) has adopted VSM to assess environmental practice's impact on productivity in the automotive sector. Badar, Verma, & Sharma (2021) have used VSM in manufacturing industry that combines Lean, Energy and Six-Sigma methodologies. This is to determine the energy usage and waste. Some other literature revealed that researchers reported the extended use of VSM. Vinodh, Ben Ruben, & Asokan (2016) combined VSM and life cycle assessment to predict the long-term success of an auto component manufacturing company. Using the extended VSM as a tool, Faulkner & Badurdeen (2014) identify lean metrics for manufacturing performance sustainability. This study uses VSM as a tool to identify wastes and find lean implementation opportunities.

3.2.2 Flow process chart

A flow process chart is a simple method that uses symbols to indicate the actions taken and show the steps in a process. It can be used selectively to show what happens to selected materials, people, or equipment. It describes the step by steps flow of activities at the micro-level throughout the complete production process. It also includes the number of persons working for those activities, processing time, type of those activities, total time taken by that individual, types of tasks, and processing time. According to work-study, all activities are classified into five types using the five standard symbols: (Marcelo et al., 2016; Kamble and Kulkarni, 2014; Al-saleh, 2011; Kanawaty, 1992).

- Operation- shows the critical steps in a process, procedure, or technique. Generally, the material, product, or parts concerned is transformed during the operation process.
- Transportation- shows the unnecessary movement of materials, equipment or employees from one place to another. It incurs additional costs, and increases lead time.
- Inspection- shows an examination of the product for quality and/or check for the product's quality. It could be in-process or at the end of the production process quality inspection.
- Delay- shows a delayed sequence of events. It can be defined as an activity that occurs between two actions or an object that is placed aside temporarily without being recorded until it is necessary.
- Storage- shows a control under some form of authorization in which material is received into or issued from storage. This study uses a flow process chart to identify the VA and NVA activities of the case company.

As observed during the case company's field visit, most operators and machines worked slowly. Because of the slow operation of the conveyor, some employees were idle. Hence, speed is a worthy determinant factor in work-study for determining the process flow of activities at a micro-level. But the rate at which operators or machines operate was not mentioned by the literature in relation to work-study.

3.2.3 Lean metrics

Lean metrics are vital in value stream analysis and decision-making (Lacerda, Xambre, and Alvelos, 2016). These metrics are essential in VSM to identify and minimize or eliminate NVA activities. Takt time, cycle time, VA time, and lead time are the most necessary and standard lean parameters suggested by recent studies when applying VSM as a tool (Lacerda, Xambre and Alvelos, 2016; Rother and Shook, 1999; Seth, Sethi and Dhariwal, 2017; Behnam, Ayough and Mirghaderi, 2018).

Lead time - is the total time taken by the product to flow through all the processes, from start to finish. It is the time associated with completing an activity (Locher, 2008; Lacerda, Xambre, and Alvelos, 2016). Usually, value-adding is less than cycle time, which is less than lead time.

Cycle time - is the time between repetitions of similar tasks. It shows how often the production method completes the product (Rother and Shook, 1999). Hence, cycle time is determined by all operations of the slowest station of the production process.

Value-added time - is the time taken to perform an operation that adds value to the product based on the value defined by the customer. (Lacerda, Xambre and Alvelos, 2016; Rother and Shook, 1999).

Takt time - is the amount of time required to produce a product to meet the available customers' demand. It is used to synchronize the production rate with sales speed (Lacerda, Xambre, and Alvelos, 2016). Takt time can be calculated using:

$$Takt\ time = \frac{Available\ working\ time\ per\ shift}{Customer\ demand\ rate\ per\ shift}$$

(Rother and Shook, 1999). It shows the rate at which the customer is buying the product.

3.3 Methodology

This study follows a methodology called a single case study approach, as reported by Ben Alaya (2016) and shown in Figure 3.1. A case study is best whenever a researcher aims to reveal the future of similar large-scale phenomena and wants to know really what happens in an organization and how the process leads to results by studying a single unit intensively (Gerring, 2004; Muñoz-Villamizar et al., 2019). In the operations management field, case studies are extensively utilized as a practical technique for evaluating the applicability of tools and methods aimed at enhancing the performance of firms (Kitchenham, Pickard, & Pfleeger, 1995). Therefore, a case study allows the researcher to get an in-depth understanding of what happens really in a company and how processes lead to outcomes (Gillham, 2000). And a case study can be used to extend and test a theory (Yin, 2003; Eisenhardt & Graebner, 2007), which is the need for this study.

For conducting the case study, a suitable organization has been identified. Relevant data are collected from the documented production file and the selected case company's shop floor using a stopwatch and informal interview. Then, time and motion studies are followed to develop the standard time for each activity and identify the VA & NVA activities. After making the desired observations and computations: CSVSM was developed, different improvement proposals were identified, and FSVSM was developed. In developing the VSM, there are two phases. The first phase is the current state map, which shows the "as-is" status of the material and information flows in the production system. The future state map (FSM) is the map that shows the future level of the organization with improved results.

3.3.1 Development of current state value stream mapping (CSVSM)

According to Shou et al. (2017), the first step to developing the CSVSM is identifying the product family. Next, by studying each process's activities' information and materials flow, the existing state VSM is plotted. Then from the CSVSM, VA & NVA activities are identified. Finally, the types of waste and bottleneck are discovered via time study, motion study, observations during the actual production process, and comprehensive discussions with managers and supervisors.

3.3.2 Future state value stream mapping (FSVSM)

VSM aims to identify waste causes and then eradicate them through the use of FSVSM, which may be implemented quickly. The aim is to create a production chain in which different processes are linked to their respective clients. Thus, each process gets as close as possible to produce only what customers need when they requisite it (Rother & Shook, 1999). As a result, each process strives to provide only what clients require at the time they require it.

To design the FSVSM, Rother & Shook (2003) propose eight steps:

i) Calculating takt time

ii) Deciding to use supermarket or sending finished goods to customers

iii) Determining where to use continuous flow

iv) Choosing where to use a supermarket pull system

v) Determining location for pacemaker

vi) Considering to level the production mix

vii) Determine the rate of movement at pacemaker

viii) Identify the required improvements.

However, the strategy of implementing the future state depends on particular desires related to the type of waste to be reduced. Therefore, planning what actions to execute and what kind of a waste to reduce is a decision that influences the successful implementation of LM and their sustainability & obstacles (de Souza & Carpinetti, 2014).

However, the approach for executing the future state depends on specific desires relating to the sort of a waste to be eliminated. As a result, deciding what steps to take and what types of waste to minimize has an impact on the successful implementation of LM as well as their long-term sustainability and obstacles.

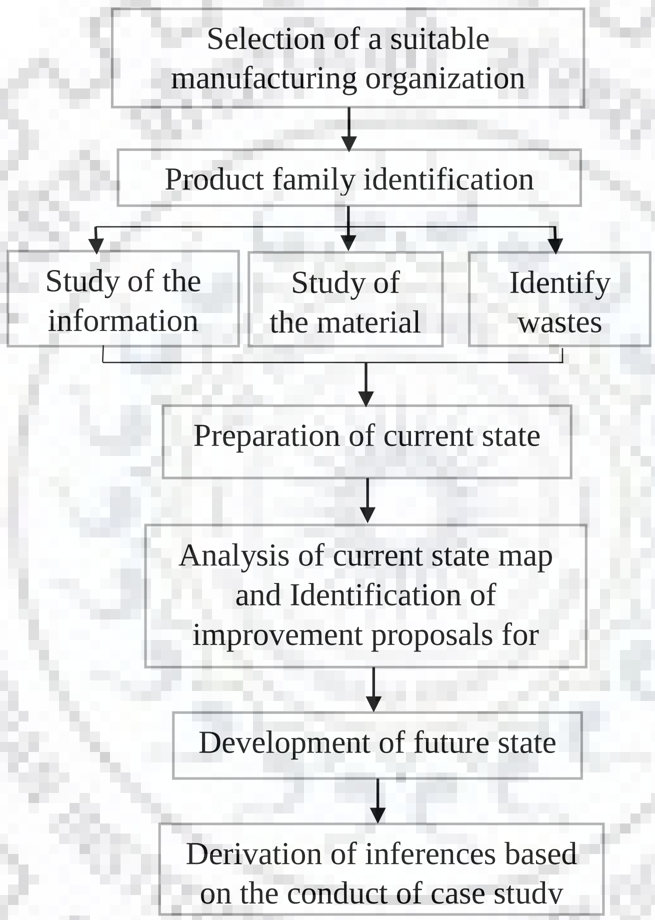


Figure 3.1 Research framework

3.4 Case study

3.4.1 Overview of the case company

The case company produces various types and models of leather shoe products. It is one of the well-known leather shoe manufacturing organizations in Ethiopia. It was established in 1939 and has more than 70 years of experience in leather shoemaking for local and global markets. The firm started to export shoes, in small quantities, in the early 1980s. It purchases the leather from local tanneries and other raw materials from abroad while using imported or its sole. And currently, it has 870 total employees.

Some of the operations performed to manufacture a typical leather shoe are:

- Cutting section

In this section the upper part of the shoe so called ‘upper’ is manufactured. Hence, upper cutting, lining cutting, and material cutting are performed. Different footwear components are cut as per the approved design and size. Trimming and shaping leather components to indicate where stitches should be placed is part of this process. The leather components are cut from the leather material using a die cutting machine. Cutting of leather to different shoe components is done by modern hydraulic presses with swing arms using moveable shaped knives (see Figure 3.2).

Figure 3.2 Leather cutting machine

- Preparation section

Insole preparation and sock lining preparation are performed in this section. It is performed in parallel with the cutting section.

- Stitching section

In stitching section, the upper components which are the outputs of the cutting section are assembled. It is equipped with sewing machines, which are designed to handle thick materials, different shapes and specialized types of stitching (see Figure 3.3). Stitching machines such as flat bed, post bed, zigzag, and eyeleting are used to assemble the various components of the upper parts of shoes. some of the operations performed in this section are stitching, trimming, folding, back part molding, back height fixing.

Figure 3.3 Upper stitching operation

- Lasting section

The uppers are moulded and shaped into the finished form on a wooden or plastic pattern called a 'last' in this stage, which is why it's called 'lasting'. A last is a hinged wooden or plastic block having similar shape as foot and used continually to produce more shoes. The closed upper, which comes from the stitching section, the insole and the bottom components are brought together to construct the shoe either by stitching, or with adhesive (see Figure 3.4). The completed uppers now need to be molded into a foot shape using a last. Different operations are performed in this section like roughing, heating and pressing, cooling, cleaning (spraying), inspection.

Figure 3.4 Lasting operation where sole, uppers and last are loaded

- Packing

This is the last section next to lasting. Some of the operations performed in section are shoebox making, tagging, and packing. The overall flow of the manufacturing operation process is shown in Figure 3.5)

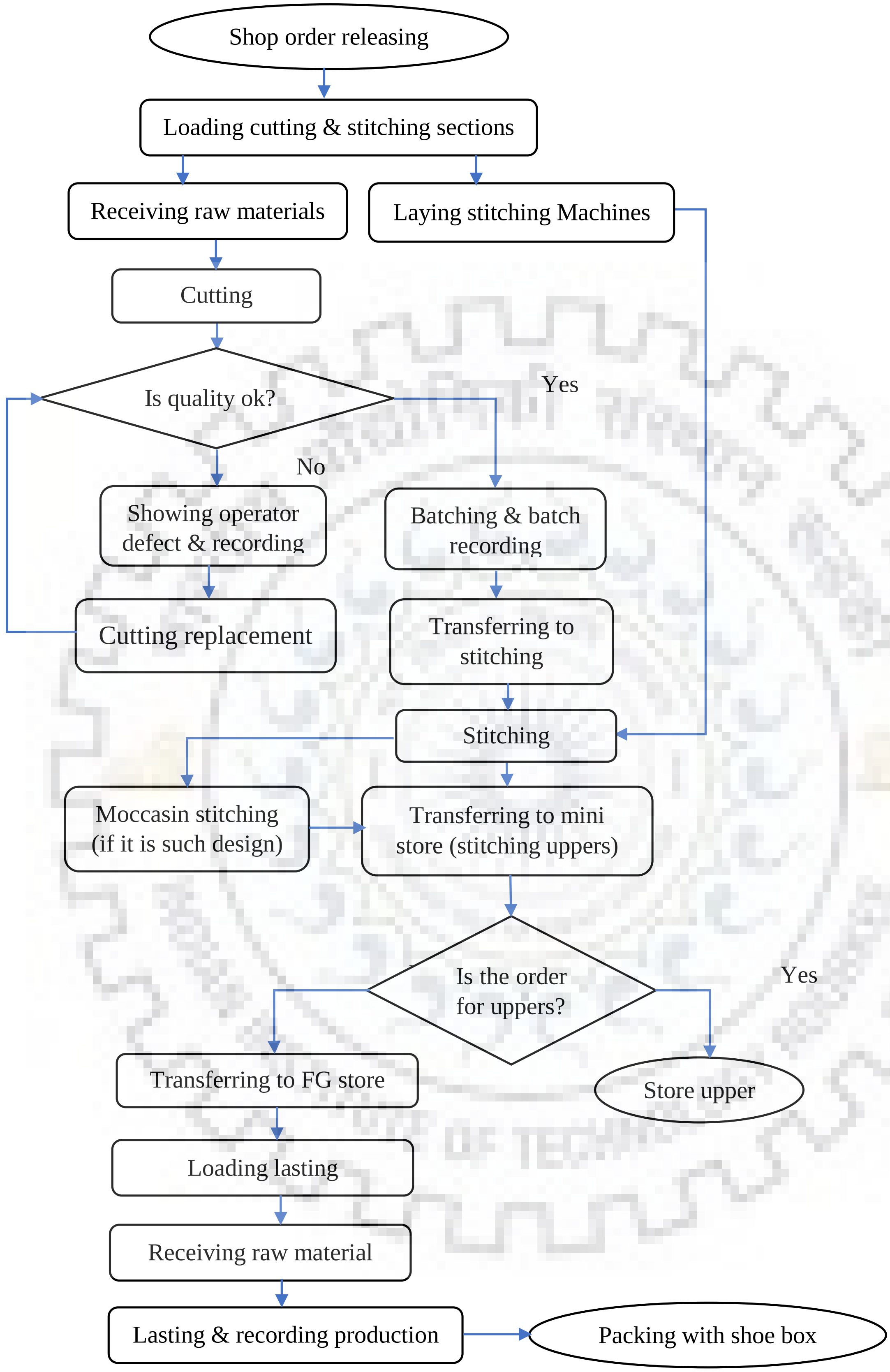


Figure 3.5 Operation process

3.4.2 Data collection and analysis

To describe the current state of any production process data is a vital input. Hence, data from the case company were collected using direct observation, informal interviews, and the factory's documented production file. According to Rother and Shook (2003), Lacerda et al. (2016), and Locher (2008), identifying and selecting specific product families is the first step in VSM.

Hence, to be focused and understand the production process in-depth, the researchers first select the product family. Criteria like Product type (Model), number of components, number of operations, number of workers, and customer type (local/export) are used as a criterion to identify the product family. Considering twenty product models SAWA model is selected for this study. SAWA model consists of the highest number of components, the highest number of operators involved, long processing time, many operations, and local and export orders. In addition to this, which the researcher makes motivated, this model has a more complicated manufacturing flow than the other models. And a detail time study and motion study is conducted to determine the current state of the standard time and to identify the VA and NVA activities. The result of the analysis for the current state is summarized as shown in Table 3.1.

Table 3.1 Summary of current state data (SAWA model)

Process Name	Cycle time	Change over time/month	Capacity (pairs)	WIP inventory	Average Waiting time	Uptime %
Cutting	16.2 min	20 min	50-150	850	4 days	98
Insole preparation	3.7 min	15 min	50-200	750	4 days	98
Stitching	156 min	465 min	65	1800	3 days	85
Sock lining preparation	4.6 min	25 min	100	899	3 days	85
Lasting	54.48 min	25 min	65	1500	3 days	88
Packing	2.2 min	-	2,800	-	2 days	100
Storing	120 min	-	122,000	-	11 days	100

In one shift, there is a working time of 9 hours. Therefore, one shift's working time is 465 minutes, which is required for the current VSM. Working days per year = 277.5 days, working days per week = 5.5 days, working hours per day = 9 hours, the number of shifts per day = 1. Break time - tea break time 15 minutes & lunchtime 1 hour = 1 hour & 15 minutes. Therefore, available working time = 9 hrs -1 hr & 15 minutes = 7 hrs and 45 minutes = 465 minutes = 27,900 Sec. and an average batch size =1,000 pairs of leather shoes. Therefore, the company has an available working time of 465 minutes (27,900 Sec.) per day. Normally, the company's batch size is 1,000 pairs. But based on availability of last and order quantity, the total batch size is subdivided into small sub-batch sizes ranging from 10 to 13 sub-batch sizes. These sub-batch sizes include all ordered sizes and colors.

Working days = 277.5 days/year; Average demand = 15,501 pairs/year; Available time = 465 minutes/day = 27,900 Sec./day

$$Average\ demand = \frac{15{,}501}{277.5\ days} = 56\ pairs\ of\ shoe/day$$

$$Takt\ time = \frac{Available\ time}{Average\ demand} = \frac{465\ min/day}{56\ pairs\ of\ shoe/day} = 8.3\ min$$

Takt time shows that customer is demanding this product at a rate of one every 8.3 minutes. It is the target rate for producing a product and its components.

The cutting, insole preparation, sock lining preparation, and packing station produce the product with a cycle time near the takt time. Nevertheless, the stitching and lasting stations have a big difference with the takt time. Hence these two stations are identified from the CSVSM in which attention should be given for further improvements.

3.4.3 Current state value stream mapping (CSVSM)

Based on the approaches recommended by Rother and Shook (1999), the data for developing CSVSM is collected. And time study in seconds was performed using a stopwatch to determine each activity's average observed time. After gathering five observations for each activity, average observed, normal, and standard times are calculated. The data collection process was also supported by taking pictures and recording videos during the actual production process. Then, the cycle times were determined. And process flow chart (using the standard symbols for storage, transportation, inspection, operation, and delay) was used to identify the VA and NVA activities.

Data were collected, starting from customers to raw material suppliers and all ways to the footwear manufacturing process. Data gathering includes the number of shifts, number of workers, processing time, changeover time, capacity, uptime, scrap rate, and inventory levels. Key performance indicators of lean metrics were adopted in the process analysis from the available literature (Lacerda, Xambre, and Alvelos, 2016; Singh and Sharma, 2009; Rother and Shook, 1999; Behnam, Ayough, and Mirghaderi, 2018) are adapted. To develop the existing VSM the organization is visited frequently. Frequent industry visits made it possible to study the operations of each activity in depth. The machines are arranged in their proper order. But WIP is stored here and there within the working areas.

Before and after every workstation, WIP is stored for a long time, which holds unnecessary spaces. The current state VSM is developed, showing the flow of information and products between workstations, as shown in Figure 3.6. The numbers inside the small boxes of the map represent the number of workers at each workstation. Each process has a data box below, containing the cycle time, change over time, batch size, capacity, scrap rate percentage, and uptime percentage. Data are collected from the case company by walking on the shop floor and asking the supervisor and operators at each workstation. The cycle and change over time are all based on the time study of each micro activity. There is one inventory triangle ahead of each process, only for SAWA products, but the total inventory is higher than shown in Figure 3.6. The stitching section is drawn slightly above the other process sections, indicating it is located one floor up. After gathering all the information and material flows required to map the CSVSM, they are connected as indicated by arrows on the value stream map, representing how each workstation receives its schedule from production planning and control. Hence, the total lead time is 14 days & 348.88 minutes, and the total cycle time is 228.88 minutes.

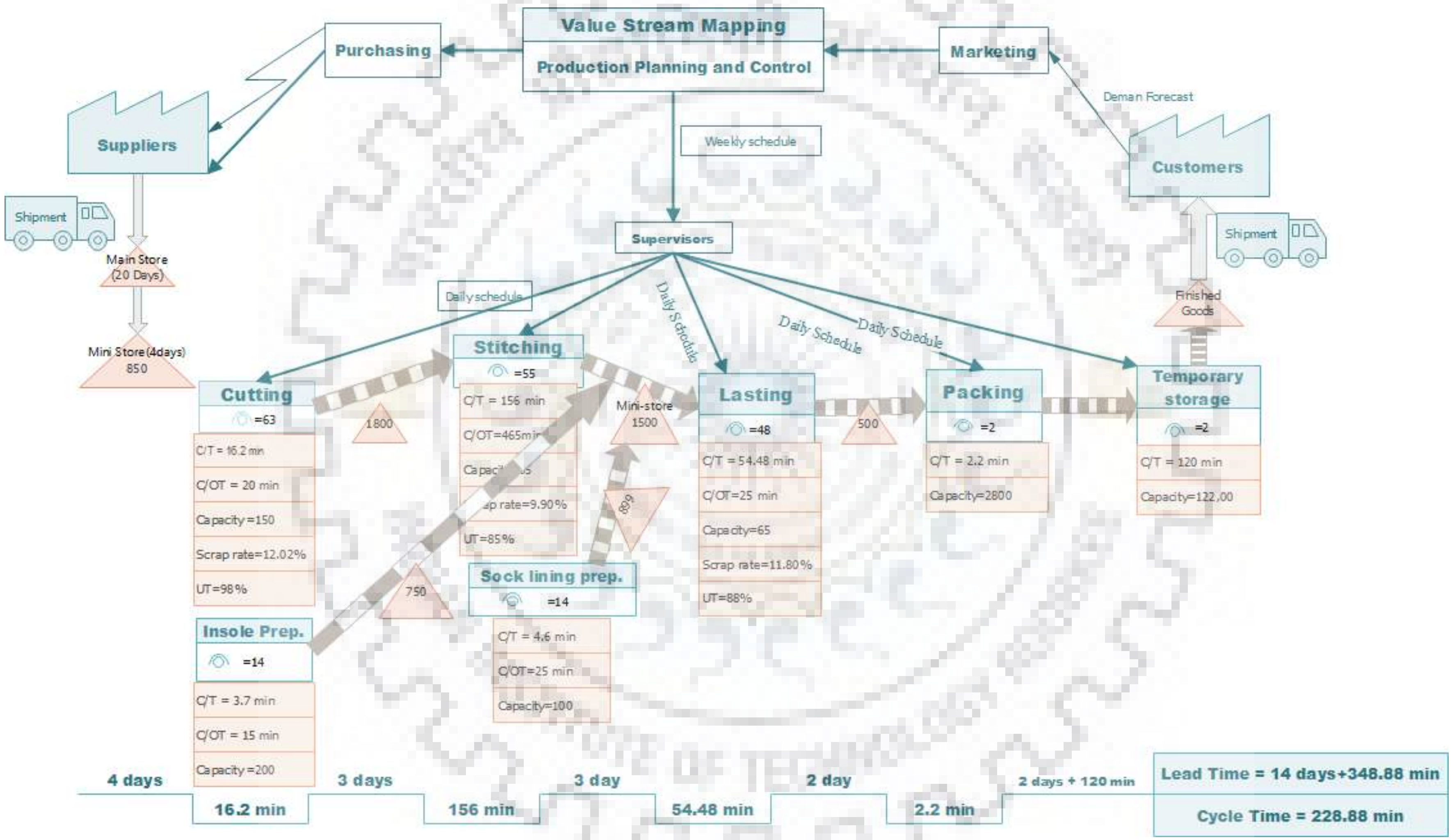


Figure 3.6 CSVSM

3.4.4 Identification and analysis of wastes

The CSVSM of the case company manufacturing process shows that some wastes are present in the process flow of the case company's production system. At the bottom of the current VSM, the time and step-line are shown in the VA and NVA steps. The main wastes are usually investigated by VSM, while unnecessary transportation and motions are identified in depth by using motion study at a micro activity level. As a result, long lead times, long cycle times, high WIP, long waiting times, unnecessary transportation, long change over time, un-efficient use of human resources, and rejection & rework are identified. Hence all these problems lead to long lead times; this study focuses on reducing lead times. In addition to this, the VA and NVA activities are identified by studying in detail the production processes using the motion study for each activity at a micro-activity level, starting from customer order requests to the storage of the end product. Motion study has been conducted at a company level using the five standard process flow chart symbols for the selected product family in a single process line. A total of 127 micro activities was analyzed using a motion study. As a result, only 13% of the total micro activities are VA activities, while the other 87% are NVA activities. This 87% NVA activity includes the necessary NVA activities. In terms of time taken, 55,920 seconds are NVA activities, and 27,900 seconds are VA activities. This indicates that the company is spending much time fulfilling the requirements before the actual production process starts, which is a very long order fulfillment process. Though the number of VA activities exceeds the number of NVA activities, their overall time taken percentage is significantly less, only 13%. Hence the case company is spending much of the time performing NVA activities.

3.4.5 Future state value stream mapping (FSVSM)

Based on the lean concepts, the real power of VSM lies in creating the FSVSM (Locher, 2008). Though many problems were identified using the production process's CSVSM and flow process chart, it would not be possible to solve all these problems once. It is because of time and budget constraints. Hence this study is focused on cycle time and lead time reduction to improve the performance and productivity of the low-level technology organization. The following solutions are proposed for the problems identified in this study using VSM and flow process chart: line balancing, kaizen, installing a conveyor system between work stations & plant layout modification, and lean implementation.

Line balancing- According to Garoma & Nahom (2014), the assembly line balancing problem is an essential aspect of a manufacturing system. It's an issue of allocating different activities or jobs to different workstations while increasing one or more objectives without breaching any process constraints. It must be constructed in such a way that the product's manufacturing rate is sufficient to meet demand. This rate of production must be translated into cycle time (Groover, 2015).

Kaizen- is a slight but continuous and sustainable improvement throughout the organization (Goshime, Kitaw, and Jilcha, 2018). It has never-ending action since there is always a better way of doing things.

Installing conveyor between work stations & plant layout- This needs to design the plant layout suitable for the production system. The speed of the conveyor system should consider the workers' skills. Overall it requires a lot of time and a huge budget to implement it.

Lean implementation- is the implementation of lean tools. These tools mentioned by (Vamsi and Sharma, 2014; Bhamu and Sangwan, 2014; Jastia and Kodali, 2015; Singh and Sharma, 2009) are 5s, just in time, TPM, VSM, Kaizen, total quality management, cellular manufacturing, etc. Implementing these tools and techniques at the company level needs a lot of time and a considerable budget.

From the proposed solutions, implementation of lean using VSM and line balancing is selected. This is because the other proposed solutions need time and budget compared to VSM and line balancing. In addition to this, line balancing can be implemented by taking a single production line as a pilot test without interrupting the production process. After studying each activity's time study and determining each activity's cycle time, a bottleneck operation was identified. For these bottleneck operations, practically line balancing between activities within the workstations was performed. It was performed practically on the shop floor. Some of the methods used are: combining similar activities, changing the sequence of operations, adding and reducing the number of operators, making the operators help each other, increasing the performance of the operators, mixing skilled operators with unskilled operators, assisting operators from exceeding operator, and making controlled & continuous supervision.

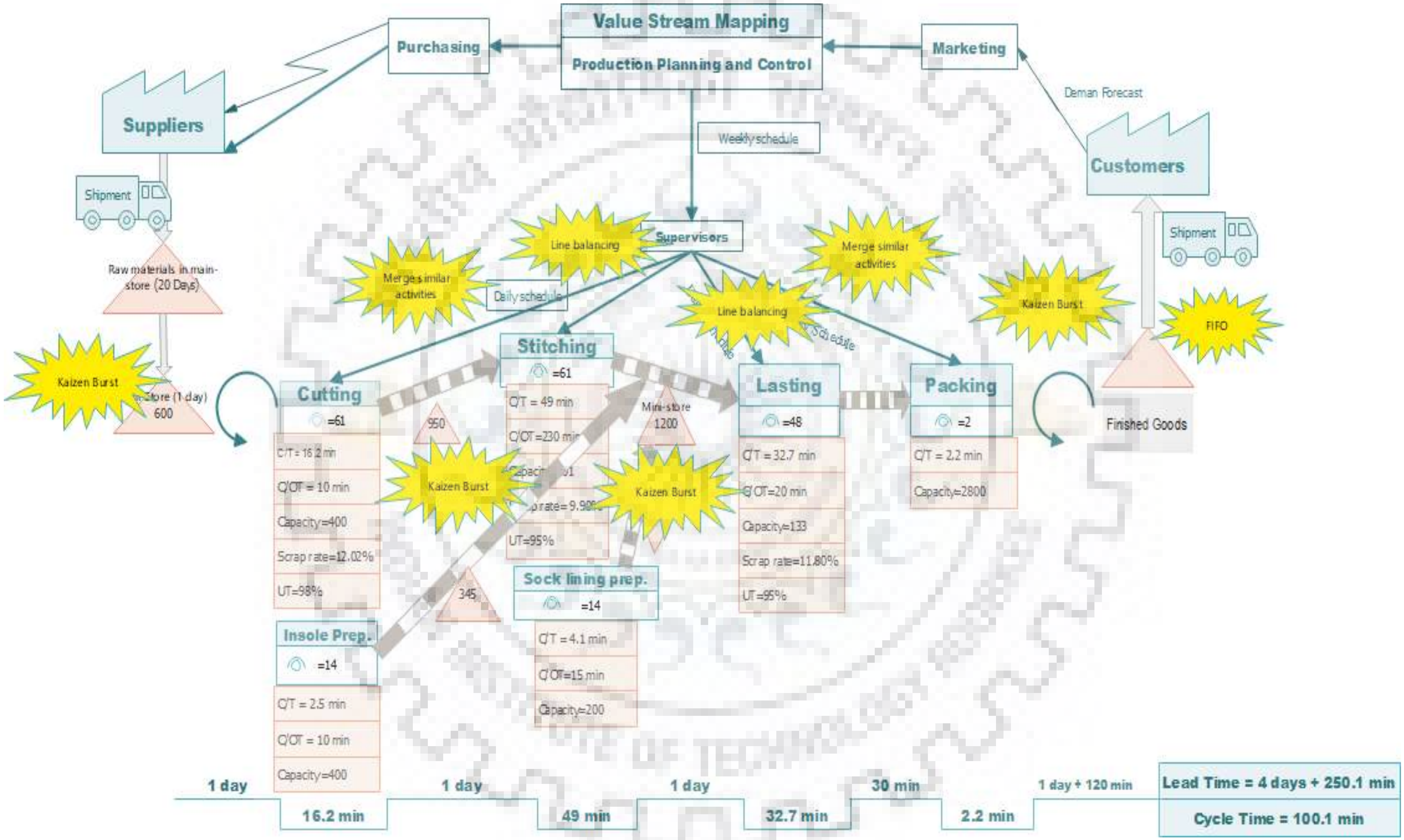


Figure 3.7 FSVSM

Langstrand (2016) also recommended such a method in creating the future state VSM to balance the production process lines and reduce cycle time. As a result, reduction of cycle time, improvement in changeover time, and reduced work in process inventory (WIP) are obtained, as shown in Figure 3.7. Therefore, the total lead time is four days and 250.1 minutes, and the value-adding or the total cycle time is 100.1 minutes. In packing section, the cycle time is 2.2 minutes. The reason why there is no improvement is that during the industrial visit it was observed that this time is the optimal time and its improvement will not bring a significant change to the overall lead time. Additionally, when many products are produced continuously it uses temporary labor forces to compensate it.

3.5 Results and discussions

The data analysis result shows that VSM is a promising lean tool in identifying waste and bottlenecks where practitioners should focus on improvement potentials. It is also a crucial tool in making productivity improvements by giving opportunities to reduce waste. The comparison of the current and future state is presented in Table 3.2. This is a promising improvement obtained from the case company. This is also evidence that VSM is a powerful technique for mapping the process flow, identifying the wastes, and showing improvement potentials in low-level technology organizations that are labor-intensive. Suppose it is implemented correctly in all the process lines, value chains, and sectors. In that case, a considerable amount of waste can be identified, reduced, and increased productivity by reducing the total cycle times and lead times. In doing so, the export performance of the sector will increase. As a result, total cycle time and lead time have reduced from 228.88 minutes to 100.1 minutes and from 14 days & 348.88 minutes to 4 days & 220.1 minutes, respectively.

Table 3.2 Comparison of the current state (CS) and future state (FS)

	Performance indicators											
	Cycle time (min)		Changeover time (min)		Capacity (pairs)		WIP (pairs)		Waiting time (days)		Up time (%)	
Process name	CS	FS	CS	FS	CS	FS	CS	FS	CS	FS	CS	FS
Cutting	16.2	16.2	25	10	50-150	400	850	600	4	1	98	98
Insole preparation	3.7	2.5	15	10	50-200	400	750	345	4	1	98	98
Stitching	156	49	480	230	65	101	1800	950	3	1	85	95
Sock lining preparation	4.6	4.1	30	15	100	200	899	800	3	1	85	95
Lasting	57.5	32.7	25	20	65	133	1500	1200	3	1	88	95
Packing	2.2	2.2	-	-	2,800	2,800	-	-	2	-	100	100
Storing	120	60	-	-	122,000	122,000	-	-	11	-	100	100

The critical operations are stitching and lasting stations. A significant improvement in cycle time reduction was obtained using line balancing in these workstations, i.e., reducing cycle time from 156 minutes to 49 minutes (stitching station) and from 57.5 minutes to 32.7 minutes (lasting station).

3.5.1 Assembly line balancing

The Assembly line balancing problem (ALBP) is allocating different activities or jobs to workstations while improving one or more objectives without breaching any constraints performed on the assembly line. It helps the organization to allocate and use the available resources effectively and efficiently. Resource optimization is one of the issues that should be addressed through assembly line balancing. As a result of the implementation of assembly line balancing in the case company, a 56.3% reduction in total cycle time and a 69.7% reduction in lead time are obtained.

3.5.2 Pull system & FIFO

Pull system implementation helps decision-makers control the flow of resources. This allows the organization to make standards scheduling demand forecasting and buying raw materials based on customer demand. It is a crucial tool to reduce the company's high level of WIP and finished product inventory. A pull system follows FIFO to dispatch the products to the customer at the intended time. It ensures the organization not to store products for a long time and uses the available resources & storage space efficiently. It maintains the cleanness of the workplace and increases the satisfaction of the employees. The reduction of inventory level is one means of increasing the productivity of the organization.

3.5.3 Implications

Nowadays, because of the increasing competition, managers realize that cost reduction will create a circumstance for reducing price, which indirectly will help companies compete in the market. In addition to this, performance and productivity improvement are critical issues to be addressed by the case company. This can be achieved using LM tools to identify and eliminate waste. Managers, on the other hand, have difficulty identifying the most promising waste-reduction opportunities. In order to solve such a problem, VSM is a potent LM tool to map the information and material flow. Therefore, the current status of the manufacturing system can be mapped and analyzed for waste elimination using VSM. This study illustrates how managers and practitioners can use VSM to identify the potential improvement areas and eliminate waste. This study shows that waste such as WIP, waiting time, and unused workforce can be reduced, which can also reduce the cycle & lead times. And this, in turn, improves production time and productivity. Hence, managers can use VSM to visualize the current level of waste present within the organization and the possibility of eliminating them.

3.6 Summary

This chapter presented Phase I of the research. It involved the identification of waste, bottleneck operation, and the potential improvement areas of the leather industry of Ethiopia. To identify the waste & bottleneck operation the current state of VSM was developed by studying the information and materials flows. Then by identifying the improvement potential areas and experimenting the proposed alternative solutions, the future state VSM was developed. According to the findings, the industry should be committed to designing an improvement action plan to improve the performance and productivity of the organization by implementing LM tools like VSM. The finding revealed that waiting, transportation, and inventory are identified as the top three most critical waste that consumes the organizations' resources.

Consequently, the next chapter presents Phase II of the research. It provides an understanding of the manufacturing system dynamics, keeping the results of phase I as input for phase II. Mainly data were gathered from the shop floor workers and using stope watch during the actual production process in the leather industry of Ethiopia. The research aims to study the leather industry, with a particular focus on footwear manufacturers.

CHAPTER 4

PERFORMANCE ANALYSIS OF THE FOOTWEAR MANUFACTURING ASSEMBLY LINE: A CASE STUDY USING VALUE STREAM MAPPING-SIMULATION MODELING (VSM-SM) (PHASE II)

4.0 Overview

This chapter presents Phase II of this research. In phase I, wastes within the manufacturing process were identified by studying the information and materials flow. In this regard, VSM is a powerful LM tool to map a manufacturing process's information and material flow. This helps to identify wastes and the most promising waste-reduction opportunities. However, VSM is limited to the static nature of the production system. Hence to compensate for the deficiency of VSM, this chapter focuses on the integration of VSM and simulation modeling. Arena simulation software is used in the footwear manufacturing industry to analyze the current performance and identify 'what-if' alternative improvement options for the modeling and simulation part. Phase III focuses on decision-making on the selection of LM tools. A systematic fuzzy QFD and FMEA approach is proposed to prioritize the critical resources and sub-elements of the failure modes.

4.1 Introduction

In today's globally competitive world market, any business's survival depends on its capability of competitiveness. Manufacturing industries must measure and analyze the performance of their manufacturing systems to compete in the global market. It helps them make immediate improvement decisions to improve their manufacturing system performance to increase their export level and increase their throughput, resource utilization, on-time delivery, etc. According to Jilcha (2015), globalization, increasing world competition, and customer expectations influence companies to pursue strategies to improve their performance and reduce costs. Competitiveness mainly depends on production cost, response time, market price, and flexibility (Garoma & Nahom, 2014)

Hence, the increasing demands for throughput improvement, cost reduction, and optimal allocation of resources have motivated research in manufacturing systems' modeling and performance analysis. It is a critical concern, especially for developing countries' manufacturing industries with labor-intensive low-level technology organizations like Ethiopia. The leather industry is one of the world's major industries, and the footwear industry is a substantial one within the leather industry's supply chain. The manufacturing processes of a typical footwear process can vary depending on the shoe's material usage and model. Generally, the manufacturing process of footwear is divided into five main phases. These are the designing, cutting, stitching, lasting, and packing stages. The most critical stages are stitching and lasting since they generally involve many operations. Ethiopian leather industries have vast amount of resources, but their export performance contribution compared to their resource availability is negligible (Ashebre et al., 2013; Mekonnen, 2008). The export performance of the footwear manufacturing industries is also stagnating below average. From 2013 to 2018, footwear producers performed, on average, only 35.9% of the planned export value (LIDI, 2019).

Hence, performance analysis & modeling is required to enhance the throughput of the leather industry. It is challenging and costly to stop the manufacturing industry's production system and test different performance improvement scenarios in the real-world manufacturing system. Hence, Said and Ismail (2014) revealed that simulation modeling is an appropriate way to represent real-life situations to enhance system performance in terms of productivity, cycle time & lead time, queues, resource utilization, and identify bottlenecks. In many fields, Discrete-event simulation (DES) modeling is a powerful tool for identifying and answering questions about the effects of changes on production processes. Specific operations-related problems have been answered by DES models (Prajapat and Tiwari, 2017). Simulating the manufacturing system using software is one of the best methods to analyze the manufacturing systems' performance and resource utilization. Though VSM is also the crucial tool in mapping the manufacturing processes' material flow and information flow, to visualize the production process, it will not show the dynamic nature of the manufacturing processes. It only shows the static view of the manufacturing process. To compensate for the deficiency of the VSM, integrating VSM with simulation will provide the static and dynamic nature of the manufacturing system. In addition, simulation is not costly in experimenting with the proposed solutions before implementing the proposed alternative scenarios into the existing manufacturing system.

Hence, to compensate for the deficiency of VSM, this study uses the integration of VSM and simulation modeling using Arena software in the footwear manufacturing industry to analyze the current performance and identify 'what-if' alternative improvement options.

4.2 Performance Analysis using lean-simulation modeling

In the 1950s, Japanese manufacturing industries have faced the problem of human resources, financial resources, and less space availability (Vamsi and Sharma, 2014). At the end of World War II, Taiichi Ohno, Toyota's executive, developed the Toyota Production System (TPS) in the automotive industry to solve the mentioned problem. Its focus was on products' quality and variety, unlike Henry Ford's mass production (António, 2016). According to (Goshime et al., 2018), the lean principle can be characterized by "doing more with fewer resources." It can be achieved using the available resources effectively and efficiently. As revealed by Atieh et al. (2015), lean manufacturing (LM) philosophy aims to eliminate NVA activities (wastes) from all the processes. Reducing waste helps organizations do the right task at the right time and in the right quantity to maintain continuous process flow (Chaurasia, 2019). VSM is a crucial lean tool in identifying opportunities for improvement and eliminating these wastes. Mainly it is used for analyzing, implementing, and maintaining lean approaches. The overall aim is to observe the flow of materials and information from the beginning of raw materials to the finished end product (Forno et al., 2014). It is a powerful tool in highlighting process inefficiencies, transactional & communication mismatches, and guiding the improvement (Meudt et al., 2017; Rother and Shook, 1999). It also helps visualize, understand, and document the materials and information flow through the value chain (António, 2016). Though VSM is the crucial tool in mapping the manufacturing processes' material and information flow, it will not show their dynamic nature. It only shows the static view of the manufacturing process. To compensate for the deficiency of the VSM, integrating VSM with simulation will provide a static and dynamic view of the manufacturing system. In addition to this, simulation is not costly in experimenting with the proposed solutions before implementing into the existing manufacturing system. Simulation-based VSM case study in the healthcare center has been reported by (Doğan and Unutulmaz, 2016) to evaluate and improve their efficiency.

As Negahban (2014) revealed, DES is a flexible tool that allows users to evaluate different options of system configurations and operating strategies to help in decision-making in the manufacturing process and see what happens before applying various alternatives into the real manufacturing system. Negahban and Smith (2014) revealed that DES is one of the most commonly used techniques for analyzing and understanding production systems' dynamics. It is also a crucial tool for gaining an in-depth understanding of a system to improve performance

(Omogbai and Salonitis, 2016). DES modeling is applicable in both the manufacturing and service industries. Regardless of the field of application, DES modeling is typically used to generate alternative solutions to find the best alternative that optimizes resource utilization (Rahman et al., 2018). It helps to increase the throughput of the industries. Some of the advantages of DES are:

- the opportunity to discover new operating processes, policies, information flows, decision rules, organizational methods, etc., without disturbing the actual system's ongoing processes.
- testing new hardware designs, transportation systems, hypotheses, physical layouts, etc. before purchasing the existing resources.
- obtaining insight into the interaction of variables and the significance of variables to the system's performance is possible.
- to perform bottleneck analysis.
- plays a significant role in understanding how the process operates.
- the possibility to evaluate 'What-if' scenarios (Daaboul et al., 2014).

DES has been applicable in the modeling and optimizing of complex manufacturing systems and assembly lines. Thus, it can answer key operational questions relating to resource utilization, resource allocation, throughput, and supply & demand (Prajapat and Tiwari, 2017). Arena simulation software is the world's leading discrete event simulation software and has been used by DES practitioners or researchers. To mention some of the various applications of DES are: to measure the performance of the supply chain (Yassine et al., 2019), to model flow of aluminum brake bracket (Neeraj et al., 2018), to evaluate and predict the performance of variable production line (Li et al., 2018), and to analyze the performance of vehicle assembly line (Sarda and Digalwar, 2018). And Atieh et al. (2015) use VSM and simulation hybrid to identify the glass industry's primary and secondary bottlenecks. Hence integrating VSM and simulation gives better decision-making opportunities by making the VSM dynamic (Atieh et al., 2015; Andrade et al., 2016). To the best of the authors' knowledge, analyzing a footwear assembly line's performance to maximize the throughput and minimize the waste by utilizing the available resources efficiently and effectively using VSM-SM has not been given attention in the literature.

4.2.1 Assembly line balancing problem (ALBP)

The line balancing problem is one of the essential features of manufacturing systems. ALBP is assigning different jobs to workstations while optimizing one or more objectives without violating any constraints imposed on the line. Over the past decades, ALBP has been one of the research fields due to its applicability to different areas such as electronics, garment, and footwear industries (Garoma & Nahom, 2014; Chen et al., 2012).

As reported by (Groover, 2015; Garoma & Nahom, 2014), the assembly line must be designed to attain the intended production rate (R_p) and enough to satisfy the production demand. Cycle time is the time at which the line operates. Hence the production rate must be changed to cycle time (T_c), taking into account some losses. In reality, some of the production time can be lost because of a lack of components required in assembly, occasional equipment failures, labor problems, quality problems, interruption of power, etc. As a result, the line will operate only for a specific time from the total available shift time. This uptime proportion is called line efficiency. The cycle time is determined by:

$$T_C = \frac{60E}{R_P} \quad (1)$$

Where: R_p = required production rate (units per hour); T_C= cycle time of the line (min/cycle); and E = line efficiency. The typical values of E range from 0.90 to 0.98 for a manual assembly line.

4.2.2 Measures of line balance efficiency

Practically it is almost not possible to get a perfect line balance. It is due to the variations in the minimum standard work element times and their precedence limitations among the work elements. But a given line balancing solution must be measured to show how good it is. Balance efficiency is one possible measure. Line balance efficiency is calculated using:

$$E_b = \frac{T_{wc}}{wT_s} \quad (2)$$

Where: T_{wc} = work content time (sum of the work element times); E_b = balance efficiency (in percentage); w = number of workers; and T_s = the maximum available service time on the line. Balance delay is one of the complements of balance efficiency. It shows the amount of time lost because of the lack of perfection in balancing and can be determined using:

$d = \frac{wT_s - T_{wc}}{wT_s}$………………………………………………………………………………………… (3)

Where: d = balance delay. A zero balance delay shows a perfect line balance.

$E_b + d = 1$………………………………………………………………………………………… (4)

4.2.3 Modeling and simulation with Arena

According to Garoma & Nahom (2014), modeling is the process of creating a model. The model, which is similar but simple to the real systems, represents the real-world manufacturing or service system. Simulation modeling aims to improve the process and service delivery using a computerized environment, testing different scenarios, and gaining immediate feedback about the proposed changes, which helps in decision making (Crema and Verbano, 2019).

In the 1980s, Rockwell Automation Company developed Arena simulation and automation software, which is a DES modeling software and a flow-oriented simulator. In Arena, the user creates a model by placing modules. The purpose of these modules is to represent processes in the user interface (Daaboul et al., 2014). Arena simulation software is broadly used to model and simulate manufacturing and service processes. It is used mainly to analyze the current performance and possible alternative working modes (Wang et al., 2009). Arena Rockwell simulation software is user-friendly and the most adaptable (Daaboul et al., 2014).

Moon (2017) revealed that simulation modeling has broad application areas in different sectors for decision-making and performance analysis, like manufacturing, health, agriculture, construction, energy, supply chain, urban and community planning, transportation, etc. Some of the simulation benefits are understanding the system, predicting the behaviors of a system, comparing different alternative solutions & plans before implementation, aiding decision-making processes, developing new tools, and training purposes (Moon, 2017). Model verification and validation are essential in modeling and simulating a manufacturing system (Garoma & Nahom, 2014). It has to be verified and validated before using a simulation model for different purposes. Verification is the process of confirming 'building a model right' that mimics the real-world process, and validation is a process of ensuring to 'building the right model.' Verification and validation check the model's internal and external consistency, respectively (Moon, 2017). In other words, verification is all about whether the software runs without any error or not, while validation compares the simulation output with the real system data. Verification evaluates whether the formal represented model is correct or not. This can be done by checking the computer code, test runs, and performing consistency checks on their statistics. And validation compares the model performance metrics obtained from the model test run to the existing systems under study (Kelton, 2015; Tayfur, 2007). Determination of the replication numbers is the other important feature of Arena simulation modeling. The individual results of the replication are independent and identically distributed. Therefore, forming a confidence interval for the truly expected performance measures is required, which is assumed sample mean (μ) across an infinite number of replications (Kelton, 2015). Therefore, it is determined using:

$$\mu = \bar{X} \pm t_{n-1,\ 1-\alpha/2} \frac{s}{\sqrt{n}} \quad (5)$$

where: $\bar{X}$= sample mean; μ= the assumed sample mean across an infinite number of replications; n= number of replications; $t_{n-1,\ 1-\alpha/2}$ = the upper $(1 - \alpha/2)$ critical point from Student's t-distribution with n-1 degree of freedom; s=sample standard deviation. A confidence interval of 95% (α =.05) is used almost in all arena simulation modeling (Rossetti, 2016; Garoma & Nahom, 2014). According to Christopher (2004), half-width confidence interval or standard error, h, can be calculated using the following formula:

$$h = t_{n-1,\ 1-\alpha/2} \frac{s}{\sqrt{n}} \quad (6)$$

4.3 Methodology

A literature review has been used as the first step to identify the gaps and opportunities. The literature review gives evidence to study VSM and simulation modeling integration to perform the performance analysis and experiment improvement scenarios of a manufacturing organization's assembly lines. As revealed by Ben (2016), this research uses a methodology called a case study approach, as shown in Figure 4.1. And a case study can be used to extend and test a theory (Yin, 2003), which is the need for this study. For conducting the case study, a suitable organization has been identified. Arena's built-in input analyzer is used to get the model's best distribution fit for the manufacturing processes' collected data. Arena simulation software has been used to model & simulate the manufacturing system and experiment with the improvement scenarios. And then the improved proposed model has developed.

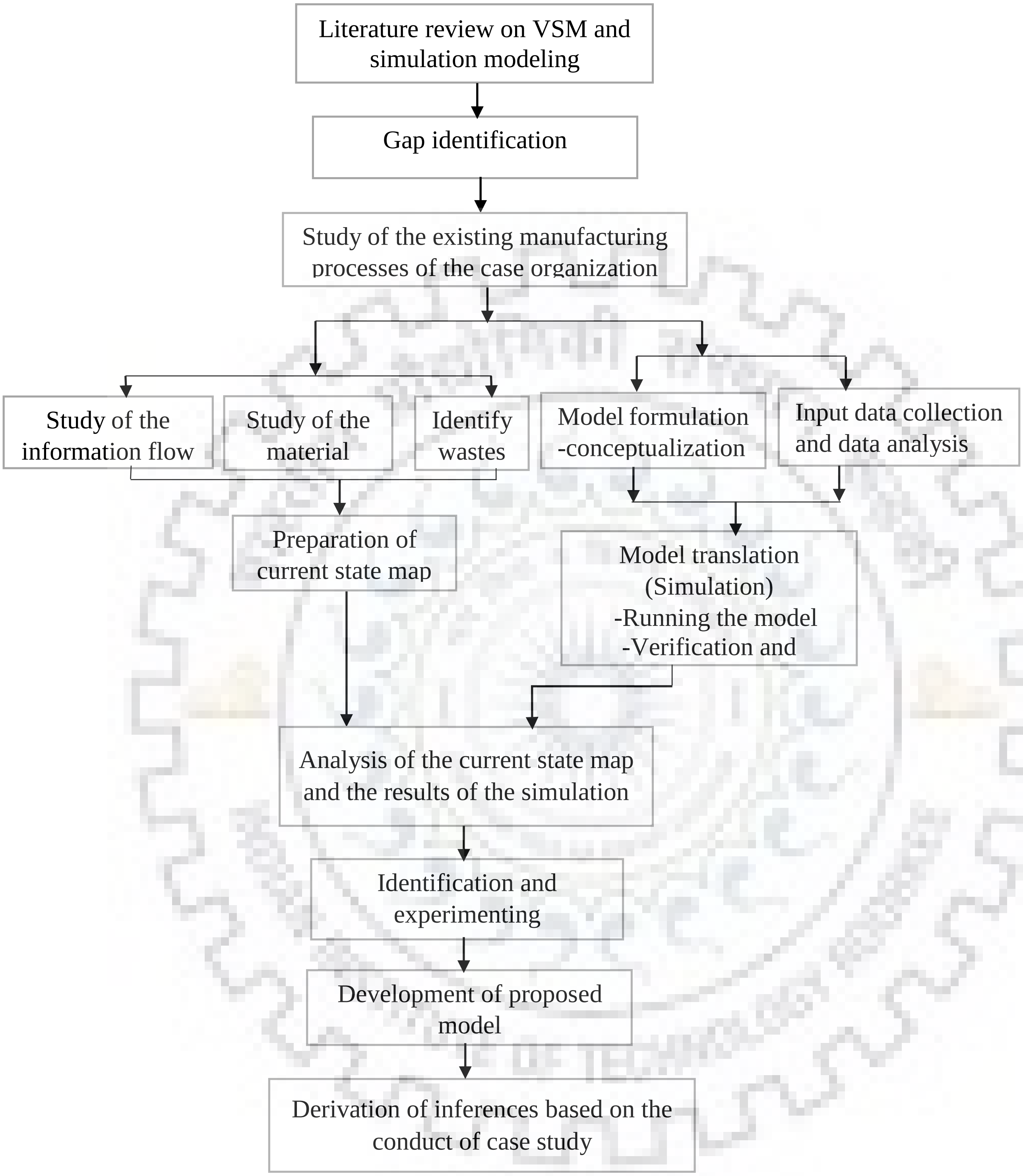


Figure 4.1 Research methodology.

4.4 Case study

4.4.1 Overview of the case company

The case company was established in 1939. It produces different types and models of leather shoe products. It is one of the well-known leather shoe manufacturing factories in Ethiopia. It has more than 70 years' experience in making leather shoes. It produces different types, sizes, and models of shoes for the local and export market. Some of the operations performed to manufacture a typical leather shoe are:

- Cutting (Upper cutting, lining cutting, and material cutting)
- Preparation (Insole preparation and sock lining preparation)
- Stitching (Stitching, trimming, folding, back part molding, back height fixing)
- Lasting (Roughing, heating and pressing, cooling, cleaning (spraying), inspection and
- Packing (shoebox making, tagging, and packing)

4.4.2 Data Collection and Analysis

According to Rother and Shook (2003) and Langstrand (2016), identifying and selecting specific product families is the first step in developing the VSM. Hence criteria like Product type (Model), number of components, number of operations, number of workers, and customer type (local/export) have been used to identify the product family. Twenty product models have been taken for computation, and as a result, the SAWA model shoe with 46 components total number is selected for this study. Then data are collected from the case company using stope watch, observation, and documented files. Time study (to develop the standard time for each activity) and motion study using process flow charts (to identify the VA and NVA activities) have been used. After studying the information flow, studying material flow, identifying the wastes, and making necessary observations & calculations, the CSVSM has been developed (see Figure 3.6).

The components to be assembled are listed in terms of parts as Toecap, Vamp, Tongue, Eye stays, Front quarter, Back quarter, Stripe, Heel counter, Heel stripe, Insole, Outsole, Vamp lining, Stiffener, Vamp reinforcement, Sock pad (sponge), and sock lining. These parts are assembled on stitching and lasting production lines. Hence, stitching and lasting assembly lines are the bottleneck operations within the production process with more significant cycle times. Thus the total number of 45 and 39 activities was identified for stitching and lasting assembly lines.

For the simulation part, data were collected from the existing production system using a stopwatch, informal interview, and direct observations during the actual production process. These data were related to the total number of tasks, the number of workers & machines for each activity, processing times of each activity, the time between arrival, conveyor speed & length, the distance between machines, production output, working hours, and defect rate. The input data's validity is increased by taking fifteen (15) numbers of data for each assembly line activity. The type of operation, machine tools & equipment, number of machines, number of workers, and the expression for the collected processing time are shown in Table 4.1 and Table 4.2.

Table 4.1 Statistical expressions for each operation of the **stitching** assembly line.

S. No	Operation type	Machines, Tools & Equipment	No. of		Expression	Squared error
			Machines	workers		
1	Loading	Table		1	NORM(36.1, 3.17)	0.025040
2	Marking vamp and stripe	Table		1	TRIA(76.5, 81, 84.5)	0.025966
3	***Marking back quarters***, front quarters, tongue and heel stripe	Table		2	90.5 + 10 * BETA(1.05, 1.15)	0.027354
4	***Skiving*** heel stripe, vamp tongue, French binding and stripe	Skiving machine1	1	1	76.5 + 9 * BETA(1.79, 1.4)	0.0917
5	***Skiving*** back & front binding for folding	Skiving machine2	1	1	47.5 + 8 * BETA(1.35, 1.38)	0.062343
6	***Skiving*** collar lining, quarter lining and tongue lining for skiving	Skiving machine3	1	1	NORM(54.9, 2.9)	0.017365
7	***Attach nylon tape*** at the edge of the back and front quarters	Table		1	125 + 10 * BETA(0.705, 0.696)	0.013542
8	Apply glue and ***Attach counter stiffener*** on the back count and attach toe puff on toe cap	Rotary coupling machine	1	1	65.5 + 6 * BETA(1.46, 0.827)	0.000846
9	***Folding*** around edge of back and front quarters	Folding machine	1	1	67.5 + 7 * BETA(1.22, 0.767)	0.059533
10	***Stitch tongue with vamp*** then attach nylon tape on it	PBSN machine1	1	1	68.5 + 4 * BETA(1.84, 1.48)	0.069015
11	***Stitch decorative*** stitch at center of vamp and tongue	PBDN machine1	1	1	53.5 + 6 * BETA(1.07, 1.1)	0.026694
12	Apply glue and attach toe cap on the vamp	Table		1	66.5 + 9 * BETA(1.37, 1.25)	0.012030
13	Stitch toe cap on vamp	PBDN machine2	1	1	45.5 + 5 * BETA(1.93, 1.93)	0.059762
14	Attach tin tape on stripe	Table		1	TRIA(73.5, 73.8, 79.5)	0.034412

S. No	Operation type	Machines, Tools & Equipment	No. of		Expression	Squared error
			Mach ines	workers		
15	***Attach front and back quarter on stripe***, then attach nylon tape on	Table		2	NORM(97.4, 1.58)	0.017591
16	***Stitch stripe*** with back and front quarters	PBSN machine2	1	1	NORM(73.4, 1.67)	0.000846
17	***Stitch quarter lining*** with each other and stitch quarter upper with each other using zig-zag machine	Zigzag machine	1	1	TRIA(49.5, 55.4, 56.5)	0.002233
18	***Stitch French binding*** on edge of quarters	PBSN machine3	1	1	44.5 + 4 * BETA(1.84, 1.48)	0.017539
19	Apply glue and reverse the binding then attach with a quarter (***attach the binding with quarter***)	Table		1	82.5 + 5 * BETA(1.04, 1.52)	0.006295
20	Apply glue and ***attach heel strap lining*** on the quarter lining and heel stripe on quarter	Table		2	56.5 + 5 * BETA(0.755, 0.988)	0.026264
21	***Stitch vamp lining*** with tongue lining and heel strap lining with quarter lining	PBSN machine4	1	1	NORM(73, 1.21)	0.041681
22	Stitch heel stripe on quarter	PBSN machine5	1	1	57.5 + ERLA(1.06, 3)	0.010907
23	Apply glue and ***attach back count on the quarter***	Table		2	58.5 + 6 * BETA(1.13, 1.05)	0.023374
24	Stitch back count on quarter	PBDN machine3	1	1	57.5 + 8 * BETA(1.11, 1.02)	0.013915
25	Apply glue and ***attach foam on the back and front quarters***	Table		2	86.5 + 4 * BETA(1.44, 1.83)	0.016915
26	Apply glue and ***attach quarter lining on quarters***	Table		1	119 + 5 * BETA(1.78, 2.08)	0.046334

S. No	Operation type	Machines, Tools & Equipment	No. of		Expression	Squared error
			Mach ines	workers		
27	Apply glue and ***attach foam on tongue*** then attach tongue lining and attach front quarter lining on front quarters	Table		3	84.5 + 8 * BETA(1.3, 1.47)	0.024088
28	***Stitch front quarter lining*** with front quarter	PBSN machine6	1	1	58.5 + 7 * BETA(0.766, 0.796)	0.024877
29	Stitch tongue with tongue lining	PBSN machine7	1	1	NORM(63.3, 1.25)	0.008369
30	Trimming excess front quarter lining (***Trimming excess FQL***)	Trimming machine1	1	1	49.5 + 5 * BETA(1.87, 1.44)	0.040241
31	***Attach eye stay reinforcement*** on eye stay	Table		1	68.5 + 5 * BETA(1.02, 0.916)	0.002414
32	Apply glue and ***attach eye stay on quarter*** and eye stay lining on the quarter lining	Table		2	76.5 + 7 * BETA(1.31, 0.615)	0.034146
33	Hammering around eye stay	Hammering machine	1	1	50.5 + 6 * BETA(1.45, 1.37)	0.015168
34	***Stitch eye stay*** and around edge of collar	PBSN machine8	2	2	149 + 5 * BETA(1.13, 1.02)	0.039277
35	In-process quality inspection	Table		1	25.5 + 8 * BETA(1.53, 1.31)	0.006458
36	Trimming excess lining of tongue and quarter (***Trimming excess LTQ***)	Trimming machine2	1	1	NORM(106, 2.19)	0.059654
37	Punch eyelet place	Eyeleting machine	1	1	47.5 + 5 * BETA(2.03, 1.5)	0.040247
38	Stitch around collar	PBSN machine9	1	1	46.5 + 7 * BETA(0.974, 0.774)	0.013899
39	Stitch tongue with quarter	PBSN machine10	2	2	178 + 7 * BETA(1.47, 1.57)	0.045122
40	Stitch lasting margin allowance	PBSN machine11	1	1	39.5 + 7 * BETA(1.53, 1.06)	0.065491

S. No	Operation type	Machines, Tools & Equipment	No. of Mach ines	No. of workers	Expression	Squared error
41	Cleaning and cutting excess threads	Table		1	90.5 + WEIB(4.37, 1.21)	0.040588
42	Burning excess threads	Hot blowing machine	1	1	73.5 + 18 * BETA(0.844, 0.551)	0.039671
43	Temporary shoe lacing	Table		1	47.5 + 9 * BETA(0.871, 0.996)	0.044474
44	Final quality inspection	Table		1	29.5 + 6 * BETA(1.35, 1.38)	0.017034
45	Rearranging pairwise and dispatch	Table		2	34.5 + 11 * BETA(0.904, 1.37)	0.002414
	Total		**27**	**56**		

Table 4.2 Statistical expressions for each operation of the **lasting** assembly line.

S. No	Operation type	Machines, Tools & Equipment	No. of Mach ines	No. of wor kers	Expression	Squared error
1	Sole roughing	Sole roughing machine	1	1	44.5 + 7 * BETA(2.06, 1.1)	0.015879
2	Last loading	Table		1	33.5 + 4 * BETA(2.67, 1.47)	0.007708
3	Last cleaning	Table		1	29.5 + 6 * BETA(1.37, 1.45)	0.002414
4	Upper loading	Table		1	30.5 + LOGN(5.23, 7.16)	0.029888
5	Sole cleaning(sole washing)	Table		1	37.5 + 6 * BETA(1.64, 1.47)	0.032258
6	Insole attaching	Table		1	29.5 + 7 * BETA(1.22, 1.22)	0.032689
7	Back part molding (hot T=120,cool T=100,waiting time=10)	Back part molding machine	1	1	39.5 + 8 * BETA(1.68, 1.26)	0.043852

S. No	Operation type	Machines, Tools & Equipment	No. of		Expression	Squared error
			Mach ines	wor kers		
8	Insert to steam and then toe lasting	Toe lasting and steam machine	2	2	54.5 + 8 * BETA(1.05, 1.07)	0.064569
9	Apply glue on sides of the upper	Table		1	NORM(46.3, 1.58)	0.008034
10	Side closing	Table		2	43.5 + 6 * BETA(0.606, 0.519)	0.017107
11	Insert to steam and heel seat lasting	Heel seat and steam machine	2	1	39.5 + LOGN(2.48, 1.52)	0.015132
12	Apply cream, cleaning and insert to heat tunnel	Heat tunnel machine	1	1	39.5 + 7 * BETA(1.13, 0.937)	0.044169
13	Heel seat shaping	Heel seat shaping machine	1	1	28.5 + 5 * BETA(1.06, 1.06)	0.025461
14	Pounding	Pounding machine	1	1	29.5 + 7 * BETA(0.872, 1.23)	0.005642
15	In-process quality inspection	Table		1	28.5 + LOGN(2.34, 1.34)	0.009388
16	In process brushing	Brushing machine1	1	1	49.5 + 8 * BETA(0.966, 0.919)	0.013740
17	1st level upper roughing	Roughing machine1	1	1	TRIA(32.5, 35, 36.5)	0.047391
18	Marking for sole sit area	Marking machine	1	2	40.5 + 12 * BETA(1.08, 0.873)	0.004444
19	2nd level upper roughing	Roughing machine2	1	1	42.5 + 14 * BETA(0.961, 0.764)	0.058704
20	1st adhesive coating on the upper	Table		2	22.5 + 9 * BETA(0.59, 0.59)	0.049114
21	The adhesive coating on the sole	Table		1	23.5 + LOGN(3.09, 2.84)	0.034695
22	2nd adhesive coating on the upper	Table		1	39.5 + 9 * BETA(1.06, 1.71)	0.015702

S. No	Operation type	Machines, Tools & Equipment	No. of		Expression	Squared error
			Mach ines	**wor kers**		
23	2nd adhesive coating on the outsole	Table		1	38.5 + 5 * BETA(1.63, 1.31)	0.023998
24	Sole and upper dryer	Dryer machine	1	-	Constant (180)	0.012629
25	Sole and upper re-activator	Re-activator machine	1	-	Constant (120)	0.019340
26	Sole attaching and pressing	Sole pressing machine	2	3	41.5 + LOGN(3.79, 3.23)	0.006530
27	Cleaning, removing temporary shoe lace and ***insert to chiller machine***	Chiller machine	1	2	48.5 + 6 * BETA(0.76, 0.929)	0.019440
28	De-lasting	De-lasting machine	1	1	TRIA(19.5, 21, 24.5)	0.021928
29	Sole stitching	Sole stitching machine	2	2	37.5 + 6 * BETA(1.65, 1.26)	0.001633
30	Apply glue and insert sock lining	Table		2	25.5 + 7 * BETA(0.908, 1.02)	0.021348
31	Painting on extra rough and apply the cream on the upper	Table		1	34.5 + 6 * BETA(1.16, 1.18)	0.012583
32	Inserting tissue paper	Table		1	NORM(39.3, 2.33)	0.038788
33	Final brushing for shine	Brushing machine2	1	1	NORM(87.8, 2.69)	0.039296
34	Shoe lacing	Table		2	49.5 + 10 * BETA(0.846, 0.813)	0.066951
35	Cleaning the sole and upper part	Table		1	51.5 + 11 * BETA(1.43, 0.999)	0.043971
36	Final quality inspection	Table		1	TRIA(2.5, 33, 36.5)	0.036962
37	shoe box making	Table		1	33.5 + 7 * BETA(1.45, 1.45)	0.016810
38	**Insert to polybag** shoebox, and model, size tagging	Table		2	21.5 + 7 * BETA(1.47, 1.61)	0.020813
39	Packing	Table		2	23.5 + LOGN(4.34, 3.72)	0.095893
	Total		**22**	**49**		

4.4.3 Statistical distribution

After collecting the data from the manufacturing system's actual production process, the next step is analyzing the data using the Arena simulation input analyzer. Figure 4.2 shows how the input analyzer analyzes and generates the results for side closing, which are the snapshot of the lasting assembly line.

Arena's built-in input analyzer is used to get the model's best distribution fit and know the probability distribution. As revealed by Eshetie et al. (2018), the Arena built-in input analyzer results are used as initial entity time for the parts.

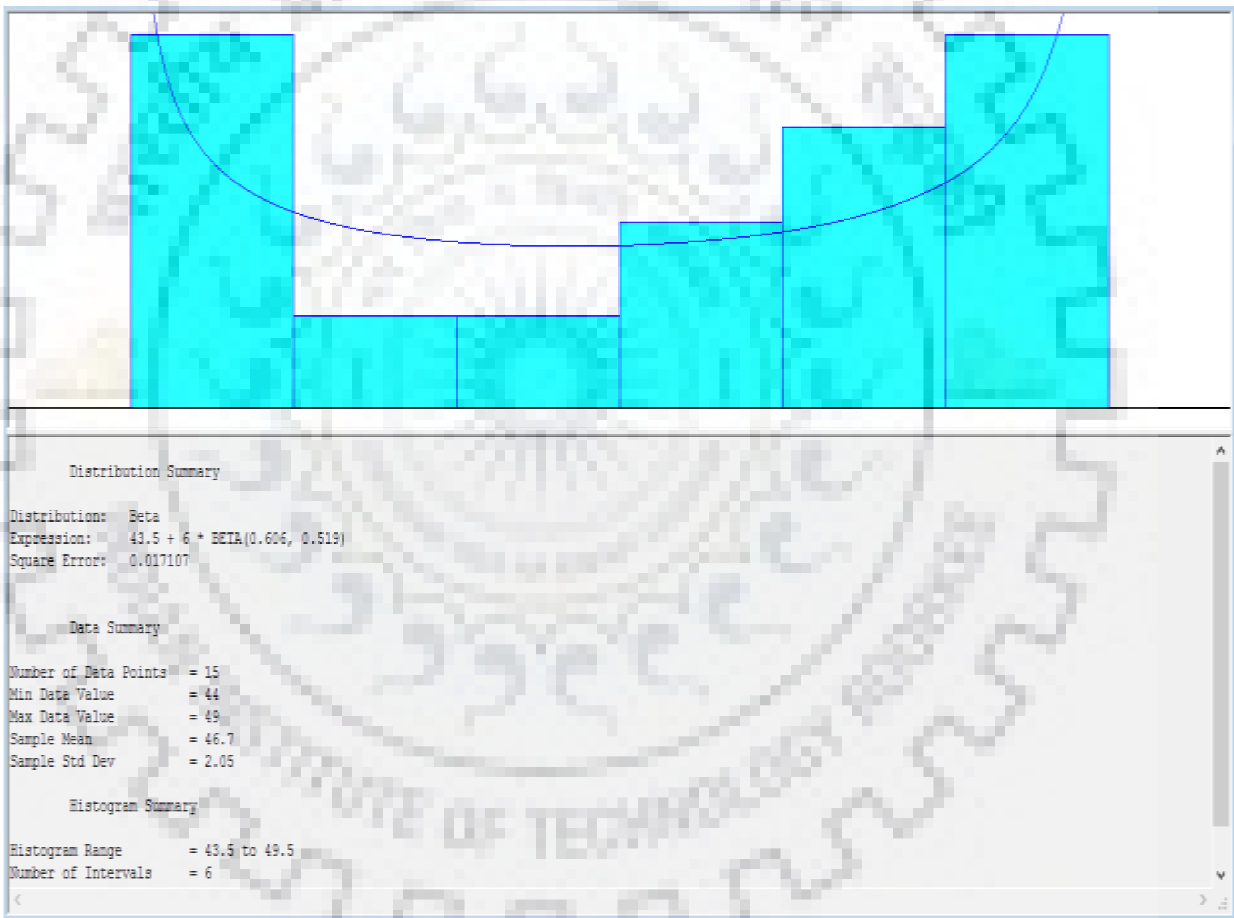


Figure 4.2 The data distribution function for the side closing of a lasting assembly line.

Determining the best fitted statistical distribution is the critical step as it affects the production system's performance. The distributions found in Arena's built-in input analyzer are Empirical, Beta, Erlang, Exponential, Lognormal, Gamma, Normal, Triangular, Poisson, Weibull, and Uniform. Selecting 'Fit All' gives the best fit of all the distributions. In relation to the validation of the given distribution for time (like Normal Beta, Uniform etc.) Kolmogorov Smirnov test is used. The “Fit all summary” gives a list of distribution function with their square error. Thus the function with the smallest square error is necessarily "the best" which is near to zero. For this particular operation its squared error is 0.017107 as shown in Figure 4.2 which likely gives a p-value greater than 0.05. For all of the assembly lines activities the squared error values are included in Table 4.1 and 4.2.

The generated result shows the following information:

Distribution: Beta; Expression: *43.5 + 6 * BETA (0.606, 0.519);* Square Error: 0.017107

Data summary: Sample Mean = 46.7; Sample Std. Dev = 2.05; Number of Data Points = 15; Min. Data Value = 44; Max. Data Value = 49.

Histogram summary: Histogram Range = 43.5 to 49.5; Number of Intervals = 6

Therefore, the function that fits best the distribution is expressed as ***43.5 + 6 * BETA (0.606, 0.519)***, and hence side closing operation follows the distribution shown in Figure 4.2 in the simulation process. This “Expression” gives the SIMAN code needed within Arena to generate random variates from distribution. It is used in Arena (process blocks or create blocks etc.). Likewise, for all stitching and lasting assembly lines operations, the best distribution fits are analyzed and used for the simulation model.

4.4.4 Simulation model development

Developing the simulation model is an important part of this study for experimentation. Declaration of the entity is the first task in developing the simulation model. Then, the declaration of workstations' location, generating path network & resources, declaration of the arrival, and processing programming. In the simulation modeling, the logic flow describes how the entity acts during its journey.

The researchers used a student version of Arena simulation software for this study. Since this version cannot include more than 150 entities and for the practical applications, the following assumptions have taken into consideration in developing the simulation model:

- Workers are responsible for the quality inspection of their work. Taking this into account for quality inspection, a 5-second allowance is added to each activity's processing time.

- Two or more related work elements that are done by a single worker are combined.
- The adjacent station's transportation time is included in the underlying processing time of each activity.
- 15% (fifteen percent) of the processing time is included as an allowance factor for each activity's processing time. It takes into consideration some unexpected conditions related to machines and workers. For example, in repositioning the work piece, the worker may take more time.
- The conveyor speed is constant, and it will not stop for the daily working hours.
- All the production materials are ready in a sufficient amount.

All the processing tasks, average processing time, and human resources required for every job are modified for the input model, taking into account the assumptions mentioned above. Based on the case company's existing production process flow systems, the Arena model was developed. It consists of different Arena modules. For example, part arrival was modeled using 'Create' modules, deciding on the conformance of the quality of the products using the 'Decide' module, and the 'Dispose' module was used to model the assembled parts output. Hence, the computer simulation model for stitching and lasting assembly lines is shown in Figure 4.3 and Figure 4.4, respectively.

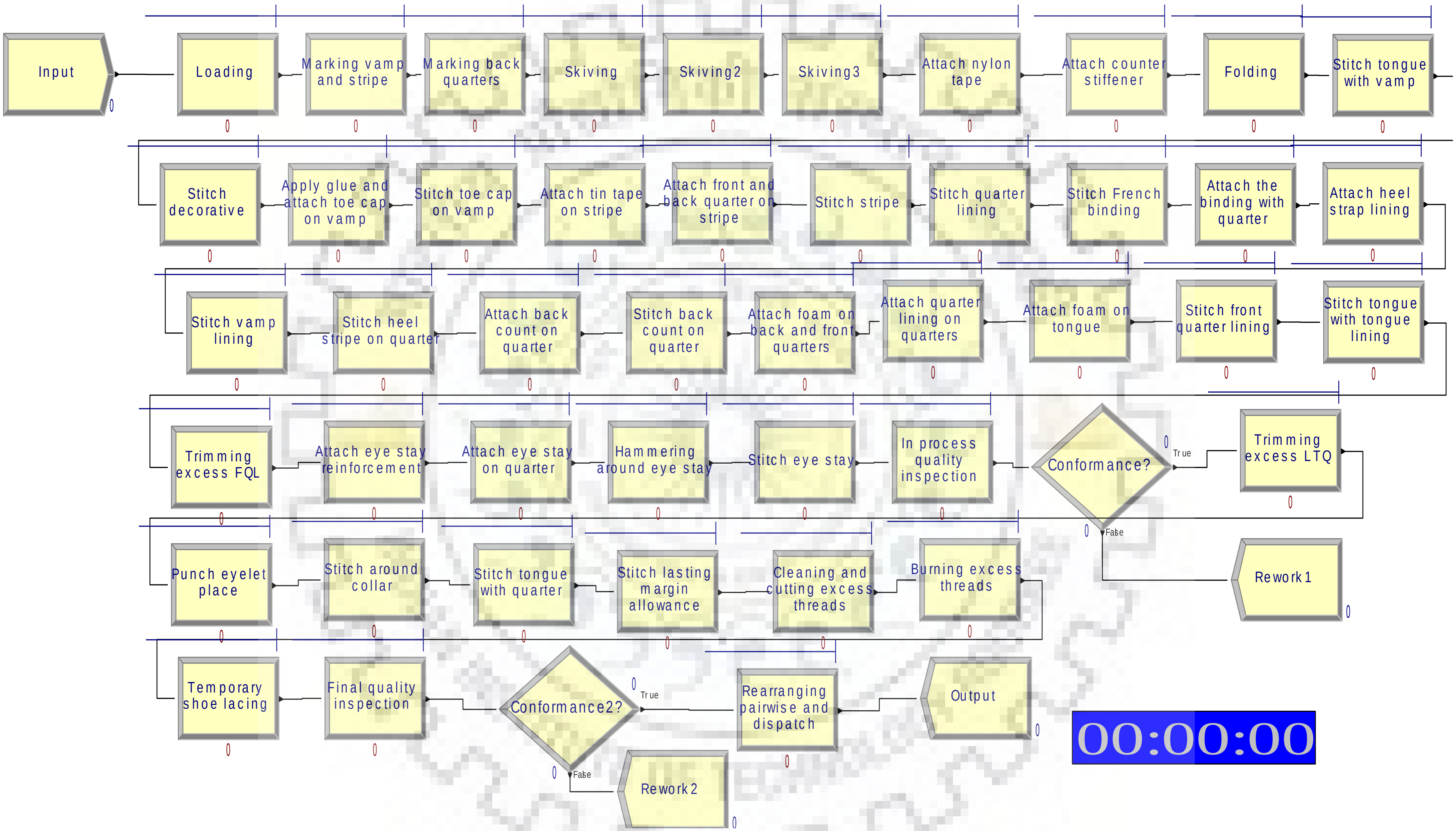


Figure 4.3 Simulation model of the existing manufacturing system of a stitching assembly line.

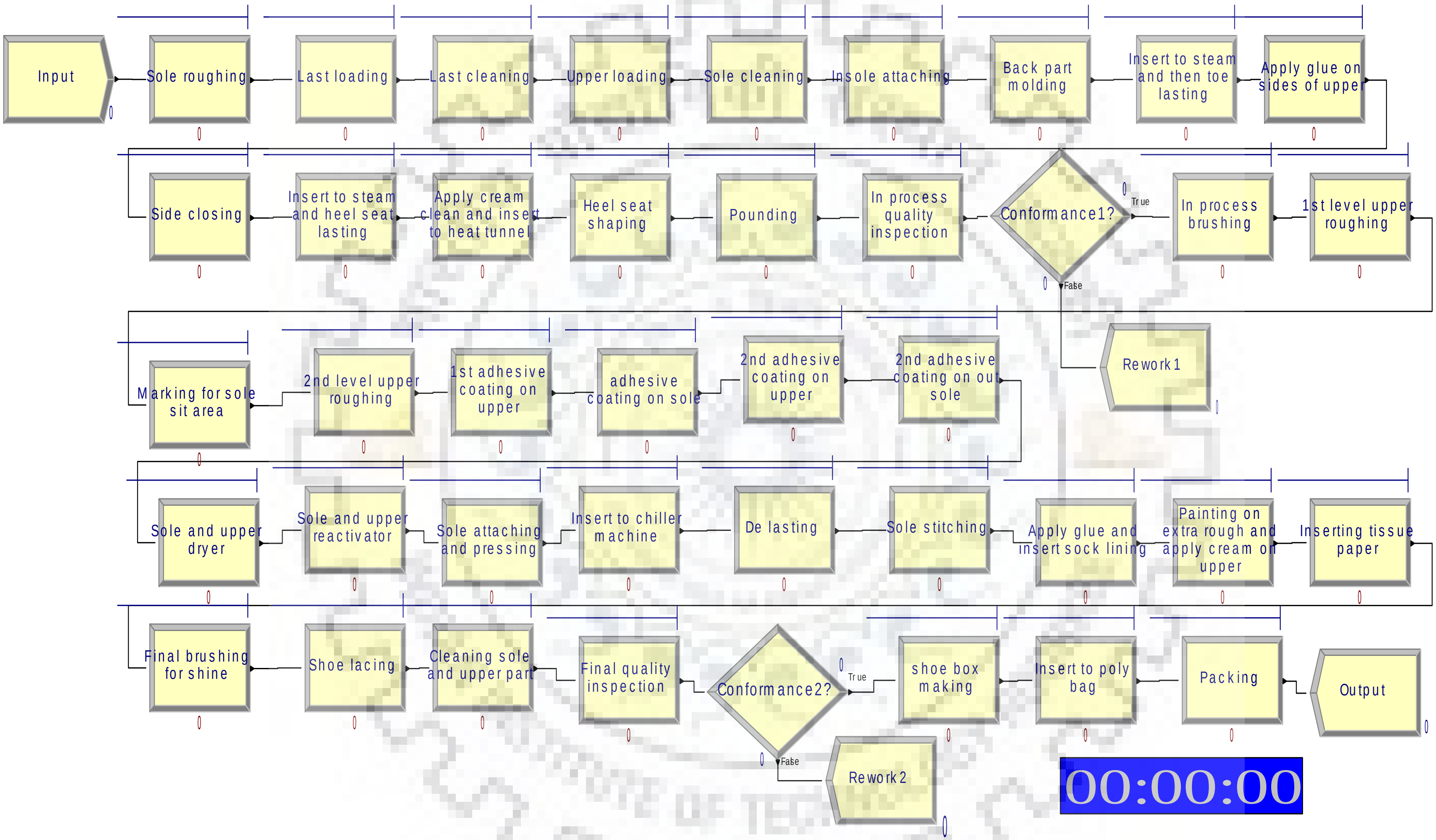


Figure 4.4 A simulation model of the existing manufacturing system of a lasting assembly line.

4.4.5 Replication number calculation

The replication number is the number of simulation runs that should be executed. Calculating the mean and standard deviation for the first ten (10) simulation runs is the first step in determining the simulation model's replication number, as shown in Table 4.3. And in assessing the reliability of the results, half-width is used. It is the sampling error introduced in taking samples. Hence by considering a 95% confidence level, the half-width can be determined, and t can be read from the t-probability distribution table.

Table 4.3 Mean, standard deviation, and half-width for the initial ten replications.

S. No.	Number of replications	Stitching AL output	Lasting AL output
1	1	190	170
2	2	191	178
3	3	191	176
4	4	191	169
5	5	192	173
6	6	191	170
7	7	190	175
8	8	190	180
9	9	191	176
10	10	190	170
	Mean	**190.7**	**173.7**
	Standard Deviation	**0.67**	**14.9**
	Half width	**0.48**	**5.35**

Using equation (6) of the literature and rearranging it, the replication numbers required, which gives a low acceptable error level, are calculated as 40 for both assembly lines.

4.4.6 Model verification and validation

Model verification is used to check whether there is a statistically significant difference between the model and the actual production system. The model is valid if there is no statistically significant difference between the two data sets. On the contrary, the model is not valid if there is a statistically significant difference between these data sets and requires additional work before further analysis is conducted. For this study, model validation is made using statistical validity by comparing the real manufacturing system's daily output for the SAWA shoe model of the existing system with the simulation model output.

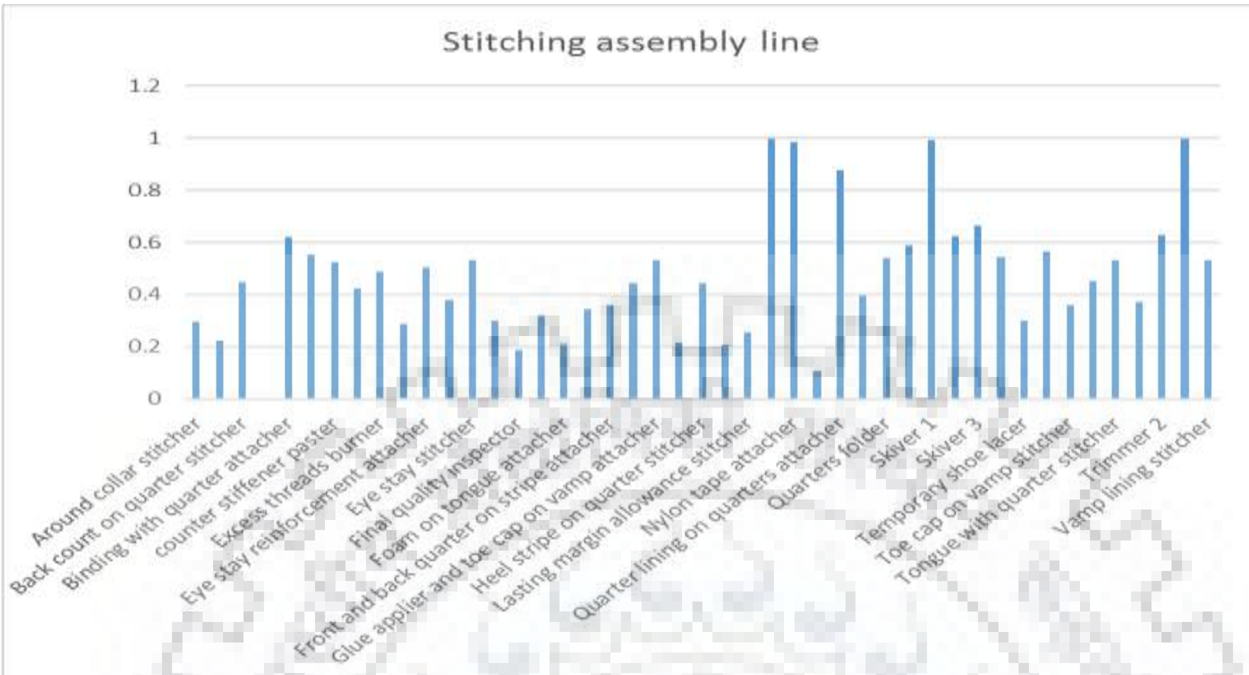
In the real manufacturing system, the daily output of the SAWA shoe model ranges on average from 177 to 183 pairs of uppers in the stitching assembly line (AL) and from 145 to 190 pairs of shoes in the lasting AL with an average output of 180 pairs of uppers and 168 pairs of shoes. The average production obtained from the simulation model for SAWA model shoe per day (7.75 hours shift) is 191 pairs of uppers in the stitching AL and 174 pairs of shoes in the lasting AL. Even though the real manufacturing system's output highly varies, the Arena simulation model's result approaches the actual manufacturing system output. Hence the simulation model represents the actual existing system and is said to be valid. In addition to this, work stations with high and low work in progress (WIP) in actual systems are also observed in the simulation model.

4.5 Results and discussions of the case study

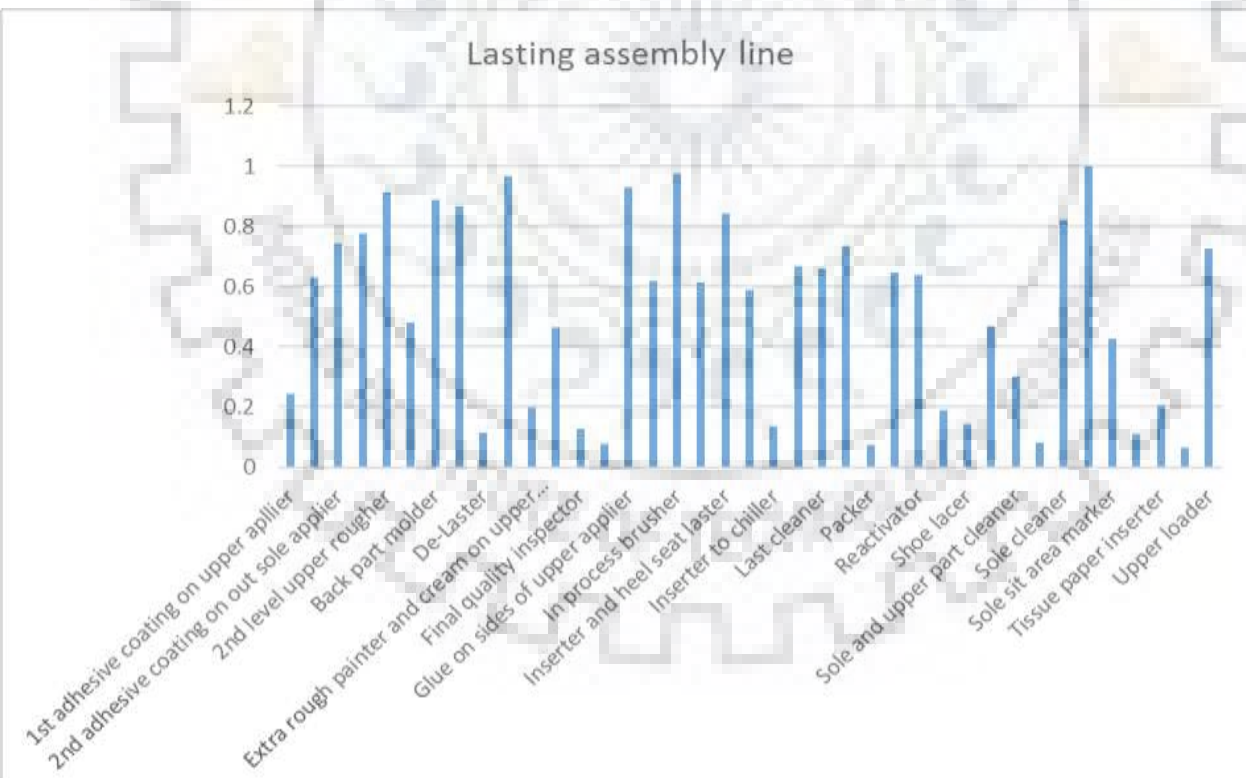
The simulation model developed using Arena simulation software was run, and the results were analyzed using a built-in Arena output analyzer. The result shows the current performance of the existing manufacturing system. It will help compare the actual real manufacturing system performance with the proposed alternative solutions. This simulation run also helps in identifying the bottleneck operation and in observing the resource utilization of the existing system. As a result, the actual performance of the model is summarized, as shown in Table 4.4.

Table 4.4 Performance of the existing system.

No.	Performance indicators	Results of the simulation model	
		Stitching AL	Lasting AL
1	Input	773	569
2	Manpower	56	49
3	Output (P) per 7.75hrs	191	174
4	Production rate (R_p) = P/7.75 hr	24.645	22.45
5	Make span or work content time (T_{wc})	3,088.13 sec. = 51.47 min	1553.59 sec. = 25.89 min
6	Work in process (WIP)	302.24 uppers	202.51 shoes
7	Production efficiency	191/773=0.247	174/569=0.306
8	Line balance efficiency (E_b)	68.3%	17.6%



(a)



(b)

Figure 4.5 Instantaneous resource utilization of (a) stitching (b) lasting assembly lines.

The simulation model's output shows that the stitching assembly line production is higher than the lasting assembly line. As it is observed during the data collection and industry visit, this also happens in the real manufacturing system. The output of the stitching assembly line is the input for the lasting assembly line. But the production of the stitching is greater than lasting. Hence, this phenomenon creates high WIP. As a result of the simulation model and the actual manufacturing system observation, piled-up WIP is observed for different models and sizes of leather shoes between the stitching and lasting assembly lines. This leads to late product delivery, difficulty scheduling the overall production system, not using the available resources efficiently, uneven workload distribution on workers & machines, affects the morale of the busy workers, creates tied-up capital, occupies space, etc.

The simulation model result shows that there is unbalanced instantaneous resource utilization (See Figure 4.5 (a & b)). As observed during the actual production process, the researchers have revealed that some workers are very busy, while some other workers are waiting for work. The unbalanced resource utilization creates waste (Muda): waiting, unreasonableness (MURI), and inconsistency (MURA). In summary, the output of these two assembly lines and their workstations are not balanced.

Generally, low production rate, high waiting time, high WIP, low production efficiency, and low line balance efficiency are obtained from the simulation model of this study.

4.5.1 Proposed alternative solution methods

The researchers have proposed and experimented with the following alternative solution methods with Arena software to get an optimal solution.

Alternative 1: Identifying bottleneck workstation with high WIP and increasing their resources.

Identifying the bottleneck workstations is the critical step in any production process. Hence by running the simulation model, workstations with a high level of WIP have been identified. From stitching line marking, vamp & stripe and nylon tap attaching registered with WIP equal to 211.42 and 61.7679, respectively. And from lasting assembly line sole & upper dryer is registered with WIP level of 169.8, then in process brushing follows with WIP level of 9.1086. Hence, adding one resource to each of these stations decreases the WIP level from 302.24 uppers to 296.34 uppers in the stitching assembly line and from 202.51 shoes to 168.64 shoes in the lasting assembly line. The lines' output increases from 191 to 205 (stitching) and from 174 to 247 (lasting). By implementing this improvement option, line efficiency becomes 65.3% and 26.9% in stitching and lasting assembly lines from its initial line efficiency of 68.3% and 17.6%, respectively.

Alternative 2: Reducing unused resources from low capacity utilization stations.

Reducing unused resources is considered an alternative proposed solution since many unused resources are observed from the simulation running results.

Table 4.5 Stations with low capacity utilization.

No.	Station	Stitching AL			
		Resource	Number scheduled	Number busy	Reduced resource
1	Marking back quarters	Back quarters marker	2	0.00	1
2	Attach back count on quarter	Back count on quarter attacher	2	0.6889	1
3	Attach heel strap lining	Heel strap lining attacher	2	0.6612	1
4	Attach foam on the back and front quarters	Foam on back and front quarters attacher	2	0.9816	1
5	Attach foam on the tongue	Foam on tongue attacher	3	0.6788	2
6	Attach eye stay on quarter	Eye stay on quarter attacher	2	0.6169	1
7	Rearranging pairwise and dispatch	Pairwise re-arranger and dispatcher	2	0.2298	1
		total	***15***		***8***
No.	**Station**	**Lasting AL**			
		Resource	Number scheduled	Number busy	Reduced resource
1	1st adhesive coating on upper	1st adhesive coating on the upper applier	2	0.4890	1
2	Apply glue and insert sock lining	Glue applier and sock lining inserter	2	0.1527	1
3	Insert to chiller	Inserter to chiller	2	0.2717	1
4	Packing	Packer	2	0.1425	1
5	Shoe lacing	Shoe lacer	2	0.2875	1
6	Side closing	Side closer	2	0.9369	1
7	Sole attaching and pressing	Sole attacher	3	0.2413	2
8	Insert to chiller machine	Sole sit area marker	2	0.8548	1
9	Sole stitching	Sole stitcher	2	0.2174	1
10	Insert to polybag	To polybag inserter	2	0.1268	1
		total	***21***		***11***

Experiment alternative solution 2 reduces the total number of 19 workforces. This means eight resources from the stitching assembly line and eleven resources from the lasting assembly line have been deducted without reducing the assembly lines' outputs. Taking the current direct labor monthly workers' salary of 1,200 Ethiopian Birr (ETB), 19 employees * 1,200 ETB*12 months results in savings of 273,600 ETB annually without reducing the outputs of both lines. This alternative solution makes the organization use the available resources efficiently and effectively. The stitching AL's line balance efficiency increases from 68.3% to 75.1%, and the lasting assembly line rises from 17.6% to 22.8%.

Alternative 3: Combination of alternatives 1 and 2.

Implementing alternative solutions 1 and 2 simultaneously; reduces WIP from 302.24 to 295.96 uppers in stitching line & from 202.51 to168.13 shoes in lasting line, reduces workforce from 56 to 53 in stitching line & from 49 to 28 in the lasting assembly line. The assembly lines' outputs increase from 191 to 204 in the stitching assembly line and from 174 to 247 in the lasting assembly line. The line efficiency decreases from 68.3% to 61.2% in the stitching assembly line and increases from 17.6% to 44.7% in the lasting assembly line.

Alternative 4: Improving the capacity of machines

Improving machines' capacity is one way to enhance the productivity of the manufacturing process. In the 'lasting' assembly line after the second adhesive coating on the outsole, there are two successive operations: sole & upper dryer and sole & upper reactivator. Those two operations are the most time-consuming operations within the assembly line, and they also determine the conveyor's speed. The conveyor's speed is determined by taking into account the drying and reactivating capacity of the machines. Hence installing machines that can dry and reactivate three pairs of shoes will reduce the drying and activation time to 60 sec. & 40 sec. Doing this would give an option to increase the conveyor's speed, shorten the conveyor's length, and improve the overall performance of the assembly line. By running the simulation model, WIP has been reduced to 128.54 shoes. The production rate has increased to 42.45 shoes per hour, output has risen to 329 shoes per day, production efficiency has increased to 0.578, and line balance efficiency has increased to 33.96%.

Alternative 5: Merging similar and consecutive activities.

Workstations with similar activities and consecutive are observed below 50% of capacity utilization during the simulation process. Hence merging these activities is taken as an alternative solution.

A similar and consecutive operation has been identified and merged, as shown in table 5, for both the assembly lines. The researchers have proposed the assembly lines' required resources to increase resource capacity utilization and line balance efficiency.

Table 4.6 Similar and consecutive activities that can be merged.

No.	Station	***Stitching AL***			
		Resource	Number scheduled	Number busy	Proposed resource
1	Marking vamp and stripe	Vamp and stripe marker	1	0.9987	
2	Marking back quarters	Back quarters marker	2	0.00	2
3	Attach eye stay reinforcement	Eye stay reinforcement attacher	1	0.5057	
4	Attach eye stay on quarter	Eye stay on quarter attacher	2	0.2878	1
5	Attach tin tape on stripe	Tin tape on stripe attacher	1	0.5630	1
6	Attach front and back quarter on stripe	Front and back quarter on stripe attacher	2	0.3615	
7	Stitch front quarter lining	Front quarter lining stitcher	1	0.4443	1
8	Stitch tongue with tongue lining	Tongue lining stitcher	1	0.4525	
		Total	***11***		***5***
No.	Station	***Lasting AL***			
		Resource	Number scheduled	Number busy	Proposed resource
1	1st adhesive coating on upper	1st adhesive coating on the upper applier	2	0.2445	1
2	The adhesive coating on sole	The adhesive coating on the sole applier	1	0.4807	
3	shoe box making	Shoebox maker	1	0.1894	1
4	Insert to polybag	To polybag inserter	2	0.0634	
5	Shoe lacing	Shoe lacer	2	0.1437	
6	Cleaning sole and upper part	Sole and upper part cleaner	1	0.303	1
		Total	***9***		***3***

Alternative 6: Combining all alternatives

Different alternatives solutions have experimented with Arena simulation software in this study. Combining all these alternatives, which is the combined alternative, has been modeled and simulated (see Figure 4.6 and Figure 4.7). Table 4.7 shows how the manufacturing system's performance measures for the suggested alternative solutions are improved concerning the actual manufacturing system. Of all the proposed alternative solutions, the combined proposed alternative solution gives better performance measures for both the assembly lines.

Table 4.7 Comparison of the proposed alternatives with major performance indicators.

Stitching AL							
No.	Alternatives	Input	Output	WIP	Make span	Workforce	E_b
1	Existing system	773	191	302.24	3,088.13	56	68.3%
2	Solution alternative 1	774	205	296.34	3088.35	58	65.3%
3	Solution alternative 2	774	191	302.36	3089.58	51	75.1%
4	Solution alternative 3	773	204	295.96	3088.80	53	61.2%
5	Solution alternative 4	773	204	295.96	3088.80	53	61.2%
6	Solution alternative 5	773	193	299.61	2,754.61	50	67.5%
7	Solution alternative 6	773	278	262.61	2,747.93	44	90.1%
Lasting AL							
No.	Alternatives	Input	Output	WIP	Make Span	Workforce	E_b
1	Existing system	569	174	202.51	1,553.59	49	17.6%
2	Solution alternative 1	569	247	168.64	1611.71	50	26.9%
3	Solution alternative 2	569	173	202.74	1559.43	38	22.8%
4	Solution alternative 3	569	247	168.13	1610.29	40	44.7%
5	Solution alternative 4	569	329	128.54	1461.01	49	33.96%
6	Solution alternative 5	569	174	202.55	1,468.07	43	18.97%
7	Solution alternative 6	569	536	31.369	1,393.53	36	76%

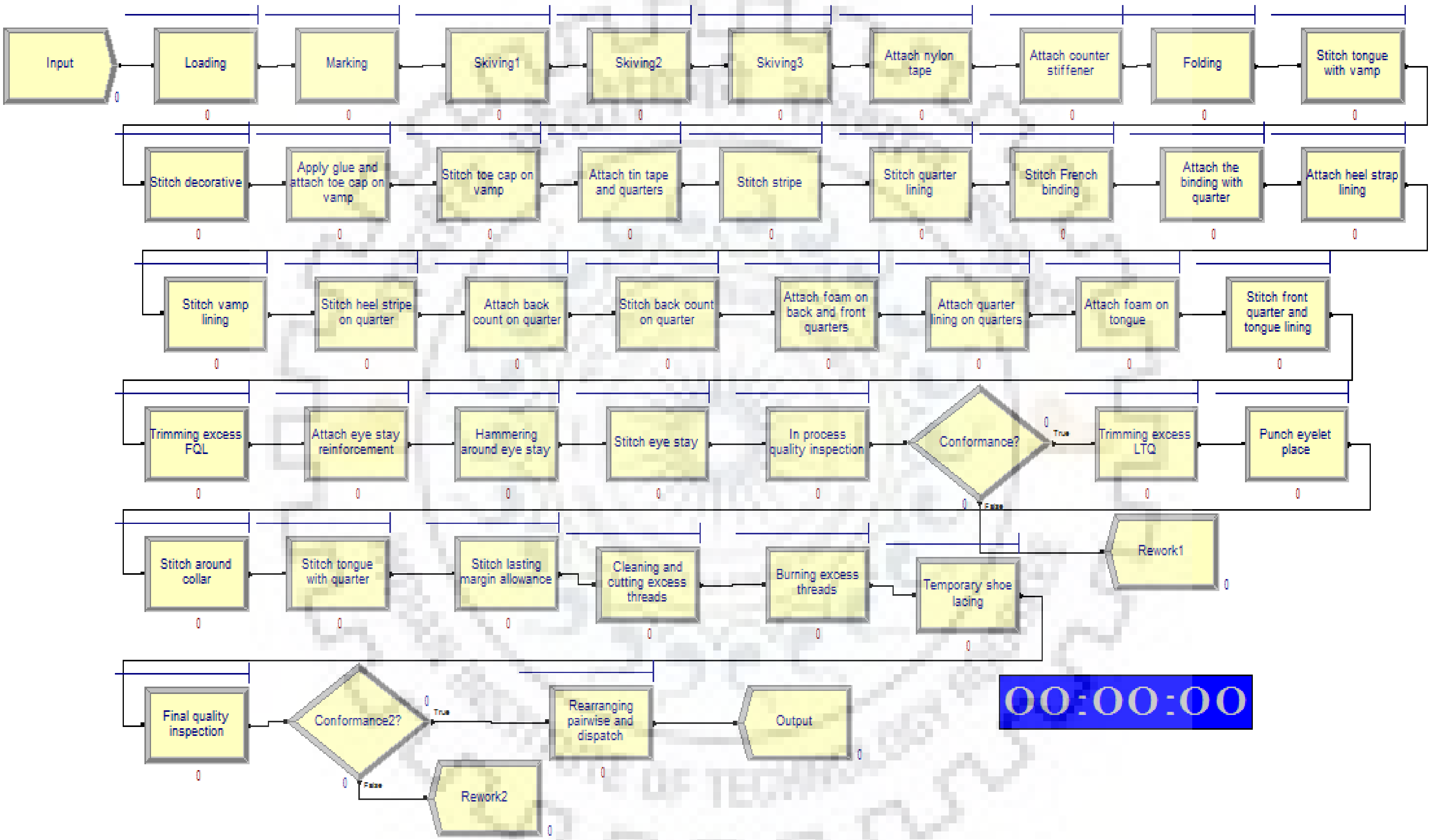


Figure 4.6 Proposed model of the stitching AL.

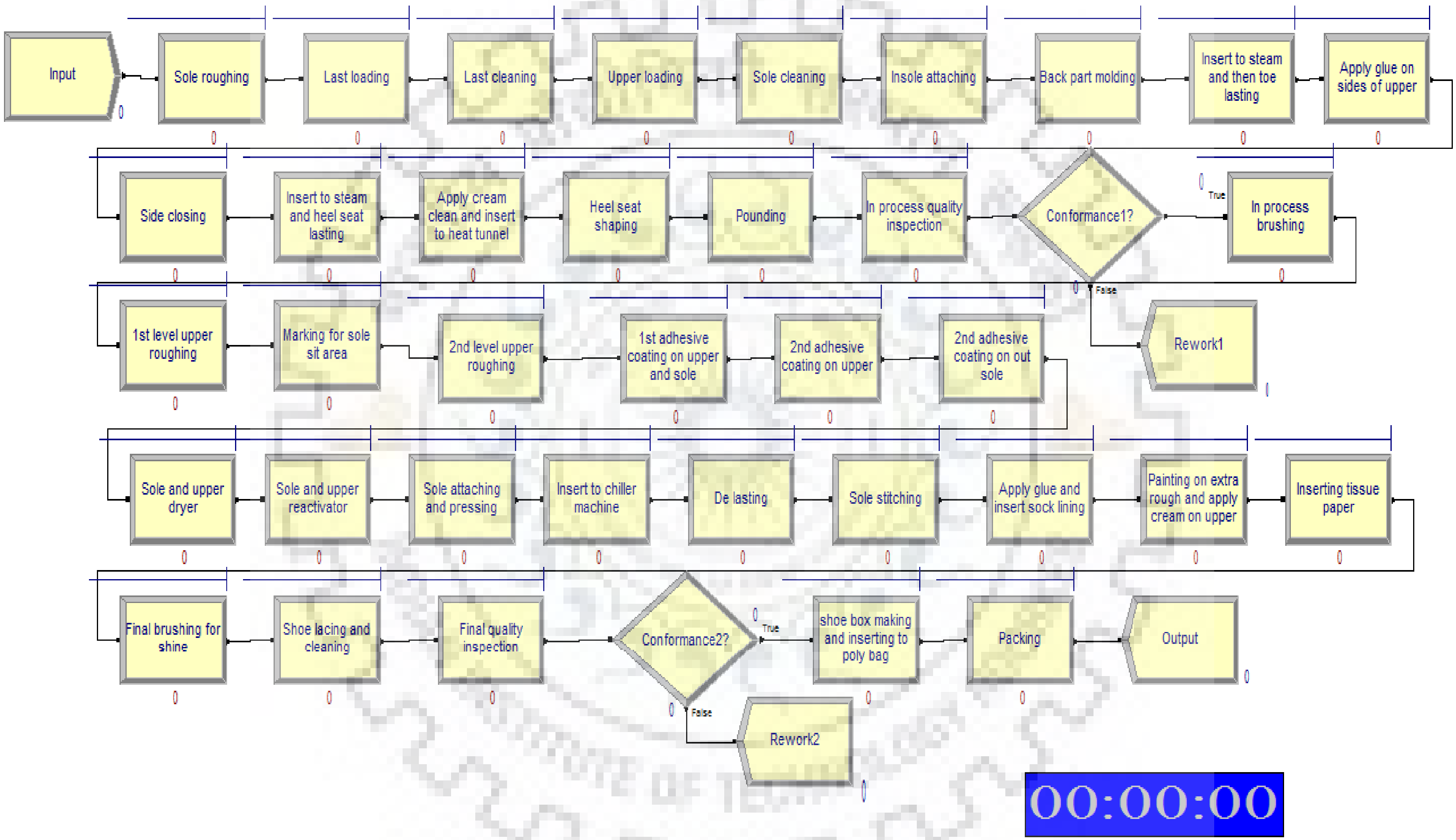


Figure 4.7 Proposed model of the lasting AL.

4.6 Summary

Modern managers realize that cost reduction will create a circumstance for the reduction of price in this competitive world. This is to be competent enough in the global market. And productivity is another issue that the manager wants to address, which is a critical concern for the case company. Such problems can be solved using lean concepts to identify and eliminate waste. But managers face difficulty in identifying the critical candidate areas for improvement and elimination of the waste. In order to solve such challenges, VSM is a powerful lean manufacturing tool to map the information and material flow. Another problem faced by managers is that it is costly to stop the production system and test different improvement scenarios. Such issues can be solved using simulation modeling by modeling and experimenting with the proposed scenarios to see how effective the proposed solution is. This helps managers in understanding the dynamic nature of the manufacturing system and saves cost and effort.

This chapter illustrates how managers and practitioners can use VSM-SM in order to identify the potential area for improvement & eliminate waste and model & experiment with different proposed improvement scenarios before implementing them into the actual manufacturing system. Hence, managers can use VSM-SM to visualize the current level of waste present within the organization & the possibility of eliminating them and model & experiment with the different types of improvement scenarios before investment. Phase III of the research is presented in the next chapter, i.e., Chapter 5.

CHAPTER 5

DECISION-MAKING ON THE SELECTION OF LEAN TOOLS USING FUZZY QFD AND FMEA APPROACH IN THE MANUFACTURING INDUSTRY (PHASE III)

5.0 Overview

This chapter presents Phase III of the research. It deals with the decision-making process in selecting suitable and appropriate lean tools for the successful implementation of LM to maximize the available resource utilization and then increase the productivity & competitiveness of the industry[2]. A systematic, integrated approach was used. It has two sub-phases. The first sub-phase uses fuzzy QFD in order to praise the most critical resources, and the second sub-phase uses fuzzy FMEA to identify the suitable lean tools for prioritized lean failure modes. Finally, a summary of the chapter is presented.

5.1 Introduction

Companies adopt lean manufacturing (LM) principles and tools for various reasons. These include global competition, an uncertain market environment, and rising customer expectations. The concepts of LM can make it possible to use their resources effectively and increase their competitiveness. According to Deif & Elmaraghy (2014) and Goshime, Kitaw, & Jilcha (2018), LM is characterized by 'doing more with less.' It focuses on reducing/eliminating waste in order to increase productivity and maximize customer values (Belekoukias et al., 2014).

With the origin of the Toyota Production System, several LM techniques and tools were developed and used to achieve lean. Some of them are TPM, JIT, TQM, kaizen, kanban, production smoothing, cellular manufacturing, one-piece flow, Value Stream Mapping (VSM), and standardized work. Most of them are adopted in discrete manufacturers (Kumar & Parameshwaran, 2018). LM techniques and tools were effectively implemented in Automotive (Vamsi & Sharma, 2014), chemical (Jilcha & Kitaw, 2015), textile industry (Hodge et al., 2011), construction (Ko, 2010; Aka et al., 2020)), and healthcare industries (Barberato et al., 2016).

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[2]***Parts of the contents of this chapter have been published in Expert Systems with Applications, Vol. 192,2022, https://doi.org/10.1016/j.eswa.2021.116416***

LM implementation is all about the raw materials used (Materials), human resources skill (Man), equipment/machine (Machine), and manufacturing methods/technology (Methods) or 4M's. These are critical for the successful deployment of LM. These 4M's may not be a big issue for the developed countries manufacturing organizations. But in developing countries like Ethiopia, the manufacturing organization with undeveloped manufacturing systems has a shortage of these 4M's. Unlike the raw materials, the machines, the accessories & spare parts are imported, the workforces are unskilled, and the technology level is low. Although there are many available lean tools, lack of standardization in the application, lack of predicting the benefits, insufficient control over the whole value stream & insufficient knowledge and insufficient view on new methods are barriers to practice lean (Tezel et al., 2018). Since LM is an integrated system, the absence of standards is an obstacle in implementing lean practice (Bhamu and Sangwan, 2014). The literature does not address the mechanism to integrate lean tools into low-level technology organizations having undeveloped manufacturing systems with a shortage of these 4M's. Hence prioritizing the 4M's and selecting appropriate lean tools out of the many available LM tools is necessary for successful lean implementation. Sawhney et al. (2010) revealed that by following failure mode and effects analysis (FMEA), lean system reliability can be improved through the critical resources, like material, equipment, personnel, and schedule.

This study presents a case study using a hybrid model in the Ethiopian manufacturing industry. The case company manufactures different models and sizes of leather shoes. Herein VSM is used to identify wastes. Wherein the fuzzy quality function deployment (FQFD) and fuzzy FMEA prioritize the wastes through critical resources. Henceforth for the prioritized waste categories, lean tools are selected. Therefore, in order to understand better the tools and techniques (what they are?), their various aspects (for what objectives? why they are used?), and their approaches (how they are used?), the following section presents about VSM, fuzzy logic, fuzzy QFD, and fuzzy FMEA.

5.2 VSM

A value stream is the collection of activities and related details required to manufacture products, beginning with raw material and finishing with the consumer, via the main flows (Rother & Shook, 1999). In manufacturing industries, anything within the production flow that adds value to customer or product is regarded as value-adding (VA). Any activity that adds no value to the customer or product is regarded as a non-value-adding activity (NVA). These NVA activities are considered as waste, which consumes resources but provides no value to consumers. The seven types of wastes in manufacturing industries, according to Shou et al. (2020), are defects, overproduction, over-processing, inventory, unnecessary motion, waiting, and transportation. VSM helps visualize, understand, and document the information and materials flow through the value chain to identify waste quickly (Lacerda et al., 2016). To develop value stream map, there are two stages. The first stage is the current state map, which depicts "as-is" status of the production system's information and material flows. The future state map depicts the firms' future level of performance with enhanced outcomes.

In 1999, VSM was presented for the first time (Rother & Shook, 1999). Since then, there have been subsequent reviews (Forno et al., 2014). The application of VSM was successfully implemented in a complicated manufacturing environment & gains a considerable reduction in cycle time (Seth, Seth, & Dhariwal, 2017). The successful application of VSM in different areas and firms were reported by researchers. To mention some of them: in the automotive industry (Lacerda et al., 2016), in the supply chain of agri-food (De Steur et al., 2016), in textile industry (Behnam et al., 2018)… and so on. Other researchers discovered the extended use of VSM. VSM, with the integration of life cycle assessment in an automotive component manufacturing industry, was studied to ensure its sustainability (Vinodh, Ruben, and Asokan, 2016). Similarly, Faulkner & Badurdeen (2014) uses the extended VSM in identifying lean metrics for performance sustainability of manufacturing firms. VSM is used in this study to recognize wastes and possibilities for lean adoption.

5.3 The fundamentals of QFD and fuzzy QFD approach

5.3.1 QFD and house of quality (HOQ)

QFD is a planning tool that was first introduced in Japan in 1972 and is used to translate client needs into technical specifications (Vinodh & Kumar, 2011; Akkawuttiwanich & Yenradee, 2018). Many sectors commonly use it to enhance decision-making processes, product design, and consumer loyalty by prioritizing the technical descriptors scientifically (Carnevalli & Miguel, 2008). The HOQ translates 'voice of the customer (VOC) (WHATs) to design requirements (HOWs) that define target values and describe how customer requirements will be met by an organization (Liang, Ding, & Wang, 2012). The VOC and technical specifications are related at the center of the HOQ to examine how the technical descriptors will meet the VOC. This relationship matrix examines how each technical requirement affects customer requirements and their degree (Ramírez, Cisternas, & Kraslawski, 2017). A correlation matrix in the HOQ is used to study the technical descriptors against each other based on the VOC. Many research works integrate and use HOQ with fuzzy logic to solve the vagueness of linguistic judgments in the HOQ assessment through a questionnaire.

5.3.2 Fuzzy logic and Fuzzy QFD

In actual decision-making, decision-makers face difficulties when dealing with vague information like true/false, very high, high, medium, and yes/no. Such information may be handled by probability theory, but measuring imprecision that mainly comes from human behavior is limited (Filketu, Dvivedi, & Beshah, 2017). The formation of fuzzy knowledge is helpful in dealing with uncertainty and subjective judgement in decision-making (Rathore, Thakkar, & Jha, 2021). Zadeh (1965) designed fuzzy logic to cope with this type of ambiguity correctly. According to Susilawati et al. (2015), the usefulness of fuzzy logic is revealed in a variety of industrial applications. To mention some of them: in service industries (Kumru & Kumru, 2013), in manufacturing industries (Azadegan et al., 2011), in the process industry (Braaksma, Klingenberg, & Veldman 2013), for supplier selection (Chan et al., 2008; Shaw, Shankar, Yadav, & Thakur, 2012), and for climate decision support systems (Habib, Akram, & Ashraf, 2017). Similarly, to build the spatial surfaces that describe the application of fertilizer in the spatial domain, Ashraf, Akram, & Sarwar (2014a) used a fuzzy controller. Then Ashraf, Akram, & Sarwar (2014b) used a type-II fuzzy controller in reducing uncertainty to define membership function. Akram, Ashraf, & Sarwar (2014) demonstrated the application of intuitionistic fuzzy digraphs in intelligent systems. They demonstrated a couple of scenarios where they have effectively implemented it. In 2016, Butt & Akram (2016) had used a fuzzy-based CPU scheduling algorithm.

To get the full benefits of the QFD, several researchers use the combination of QFD with other tools. Haq & Boddu (2017) have applied fuzzy QFD to integrate with the analytical hierarchy process (AHP). Vinodh & Kumar (2011) used fuzzy QFD to prioritize lean enablers. Rodrigues and Ribeiro (2016) have reported using the fuzzy QFD method in an automotive company in choosing the criteria for supplier selection. In translating the linguistic judgments to numerical values, fuzzy logic is used throughout the methodology. This study treats waste as customer requirements, and fuzzy QFD prioritizes the critical resources in the first phase based on the identified wastes.

5.3.3 Triangular fuzzy number (TFN)

The triangular affiliate function is widely used to represent fuzzy numbers and is characterized by triple numbers (a, b, c). TFN membership function can be presented using the following equation:

$$\mu_{\tilde{A}}(x) = \begin{cases} (x-a)/(b-a), & a \le x \le b, \\ (d-x)/(d-b), & b \le x \le d, \\ 0, & otherwise. \end{cases}$$

Let $\tilde{A} = (a_1, a_2, a_3)$ and $\tilde{B} = (b_1, b_2, b_3)$ $be\ two\ positive\ triangular\ fuzzy\ numbers.$ On these fuzzy numbers, simple fuzzy arithmetic operations are:

Addition: $\tilde{A} + \tilde{B} = (a_1 + b_1,\ a_2 + b_2,\ a_3 + b_3);$

Subtraction: $\tilde{A} - \tilde{B} = (a_1 - b_1, a_2 - b_2,\ a_3 - b_3);$

Multiplication: $\tilde{A} \times \tilde{B} = (a_1 b_1, a_2 b_2, a_3 b_3);$

Division: $\tilde{A} \div \tilde{B} = \frac{a_1}{b_3}, \frac{a_2}{b_2}, \frac{a_3}{b_1}$ (Wang et al., 2009; Dubois and Prade 1980). The fuzzy number is graphically illustrated, as shown in Figure 5.1 (Klir & Yuan, 1995; Susilawati et al., 2015).

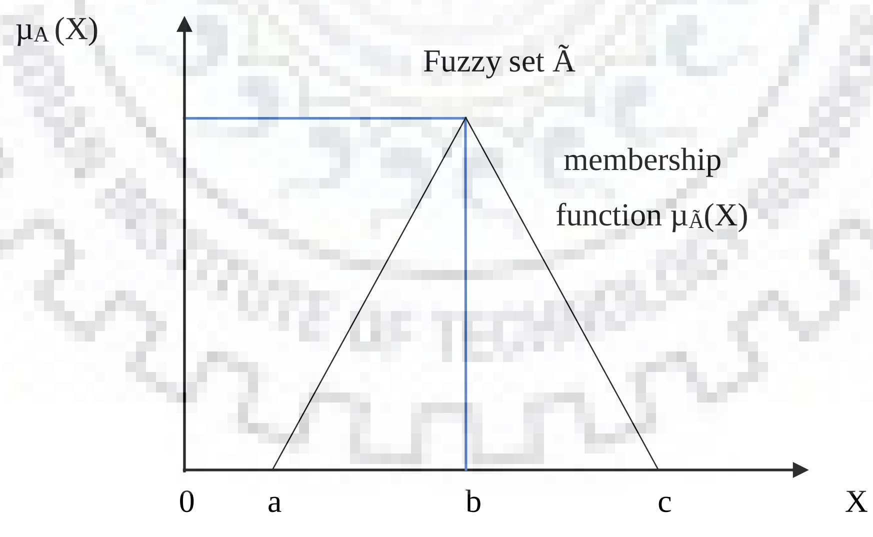


Figure 5.1 Triangular membership function.

5.4 Failure mode & effect analysis (FMEA) and fuzzy FMEA

FMEA is a structured approach used to determine and prioritize the possible modes of failure, frequency of occurrence, and criticality to evaluate them based on the risk priority number (RPN) (De Souza & Carpinetti, 2014; Sawhney et al., 2010). The FMEA is an organized analysis tool that helps practitioners define, identify, and eliminate potential failure modes from the design, process, system, and service (Cicek & Celik, 2013). FMEA method is used in different application areas like mechanical & process industries (Braaksma et al., 2013), automotive (Xu et al., 2017), chemical (Antonio & Lapa, 2004), and nuclear industries (Antonio C.F. Guimarães & Lapa, 2004). Some authors used FMEA with other tools like fuzzy AHP (Abdelgawad & Fayek, 2010; Ganguly & Kumar, 2019). Usually, assessing the risk and prioritizing the failure modes are performed by determining the RPN. The higher the RPN value of a failure mode, the higher the associated risk, which needs great attention. Similarly, the smaller the RPN value, the lesser the risk. RPN calculations are traditionally done using the following formulas:

$$RPN = O \text{x} S \text{x} D \quad (1)$$

Where O (occurrence) is the likelihood of failure, S (severity) is the magnitude, and D (detection) is the likelihood that failure will not be observed.

The risk parameters are evaluated based on a 5, 7, and 10-point scale to determine the failure modes' RPN value (Geramian et al., 2020). In Eq. (1) O, S, and D are crisp numbers. Hence the value of RPN is also a crisp number. Though this is a usually accepted method to calculate the crisp number, RPN's final value is also a crisp number and has some drawbacks, as criticized by many authors. First, RPN's identical values may be generated from different risk factors, however their hidden risk consequences could be vastly different (Sawhney et al., 2010; Gargama & Kumar, 2011; Liu et al., 2011). Second, it is challenging to precisely give numerical feedback on the risk parameters for the experts. Hence, a slight deviation of one rating may dramatically affect the RPN (Gargama & Kumar, 2011; Mandal & Maiti, 2014). Third, while determining the RPN values, the relative relevance weights of risk factors is not considered (Gargama & Kumar, 2011; Zhang & Chu, 2011). Fourth, the formula for determining RPN is arguable and lacks a scientific basis (H.C. Liu, Chen, You, & Li, 2016).

Hence to overcome the drawbacks mentioned above, many authors recommend applying the fuzzy set theory. Mandal and Maiti (2014) suggest using fuzzy logic integrated with FMEA. In FMEA to evaluate the risk and prioritize the failure modes, Chin et al. (2009), Parameshwaran et al. (2010), and Wang et al. (2009) proposed the use of fuzzy FMEA using fuzzy weighted geometric mean (FWGM) and centroid defuzzification approach (CDA). This study uses the FWGM method for FMEA analysis. This chapter of the study investigates the combined use of fuzzy QFD, process FMEA, plant layout, and VSM methods to apply in determining which lean tools are appropriate. The integrated use of these widely recognized techniques provides a standard for practicing lean implementation.

5.5 Methodology

Figure 5.2 demonstrates the approach adopted by this research report. The study uses the combination of plant layout, VSM, fuzzy QFD, and process FMEA to improve critical resources in a manufacturing organization. In the first phase, wastes are identified using VSM, and with the framework of QFD, fuzzy numbers are integrated. Then the importance weights for the wastes are determined. Then, the HOQ between the identified wastes (WHATs) and the critical resources (HOWs) is developed, followed by identifying the most essential and vital resources. In the second phase, fuzzy FMEA is used to select suitable lean tools for the prioritized lean failure modes of crucial resources.

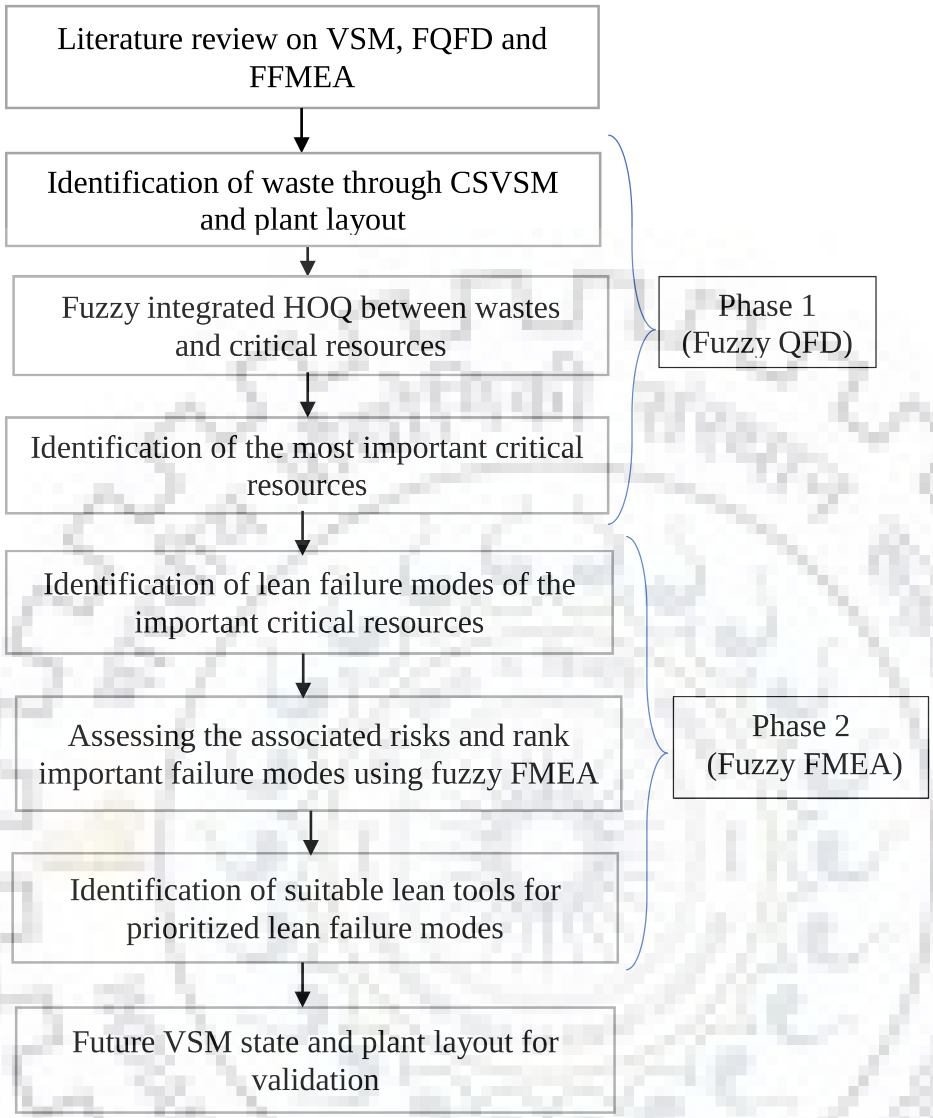


Figure 5.2 The framework of the study.

5.5.1 Developing the present state VSM and plant layout

Identifying the product family is the initial stage in developing the CSVSM and existing state plant layout. By studying the information and materials flow of each process's activities, the CSVSM is plotted. The VA and NVA actions are identified using the CSVSM. The resources that lead to waste are identified using a time study, observations, and extensive discussions with supervisors and managers.

5.5.2 Fuzzy QFD

In this study, fuzzy QFD in the HOQ integrates the identified types of wastes and critical resources. The identified wastes (WHATs) are considered as requirements of the customers and the critical resources (HOWs) as technical requirements in the HOQ. Some of the HOQ matrices are not included in this report, such as the preparation (planning) matrix, the technical and target (goal) analysis sections, as they do not apply to this study (Almannai, Greenough, & Kay, 2008).
According to Bottani (2009), the fuzzy QFD calculation and the HOQ matrix are defined in the steps below: Step-1: Identifying the importance of customer requirements, i.e., wastes. To properly rank the identified wastes, importance weights should be given (W_i) (i=1, …, n). Importance weights are obtained from managers, supervisors, and expert's opinions using linguistic terms. Hence fuzzy triangular numbers are used. The importance weights and their associated fuzzy numbers for the identified wastes are shown in Table 5.1. For the importance weights, a 4-point scale is used to express the study's linguistic values (Bottani & Rizzi, 2006).

Table 5.1 Fuzzy numbers for ranking wastes with their importance weights.

Fuzzy number	Importance weights(Wi)
(0.7; 1; 1)	Very high (VH)
(0.5; 0.7; 1)	High (H)
(0; 0.3; 0.5)	Low (L)
(0; 0; 0.3)	Very low (VL

Step-2: Calculating the relative importance (RI) of critical resources (HOWs). The relationships are evaluated using managers, supervisors, and expert's opinions. Hence to express the relationships, fuzzy triangular numbers, correlation, and RI are used. In the HOQ, the affiliation matrix (R_{ij}) where (i=1, …, n; j=1, …, m) is a matrix whose entry (i, j) shows how j-th critical resource generates i-th waste. Corresponding to the degree of relationships (Ma, Chu, Xue, & Chen 2017), the fuzzy numbers are shown in Table 5.2. As revealed by Bottani (2009), after evaluating the relationship between wastes and critical resources, the RI of the j-th critical resources (RI_j) is computed using:

$$RI_j = \sum_{i=1}^{n} W_i \otimes R_{ij,} \qquad j = 1, \dots, m \tag{2}$$

The effect of RI_j on $RI_{j'}$, $(j \neq j')$ of the critical resources is expressed in the correlation matrix formed at the roof of HOQ. Let the correlation entry is defined as $T_{jj'}$.

Table 5.3 displays the degree of the association on the 4-level scale and their corresponding fuzzy numbers.

Step-3: Calculating the final score of critical resources. Having a correlation between the critical resources in the roof of the HOQ matrix, the last score of j-th critical resources is computed using:

$$Score_j = RI_j \oplus \sum_{j \neq j'} T_{jj'} \otimes RI_{j'}, j = 1, \ldots, m. \quad (3)$$

Since the measured value (l, m, u) is a fuzzy number, a crisp value is calculated using the following formula:

$$crisp\ value = \frac{l+2m+u}{4} \quad (4)$$

Then the critical resources are prioritized based on the crisp values.

Table 5.2 Fuzzy numbers with a corresponding degree of relationships.

Fuzzy number	Degree of relationship
(0.7; 1; 1)	Strong (S)
(0.3; 0.5; 0.7)	Medium (M)
(0; 0; 0.3)	Weak (W)

Table 5.3 Fuzzy numbers & degree of correlation used in the correlation matrix.

Fuzzy number	Degree of correlation
(0.3; 0.5; 0.7)	Strong positive (SP)
(0; 0.3; 0.5)	Positive (P)
(-0.5; -0.3; 0)	Negative (N)
(-0.7; -0.5; -0.3)	Strong negative (SN)

5.5.3 Fuzzy FMEA

There are many lean techniques and tools to implement lean in the manufacturing industries (Vinodh et al., 2010). But the organizations are facing difficulties in selecting the appropriate lean tools. It is costly, time-consuming, and most firms cannot apply all lean techniques for all the resources (Vinodh, Shivraman, & Viswesh, 2012). A critical issue, especially for low-level technology organizations, is the fear of investing in changes that take time and budget for results. Hence, after prioritizing the essential resources using fuzzy QFD, a profound study will be carried out to determine which sub-elements make the organization fail leanness. These sub-elements in this study are referred to as failure modes. A fuzzy RPN analysis is to be conducted to quantify the associated risks and rank the failure modes. And to complete the calculations with process FMEA, data is collected from managers, supervisors, and experts in linguistic terms using a structured questionnaire. Table 5.4 displays the three factors, linguistic terms (ratings), descriptions, and fuzzy numbers (Ma, Chu, Xue, & Chen, 2017; Bhuvanesh Kumar & Parameshwaran, 2018).

Table 5.4 Fuzzy ratings for occurrence (O), severity (S), and detection (D)

Ratings	Fuzzy number	Descriptions		
		Occurrence (O)	Severity (S)	Detection (D)
Very high (VH)	(7, 9, 9)	All workers remember the events and happen very often	Increase cost in the long-term and highly affects the production system	Failure can be detected only after its occurrence
High (H)	(5, 7, 9)	Events are observed by only managers & the people involved	Increased cost in the medium-term and delays the production flow	With a high-level of examination, failure can be identified
Medium (M)	(3, 5, 7)	Managers remember a small number of events	Increased cost in short-term and delays the production flow	Failure can be detected with a medium chance
Low (L)	(1, 3, 5)	Managers recall very few events	A small increase in cost in the short-term but will not impact the production flow	Failure can be detected with small inspection before it occurs
Very Low (VL)	(1, 1, 3)	The occurrences are collected only by managers with difficulty	A minimal increase in cost in the short-term due to the improper use of resources	Failure can be identified directly before its occurrence

The RI of the risk factors is considered in this study. Table 5.5 displays fuzzy numbers and linguistic meanings used for the relative weight of O, S, and D (Bottani & Rizzi, 2006). This study uses a fuzzy weighted geometric mean (FWGM) by taking the risk factors' RI weights. It solves the disadvantages of standard FMEA, which calculates the RPN value by multiplying the O, S, and D values.

Table 5.5 Fuzzy numbers and linguistic values of the risk factors' relative weight.

Fuzzy numbers	Linguistic value
(0.7, 1, 1)	Very high (VH)
(0.5, 0.7, 1)	High (H)
(0, 0.3, 0.5)	Low (L)
(0, 0, 0.3)	Very low (VL)

To calculate the FRPN, aggregating the subjective opinions of the FMEA team members is computed using eq. 5 to 10 (Gargama & Chaturvedi, 2011; Parameshwaran et al., 2010).

$$\tilde{R}_i^O = \sum_{j=1}^{m} h_j \tilde{R}_{ij}^O = \left(\sum_{j=1}^{m} h_j \tilde{R}_{ijL}^O, \quad \sum_{j=1}^{m} h_j \tilde{R}_{ijM}^O, \sum_{j=1}^{m} h_j \tilde{R}_{ijU}^O \right), i = 1, \ldots, n, \quad (5)$$

$$\tilde{R}_i^S = \sum_{j=1}^{m} h_j \tilde{R}_{ij}^S = \left(\sum_{j=1}^{m} h_j \tilde{R}_{ijL}^S, \quad \sum_{j=1}^{m} h_j \tilde{R}_{ijM}^S, \sum_{j=1}^{m} h_j \tilde{R}_{ijU}^S \right), i = 1, \ldots, n, \quad (6)$$

$$\tilde{R}_i^D = \sum_{j=1}^{m} h_j \tilde{R}_{ij}^D = \left(\sum_{j=1}^{m} h_j \tilde{R}_{ijL}^D, \quad \sum_{j=1}^{m} h_j \tilde{R}_{ijM}^D, \sum_{j=1}^{m} h_j \tilde{R}_{ijU}^D \right), i = 1, \ldots, n, \quad (7)$$

$$\widetilde{w}^O = \sum_{j=1}^{m} h_j \widetilde{w}_j^O = \left(\sum_{j=1}^{m} h_j \widetilde{w}_{jL}^O, \quad \sum_{j=1}^{m} h_j \widetilde{w}_{jM}^O, \sum_{j=1}^{m} h_j \widetilde{w}_{jU}^O \right), \quad (8)$$

$$\widetilde{w}^S = \sum_{j=1}^{m} h_j \widetilde{w}_j^S = \left(\sum_{j=1}^{m} h_j \widetilde{w}_{jL}^S, \quad \sum_{j=1}^{m} h_j \widetilde{w}_{jM}^S, \sum_{j=1}^{m} h_j \widetilde{w}_{jU}^S \right), \quad (9)$$

$$\widetilde{w}^D = \sum_{j=1}^{m} h_j \widetilde{w}_j^D = \left(\sum_{j=1}^{m} h_j \widetilde{w}_{jL}^D, \quad \sum_{j=1}^{m} h_j \widetilde{w}_{jM}^D, \sum_{j=1}^{m} h_j \widetilde{w}_{jU}^D \right), \quad (10)$$

Where $\tilde{R}_i^O = (\tilde{R}_{iL}^O, \tilde{R}_{iM}^O, \tilde{R}_{iU}^O), \tilde{R}_i^S = (\tilde{R}_{iL}^S, \tilde{R}_{iM}^S, \tilde{R}_{iU}^S)$ and $\tilde{R}_i^D = (\tilde{R}_{iL}^D, \tilde{R}_{iM}^D, \tilde{R}_{iU}^D)$ are aggregated O,S , and D ratings for failure mode FM_i and $\widetilde{w}^O = (\widetilde{w}_L^O, \widetilde{w}_M^O, \widetilde{w}_U^O), \widetilde{w}^S = (\widetilde{w}_L^S, \widetilde{w}_M^S, \widetilde{w}_U^S)$, and $\widetilde{w}^D = (\widetilde{w}_L^D, \widetilde{w}_M^D, \widetilde{w}_U^D)$ are aggregated fuzzy weights for O, S, and D.

Therefore, the FRPN is calculated using eq. (11) (Wang et al., 2009).

$$FRPN_i = (R_i^O)^{\frac{\widetilde{w}^O}{\widetilde{w}^O + \widetilde{w}^S + \widetilde{w}^D}} \times (R_i^S)^{\frac{\widetilde{w}^S}{\widetilde{w}^O + \widetilde{w}^S + \widetilde{w}^D}} \times (R_i^D)^{\frac{\widetilde{w}^D}{\widetilde{w}^O + \widetilde{w}^S + \widetilde{w}^D}}, i = 1, \ldots, n. \quad (11)$$

Where the i^{th} failure mode's fuzzy RPN value is $FRPN_i$.

$\widetilde{w}^O, \widetilde{w}^S, and\ \widetilde{w}^D$ are the fuzzy weights of O, S, and D.

It is conceivable to compute the value of FRPN using eq. (11), but the equation with the products and the power of fuzzy numbers is too complicated. Hence, the FRPN of each failure mode can be calculated using alpha-level sets using a linear programming model (LP) (Parameshwaran et al., 2010; Wang et al., 2009).

$$Min\ Z_1 = u_1 ln\left(\tilde{R}_i^O\right)_\alpha^L + u_2 ln\left(\tilde{R}_i^S\right)_\alpha^L + u_3 ln\left(\tilde{R}_i^D\right)_\alpha^L \tag{12}$$

s.t. $u_1 + u_2 + u_3 = 1,$

$$(\widetilde{w}^O)_\alpha^L . Z \le u_1 \le (\widetilde{w}^O)_\alpha^U . Z,$$

$$(\widetilde{w}^S)_\alpha^L . Z \le u_2 \le (\widetilde{w}^S)_\alpha^U . Z,$$

$$(\widetilde{w}^D)_\alpha^L . Z \le u_3 \le (\widetilde{w}^D)_\alpha^U . Z,$$

$$Z \le 0,$$

$$Max\ Z_2 = u_1 ln\left(\tilde{R}_i^O\right)_\alpha^U + u_2 ln\left(\tilde{R}_i^S\right)_\alpha^U + u_3 ln\left(\tilde{R}_i^D\right)_\alpha^U \tag{13}$$

s.t. $u_1 + u_2 + u_3 = 1,$

$$(\widetilde{w}^O)_\alpha^L . Z \le u_1 \le (\widetilde{w}^O)_\alpha^U . Z,$$

$$(\widetilde{w}^S)_\alpha^L . Z \le u_2 \le (\widetilde{w}^S)_\alpha^U . Z,$$

$$(\widetilde{w}^D)_\alpha^L . Z \le u_3 \le (\widetilde{w}^D)_\alpha^U . Z,$$

$$Z \le 0,$$

Where $\left[\left(\tilde{R}_i^O\right)_\alpha^L, \left(\tilde{R}_i^O\right)_\alpha^U\right], \left[\left(\tilde{R}_i^S\right)_\alpha^L, \left(\tilde{R}_i^S\right)_\alpha^U\right], and\ \left[\left(\tilde{R}_i^D\right)_\alpha^L, \left(\tilde{R}_i^D\right)_\alpha^U\right]\ are\ the\ \alpha - level\ sets\ of\ O, S, and\ D\ ratings\ and$ $[(\widetilde{w}^O)_\alpha^L, (\widetilde{w}^O)_\alpha^U], [(\widetilde{w}^S)_\alpha^L, (\widetilde{w}^S)_\alpha^U], and\ [(\widetilde{w}^D)_\alpha^L, (\widetilde{w}^D)_\alpha^U]\ are\ the\ \alpha\ level\ sets\ of\ the\ risk\ factor\ weights$

Let z^*_1 and z^*_2 be the optimal objective function values of models (12) and (13). Then $(FRPN_i)_\alpha^L = exp(z_1^*)\ and\ (FRPN_i)_\alpha^U = exp(z_2^*)$. By setting different sets of α-level, different $FRPN_i$ values can be generated using:

$$FRPN_i = \bigcup_\alpha \alpha . [\ (FRPN_i)_\alpha^L,\ (FRPN_i)_\alpha^U], 0 \le \alpha \le 1 \tag{14}$$

Since intervals characterize the FRPNs, then the defuzzified centroid of $\tilde{A}$ is computed by the following equation (Wang et al., 2009; Gargama and Chaturvedi, 2011):

$$\tilde{x}_0\left(\tilde{A}\right) = \frac{\int_a^d x\mu_{\tilde{A}}(x)dx}{\int_a^d \mu_{\tilde{A}}(x)dx}, \tag{15}$$

Where $\tilde{x}_0(\tilde{A})$ *is the defuzzified value*. When $\Delta\alpha_i \equiv 1/_n$, *where* $\Delta\alpha_i = \alpha_{i+1} - \alpha_i$, *and* $\alpha_i = 1/_n, i = 0, \dots, n.$ then its defuzzified centroid can be determined using (Wang et al., 2009):

$$\int_a^d \mu_{\tilde{A}}(x)dx = \frac{1}{2n}\left[\left((x)_{\alpha_0}^U - (x)_{\alpha_0}^L\right) + \left((x)_{\alpha_n}^U - (x)_{\alpha_n}^L\right) + 2\sum_{i=1}^{n-1}\left((x)_{\alpha_i}^U\right) - (x)_{\alpha_i}^L\right], \quad (16)$$

$$\int_a^d x\mu_{\tilde{A}}(x)dx = \frac{1}{6n}\left[\left((x)_{\alpha_0}^{2U} - (x)_{\alpha_0}^{2L}\right) + \left((x)_{\alpha_n}^{2U} - (x)_{\alpha_n}^{2L}\right) + 2\sum_{i=1}^{n-1}\left((x)_{\alpha_i}^{2U}\right) - (x)_{\alpha_i}^{2L}\right]$$
$$+ \frac{1}{6n}\sum_{i=0}^{n-1}\left((x)_{\alpha_i}^U\right)\cdot(x)_{\alpha_{i+1}}^U - (x)_{\alpha_i}^L\cdot(x)_{\alpha_{i+1}}^L \quad (17)$$

Using the preceding formulae, the unit interval [0, 1] is divided evenly by the sets of alpha levels to calculate the defuzzified centroid value. The failure modes are prioritized and ranked by sorting their defuzzified centroid values. The higher the centroid value, the higher the risk, the higher the priority, and the lower the centroid value, the lower the risk, the lower the priority. Prioritizing the failure modes based on the calculated centroid values provides a list of failure modes' ranks. Based on their level, detailed analysis, the study of the literature, and discussion with industry managers and experts, appropriate tools/projects for lean implementation are selected.

5.5.4 Future state value stream mapping (FSVSM) and plant layout

Analyzing the CSVSM and plant layout in detail provides to observe the potential improvement areas and proposed improvement scenarios. By applying the proposed improvement options and modifications, the proposed FSVSM is developed. Implementation of lean takes time to see the results of all the proposed improvement scenarios. Hence all the proposed improvements cannot see precisely. But validation is made by comparing the performance metrics of the CSVSM and FSVSM.

5.6 Case study

This study was conducted in an Ethiopian leather footwear manufacturing company. For the sack of company privacy hereafter, the case company is referred to as ABC. ABC manufactures different types, models, and sizes of leather shoe products. It was established in 1939. In the early 1980s, the company began exporting shoes in limited quantities. ABC gets its leather from local tanneries and other inputs from outside, and it makes its own or imports the sole.

5.6.1 Current state VSM and plant layout development

The first step in developing the CSVM and plant layout is identifying the product family. As revealed by Ariafar & Ismail (2009), plant layout significantly impacts the performance of manufacturing processes. The existing VSM is developed through plant layout by visiting the organization frequently. Visiting the industry frequently allowed for a thorough examination of each activity's operations. The machines are set up in the correct order. However, WIP is scattered & stored throughout the work locations and before & after each workstation for long time, taking up needless space. The developed current plant layout shows the flow of products between each workstation (see Figure 5.3).

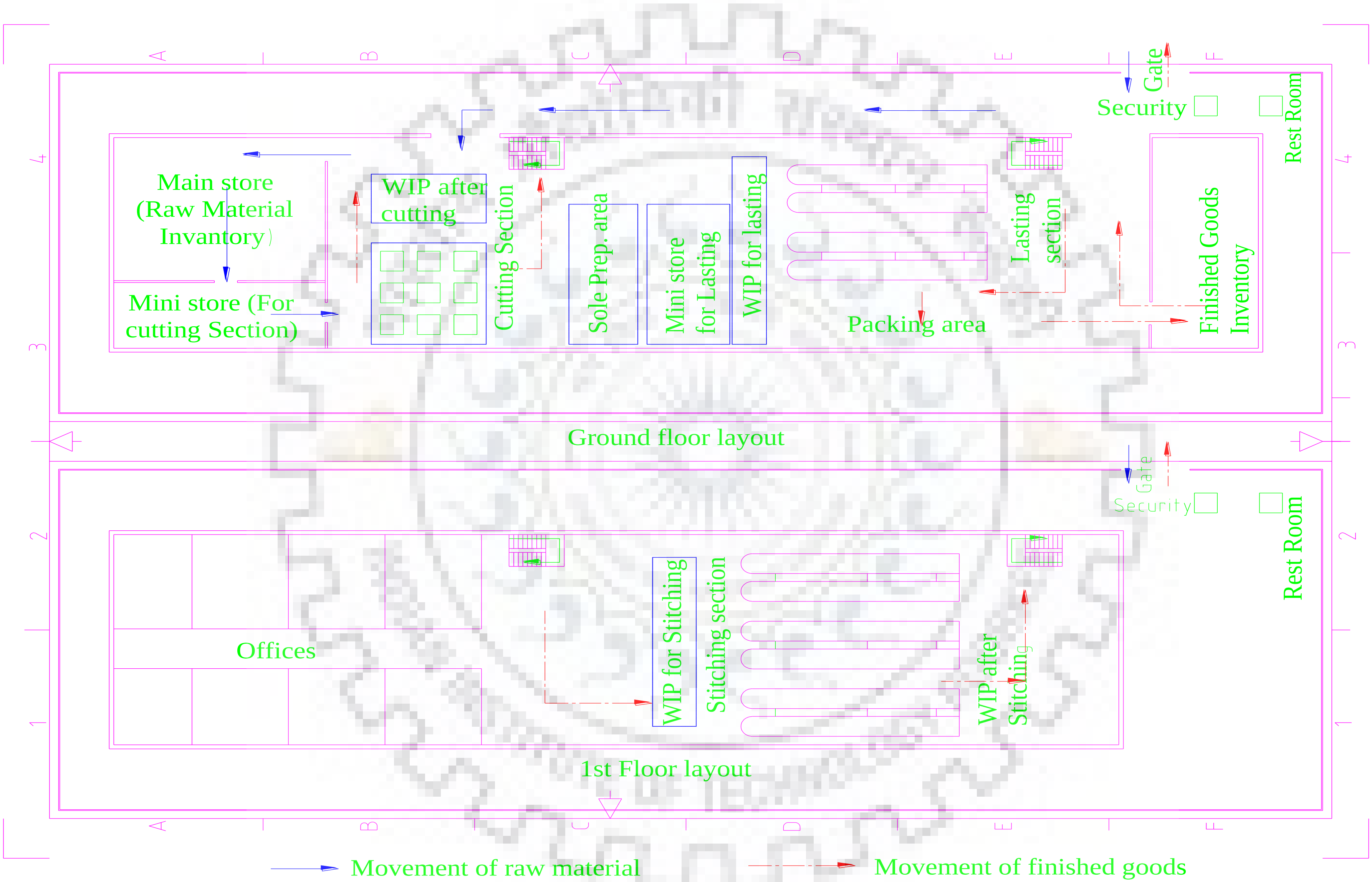


Figure 5.3 The current plant layout

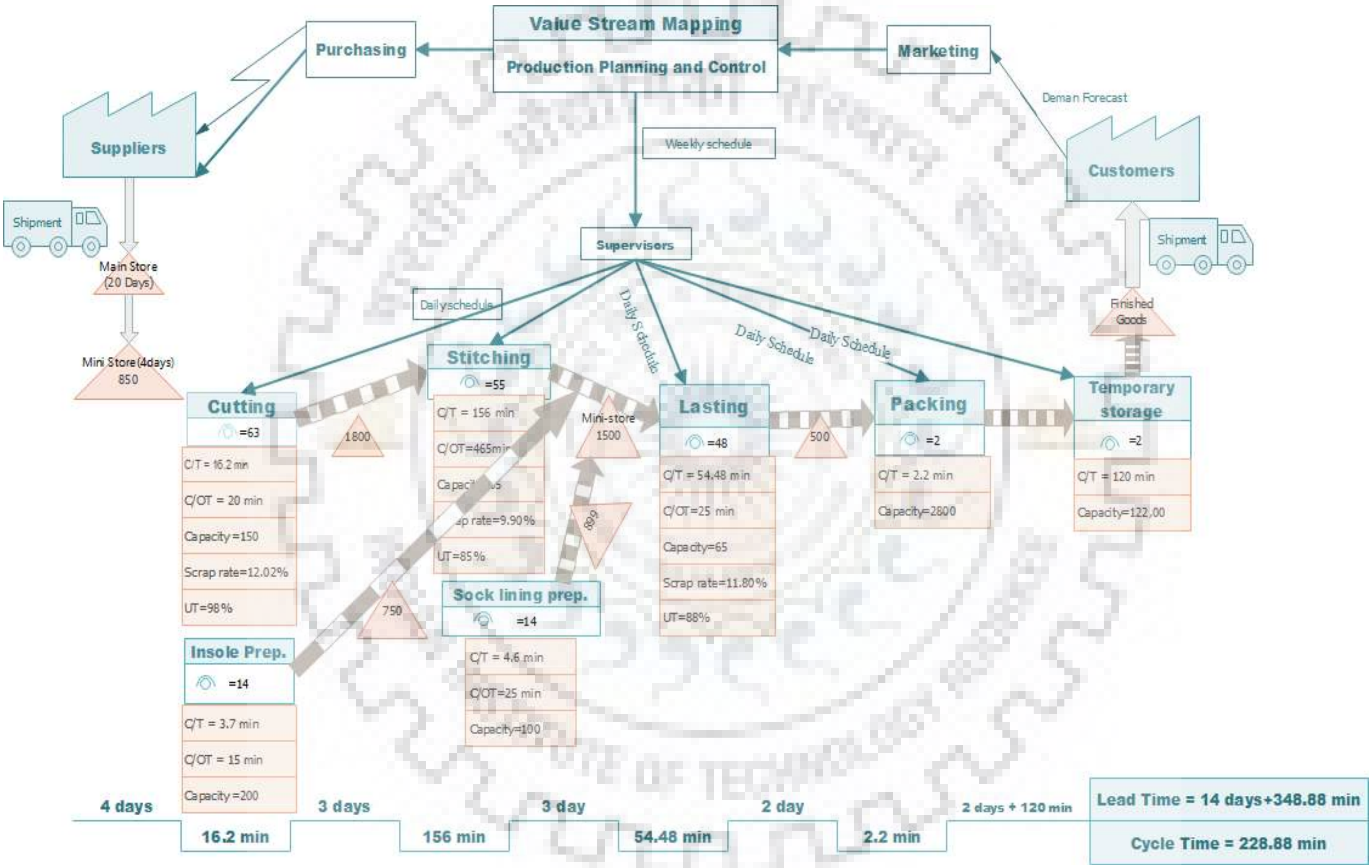


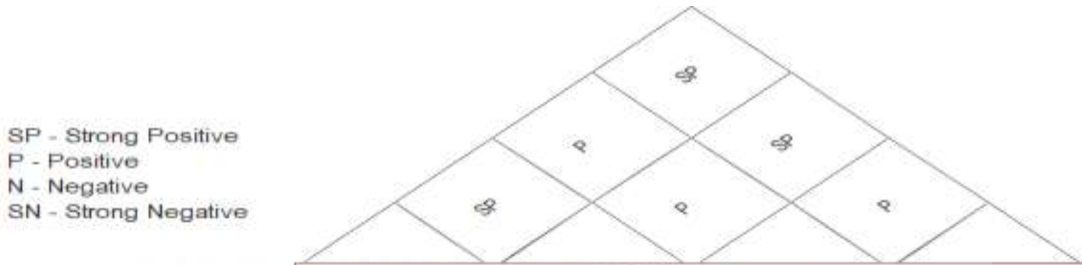
Figure 5.4 CSVSM

Arrows indicate the movement of materials, WIP, and finished products. The system begins with receiving raw materials from the main store and flows through the cutting, stitching, lasting, and packing sections. In each area, there is an in-process inspection and temporary storing space. Finally, products are stored in inventory in the store until they get dispatched out. Parts within the plant flow in batches of size. The batch size depends on the number of orders. After examining the existing production process closely, the CSVSM is developed, as shown in Figure 5.4, by plotting the selected product family's information and material flows. The CSVSM is used to determine the wastes that should be minimized or eliminated. The resources that lead to waste are discovered through time study and observations (Gemba walk) as well as extensive discussion with supervisors and managers.

The cycle time, available time, up-time, and change over time for different processes involved to produce SAWA model shoes are quantified. The CSVSM and layout are evaluated and discussed with managers, supervisors, and experts to summarize the defined wastes. The organization has significant waste and NVA operations, including defects, waiting, labor productivity, unnecessary movement, transportation, inventory, and long lead time.

5.6.2 Fuzzy QFD

The HOQ is formed between WHATs (wastes) and HOWs (critical resources) to prioritize essential resources. In this study, the wastes are considered as the customer requirements and critical resources as technical requirements in the HOQ. The relationship between the WHATs and the HOWs is assessed through questionnaires from managers, supervisors, and experts, including linguistic values. Therefore, TFNs presented in Table 5.1 to Table 5.3 are used to express the importance weights, correlation, and relationship evaluation. Then after developing the relationship & correlation matrix, the computation of RI using equation (2), score using equation (3), and ranking using equation (4) are done as described in the methodology section. Figure 5.5 shows the defined HOQ with the ranking of essential resources.



		Critical Resources			
Wastes	Weight (W_i)	People	Equipment	Materials	Schedule
Defects	H	S	M	W	S
Labor productivity	VH	S	M	M	M
Excessive movement	VH	S	S	M	
Waiting	H	S		M	S
Raw material	H			S	
Inventory	L	M		S	W
Transportation	L	S		S	M
Lead time	H	M	S	W	S
	RI_j	(4.98; 4.2; 5.55)	(1.06; 2.25; 3.4)	(0.92; 2.65; 4.7)	(1.26; 2.75; 4.5)
	$Score_j$	(5.676; 7.495; 13.43)	(2.932; 6.52; 12.785)	(0.92; 5.644; 11.425)	(3.072; 6.77; 13.115)
	Crisp Values	8.524	7.18925	5.90825	7.43175
	Rank	1	3	4	2

Figure 5.5 The HOQ

The results of the HOQ show people score the highest value, followed by schedule, equipment, and materials. Since the aim is to implement lean practices and a continuous improvement process, more emphasis will be given to the elements that generate higher waste. As a result, the top two resources (*people* and *schedules*) are initially focused on implementing lean methods and eventually identifying their components. These elements are referred to as failure modes in this study because of their potential implications and risks.

5.6.3 Fuzzy FMEA

An in-depth understanding of the critical resources and their sub-elements results in finding six modes of failure from people and six modes of failure from the schedule. These are inspection, purchasing of raw materials, manufacturing quantity & delivery format, material cutting, tool searching, manufacturing process, worker's involvement, and layout. To perform the fuzzy FMEA analysis the following steps have been followed:

Step-1: Assessment of the failure modes by three FMEA team members

The three team members are of varying significance based on their respective domain knowledge, skills, and experience.

The relative weights are allocated to the three-team members as 50%, 30%, and 20% to reflect their opinion in FMEA analysis. The assessment of these failure modes obtained from the three FMEA team members is shown in Table 5.6.

Table 5.6 Assessment of the failure modes.

Risk factors	FMEA team members	Factor weights	Failure modes											
			1	2	3	4	5	6	7	8	9	10	11	12
Occurrence	TM1 (50%)	H	VH	M	VH	H	H	VH	M	H	H	H	H	H
	TM2 (30%)	VH	VH	VH	H	H	M	H	VH	H	M	H	VH	H
	TM3 (20%)	H	H	H	H	H	H	VH	H	VH	VH	H	H	H
Severity	TM1 (50%)	VH	H	M	M	L	M	VH	VH	M	H	VH	M	H
	TM2 (30%)	H	H	H	L	VH	L	VH	H	H	L	H	L	VH
	TM3 (20%)	VH	VH	H	L	H	L	H	VH	VH	L	VH	L	VH
Detection	TM1 (50%)	H	M	H	H	VH	L	VH	H	H	H	VH	H	VH
	TM2 (30%)	VH	H	L	H	VH	H	H	H	H	VH	H	L	H
	TM3 (20%)	VH	VH	L	H	H	L	H	VH	VH	VH	VH	L	VH

Step-2: Aggregating: the FMEA team members' subjective opinions

Based on the information in Table 5.6, the information assessment made by the three team members for the twelve failure modes is first aggregated using eq. (5 to 10) and shown in Table 5.7.

Table 5.7 Aggregated fuzzy information assessment

Failure modes	Occurrence	Severity	Detection
FM_1	(6.6, 8.6, 9)	(5.4, 7.4, 9)	(4.4, 6.4, 8)
FM_2	(4.6, 6.6, 8)	(4, 6, 8)	(3, 5, 7)
FM_3	(6, 8, 9)	(2, 4, 6)	(5, 7, 9)
FM_4	(5, 7, 9)	(3.6, 5.6, 7)	(6.6, 8.6, 9)
FM_5	(4.4, 6.4, 8.4)	(2, 4, 6)	(2.2, 4.2, 6.2)
FM_6	(6.4, 8.4, 9)	(6.6, 8.6, 9)	(6, 8, 9)
FM_7	(4.6, 6.6, 8)	(6.4, 8.4, 9)	(5.4, 7.4, 9)
FM_8	(5.4, 7.4, 9)	(4.4, 6.4, 8)	(5.4, 7.4, 9)
FM_9	(4.8, 6.8, 8.4)	(3, 5, 7)	(6, 8, 9)
FM_{10}	(5, 7, 9)	(6.4, 8.4, 9)	(6.4, 8.4, 9)
FM_{11}	(5.6, 7.6, 9)	(2, 4, 6)	(3, 5, 7)
FM_{12}	(5, 7, 9)	(6, 8, 9)	(6.4, 8.6, 9)
Important weights	(0.56, 0.79, 1)	(0.64, 0.91,1)	(0.6, 0.85, 1)

Step-3: The computation of α-level sets of each FRPNs (see Table 5.8).

Step-4: Defuzzify the FRPNs using defuzzification Centroid method

The equations given in the methodology were used for calculating the fuzzy RPN. By setting different alpha levels, various fuzzy RPN levels can be determined. In this study, to get eleven fuzzy RPN values, the alpha values are set from 0 to 1, and the calculated values in intervals are shown in Table 5.8. Therefore, the crisp values are obtained using the CDA. The failure modes are then ranked based on their centroid values (see the last row of Table 5.8).

Table 5.8 Alpha-level set and fuzzy RPN values

α	Failure Modes											
	FM1	FM2	FM3	FM4	FM5	FM6	FM7	FM8	FM9	FM10	FM11	FM12
0	[5.368, 8.653]	[3.795, 7.6517]	[3.820, 7.8622]	[4.880, 8.2768]	[2.638, 6.7859]	[6.332, 9.0000]	[5.457, 8.6535]	[5.020, 8.6535]	[4.374, 8.0886]	[5.926, 9.0000]	[3.153, 7.2304]	[5.792, 9.0000]
0.1	[5.571, 8.531]	[3.998, 7.4703]	[4.044, 7.6805]	[5.086, 8.1436]	[2.848, 6.5790]	[6.532, 8.9333]	[5.659, 8.5346]	[5.221, 8.4912]	[4.583, 7.9269]	[6.128, 8.8934]	[3.369, 7.0375]	[5.993, 8.8800]
0.2	[5.773, 8.408]	[4.201, 7.2884]	[4.265, 7.4975]	[5.291, 8.0101]	[3.057, 6.3718]	[6.733, 8.8667]	[5.861, 8.4159]	[5.422, 8.3288]	[4.790, 7.7646]	[6.329, 8.7868]	[3.583, 6.8437]	[6.194, 8.7600]
0.3	[5.975, 8.284]	[4.403, 7.1060]	[4.484, 7.3130]	[5.496, 7.8760]	[3.265, 6.1644]	[6.933, 8.8001]	[6.062, 8.2973]	[5.622, 8.1663]	[4.997, 7.6014]	[6.531, 8.8604]	[3.795, 6.6490]	[6.395, 8.6401]
0.4	[6.177, 8.159]	[4.605, 6.9233]	[4.701, 7.1271]	[5.701, 7.7415]	[3.472, 5.9566]	[7.133, 8.7334]	[6.264, 8.1790]	[5.823, 8.0037]	[5.203, 7.4374]	[6.732, 8.5740]	[4.007, 6.4534]	[6.596, 8.5202]
0.5	[6.378, 8.033]	[4.807, 6.7400]	[4.916, 6.9396]	[5.905, 7.6065]	[3.678, 5.7486]	[7.333, 8.6668]	[6.466, 8.0608]	[6.024, 7.8411]	[5.409, 7.2725]	[6.933, 8.4678]	[4.217, 6.2568]	[6.797, 8.4003]
0.6	[6.580, 7.905]	[5.009, 6.5562]	[5.130, 6.7505]	[6.109, 7.4709]	[3.884, 5.5402]	[7.533, 8.6003]	[6.667, 7.9427]	[6.224, 7.6783]	[6.614, 7.1067]	[7.134, 8.3617]	[4.426, 6.0592]	[6.998, 8.2804]
0.7	[6.782, 7.777]	[5.211, 6.3719]	[5.343, 6.5595]	[6.313, 7.3349]	[4.089, 5.3315]	[7.733, 8.5337]	[6.869, 7.8249]	[6.425, 7.5155]	[5.819, 6.9399]	[7.335, 8.2557]	[4.635, 5.8604]	[7.199, 8.1607]
0.8	[6.983, 7.648]	[5.412, 6.1870]	[5.554, 6.3667]	[6.516, 7.1983]	[4.294, 5.1223]	[7.933, 8.4672]	[7.070, 7.7073]	[6.625, 7.3526]	[6.024, 6.7719]	[7.536, 8.1499]	[4.842, 5.6605]	[7.400, 8.0409]

0.9	[7.185, 7.517]	[5.614, 6.0016]	[5.765, 6.1719]	[6.720, 7.0611]	[4.498, 4.9128]	[8.134, 8.4007]	[7.271, 7.5899]	[6.826, 7.1895]	[6.228, 6.6028]	[7.737, 8.0442]	[5.050, 5.4593]	[7.601, 7.9213]
1	[7.386, 7.386]	[5.815, 5.8154]	[5.974, 5.9749]	[6.923, 6.9233]	[4.702, 4.7028]	[8.334, 8.3342]	[7.472, 7.4728]	[7.026, 7.0264]	[6.432, 6.4325]	[7.938, 7.9387]	[5.256, 5.2568]	[7.801, 7.8017]
Centroid	7.1412	5.7572	5.8994	6.6969	4.7132	7.8889	7.1940	6.9008	6.3249	7.6346	5.2222	7.5314
Priority ranking	5	10	9	7	12	1	4	6	8	2	11	3

The present case study shows the failure modes and their potential effects, root cause, and recommended lean projects in Table 5.9. Hence the study uses fuzzy FMEA method to prioritize the twelve failure modes.

Table 5.9 FMEA table

Critical resources	Manufacturing environment									
	Type of wastes	Lean failure modes	Occurrence	Potential effects	Severity	Root cause	Detection	Centroid	Rank	Recommended lean projects
People	1. Defects	Material cutting	VH	Inappropriate size of components	H	Unskilled operator/fatigue	M	7.1412	5	Training the operator and provide break time
	2. waiting	Material loading	M	Time-consuming	M	Unskilled operator	H	5.7572	10	Training the operator
	3. over-processing	Inspection	VH	Uncertain waiting	M	Unskilled operator	H	5.8994	9	Training the operator
	4. Waiting	Tool searching	H	Time-consuming	L	Unexperienced operator	VH	6.6969	7	Layout modification and workplace organization
	5. Defects	Manufacturing process	H	Defective products	M	Unskilled operator/fatigue	L	4.7132	12	Training the operator and provide break time
	6. Inventory	Manufacturing process	VH	High WIP	VH	Unskilled operator /fatigue	VH	7.8889	1	Training the operator and provide break time

Schedule	7. Overproduction	Raw materials Purchasing	M	High levels of inventory	VH	Lack of standard purchasing schedule	H	7.1940	4	Pull system, FIFO
	8. Inventory	Manufacturing quantity & delivery format	H	Finished goods pile up	M	No proper schedule of delivery	H	6.9008	6	Standard delivery schedule
	9. Transportation	Layout	H	Raw materials' long and unnecessary movement	H	The initial plan of the plant layout	H	6.3249	8	Facility planning and layout modification
	10. Motion	Workers movement due to the work environment	H	Internal traffic	VH	Poor workstation arrangements	VH	7.6346	2	Layout modification and facility planning
	11. Inventory	Manufacturing process	H	High level of WIP	M	Unbalanced assembly line workstations	H	5.2222	11	Assembly line balancing
	12. Transportation	Manufacturing process	H	Unnecessary transportation leads to long lead time	H	The initial plan of the plant layout	VH	7.5314	3	Layout modification and facility planning

After prioritizing the failure modes, they are presented as follows: Manufacturing process, workers' involvement (movement), raw materials purchasing, material cutting, manufacturing quantity & delivery format, tool searching, layout, inspection, and material loading. To overcome the wastes suitable lean projects are chosen related to these modes of failure. Lean projects are selected for execution based on decision-makers' interests regarding the top few failure modes.

5.6.4 Future state VSM and plant layout

The fuzzy FMEA analysis result shows that high WIP in the manufacturing process, workers' movement (involvement) due to work environment, raw materials purchasing, material cutting, and inefficient manufacturing process are the failure modes positioned in the top priority lists. The selected lean projects are: facility planning & layout modification, pull system & FIFO (First-in, first-out), and line-balancing for these failure modes.

The results of the VSM show that stitching and lasting are the main processes that take a higher time, and most of the manufacturing activities are performed. After stitching, the next operation is lasting. But the cycle time of stitching is higher than lasting, which creates high WIP. This indicates a problem of flow production in the manufacturing process, which needs line balancing. Since there is doubt about the quality of raw materials, it is becoming a norm to produce 15% more than the ordered quantity to compensate for products' defects due to raw materials problems, which indirectly increases the WIP. Due to the lack of standards in purchasing and delivery schedules, inventory levels are kept very high. The workers have an unbalanced workload due to the lack of line balancing among the workstations. Hence after an in-depth investigation of all the activities within the manufacturing processes through Genba walk and time study, line balancing of the manufacturing processes is made. After making the proposed modifications, the FSVSM is presented and shown in Figure 5.6. The order fulfillment process of the company is very long and complicated. Every step needs a check and balance of the order quantities and qualities, which leads to a long lead time. It also creates order delays, customer dissatisfaction, and complaints. A pull system is suggested to be integrated into the company to reduce such problems and help the company to reduce manufacturing costs and overproduction. FIFO procedure is followed to minimize WIP inventory stacking & products for a long time and deliver a better product. And practically, line balancing between work stations is implemented to attain the production flow system. The changes in change over & cycle time, waiting, transportation, NVA, and other modifications are noted in FSVSM.

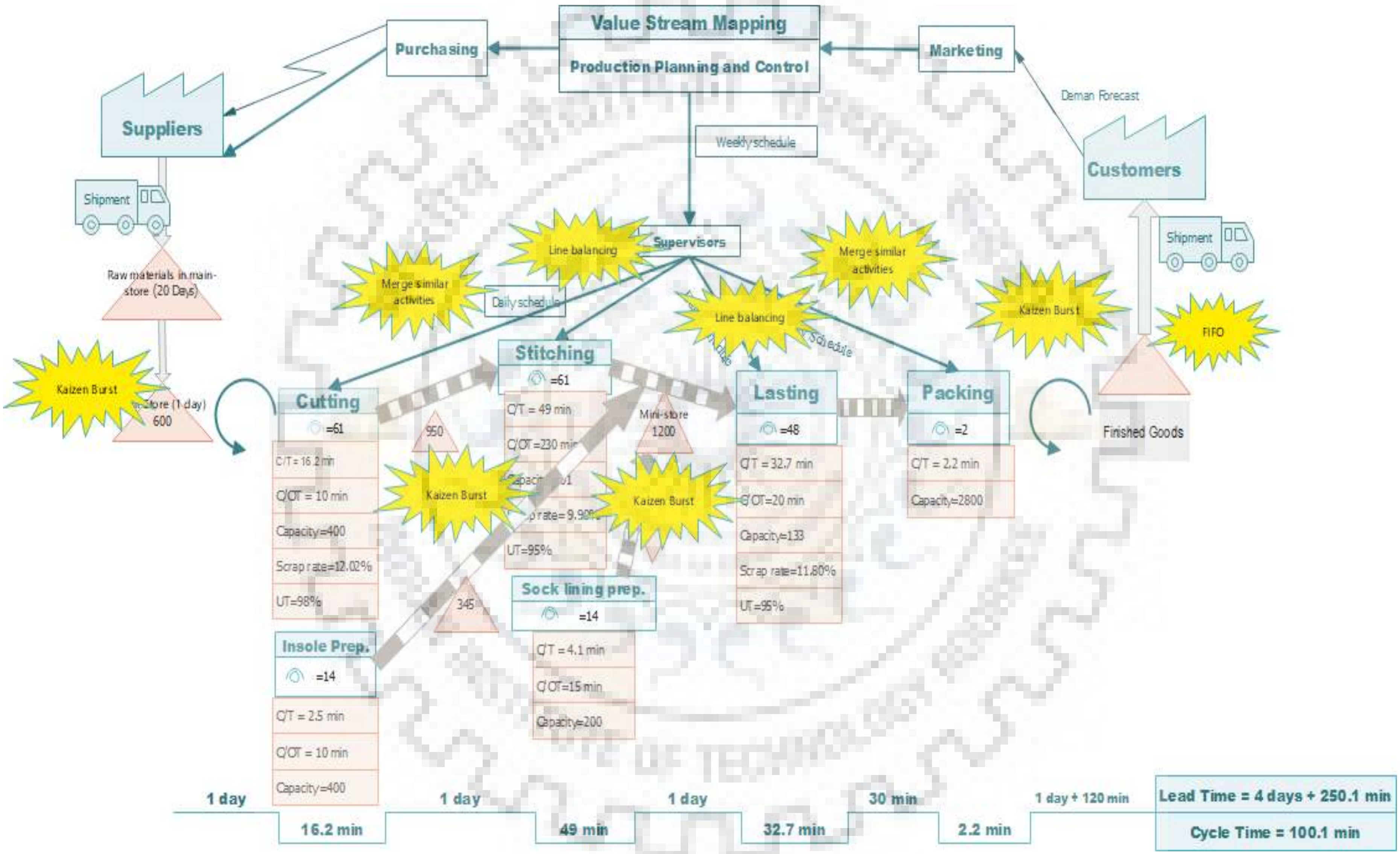


Figure 5.6 FSVSM

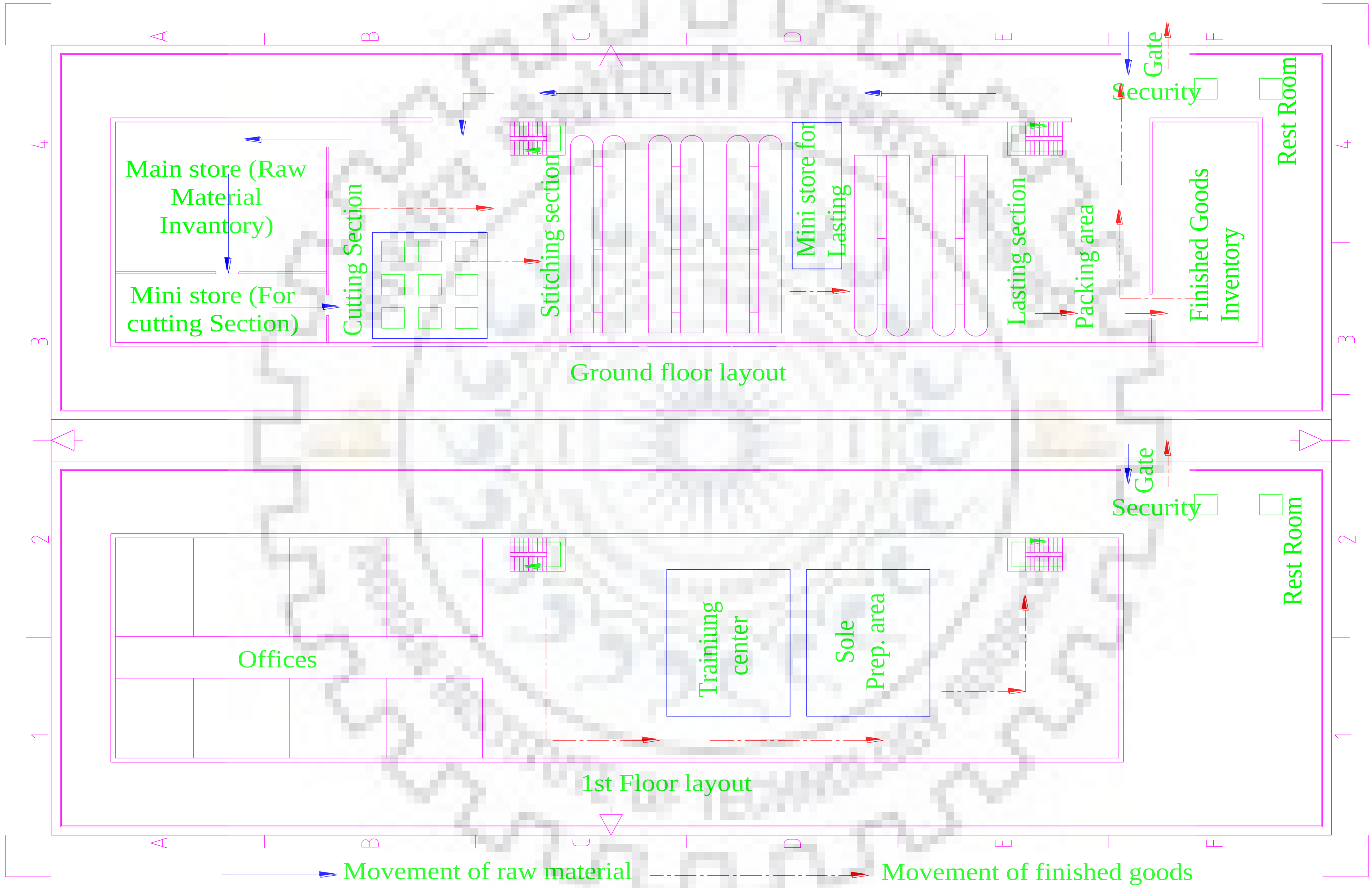


Figure 5.7 Proposed modified future plant layout

The proposed modified future plant layout is presented in Figure 5.7, where the stitching section replaces the sole preparation and mini store for the lasting area. Consequently, this dramatically reduces waiting time, transportation of raw material, and the number of employees. It also makes the production system to have a flow production system. Alternatively, a conveyor system can be installed from the cutting section to the stitching section and from the stitching section to the lasting section.

Table 5.10 Comparison of the current and future state

Key measures	Current state	Future state	Improvements
Total cycle time (min)	228.88	100.1	128.8
NVA time (Including transportation and temporary storage)	14 days and 120 min.	4 days and 150 min.	10 days
Total lead time	14 days and 348.88 min	4 days and 250.1 min	10 days and 98.78 min
Number of workers required (No's)	202	200	2
WIP (pairs)	4,650	2,750	1,900

5.7 Results and discussions

The most significant resources (schedule and people) are chosen for an in-depth analysis of the cause and their effects from fuzzy HOQ analysis. The waste sub-elements are evaluated by using the FWGM method, using α-cut values. The failure modes are prioritized using the CDA. After an in-depth analysis of the process FMEA, significant lean projects are selected like assembly line balancing, pull system & FIFO, and plant layout modification & facility planning. After the implementation of lean projects, the results are noted from the FSVSM shown in Figure 5.6. The key operational performance measures of a manufacturing industry like lead time, cycle time, labor productivity, and WIP for the current and future lean implementation scenarios are shown in Table 5.10. The successful validation of the model is confirmed by comparing the CSVSM with the FSVSM using a case study from the manufacturing organization (see Table 5.10).

5.7.1 Assembly line balancing (ALB)

ALB problem is a problem of assigning different jobs to workstations while enhancing one or more goals without violating any line constraints. It assists the company in successfully allocating and utilizing available resources. One of the difficulties that ALB should solve is resource optimization. In this study, reduction in cycle time (56.3%) and lead time (69.7%) was obtained as a result of ALB implementation.

5.7.2 Pull system & FIFO

The use of a pull system aids decision-makers in controlling the flow of resources. It enables the company to set standards for purchasing raw materials and estimating demand in order to satisfy the customers' needs. And it is a critical tool for the organization to use in order to reduce WIP & finished goods inventory that is held for an excessive amount of time and takes up a lot of space in the plant. In order to dispatch the products to customer on time and confirm that they are not kept in inventory for an extended period of time, FIFO format is used with pull system. This helps to keep the workplace clean and boosts employee satisfaction. According to Isaksson & Seifert (2014), one way to improve the organization's productivity is to reduce the inventory level.

5.7.3 Plant layout modification and facility planning

Plant layout modifications yield excellent results to achieve the goal of this research. Internal traffic is largely minimized and increases the participation of the worker. This will increase labor productivity. To reduce WIP & waiting time between work stations, every production process section should communicate with the production and planning department internally through intranet. It saves time and energy spent in checking and counting every part and reduces the lead time. The proposed solution will reduce the distance of transportation of materials and transportation activities by more than 75%. This makes the organization have a flow production system. The number of workers required is reduced from 202 to 200. Time, distance, and energy expended on storing and retrieving the WIP are also reduced.

5.7.4 Training

Implementing on-job training is one of the mechanisms to increase labor productivity. Providing on-job training helps the employees improve communication, improve their skills, improve satisfaction & morale, improve their performance, and motivate them. These directly benefits the organization in reducing employee turnover, increasing labor productivity, and adhering to quality standards. No matter what technical level the company’s employees are at, there is always room for improvement. Employees need to engage in ongoing learning regularly to stay up-to-date with the latest developments. In addition to on-job training, providing a tea break is recommended for the case company, primarily in the cutting section. The employees are working standing up for a long time without a break. Hence ergonomically, it is not recommended. Besides the technical training, training the employees on kaizen gives a comprehensive insight into waste, their cause, and mechanism to reduce them. This makes the employees use their talent to reduce waste and find their way of doing things better.

5.8 Summary

In this chapter, Phase III of the research is presented. It examined how a decision can be made in selecting suitable LM tools. Lean practitioners and managers need to identify critical resources and major waste types before implementing a lean program. It saves time by analyzing only the most critical resources for a successful lean implementation since its focus is only on the most important resources. This study demonstrates how wastes are identified using VSM by managers and practitioners, fuzzy QFD method to identify critical resources, which creates the major wastes, and fuzzy FMEA method to identify the failure modes. And the sub-elements of the wastes are evaluated using FWGM and α-cut values. Then in prioritizing the failure modes, the CDA is used. The applicability of the proposed approach is demonstrated through a case study of an Ethiopian shoe manufacturing firm. The findings provided empirical evidence that people and schedule are the critical resources. In the next chapter, Phase IV of the research is presented. It focuses on investigating the effect of QM practices on OP.

CHAPTER 6

THE IMPACT OF QUALITY MANAGEMENT PRACTICES ON OPERATIONAL PERFORMANCE OF LOW-LEVEL TECHNOLOGY ORGANIZATIONS: THE CASE OF ETHIOPIA (Phase IV)

6.0 Overview

Quality management's performance aspect is concerned with quality, operational, and business performance metrics. This chapter presents Phase IV of the research. It discusses the examining of selected QM practices in relation to OP. A literature review on QM practices and OP is conducted to identify the QM practice constructs and OP measures. Data were gathered using a structured questionnaire from Ethiopian LPMI. Hypotheses development and methodological issues are discussed. Finally, a summary of the chapter is presented.

6.1 Quality management and Operational performance

6.1.1 Introduction

With the increasingly competitive global market, manufacturing firms need the adoption of modern philosophy of management to improve their OP, bringing organizational-wide change (Addis et al., 2019). According to Arunachalam & Palanichamy (2017), several scholars claimed that quality management (QM) is one of the holistic and strategic management philosophies to achieve these outcomes. QM practice aims to improve organizations' OP. As revealed by Salaheldin (2009), QM practice helps organizations to enhance their OP. These are production costs reduction, improving delivery performance, reducing scrap, increasing productivity, improving flexibility, and improving products quality. Organizations that practice QM can gain significant benefits such as products with high-quality, happier customers, lower operating costs, financial performance improvement & innovation results, and even increased employee satisfaction (Dubey, 2015; Ahmad et al., 2013; Zehir et al., 2012). It focuses on quality improvement, reducing rework & waste, fulfilling customer expectations & requirements, enhanced employee empowerment & engagement, process management, solving problems in teams, top management dedication & regular support, employees training & growth, applying scientific methods to measure results on a regular basis, benchmarking, and other sets of vital success factors (Aquilani, Silvestri, Ruggieri, & Gatti, 2017; Sabella, Kashou, & Omran, 2014;

Agus & Hassan, 2011; Kaynak, 2003). Several studies revealed the significant effect of QM practice on OP (Demirbag, Koh, Tatoglu, & Zaim, 2006; Saravanan & Rao, 2007; Sadikoglu & Zehir, 2010; Vasantharayalu & Pal, 2016; Norah Dhafer, Alshehri, & Aziz, 2015; Kiprotich, Njuguna, & Kilika, 2018; Brah, Tee, & Rao, 2002; Truong et al., 2014; Saleh et al., 2018; De Cerio, 2003). The majority of the research focuses on Western industrialized countries or other organizations with capital-intensive. The studies' results regarding QM practice in developed countries may not be appropriate and applicable to nations with low-level technology organizations and different cultural contexts. According to Scott (2006), low-level technological firms are described as labor-intensive. It includes the furniture, clothing, and footwear sectors. Manufacturing organizations in Ethiopia are primarily labor-intensive or don't have too advanced technology requirements (Addis et al., 2019).

Though some research on the causal link between QM practice and organizational performance has been undertaken in several industrialized and developing nations (Chavez, Gimenez, Fynes, Wiengarten, & Yu, 2013; Temtime & Solomon, 2002; Kiprotich et al., 2018; Sabella et al., 2014), less attention is given to researches in relation to the impact of practicing QM on the OP of developing countries with low-level technology organizations like Ethiopia. Previous studies in Ethiopia related to QM are merely descriptive and focus on assessing QM practices concerning quality-related problems (Beshah & Kitaw, 2014; Belai, 2007; Kitaw & Bete, 2003). Similarly, Beshah (2011) reported the need for research focusing on QM practices and their effect on firms' performance outcomes such as profitability and OP in developing countries like Ethiopia. Kragh (2016) reported that African organizations' economic, sociological, and political contexts diverge significantly from the method guiding management practices in the industrialized and advanced world. This study considered the Ethiopian leather products manufacturing industry (LPMI) as a case study. Since this industry exemplifies low-level technological organizations' key characteristics and has no sophisticated technological requirements, it has been chosen as a case study. Ethiopia's LPMI is currently the leading in the growth of Africa's leather industry. In terms of livestock population, it is first in Africa & tenth globally. Despite the availability of potential indigenous resources, the Ethiopian LPMI has not yet fully utilized the available resources to a considerable amount (Gebeyehu, 2018; Altenburg, 2010). Hence, this chapter of the study investigates the impact of QM practice on what Slack, Brandon-Jones, & Johnston (2013), Ahmad & Schroeder (2003), and Belekoukias et al. (2014) consider the essential measures of OP(cost, quality, speed, flexibility, and dependability).

6.1.2 QM practices

For several decades, firms have been using QM as a strategy to increase business performance and (Arumugam, Ooi, & Fong, 2008). According to Clegg et al. (2013), it has been thoroughly studied. Much has been written on both a philosophical and realistic level to help various economies to digest its strategic benefits. However, it will take several decades for the discipline to mature (Prajogo & Cooper, 2010b). Hence, rigorous studies are needed to fully comprehend the philosophy of the QM and its organizational consequences. QM is a multifaceted concept, as reported by numerous studies. According to Kaynak (2003), several research design problems should be considered in QM research, the most critical of which is understanding the multidimensionality of the QM construct.

Addis et al. (2019) categorized the soft aspects of QM practices into five constructs, namely: commitment of top management, continuous improvement, employees' participation, teamwork, and customer focus. Accordingly, process improvement, adopting the philosophy, benchmarking, executive commitment, closer to suppliers & customers, employee empowerment, training, zero-defects approach, flexible manufacturing, and measurement were identified as elements of QM's framework (Arumugam et al., 2008). Based on the previous extensive research on QM practice, Arunachalam & Palanichamy (2017) has identified nine core elements of the QM practice, namely: employee training, employee empowerment, appraisal systems, continuous improvement, top management's commitment, teamwork, customer focus, involvement of employee, and organizational trust. These sets of QM practices have been frequently cited as essential success factors of QM in many studies (Sadikoglu & Olcay, 2014; Aquilani et al., 2017; Sabella et al., 2014). Similarly, Ahmad et al. (2013) has used the leadership of top management, human resource, supplier management, information analysis, management policies & strategy, customer focus, continuous improvement, and work process as elements of QM practices. Therefore, as revealed by the recent literature (Addis et al., 2019; Bajaj, Garg, & Sethi, 2018; Sabella et al., 2014; Lakhal, 2014); continuous improvement, employees participation, teamwork, customer focus, and commitment of top management are the most commonly and frequently used dimensions of QM practice. This study also uses these dimensions to operationalize and hypothesize QM practice's effect on OP.

6.1.3 Operational performance (OP)

QM's performance aspect is concerned with quality, operational, and business performance metrics (Samson & Terziovski, 1999). Nawanir, Teong, & Othman (2013) and Kaynak (2003) revealed that an organization’s quality, cost, productivity, and delivery outcomes are referred to as OP. Saleh et al. (2018) defined OP as the performance of organizations’ internal operations like product quality, productivity & customers satisfaction. Similarly, Kebede & Virdi (2020) described OP as the ability of organizations to satisfy order cycle time & delivery capacity, minimize operational management costs, and increase the efficiency of raw material use. OP is extremely important for manufacturing firms because it leads to better production efficiency, increased profit, better products quality, delighted customers, and increased sales volume (Truong et al., 2014; Ou et al., 2010; Kaynak, 2003). OP indicators are considered the immediate results of QM practice (Salaheldin, 2009).

Concerning the measuring metrics, using a single measure does not index organizational OP (Bayraktar et al., 2009). Thus, several researchers suggested various indicators and dimensions for operational performance. For instance, Ataseven, Prajogo, & Nair (2014) used cost, quality, & delivery time. Jabbour et al. (2013) used delivery, flexibility, quality, cost, development of a new product, & time to market. Whereas productivity, quality, cost, inventory reduction, & delivery were used by Nawanir et al. (2013). For organizations' operational success, a model can be built using delivery time, quality, and cost as dimensions of OP (Corbett & Van Wassenhove, 1993). In another study, Samson & Terziovski (1999) operationalized OP concepts using quality, delivery, and productivity performance indicators.

According to Slack, Brandon-Jones, & Johnston (2013), the core elements of OP include quality, cost, speed, flexibility, and dependability. Recent researchers use cost, speed, dependability, quality, and flexibility to measure the organizations' OP (Belekoukias et al., 2014; Abdallah et al., 2016). In particular, Hallgren & Olhager (2009) have suggested using delivery time, quality, flexibility, and cost to measure OP of manufacturing industries. These metrics are the basis of production capabilities which results in competitiveness. Hence, delivery time (speed), flexibility, quality, cost, and dependability are the most commonly and frequently used OP measures (Truong et al., 2014; Nawanir et al., 2013; Nabass & Abdallah, 2018; Leite & Braz, 2016; Kebede & Virdi, 2020). And these measures are also used in this study. Thus this study investigates the effect of QM practice constructs (commitments of top management, employees’ participation, continuous improvement, customer focus, and teamwork) on OP. These are recognized as pillars of the QM practices on the essential measures of OP, i.e., flexibility, dependability, speed, quality, and cost.

6.1.4 The relationships between QM practices and OP

As previously mentioned, the relationship between QM and OP in developing countries with low-level technology has received little attention, despite the fact that QM is likely to influence various aspects of OP measures. The various performance measures concerning QM practice are categorized as business, corporate, organizational, operational, innovation, financial & non-financial, and quality performances (Salaheldin, 2009). OP is one of the organization's performance measures that reflects the company's internal operation regarding waste & cost reduction, improving quality, delivery performance, flexibility, and productivity, which is one of the concerns of this study.

Previous empirical studies have claimed that QM practice enables organizations to improve OP in terms of flexibility, delivery time, productivity, quality, and cost (Kibe & Wanjau, 2014; Sadikoglu & Olcay, 2014; Sadikoglu & Zehir, 2010; Tan, 2013; García-bernal & Ramírez-alesón, 2015; Truong et al., 2014). The relationships between QM and OP have only been studied in a few countries; most of them are in developed nations. There are various other reasons to encourage the use of QM in Ethiopia. According to Kitaw & Bete (2003), economic growth is the most significant to meet national desires. Beshah (2011) has also reported that the government considered quality at the national level as infrastructure for development. As previously described, the aim of this study is to address the Ethiopian LPMI. Addis et al. (2019) revealed that this sector is found at a low-level, mainly due to comprehensive quality-related issues. So far, studies in the industry have been conducted from various perspectives. To mention some of them: performance enhancement using total performance scorecard (Cherkos, 2011), manpower development (Gebeyehu, 2014), using supply chain and industrial cluster theories to improve Ethiopian leather's global competitiveness (Jote & Kitaw, 2018), and using QM as a tool to improve employees job satisfaction (Addis et al., 2019). So far no study on QM in relation to OP has been conducted in Ethiopian LPMI. Hence, conducting a study in this topic be extremely beneficial to the Ethiopian LPMI and to organizations with low-level technology in general. Hence this study aims to enable a comprehensive understanding on the effects of QM practices on the OP measures and showing the link between QM practice activities and their effects on OP of low-level technology organizations.

6.2 Development of Hypotheses

This part hypothesizes the relationship between the QM practice constructs and OP, taking Ethiopian LPMI as a case study.

i. Top management commitment (TMC)

TMC is the essential factor of implementing QM (Sadikoglu & Olcay, 2014). Discussion about QM without top management initiatives is incomplete (De Hoogh et al., 2005). Previous researchers have found that TMC in practicing QM significantly affects OP (Zahari & Zakuan, 2016; Chauke, Edoun, & Mbohwa, 2019; Samson & Terziovski, 1999; Truong et al., 2014). According to Gosen, Babbar, & Prasad (2005), concerning QM practices, Political, economic, social, and organizational variables present a particular challenge to operations in developing-country companies with low-level technology. According to (Lakhe & Mohanty (1994), these organizations consider quality as extra optional, but according to Feigenbaum (1990), quality is a fundamental strategy without which an organization cannot thrive. In developing countries, quality has also been regarded as a technique of enhancing the competitiveness of all types of firms (Gosen et al., 2005). Unfortunately, low-level technology firms have separated manufacturing function from their quality function in developing nations. These firms suffer from lack of managerial commitment and consistent support to improving efforts & motivation (Gosen et al., 2005). Similarly, Yeshanew & Raju (2016) has reported that many Ethiopian organizations failed in quality program implementation due to a lack of management commitment. Hence TMC is more important in Ethiopian organizations. Hence, the following hypothesis is suggested:

H_1: TMC is positively and significantly linked to the OP of Ethiopian organizations.

ii. Employees participation (EP)

Involvement and empowerment are two ingredients of the participation of employees in QM practices. Employees should be encouraged to use workers' talent and creativity (Deming, 1986). It is impossible to implement QM practices without the participation of all employees (Mersha, 1997). The empowerment of employees plays a great role in successfully implementing QM, as QM gives emphasis on the involvement of all employees (Mustafa & Bon, 2012).

According to Prajogo & Cooper (2010), employee involvement creates a communication channel that allows workers to address their concerns about quality issues. Recent researchers revealed that in practicing QM, EP has a significant effect on OP (Chauke et al., 2019; Vasantharayalu & Pal, 2016; De Cerio, 2010). As mentioned by Lakhe & Mohanty (1994), lack of employees participation, their role in quality issues, and internal communication are obstacles encountered in practicing quality management in low-level technology organizations. As QM philosophy requires, decision-making should be decentralized in part. Hence empowerment of employees is needed to solve quality-related problems at the source and report to management (A. V. Feigenbaum, 1990). Indeed, the relationship between EP and OP for Ethiopian organizations has not been studied. Hence, the following hypothesis is suggested:

H_2: EP positively and significantly related to the OP of Ethiopian organizations.

iii. Customer focus (CF)

The extent to which firms consistently meet customers' demands and expectations is measured by customer satisfaction (Zhihai Zhang, 1997). CF refers to how firms understand their customers' requirements and aspirations to design goods that meet those demands and how they investigate customer complaints to make necessary changes (Ahire, Golhar, & Waller, 1996). Since customer satisfaction affects a company's success or failure, CF is sometimes viewed as the crucial value of QM (Sarathy, 2013). Experts highlighted CF as essential in low-level technological enterprises operations context in developing nations in terms of cultural/social concerns (Gosen et al., 2005). They have not been as customer-focused as their Western competitors, focusing only on sales rather than their customers' satisfaction (Gosen et al., 2005).

Several previous studies revealed that CF has a is significantly positive relation with OP (Vasantharayalu & Pal, 2016; Samson & Terziovski, 1999; Chauke et al., 2019; Sadikoglu & Olcay, 2014; Phan, Abdallah, & Matsui, 2011; Khanna, Sharma, & Laroiya, 2011; Arumugam et al., 2008). However, in Ethiopian organizations' context, this has received less attention (Yeshanew & Raju, 2016). Based on this context, it is hypothesized as follows:

H_2: CF positively and significantly affects the OP of Ethiopian organizations.

iv. Teamwork (TW)

TW refers to how much an organization encourages employees to collaborate as a team and take on more responsibility for their work (Boon et al., 2007). It is thought to foster a sense of community among employees and encourage more information sharing among coworkers. In relation to QM, TW is believed to help foster continuous improvement by encouraging collaborative efforts to identify and solve quality issues. Studies have inferred that TW is central to practice QM (Arunachalam & Palanichamy, 2017). According to Modgil & Sharma (2016), TW is inferred as one of the problem-solving techniques to improve organizations' OP. According to Deming, people within the firm in different departments (production, design, research, and so on) must work as a team instead of separately within their functions to anticipate difficulties in production and improve the quality of present & future outputs (Addis et al., 2019). This is due to the fact that QM is easier to adopt in work cultures that emphasize collaboration and cooperation (Baird, Hu, & Reeve, 2011).

Additionally, the successful practice of TW increases employees' competence, knowledge, and consistency of their efforts. They will enhance the company's performance in areas like quality and cost reduction (Sadikoglu & Zehir, 2010). Research studies revealed that teamwork is positively linked to organizational outcomes (Delarue et al., 2008). In the Ethiopian context, a positive relationship between TW and OP can be expected. Ethiopia has a model so-called '1to 5' approach to promote workplace social reforms (Addis et al., 2019). This method was suggested to divide employees into a group of five, having a single group leader in each group to monitor them. It aims to encourage teamwork, bring collaborative working culture, and boost productivity by improving the working culture. Indeed, there has not been any research into the relationship between TW and OP in Ethiopian organizations. However, based on the literature, it can be inferred that TW is likely to improve OP in Ethiopia. Hence, the following hypothesis is suggested:

H_4: TW positively and significantly affects the OP of Ethiopian organizations.

v. Continuous improvement (CI)

CI stands for never-ending improvements and the development of procedures to find better techniques for converting inputs into outputs (Addis et al., 2019). According to Sarathy (2013), it is a concept of improvement initiatives that aims to enhance success and decrease failure. This means that managers need to evaluate regularly the current products, systems, and processes against specified excellence criteria to discover areas for improvement (Sinha, Garg, Dhingra, &

Dhall, 2016). Several studies have reported that CI significantly affects OP (Kiprotich et al., 2018; Bell & Omachonu, 2011; Salaheldin, 2009; Arnold, 2014; Arumugam et al., 2008; Salah, 2018). However, the effect of CI on OP has not been addressed in Ethiopian low-level technology organizations. Based on the literature, it appears CI is likely to enhance OP of Ethiopia industry. Hence, the following hypothesis is suggested:

H_5: CI positively and significantly affects the OP of Ethiopian organizations.

6.3 Methods

This part describes a research model, instruments, population & sample size, data gathering techniques, and the study variables' used. In addition, the methods of data analysis utilized to examine the correlations between QM and OP are discussed.

6.3.1 Sampling procedures

As previously stated, the current study is focused on Ethiopia's LPMI. Five samples of ISO 9001:2008 certified organizations were chosen for the survey from Addis Ababa, Ethiopia's capital, where 98 percent of the country's LPMI are located (Gebeyehu, 2014). Depending on their profitability and numbers of employees involved, sample companies from Addis Ababa were selected, representing 70% of the total companies. For this research, the sampling unit consisted of regular workers engaged in different activities like stitching, cutting, lasting, and finishing used to make the leather footwear. A formal approach was followed through the concerned channels to get permission from the companies for conducting the study. A simple random sampling method was used to select a random sample of employees with the help of production managers and supervisors. Hair et al. (2019) suggested using parameter ratios to compute sample sizes. It is the sample sizes to the number of measurement items ratio. In order to get a meaningful estimate, the acceptable parameter ratio is 15:1 or preferably 20:1 (Hair et al., 2019). Hence in this study 15.29:1 parameter ratio was used, indicating sufficient sample size. Therefore, the sample size was 321 workers, representing 69% of the shop floor workers. Following a thorough review, 216 responses were valid, representing a response rate of 67 %. According to Baruch's (1999) suggestion, this response rate is acceptable compared to 60-20 % of the conventional population.

6.3.2 The research instrument

A self-completion well-structured questionnaire was used to survey workplace practices. In QM studies, questionnaires are a widely used data collection approach. The first part of the questionnaire contains the general personal information of the respondents. While part two includes two sections. The first one contains the five QM practice dimensions, and the second one contains five items that represent OP (see Table 6.1).

Table 6.1 Measurement items

Measures of QMP	Survey statements
Top management commitment (TMC)	Managers are involved actively in quality management activities (TMC1)
	Managers related quality with cost objectives (TMC2)*
	Managers comprehensively review quality issues periodically (TMC3)
	Managers are highly committed to understanding the organization's working conditions (TMC4)
	Managers assign adequate resources to train the employees (TMC5)
	Managers strongly encourage participation of staff in quality improvement activities (TMC6)
Employees participation (EP)	Employees are encouraged to solve problems related to quality (EP1)
	The quality objective-setting process is comprehensive within the company (EP2)
	Employees' involvement in the quality-related decision-making process are encouraged (EP3)
	Quality related suggestions given by the employees are valued seriously (EP4)
	Employees are rewarded for results of outstanding quality performance (EP5)*
Customer focus (CF)	Our company extensively collects customer complaint information (CF1)
	A program is developed to ensure effective customer communication (CF2)
	Customer complaints related to quality are given top priority (CF3)
	Our company has its own marketing research to gather products improvement suggestions (CF4)
	A customer satisfaction survey is conducted regularly by our firm (CF5)
	Customer requirements are carefully taken into consideration during new product design (CF6) *
Teamwork (TW)	Teamwork and involvement are regular practices in our company (TW1)
	In our company, to help quality-related teams, resources are available (TW2)
	All employees are encouraged to participate in a quality improvement team works (TW3)*
	In our company, decisions in the workplace are made through consensus (TW4)

	In our company, cross-functional teams are formed in order to solve quality problems (TW5)*
Continuous improvement (CI)	In our company, employees receive training on a regular basis to improve their skills (CI1)
	Performance evaluation of the employees is focused on improvement, not on criticism (CI2)
	Workstations' quality information is visually displayed at each workstation (CI3)
	As a means of communication, signboards and labels are utilized (CI4)
	Information related to the cost of quality and finance are visually displayed (CI5)*
Operational performance (OP)	Cost (e.g. labor productivity, utilization of resources, efficiency, cost per operation hour) (C)
	Quality (e.g. defects per unit, scrap level, customer complaints, warranty claims, customer satisfaction) (Q)
	Dependability (e.g. average lateness of customer orders, schedule adherence, orders delivered late (%), proportion of products in stock) (D)
	Speed (e.g. cycle time, frequency of delivery, customer query, order lead time) (S)
	Flexibility (e.g. change over time, time to change schedules, range of products, time needed to develop new products) (F)

Note: To increase construct validity, the item marked with an asterisk (*) was eventually removed.

A total of 28 elements were initially adopted from previous studies to characterize the five selected constructs of QM practice (Conca et al., 2004; Das et al., 2008; Addis et al., 2019). And five elements of OP were initially adopted from previous studies (Nabass & Abdallah, 2018; Salaheldin, 2009; Nawanir et al., 2013). These studies were chosen because the measurement scales they used were theoretically sound. Additionally, they offered substantial support for the measuring scales' reliability and construct validity. The items listed in Table 6.1 were checked by three academicians conducting research in the same area and two experts from Leather Industry Development Institute (LIDI) to validate the questionnaires' content. Primarily the questionnaire was translated to Amharic (local Ethiopian language) to avoid an understanding gap. First, the authors translated it, and two language professionals proficient in both languages confirmed contextual equivalency and, if necessary, amended or added additional items.

Furthermore, to validate the questionnaire, a pilot test was made using twenty respondents from two sample firms before being used for data collection (Robson, 2002). The objective was to exclude questions that aren't relevant or vague check the appropriateness, understandability, and readability of items in Ethiopian firms' context. As a result of the feedback, some items and the survey instrument's layout were modified (Saunders, Lewis, & Thornhill, 2009).

6.3.3 Method of data analysis

The research model presented in Figure 6.1 was analyzed using SEM. It was selected as an analysis tool since it effectively tests hypotheses about correlations between latent and observable variables in the model (Psomas & Fotopoulos, 2009). Regression analysis can be used instead of SEM. But SEM has some advantages over regression analysis. These are: modelling of measurement errors & unexplained variances, simultaneous testing of relationships, ability to link micro- and macro-perspectives, best-fitting model and theory development. The limitations in using the SEM compared to regression analysis are: difficulty in choosing & using SEM software packages; complexity; limited use in exploratory research etc. (Nunkoo & Ramkissoon, 2012).The current study used a methodology that has been used in previous studies to accomplish the SEM analysis (Kaynak, 2003; Sit et al., 2009). SEM combines CFA and path analysis and is referred to as a hybrid of path analysis (Kline, 2007). To analyze the data, they recommend four steps which include the following:

(1) Multivariate analysis (to test the assumptions)

(2) Conducting exploratory factor analysis (EFA) – in order to investigate the constructs of QM practice dimensions.

(3) Using confirmatory factor analysis (CFA) - to test if the measurement model derived from EFA suited the data well.

(4) Examining the relationships between QM practice and OP using structural analysis.

6.4 Data analysis and results

As mentioned above, direct workers are the focus of this study. According to descriptive statistics, more than half of the respondents (56.94%) were female, with most of them working in the stitching department. Most of the respondents were young, with 78.7 % under 35, and 80.56 % had working experience not more than ten years.

6.4.1 Testing the assumptions

Assumptions about sample size, multicollinearity, variables' scale, normal distribution, and outliers should be evaluated first before undertaking multivariate data analysis (Hair et al., 2019). Regarding sample size, Hair et al. (2019) suggested 100 to 200 observations to be sufficient. As a result, the current study's sample size of 216 is reasonably acceptable. The study variables' skewness and kurtosis are within acceptable ranges (±1), implying that there is asymmetry distribution (Sit et al., 2009; Kaynak, 2003). The correlations among the variables were examined and found less than 0.9. According to Hair et al. (2019), this implies that multicollinearity was not an issue. Altogether, these essential assumptions of the multivariate model suggest that the study has no statistical violations.

6.4.2 EFA

The construct's unidimensionality was assessed using EFA with varimax rotation (Sit et al., 2009; Psomas & Fotopoulos, 2009). The interrelatedness among the items was assessed via EFA. This study deleted items having factor loadings less than 0.5 (Talib et al., 2013). Hence, TMC1, EP5, CF6, TW3, TW5, and CI5 were removed from the analysis. According to Talib et al. (2013), Cronbach's alpha coefficient is the most often used method for determining the scale's homogeneity. Hence, it was used to assess QM practices' constructs reliability. Therefore, the α-values for each factor was obtained as follows: TMC = 0.904, EP = 0.905, CF = 0.875, TW = 0.831, and CI = 0.893. Accordingly, these values exceed 0.7 (as shown in Table 6.3), which is the minimum acceptable level (Hair et al., 2019).

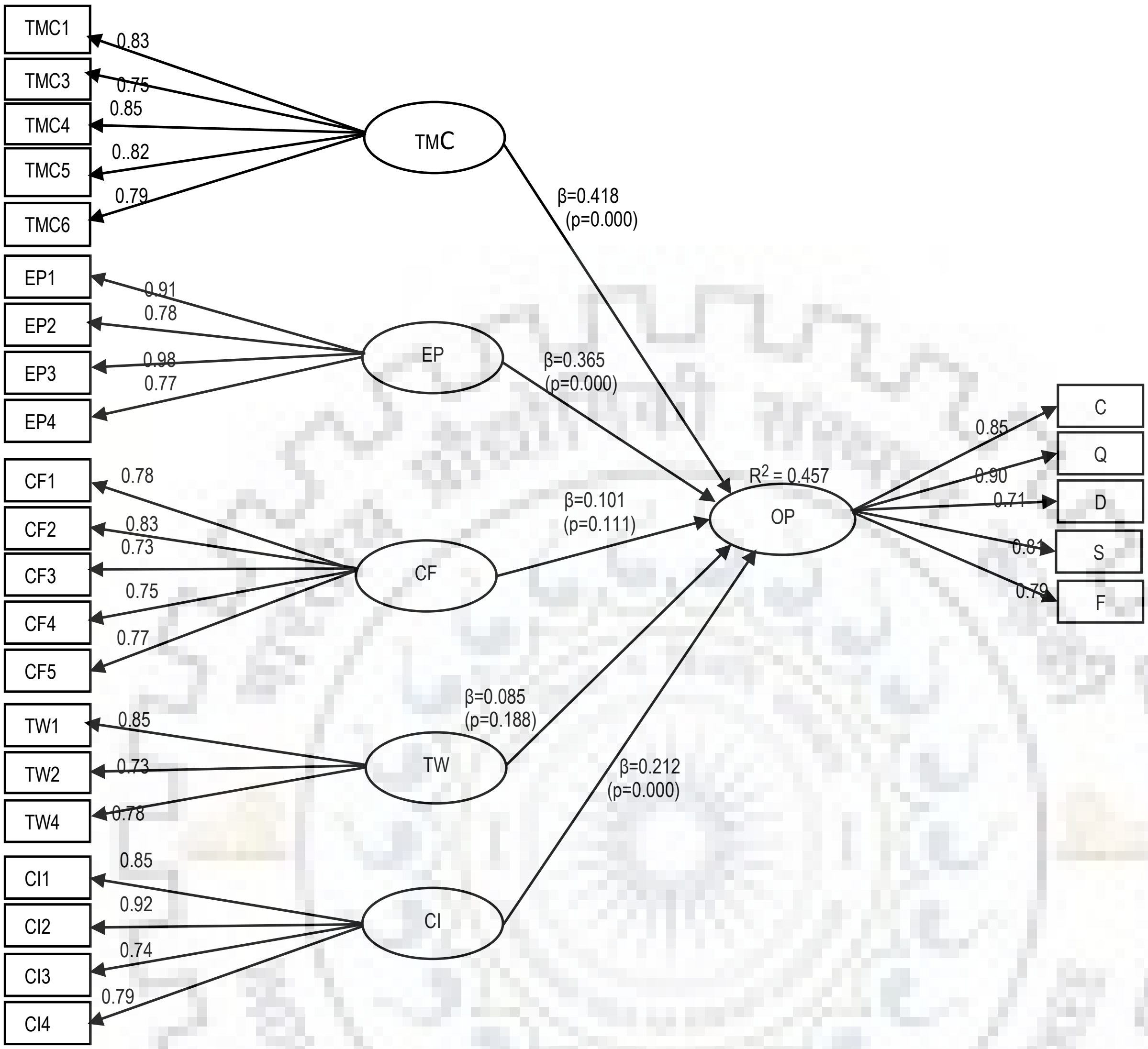


Figure 6.1 The relationship model between QMP and OP.

Notes: The diagram shows the standardized parameters. The p-value is presented in brackets. TMC: top management commitment; EP: Employees participation; CF: customer focus; TW: teamwork; CI: continuous improvement; and OP: operational performance.

6.4.3 CFA

CFA was used to test the measurement model that was refined during EFA. To estimate model, the following fit indices are used:

- the ratio of chi-square to degree of freedom (X^2/df),
- parsimony goodness-of-fit & goodness-of-fit index (PGFI & GFI),
- parsimony normed & normed fit index (PNFI & NFI),
- root mean square error of approximation (RMSEA),

- Parsimony & comparative fit index (PCFI & CFI), and
- the consistent version of Akaike's information criterion (CAIC).

These were selected because these indices' ability to account for model degrees of freedom and complexity (Kaynak, 2003). Comparison of the proposed values and predicted model fit indices demonstrate that the measurement model fits the data satisfactorily (see Table 6.2).

Table 6.2 A test result of the models.

Goodness-of-fit statistics	Measurement model	Structural model	Values proposed for adequate model fit to the data
X^2 test statistics/*df*	1.878	2.217	≤5[a]
PGFI	0.687	0.686	≥ 0.50[b]
PNFI	0.760	0.761	≥ 0.50[b]
RMSEA	0.064	0.075	≤1.00[c]
CFI	0.934	0.905	≥ 0.90[d]
PCFI	0.816	.819	≥ 0.50[e]
NFI	0.870	0.841	≥ 0.80[f]
GFI	0.849	0.819	≥ 0.80[e,f]
CAIC	960.596	1015.117	≤ Saturated Model and Independent Model[d]
CAIC for Saturated Model	2237.723	2237.723	-
CAIC for Independent Model	4263.627	4263.627	-

[a]Schumacker & Lomax, (2004); [b] Mulaik et al. (1989); [c]Browne & Cudeck (1992); [d]Modgil & Sharma (2016) [e]Salaheldin, (2009); [f]Forza & Filippini (1998).

In addition, CFA was used to determine convergent and discriminant validity. Hair et al. (2019) proposed three criteria to evaluate the convergent validity of CFA model: (i) factor loadings (k) of all indicators > 0.50; (ii) composite reliability (CR) > 0.70, and (iii) average variance extracted (AVE) by each construct > 0.50. All of the k-values are significantly higher than 0.50. All latent constructs' CR is not only adequate but also well exceeds the threshold of 0.7. And the AVE is higher than 0.5, indicating that the model has adequate convergent validity (see Table 6.3). Generally, the findings confirmed that the latent construct's measurement is internally consistent.

The approach provided by Fornell & Larcker (1981) was used to evaluate discriminant validity. According to this literature, 'the squared correlation between any two constructs should be less than AVE.' This means AVE > correlation^2. Since this requirement is met in every case, the discriminatory validity was found to be acceptable (see Table 6.3).

Table 6.3 The research instrument's reliability and validity.

Constructs	Indicators	Loadings	AVE	Cronbach's α	CR	Correlation²	VIFs
TMC	TMC2	0.789	0.617	0.904	0.889	0.325	1.498
	TMC3	0.74					
	TMC4	0.81					
	TMC5	0.812					
	TMC6	0.773					
EP	EP1	0.851	0.656	0.905	0.884	0.06	1.458
	EP2	0.801					
	EP3	0.789					
	EP4	0.797					
CF	CF1	0.816	0.662	0.875	0.907	0.044	1.055
	CF2	0.843					
	CF3	0.772					
	CF4	0.81					
	CF5	0.825					
TW	TW1	0.869	0.733	0.831	0.892	0.057	1.047
	TW2	0.837					
	TW4	0.862					
CI	CI1	0.889	0.712	0.893	0.908	0.142	1.158
	CI2	0.885					
	CI3	0.808					
	CI4	0.789					

Furthermore, the study examined whether a common method bias contaminated the research model. The multicollinearity test is a complete process for assessing both vertical and lateral collinearity at the same time using variance inflation factors (VIFs). According to Kock & Lynn (2012), if the VIF from the collinearity test is $\leq$ 3.3. Hence, the model is deemed free of common method bias. The greatest VIF value is 1.498, as shown in Table 6.3, suggesting the model is devoid of common method biases.

6.4.4 The structural model's test results

After building the measurement model through CFA, structural analysis was performed to test the study's hypotheses using AMOS software Version 21. The results of SEM analysis of the association between QM practice and OP are presented in Figure 6.1. The estimated standardized path coefficient (β) and the variance explained by the model (R^2) are shown in the diagram (Modgil & Sharma, 2016; Singh et al., 2018). The statistics used to assess the measurement model are similar to evaluate the hypothesized model's goodness of fit (see Table 6.2). The five elements QM practice were handled as endogenous variables, while OP was treated as an exogenous variable. In general, the overall structural model shows a good fit for the data. The model's coefficient of determination (R^2) is 0.457 percent. This implies that the model shows 46 % of the variance in OP is explained by explanatory factors (QM practices). As a result, the QM practices described in this study can be said to play an essential role in increasing OP. The summary of the structural model's analysis is shown in Table 6.4. It shows the structural parameters' standardized regression coefficients (β), which can be used to assess the hypotheses' validity. TMC ($\beta = 0.418$), EP ($\beta = 0.365$) and CI ($\beta = 0.212$) at $p < 0.01$ are all positively significant to OP, implying that H_1, H_2, and H_5 are supported. While, CF ($\beta = 0.101$; $p > 0.05$), TW ($\beta = 0.085$; $p > 0.05$), were found to have insignificant effect on OP. Implying that H_3 and H_4 are not supported.

Table 6.4 Structural model's results.

Hypo.	path	SE	β	p-value	Results
H_1	TMC ⟶ OP	0.066	0.418	0.000	Supported
H_2	EP ⟶ OP	0.058	0.365	0.000	Supported
H_3	CF ⟶ OP	0.047	0.101	0.111	Not supported
H_4	TW ⟶ OP	0.047	0.085	0.188	Not supported
H_5	CI ⟶ OP	0.51	0.212	0.000	Supported

6.5 Discussion

QM practice is regarded as a quality-oriented approach and has a crucial effect on OP. The impact of QM practices on the OP of Ethiopian manufacturing firms is empirically investigated in this study. As a result, TMC, EP, & CI have significant and positive effects on OP. In contrast, CF and TW have an insignificant relationship with OP. It is in accordance with previous studies by Modgil & Sharma (2016), Truong et al. (2014), Shahid, Faisal, & Aftab (2014), Salaheldin (2009), and Samson & Terziovski (1999). They revealed that not all QM practices have a substantial effect on OP. The explanation for the result is that increasing the three QM practices enhances the organizations' OP, which leads to an increase in the competitiveness of the organizations.

TMC, in particular, has the greatest impact on OP, implying that the role of managers is high in organizations' performance improvement. This finding supports the previous studies' results by Samson & Terziovski (1999), Singh et al. (2018), Kaynak (2003), Nair (2006), Lakhal et al. (2006), Modgil & Sharma (2016), and Saleh et al. (2018). However, low-level technology firms find that lack of managerial commitment is one barrier to QM adoption (Gosen et al., 2005;

Prasad, Motwani, & Tata, 1999). Based on the study's results, managers who are more committed to understanding the working condition, being helpful, and giving workers liberty to address problems can contribute to the improvement of OP. Therefore, TMC is a critical QM practice that may help with all quality enhancement aspects by devising effective plans and assigning adequate resources (Sweis et al., 2016).

EP is the next most common practice with a strong positive relationship with OP. Employees are the most crucial tangible capability in organizations (Anagha & Magesh, 2016). This can secure employee loyalty and increase emotions of ownership, resulting in motivated employees who catalyze the company's OP. The findings show the necessity of recognizing employees' participation to achieve better quality performance. This can be done by empowering employees in the decision-making process related to quality and listening to their comments during participation. This finding supports the result of previous researchers Salaheldin (2009), Vasantharayalu & Pal (2016), and De Cerio (2003). They reported that the participation of employees within the organization in the form of job involvement and empowerment helps the organization enhance its OP. As revealed from the workers, due to the bureaucratic work environment, they do not directly communicate with managers. They are only engaged in performing the orders given by the managers. This indicates the firm's dominance of a 'top-down hierarchical structure.' This type of organizational structure restricts employees' direct involvement in organizational issues instead of relying only on top management's judgments and orders. However, scholars emphasize employee involvement as it is a key feature of QM and allows them a sense of participation in their activities and increases their success in their activities (Karia & Asaari, 2006). In the case of developing nations' low-level technology firms, less employees participation and lack of internal communication have also been noted as barriers to QM implementation (Gosen et al., 2005; Prasad et al., 1999).

The analysis results show that CF, which is one of the elements of QMP, has no significant impact on OP. According to Qasrawi et al. (2017), it takes time to see the impact of CF on firms' performance. This is especially true in Ethiopia, where the majority of manufacturing companies are still new to QM practice. However, the finding of this study contradicts the results of several earlier studies (e.g., Sadikoglu & Olcay, 2014; Chauke et al., 2019). According to Arumugam et al. (2008), CF found to be the most strong discriminating element of quality performance. Likewise, Samson & Terziovski (1999) studied the association between QM practices and OP in manufacturing organizations. The study observed significant relationship in cross-sectional senses.

The CF was one of the QM practice dimensions with the strongest significant predictors of OP. Besides the findings of this study, shop floor workers feel that personnel in managerial positions are solely responsible for the ongoing series of interactions with consumers. On the other hand, scholars believe that employee-customer relations are crucial in firms building confidence, exhibiting competence, and being respectful (Jamal & Adelowore, 2008). From the standpoint of low-level technological firms, the workforce's thinking must be changed to be CF, understanding the long-term benefits that may be gained from client loyalty (Gosen et al., 2005).

Similarly, TW showed an insignificant relationship with OP. This finding contradicted previous studies' results (Qasrawi et al.., 2017; Zakuan et al., 2010; Valmohammadi, 2011; Fotopoulos & Psomas, 2010). They reported that higher levels of QM practice maximize organization performance. In particular, Hamilton et al.(2003) revealed that sewing in teams improved productivity by about 18% in textile manufacturing firms. Cohen et al. (1996) found that work organization that included teams and high participation of employees significantly influenced both quality and efficiency. These all support the importance of teamwork for the effectiveness of OP. The current study's findings reflect a typical social attitude in Ethiopia. Compared to the other social interactions, people give less value to 'working together.' Research participants in the actual production process revealed that workers have a tendency to concentrate intensely and solely on performing to their best ability. This is because performance evaluation and reward are related to a particular reason related to individuals. One probable reason for this could be the employees' educational level. In Ethiopian LPMI, the majority of the shop floor workers are 'less educated' (Gebeyehu, 2014). Therefore, firms should raise awareness and train employees about the necessity of work-together to create a more vibrant workplace.

The third most common QM practice with a significant and positive association to OP was revealed to be CI. The result is in accordance with previous studies, which show that CI significantly improves OP (Kiprotich et al., 2018; Salah, 2018; Kebede & Virdi, 2020). Particularly, Kebede & Virdi (2020) has reported that CI is the only approach that ensures the long-term viability of organizational productivity, which enhances the OP of the organization. CI in QM can be achieved by improving an employee's performance (Zakuan et al., 2012). Employees must be encouraged to express their thoughts on enhancing working processes to bring CI throughout the organization (Sinha et al., 2016). The most significant aspect of QM that characterizes CI is innovation (Talib et al., 2013). It is concerned with the never-ending pursuit of processes and improvements to discover best techniques of producing valuable outputs. However, based on the response of shop floor employees, workers engaged within the actual manufacturing process are not encouraged to bring new ideas and solve problems. This indicates organizations have a lower view that innovation can only develop in an environment that supports it. Moreover, CI is among the most important QM practices that affect manufacturing organizations' quality performance (Arumugam et al., 2008). Thus training the employees regularly, improvement-based employees' performance evaluation, visual display of information, and signboard as a communication tool can encourage CI efforts. Eventually, this will result in an improved OP.

6.6 Summary

In this chapter, Phase IV of the research is presented. OP is a multifaceted issue that is influenced by QM practices. OP is the ability of organizations to satisfy order cycle time & delivery capacity, minimize operational management costs, and increase the efficiency of raw material usage. And it is extremely important for manufacturing firms because it leads to better production efficiency, increased profit, better products quality, delighted customers, and increased sales volume. Hence this chapter examines the transferability of QM practices to the LPMI of Ethiopia by validating the relations between QM practices and OP. The findings provided empirical evidence that TMC, EP, and CI could result in enhanced OP levels. While CF and TW have insignificant effects on OP. This implies that CF & TW aren't as vital as the other QM practices in enhancing the OP. Overall, TMC, PE, and CI are found to correlate significantly and positively with OP, and their implementation does payoff for Ethiopia's LPMI OP.

CHAPTER 7

CONCLUSIONS AND SCOPE FOR FUTURE WORK

7.0 Overview

The purpose of the research described in this thesis is to examine and generate knowledge on how manufacturing industries integrate LM in to their manufacturing systems for their competitive advantages. The study was divided into four phases. Phase I involved in identification of waste, bottleneck operation and potential improvement areas. Phase II involved in performance analysis of the footwear manufacturing assembly line. Mainly its focus is on analyzing the dynamics performance of the manufacturing system. Phase III focused on systematic and integrated approach in making decisions on the selection of LM tools using fuzzy QFD and fuzzy FMEA. Phase IV emphasizes on understanding the relationship between QM practices and OP. Mainly its focus is on the effects of QM practices on OP of manufacturing organization from low-level technology organizations perspective. This chapter summarizes and presents the conclusions obtained from present research work. The first part presents conclusions and reconnection of research findings to the research questions.

Then the subsequent section presents contributions of the research, followed by scopes for future work.

7.1 Conclusions and Reconnection to the Research Questions

7.1.1 RQ1

The RQ1 was: *What is the possible way to reduce the lead times of the Ethiopian leather industry? (Phase I)*

The objective was to identify the wastes, bottleneck operation, and potential improvement areas to reduce the lead time & improve the productivity of the organizations. For waste identification, VSM is used. Time study for each activity was used to determine the cycle time of each assembly section.

The finding revealed that waiting, transportation, and inventory are the top three most critical waste that consumes the organizations' resources.

The finding revealed that:

- VSM is a crucial tool in identifying wastes, bottleneck operation & improving potential areas in manufacturing organizations, especially in low-level technology organizations with labor-intensive organizations.
- Waiting, transportation, and inventory (WIP) are identified as the top three most critical waste that consumes the organizations' resources.
- Time and motion studies are used to identify the value and non-value-adding activities.
- Overall, 'lasting' section is obtained as the bottleneck station. The bottleneck operation is from the stitching section "stitch tongue with quarter (213 sec.)". And from lasting section "final brushing (91 sec.)" is the bottleneck operation.
- Assembly line balancing is used to reduce the waste and bottleneck operation cycle time.
- As a result, 56.3% cycle time reduction and 69.7% reduction in lead time were obtained, confirming its application in low-level technology organizations to improve their performance and productivity.

7.1.2 RQ2

The RQ2 was: *How is it possible to analyze the dynamics performance of the manufacturing processes? (Phase II)*

The main objective was to analyze the performance of footwear manufacturing assembly lines and increase production by maximizing performance measurements like throughput and resource utilization. In Phase I the static nature of the manufacturing process was analyzed, and waste & bottleneck operations were identified. In this phase, its focus was on the dynamics performance of the manufacturing process. Hence its focus was on the stitching and lasting assembly lines. After gathering relevant data, the current manufacturing system was modeled and simulated using a student version of Arena simulation software. All the input data were analyzed using a built-in Arena input analyzer.

The important findings are presented as follows:

- Six solution alternatives were developed and experimented with Arena simulation software. These are identifying bottleneck workstations with high WIP & increasing their resources, reducing unused resources, combining options one & two, improving machines' capacity, merging similar & consecutive activities, and combining all the alternatives.

- Alternatives combination of all options gives a better performance of the footwear manufacturing system, which increases throughput and resource utilization
- As a result, line balance efficiency was increased from 68.3% to 90.1% in stitching and 17.6% to 76% in lasting assembly lines
- The proposed solution can be applied in footwear sectors and other areas such as the textile, garment, and automotive industries
- Manufacturing organizations can use simulation modeling to understand how the system behaves if something is changed. It helps evaluate the changes in the implementation of different alternative solutions before implementing them into the actual manufacturing systems.

7.1.3 RQ3

The RQ3 was: *How can LM be integrated into not well-developed manufacturing systems? (Phase III)*

The main objective was to develop an optimal procedure in decision-making while selecting the appropriate lean tools from the many available lean tools. The combined use of fuzzy FMEA & QFD, plant layout, and VSM was empirically investigated. The traditional FMEA calculates the RPN value by multiplying factor scores transformed from the probability of problem incidence, not considering the factors' relative importance.

In comparison with conventional selection models, this model brings the following benefits:

- In assessing the failure modes' O, S, and D managers, supervisors, and experts' knowledge & opinion are considered to capture diversified opinions.
- The RI of the risk factors is considered when prioritizing failure modes, making the proposed FFMEA more practical and realistic.
- Since its focus is only on the most critical resources, it saves time by evaluating only the highest-priority resources.
- Identifying the failure modes, their sub-elements, and the proposed lean projects confirm lean implementation's reliability.

Experimenting with a case study enables practitioners and decision-makers to identify the most critical resources, significant waste, and high & less essential activities. This helps practitioners implement lean projects by making simple changes with fewer resources and integrating the existing system into the LM system. In this research, FWGM and CDA address most of the criticisms concerning integrated fuzzy models. It prioritizes and ranks the most critical resources' failure modes based on different alpha levels and centroids values.

Developing the standard time for each activity (standardization) through time study helps to develop the cycle and lead times of the production processes. The successfulness of the model is validated by comparing the CSVSM and FSVSM using the manufacturing industry's case study. As a result, significant improvements in:

- total cycle time reduction (128.8 min.)
- reducing NVA time, including transportation & temporary storage (10 days) (to increase the VA activities)
- reducing total lead time (10 days and 98.78 min.)
- reduction of the number of workers required (2) and
- WIP inventory (1,900 pairs) was obtained.

Hence, the positive outcomes have substantial impacts on the performance of the industries in terms of speed, cost, quality, labor productivity, effectiveness, and WIP inventory reduction. After getting the intended benefits of the performance of the industries, practitioners can focus on the remaining resources to identify and eliminate the remaining wastes.

7.1.4 RQ4

The RQ4 was: *What is the impact of QM practices on the OP of the Ethiopian leather industry? (Phase IV)*

The main objective was to use QM practices to improve the organizations' OP and competitiveness. The relationship between QM practices and OP was studied to understand the effects of QM practices on OP.

The important findings are presented as follows:

- Some QM practices have been recognized as being more important in improving OP. The result shows that TMC, EP, and CI have the strongest impact on achieving OP.

- ‘CF’ and ‘TW’ have an insignificant effect on OP. This implies that ‘CF’ & ‘TW’ aren't as vital as the other QM practices in enhancing the OP.
- QM practices should be implemented holistically to gain the important significant effects on OP. This directly increases profitability by increasing production efficiency and reducing production costs.
- To realize the rewards of QM practices, employees must be motivated through tactics such as monetary compensation for the best solution to a quality problem, providing regular training, encouraging teamwork, and regularly conducting customer surveys are required.

7.2 Contribution of the Research

Manufacturing industries strive to adopt lean concepts to maximize their resources like staff, facilities, materials, and schedules to be economically effective. On the other hand, manufacturing industries' hidden enemies, i.e., wastes, are hindering them. Manufacturing organizations are in fear which improvement tools and how to implement them because of fear of its consequences. Therefore, it is imperative for any organizations to develop a systematic approach to tackle these wastes and increase productivity. One challenging issue with LM is selecting the suitable, appropriate tool among the many LM tools. This is a challenging issue, especially for developing nations having a lack of resources and undeveloped manufacturing systems. Hence, this research was conducted to develop a systematic approach for the successful implementation of LM, focusing on increasing organizations' competitiveness.

This research generated knowledge on how LM can be used for the enhancement of organizations' productivity and competitiveness by utilizing their available resources efficiently and effectively. Mainly it focuses is on discrete manufacturers taking the LPMI of Ethiopia as a case study.

The main contributions of the research are listed as follows:

- The application of VSM in low-level technology was investigated. In relation to this, time & motion studies are applied to determine the standard times for each activity, which helps determine the cycle and lead times and identify the VA & NVA activities.
- Bottleneck operation & station was identified as ‘stitch tongue with quarter’ and ‘lasting station’.

- The top three most critical waste that consumes the organization's resources are waiting, transportation, and inventory (WIP).
- Performance measurement and analysis was conducted using VSM with the integration of simulation modeling (VSM-SM). This is a new effort to analyze the dynamic performance of manufacturing systems after studying their static nature. With the help of simulation modeling, manufacturing systems can be experimented without disturbing the actual manufacturing systems.
- The empirical evidence enriches the LM literature by considering organizations in labor-intensive and low technological level organizations in the developing world.
- The application of Fuzzy QFD and FMEA is demonstrated in the domain of LM. The prioritizing of the critical resources for the identified wastes and failure modes was conducted using fuzzy QFD and FMEA. Its aim was to use these integrated approaches to make optimum decisions in selecting the appropriate LM tools.
- The integrated systematic approach for LM implementation will help organizations to detect the wastes, the critical resources, failure modes, identify improvement areas and bring sustainability of OP, which enhances the profitability of organizations.
- The empirical evidence shows how the manufacturing organizations, especially the low-level technological organizations, are using their resources inefficiently. These developed systematic approaches will help organizations integrate LM easily into their existing systems and efficiently enhance their resource utilization.
- The research contributes to the dearth of research on the area of Multi-criteria decision making (MCDM) for successful LM implementation and OP improvements.
- Most of the previous studies On LM focus on well-developed manufacturing systems of developed nations with sufficient resources. This study opens a new insight into the not-well-developed manufacturing systems in developing nations with a lack of resources.
- The relationship study between QM and OP opens various research avenues in operations management.
- The effects of QM practices on OP have been studied. It augments the existing understanding of the issue by establishing knowledge about how one is constituted in the corpus of the other. The finding provides valuable comprehension for practitioners to use QM in order to maximize profit through the enhancement of organizational OP.

- The research demonstrated useful methodologies for identifying & minimizing wastes and efficient resource utilization. The study showed that LM tools could be used to improve the OP of organizations. It helps to establish the priority of technical solutions for OP improvement. Other organizations may acknowledge these methodologies to facilitate the MCDM process in decision-making to select the appropriate LM tools to enhance their OP.

7.3 Scope for Future Work

The present study was focused on examining how manufacturing industries enhance their competitiveness through LM. Its focus was on discrete manufacturing systems. The finding provides important insights into the true worth of LM implementation in enhancing organizations' productivity and competitiveness.

- The present study investigated the applicability of VSM, which is a crucial tool in reducing waste and increasing the productivity of organizations. Future research may include applying VSM to all processes within the value chain. This shall lead to enhancing the productivity of organizations throughout the value chain.
- In this study, Ethiopian LPMI was targeted. It would be worthy of conducting research that includes different product lines and a wide range of organizations in the future.
- Studying the critical success factors for implementing lean-VSM concepts is recommended for future research.
- The present study examined the fuzzy integrated model in the leather sector's manufacturing industry. Hence, the proposed model can be further investigated by applying it to different organizations and sectors. And also, the study has considered managers, supervisors, and experts' opinions by giving different weights. Therefore, assessing the information from a single manager of the organization can be regarded as future research work. And in the future, various industries can experiment with cost benefit analysis using this approach.
- This study focused on the successful implementation of LM practice for competitive advantage. Further study can be conducted on the effects of LM practice on OP.
- The present study examined OP in relation to QM. Some of the QM practices were identified as important to improve OP. Further analysis can be carried out to relate QM with other performance measures like financial performance, organizational performance, …etc.

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