ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY (AAIT)

SCHOOL OF MECHANICAL & INDUSTRIAL ENGINEERING (SMIE)

(INDUSTRIAL ENGINEERING STREAM)

MINIMIZATION OF DEFECTIVE PRODUCTS IN ABYSSINIA TANNERY INDUSTRY

A MASTERS THESIS SUBMITTED TO SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA INSTITUTE OF TECHNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR DEGREE OF MASTERS OF SCIENCE IN INDUSTRIAL ENGINEERING STREAM

MAIN ADVISOR: DR. AMEHA MULUGETA

CO-ADVISOR: SHIMELIS TILAHUN (PHD CANDIDATE)

DONE BY: MAHLET ZEBENAY

JUNE, 2019

MINIMIZATION OF DEFECTIVE PRODUCTS IN ABYSSINIA TANNERY INDUSTRY

A MASTERS THESIS SUBMITTED TO SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA INSTITUTE OF TECHNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR DEGREE OF MASTERS OF SCIENCE IN INDUSTRIAL ENGINEERING STREAM

MAIN ADVISOR: DR. AMEHA MULUGETA

CO-ADVISOR: SHIMELIS TILAHUN (PHD CANDIDATE)

DONE BY: MAHLET ZEBENAY

ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY (AAIT)

SCHOOL OF MECHANICAL & INDUSTRIAL ENGINEERING (SMIE)

(INDUSTRIAL ENGINEERING STREAM)

JUNE, 2019

Addis Ababa University

Addis Ababa Institute of Technology

School of Mechanical and Industrial Engineering

This is to certify that the thesis prepared by Mahlet Zebenay, entitled: Minimization of Defective Products in Abyssinia Tannery Industry and submitted in partial fulfillments of the requirements for the degree of Master of Science (Mechanical and Industrial Engineering) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by the Examining Committee:

Dr. Gezahegh ______________ ______________
Internal Examiner Signature Date

Dr. Merertu ______________ ______________
External Examiner Signature Date

Dr. Ameha Mulugeta ______________ ______________
Advisor Signature Date

Mr.Shimelis Tilahun ______________ ______________
Co-Advisor Signature Date

Dr.Yilma ______________ ______________
School Dean Signature Date

DECLARATION

I hereby declare that the work which is being presented in this thesis entitled **"MINIMIZATION OF DEFECTIVE PRODUCTS IN ABYSSINIA TANNERY INDUSTRY"** is original work of my own, had not been presented for a degree of masters in any other university, in any projects by any means, and all the resource materials used for this thesis had been accordingly acknowledged.

-- --

Mahlet Zebenay Date

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

-- --

Dr. Ameha M. (Advisor) Date

-- --

Dr. Shimelis T. (Co-Advisor) Date

AKNOWLEDGEMENT

First and for most I would like to thank the almighty GOD and his mother for giving me the courage and strength to start and complete this research.

Next, I would like to express my deepest and grateful thanks to my advisor Dr. Ameha Mulugeta for his unreserved and continuous assistance to complete this research. His encouragement, excellent guidance, creative suggestions and critical comments have greatly contributed to this thesis. I am also really indebted to my co-adviser Mr. Shimelis for his encouragements, motivation and his friendly approach. I have learnt a great deal of knowledge and skills from both.

I would like to thank my friends and classmates; it was also such a nice time that I had all of the support was fantastic. I would also like to acknowledge the management and workers of Abyssinia Tannery Industry mainly Mr. Solomon, Mr. Yetayal and different organizations for their cooperation and assistance to get valuable information for the research and who have responded to my data collection.

Last but not least, grateful acknowledgement to ***all my family*** members.

ABSTRACT

Producing quality product is one of the major determinants that enable manufacturing organizations to compete in the global market. There are many causes for the occurrence of defective products. Hence, to avoid any further problem corrective measures should be taken. The main objective of this thesis is to develop a continuous quality improvement model that integrate lean and six sigma, which coherently applies the principles to reduce the defect level in Abyssinia Tannery Industries. The case study is mainly based on primary and secondary data sources and the main secondary data sources are company record, reports and literature review. Data collected from primary data sources are process flow, cause of defects and type of defects. And frequency of occurrence of defect, amount of low-grade level, defect, their impact, which defect affect the company most and cost encored to treat the defective one etc. were collected from secondary sources. In addition, both qualitatively and quantitatively methods used to analyze the data and by using lean and six sigma tool and techniques. The proposed structure is built upon the existing define, measure, analyze, improve and control structure, which is well renowned in the literature. There are multidimensional causes related to human, machine, material, method, process and organizational factors for the occurrence of defect. To solve the problems associated with these causes, proactive, organized and continuous quality improvement model is required. To improve the quality by reducing defect, Integrated Continuous quality Improvement model consisting lean and six sigma developed based on case study result. Six Sigma and lean are related and share common grounds in terms of striving to achieve customer satisfaction. The integration between the two approaches is lean within six-sigma type of integration and use design of experiment and future value stream mapping for improvement purpose. Their integration is concluded to be possible and beneficial for defect reduction in Abyssinia tannery.

Keywords: *Lean six sigma, leather defects, Taguchi technique, design of experiment (DOE), Continuous Improvement, wastes,*

Table of Contents

List of Figure

List of Table

List of Acronyms

DMAIC- Define Measure Analyze Improve Control

DPMO- Defect Pre-Million Opportunity

SS- Six Sigmas

DFSS- Design for Six Sigma

TM- Taguchi Method

LSS- Lean Six Sigma

JIT- JUST IN TIME

VSM- Value Stream Mapping

SIPOC- Supplier Input Process Output Customer

ANSI- America National Standard's Institute

CSF- Critical Success Factors

DMADV- Define, Measure, Analyze, Design and Verify

VA- Value Added activity.

NVA- None Value Added activity.

TQM- Total Quality Management

UNIDO-United Nations Industrial Development Organization

CSA-Central Stastical Agency

ELICO- Ethio-Leather Industry PLC

LIDI-Leather Industry Development Institute

SPC-Stastical Process Control

LP- Lean Practices

P-D-C/S-A- Plan-Do-Check/Study-Action

DOE-Design of Experiment

VIF- Variance Inflation Factor

CHAPTER ONE

INTRODUCTION AND BACKGROUND OF THE STUDY

1.1 Introduction

The global competition has forced business companies to examine their operation for the purpose of making improvement to their practices. This improvement involves better continuous improvement and result in higher level of quality. Minimizing defect is very important for ensuring the quality of products (Mondal, Hasan, & Islam, 2017). And manufacturing a quality product is mandatory to sustain in this global competitive market (Uddin S.M. and Rahman C.M.L, 2014).

When a defect is detected in the final inspection, the defective product is downgraded as the product cannot be exported. And the defective pieces can be made exportable with alterations, but it costs more money as utilizes more resources to produce the same items.

A variety of methodologies are available for improving the process. These include Six Sigma, Lean Management, Lean Six Sigma, Re-engineering, Total Quality Management, Kaizen and Process Excellence (Gershon, 2010).

A process improvement tool used for this research paper is lean six sigma approach. Lean Six Sigma (LSS) has turned out to be a common tool to advance operational excellence in manufacturing (Albliwi *et al.*, 2014; Timans *et al.*, 2012) and other fields (Chiarini, 2012; Psychogios *et al.*, 2012).

Psychogios and Tsironis (2012) reported that LSS methodology is not a standardized procedure and so it can be used in various sectors. There are a variety of methods used in order to apply the LSS, but the most characteristic is the DMAIC model.

Silva *et al.* (2012) also mention that Six Sigma and Lean acting together can become even more effective, as their strong points are able to cover the other’s gaps or deficiencies. This combination may create a synergy which exercises a great impact over the general performance of the business processes (V. Raja Sreedharan and R. Raju, 2016).

Generally, lean six sigma is used to reduce defect and process variation. LSS notion is the integration of two quality management concepts which are Lean approach and Six Sigma whereby it efforts to rise the scope and size of enhancements attained by either concept alone (Chan, Jie, Kamaruddin, & Azid, 2014).

However, other improvement methods like lean, six sigma, TQM and kaizen have its own limitation for the application on this research and doesn't fit with the scope of the research.

1.2. Background and Justifications of the Study

Currently the development of industrialization and the growth of competition across the globe force companies to work for the improvement in quality, customer satisfaction and cost as a major strategy to sustain in the system. Such competition is familiar in the tannery sector.

African countries hold for only 4 percent of world leather production capacity and 3.3 percent of value addition in leather. Most African countries including Kenya, essentially export raw hides and skins and wet blue leather and account a low production capacity for finished leather (World Bank report, 2015).

Quality and size are essential in determining the final customer of the leather produced. As hides in Botswana are generally of low quality and smaller in size compared to those produced in bordering Republic of South Africa and Namibia, they are less competitive in the global markets (Koloka O and Moreki J C, 2010).

According to UNIDO report on Ugandan leather sector, the export quantity is low because of the product is incapable to meet the specification and 30% of the product satisfy I, II, III grade and 70% are under IV, V, VI quality grade.

Ethiopia has Africa's second largest and the world's eighth largest livestock population (CSA, 2012). But the very high livestock base is not currently fully exploited due to various reasons. The huge potential for investment in tannery industry is still at its infant stages even though the sector is one of the priority sectors identified by the government (Zakaria, Claire, Anas, Roxane, Narcis and Matthieu, 2016).

The emergence of modern tanning in our country dates back to 1918 and 1927 with the foundation of the then Darmar/Awash (currently ELICO) and ASCO (currently Addis tannery) tanneries, respectively. Between 1954 and 1976 Dire, Modjo and Kombolcha tanneries were established (Mohammed Adam, 2019).

Most of the Ethiopian tannery industries are currently under tough competition due to the deterioration in quality of leather (Hailu, Tabuchi, Ezawa and Jilcha, 2017).

The tough competition is due to several reasons from those low-quality grades is one of the causes. From the six quality grades, one to three quality grades are best quality grade which have low defects but four to six grades are relatively have high defect level and low quality. The studies mentioned below shows that Ethiopian tanneries have significant low-quality grade and reject problem.

From the study made in three tanneries, the sampled skins lied in grade 5 are 21.8% in Bahirdar tannery (Assefa et al., 2012) and in Addis Ababa and Modjo tanneries 32.4 % (Urgessa, 2013). The proportion of grade 6 in Bahirdar tannery is 44% reported by (Urgessa, 2013) and in Modjo export tannery 24.9% reported by (Berhanu et al., 2011). The proportion of reject is 12% in Bahirdar tannery (Assefa et al., 2012) and 4.8% recorded in Modjo export tannery (Berhanu et al., 2011).

Currently, there are 30 tanneries transforming hides and skins to different types of finished leather (LIDI, 2018). From those Abyssinia Tanneries is one of finished leather processing company with an annual capacity of 7,140,000 sq. ft finished Goat and Sheep skins leather. In Abyssinia tannery, the raw skin is collected from butcheries, municipal abattoirs, middlemen and local skin collectors and pass several steps to get the finished leather. Significant low-quality grades are apparent in the company due to the inability to meet the specification of thickness, tear strength, tensile strength, color, and other natural defects. This thesis propose improvement model for continuous quality improvement by defect reduction.

Justification of the Study

The study focuses on identification of barriers to minimize defect and develop continuous quality improvement model for Ethiopian tannery industries by taking Abyssinia tannery as a case company.

The study is conducted in Abyssinia tannery industry because tannery is one of the prior sectors for the government because of the high natural comparative advantage in the country that is high livestock population and the government is not attaining expected outcome from the sector. Abyssinia tannery is a company located at Addis Ababa, Ethiopia and the company are mainly known for finished leather production. The reason for choosing this company is according to (LIDI, 2018) report it is among the best five tanneries in Ethiopia on good performance and long tanning experienced company but there is return for non-conformity with the specification and this affect company image.

From the company first quarter 2018/19 performance report the variance level is 50.3% lower from the planed gain in birr and from the causes of variances non-conformity result from quality problem account

58% and the sum of other causes account 42%, this leads to high revenue loose. So, working in this area help the company to avoid low quality level and return problem.

This research paper proposes the synergistic combination of six sigma and Lean for quality improvement. Because the integration of lean and six sigma help to address the defect occurs in the product and help to reduce the non-value adding activities in the company. Silva *et al.* (2012) mention that Six Sigma and Lean acting together can become even more effective, as their strong points are able to cover the other's gaps or deficiencies. And help to improve the size and scope of improvement when different tools are integrated.

1.3 Problem Statement

In Abyssinia tannery selection or quality check is conducted on the process of treatment mainly at wet-blue, crust and finished leather stage. Export and local sale order of finished product a total of 1,258,944 sq. ft. in a year is ordered by the customer providing sample and the finished product were selected or inspected by own selectors. The selection result shows that from a total order 59.47% is returned for non-conformity because of quality problem or occurrence of defect (company report). Some of the defects in the tannery are unable to meet set standards for thickness, color, tear strength, tensile strength and the existence of other natural defects etc. These defective products are either downgraded or returned for retreatment, the returned items for rework are treated with chemicals and other methods. In this case the company concern is going to be survival rather than competing in the international market.

In the company, there are six quality grade levels for the products this are I, II, III, IV, V, VI and the sixth grade divided in to three parts (i.e. VIA, VIB, VIC) and grade one to three are high quality or low defect level products. The export market agree to take one to three grades but based on the review of company selection result the product which meet the I-III grade are 7,661 from a total sample of 47,899 that is 15.99% **(Appendix-B).**Even though, the company plan to supply their products both to the local and international market but it gives high priority to export so, in this case because of the low-quality grade of the product most of the finished leather are supplied to the local market.

1.4 Research Question

1. What is the current product defect level in Abyssinia tannery industry?
2. What are significant cause of defects in Abyssinia tannery industry?

3. How to minimize the defective product by using Lean and six sigma integration approach in Abyssinia tannery?

1.5. Objective

Taking the above problem into consideration, this study plans to achieve the following objectives:

1.5.1 General Objective

The general objective of the study is to propose improvement model for minimizing defective product in Abyssinia tannery industry.

1.5.2 Specific Objective

The specific objectives are as follows: -

- To assess the current product defect level of the company
- To identify the causes of defects
- To develop a model for continuous quality improvement by defect reduction.

1.6 Significance of the Research

Based on the objective of the research, the ultimate result can facilitate the company to solve the low-quality level problem and production manager can receive the improved solution and implement it into the plant. In addition, the study used as a reference for those who work in this area.

1.7. Scope of the Study

The scope of this thesis work were focus on proposing improvement solution for minimizing defective product and low grade in Abyssinia tannery by application of lean and six sigma integration model. And due to occurrence of defect in daily basis the six month recorded data in the company were collected. The latest six-month defect, rework and reject data were collected from the case company Abyssinia tannery for further analysis. And the research work was focus on process variation caused by quality problem or defective product. In addition, the company produces finished leather from Goat skin, sheep skin and cow hide. But the researcher focus was goat skin production process because company's main product or known for goat skin processing.

1.8. Organization of the Paper

The paper is organized in seven chapters. The preceding chapter is an introductory part, which contains the problems, objectives, scope, and significance of the study. Chapter two the literature review part on how to integrate lean and six sigma, lean tools, wastes definition benefits highlights review of studies on defect reduction and gap of the literature. Chapter three the methodology, tools and methods of data analysis, data source discussed. Chapter four deals with the over view of Ethiopian tannery sector and the company background. Chapter five contains the data collection and analysis, result and discussion in detail. Chapter six deals the proposed continuous quality improvement model, model development criteria, implementation procedure and validation of the model. Finally the conclusion, recommendation and future study area.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

The review of literature is used for this study to better understand the subject matter and identify alternative ways of how the topic has been previously addressed and for this condition different journals, articles, and books are reviewed on the area of quality, minimizing defective product, quality improvement tools and lean six sigma approach.

2.2 Quality Evolution

New quality systems have developed from the beginning of Juran, Deming and the early Japanese practitioners of quality and quality has functional beyond manufacturing into service sectors like distribution, education, healthcare and government sectors. During the last three decades, simple inspection activities have been replaced or supplemented by quality control, quality assurance and now to total quality management (TQM).

Quality is defined in different ways depending on who is defining it and what product or service it is related to. Some of the definitions are given below:

- Fitness for purpose or use (Juran,1974)
- Quality should be aimed at the needs of the consumer, present and future (Deming,1986)
- The total composite product and service characteristics of marketing, engineering, manufacturing, and maintenance through which the product and service in use will meet the expectation by the customer (Feigenbaum,1983)
- Conformance to requirements (Crosby,1979)
- All features and characteristics of a product or service that bears on its ability to satisfy given needs- America National Standard's Institute (ANSI) and American society for quality control (ASQC).

"*The most General definition of quality is the extent to which a product or service meets and/or exceeds a customer's expectations (Buzzell & Gale, 1987; Gronroos, 1990; Zeithaml et al., 1990)*"

2.3 Process Variation

Process variability refers to a divergence between the actual and the expected performance. All manufacturing and measurement processes comprises variation between people, equipment, processes, and products (Ericson Oberg, Anna & Astrand, Erik. (2017). There are two types of variation depending on whether the causes are common or assignable. Assignable causes can often be identified while common causes are numerous and difficult to identify individually.

A stable process only contains common variation and is therefore predictable, meaning that the average process value is constant and the variability is controlled. An unstable process is unpredictable and contains one or a few assignable causes of variation. In an unstable process, the assignable causes can be identified and need to be eliminated.

Statistical process control (SPC) is a strong set of tools that helps in the visualizing and identification of assignable causes of variation in any process (S. Bereman, R. Johnson, J. Bollinger, Y. Boss, N. Shulman, B. MacLean, N. Hoofnagle, J. MacCoss, 2014).

There are internal and external factors of variability; Internal factors like imprecise equipment, untrained workers, and lack of standard operating procedures and External factors like inconsistent raw materials, supplier delivery delays, changing consumer tastes & necessities, and varying economic conditions. Variation in the production process leads to lack of product consistency (Lalit Kumar and D. R. Prajapati, 2014). The co-founding variables or some of the factors that causes defect on leather product are thickness, skin quality, PH, % of elongation and size of skin etc. This paper focuses on process variation caused by quality issue or occurrence of defect in the process.

2.4 Bibliographical Background

A total of 191 literature containing the keywords 'Lean', 'Six Sigma' and ‘Lean six sigma’ in their titles were searched and classified based on their theme, adopted research methodology, objective, type of industry, country where the research conducted and year of publication perspective. And the reviewed articles are gathered from leading databases such as Emerald, Taylor and Francis, IEEE, Elsevier and Google Scholar dated from January 2000 to 2019. And as shown in the figure below the trend of this publication is different for the three approaches.

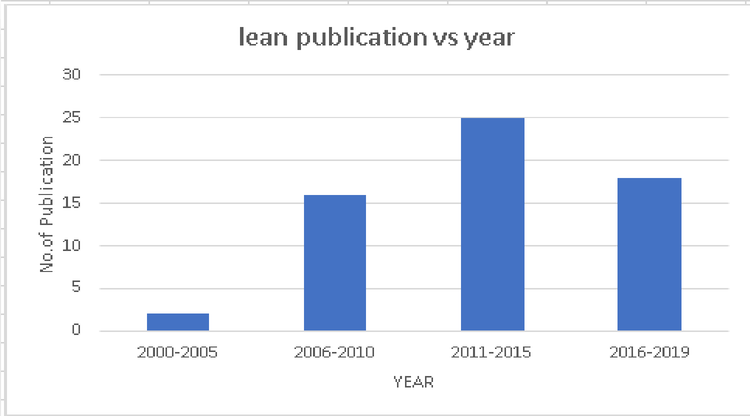


Figure 1 Lean Publication Vs Year

Figure 1 shows that the number of published papers on lean approach were increasing from 2000 to 2015 and then start decrease after 2016.

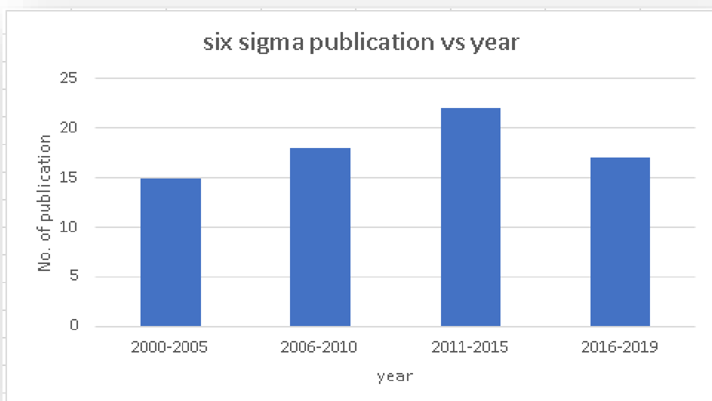


Figure 2 Six sigma publication Vs Year

Likewise, Figure 2 display that six sigma publication were increasing from 2000 to 2015 but after 2016 the number of publications start decreasing. This is a result of the attempts to increase the scope and size of improvements achieved by either lean or six sigma concept alone (Chan, Jie, Kamaruddin, & Azid, 2014).

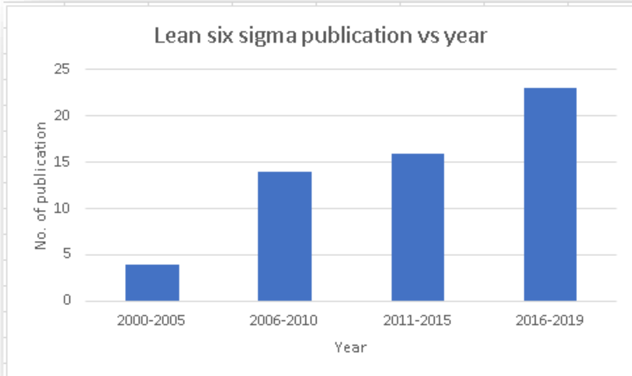


Figure 3 Lean six sigma studies Vs year

The Result from figure 3 demonstrate that the number of studies in the lean six sigma approach has grown significantly from time to time. Because of it is advanced quality management concept (Hoerl & Gardner 2010) and the benefits of LSS have been demonstrated by several studies in different sectors (Costa & Godinho Filho, 2016; Filho, Ganga, & Gunasekaran, 2016; Albliwi, Antony, & Lim, 2015; Grima, Marco-Almagro, Santiago, & Tort-Martorell, 2013)

In addition, the researcher tries to perceive the intention that different authors use these tools and in case of six sigma most of the journals goal were improving the quality of the product using six sigma tools or continuous quality improvement. And figure 4 illustrate that the high valued objective the researcher achieved by implementing lean six sigma is continuous quality improvement, it shows quality problem has been a concern for many studies and case companies.

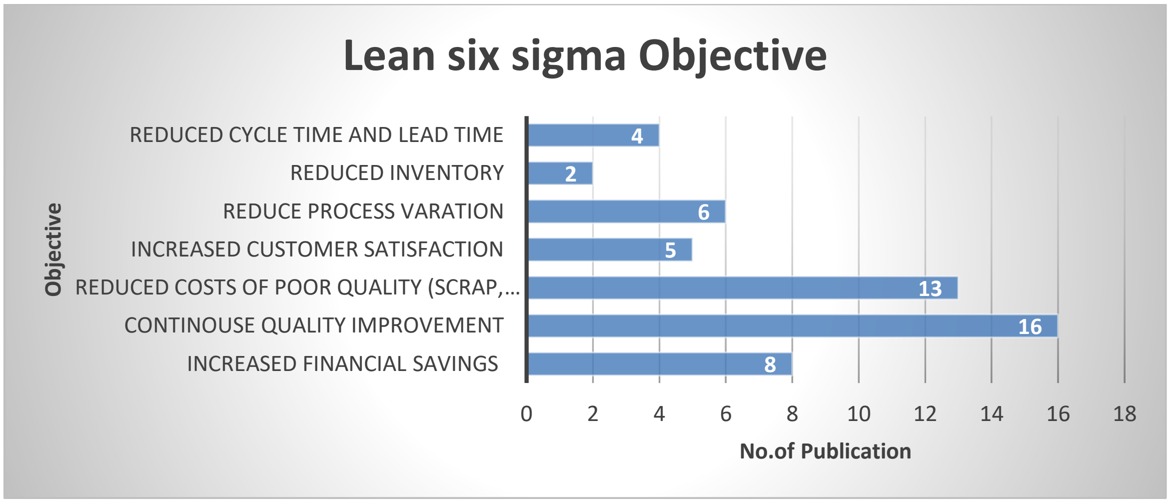


Figure 4 Aim of lean six sigma Publication

Considering the geographical spread of Lean six sigma shows that there are publications widespread in different areas widely in four continents (America, Africa, Asia, and Europe).

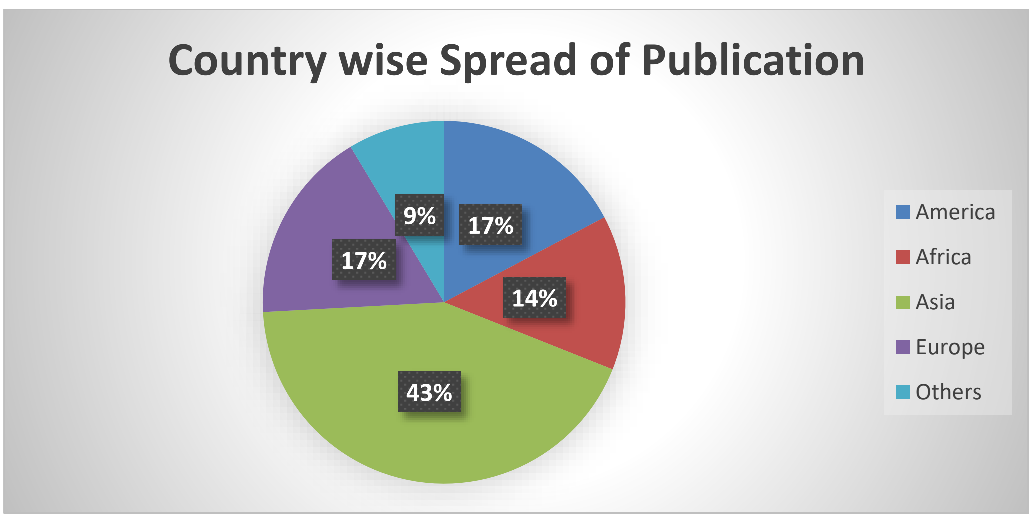


Figure 5 Country wide spread of publications

Figure 5 indicates that the number of publications on implementation of lean six sigma tool in Africa is relatively lower than other continents even though the different researcher implements the LSS tool in different sectors or industries like manufacturing, service giving, hospital, pharmacy, textile, automotive assembly and other sectors and successfully meet the planed objective (Albliwi, Antony, Lim, & Wiele, 2014).

2.5. Overview of Quality Improvement Tools and Methods

Selection of appropriate quality tools and techniques is important if organization wish to achieve a continuous improvement in quality (Sokovic M., Jovanovic J., Krivokapic Z. and Vujovic A, 2009). Quality control tools have been used widely for continuous process improvement and monitoring the overall operation in manufacturing fields (Pratik J. Patel, Sanjay C. Shah, Sanjay Makwana, 2014). Quality tools, methods and approaches used for quality improvement are quality management system, total quality management, seven QC tool and others (Moonsamy & Singh, 2012)

Organizations need to improve their processes to continually achieve customer satisfaction and to do that in an effective and efficient way quality tools should be used. All tools have proved to be useful and effective by different researchers. There are several improvement techniques so far, the following are common ones:

A. Total Quality Management

Abdaziz, Azrilah & Alzhrani, Khadijah & Alotaibi, Bashayer. (2016). mention that Saudi industries that adopting the TQM concept successfully gain a competitive advantage over their local as well as global competitors.

But according to (Antony, J., Snee, R., & Hoerl, R. ,2017) TQM have limitations Firstly, the belief that companies should focus on customer satisfaction and culture change, even though all in favor of the customer satisfaction and changing culture. However, at some point management needs to see tangible improvements to the bottom line. Secondly, the absence of formal methodology for TQM implementation and the third limitation is because of the measurement and metrics were not highlighted, TQM become more of a culture imitative rather than business improvement initiative.

B. Taguchi Method/Design of Experiment

Design of Experiments (DOE) is a powerful statistical technique introduced by R. A. Fisher in England in the 1920's to study the effect of multiple variables simultaneously. The design of experiment techniques was used for organized design optimization. When DOE was performed, the performance of each test set was evaluated using the verified numerical analysis. In this way, the efficiency of the optimization was improved to save time and cost (Kim, J.-H., Lee, H.-C., Kim, J.-H., Choi, Y.-S., Yoon, J.-Y., Yoo, I.-S.,

& Choi, W.-C., 2015). DOE using Taguchi approach attempts to improve quality which is defined as the consistency of performance. Consistency is achieved when variation is reduced. The prime motivation behind the Taguchi experiment design technique is to achieve reduced variation (also known as Robust Design).

Taguchi method arranges a special design of orthogonal array (OA) to study the entire input parameter in much less experiments. It is an efficient tool for designing high quality manufacturing systems. Taguchi method has gained its recognition for undertaking engineering analysis (P.P. Badgujar, M. G. Rathi, 2014). The application of taguchi method with integration of other improvement methods to determine the optimum combination of factors of a station cause a reduction of most critical defective components and overall reduction of the level of non-conformity (Fabio A. Fernandes and Sergio D. Sousa, 2013).

Benton, W. C argue that taguchi method have limitations; First, although the basic ideas of the TM are simple, the statistical procedures are complex and can be difficult to implement. Secondly, TM increases overhead without offering benefits which can immediately be quantified.

C. Statistical Process Control/SPC

Statistical process control (SPC) is a procedure in which data is gathered, ordered, examined, and interpreted so that a process can be sustained at its existing level of quality or enhanced to a higher level of quality (Lalit Kumar and D. R. Prajapati, 2014). SPC tools are used most frequently because it identifies quality problems through the production process.

Pavol Gejdos (2015) declare that SPC and DMAIC model as tools for continuous quality improvement. This tool combination helps for attaining the desired objectives of quality improvement and efficient manner can help solve all tasks and problems of the process of quality improvement.

D. Lean Manufacturing

Lean is a management approach for processes improvement as well as a methodology that is focused on reducing cost, cycle time, waste in processes and increase productivity (Sundar, R., Balaji, A. N., & Kumar, R. M. S. (2014)

E. Six Sigma

Six Sigma can be realized as an organized methodology for continuous process improvements and quality management which uses improvement experts and statistics to rise customer satisfaction, reduce process variation and attain strategic objectives (Schroeder, Roger & Linderman, Kevin & Liedtke, Charles & Choo, Adrian, 2008).

F. Seven Quality Control tools/ 7QC Tools

The Seven Quality control tools were applied as per the nature of the steps of problem solving and the finding after completion of the implementation in tannery industry the excessive defect is reduced 42.71% and the reject is minimized by 35.80% (Haftu Hailu, Hideki Tabuchi, Hiroshi Ezawa and Kassu Jilcha, 2017). According to (lim Sanny and Ria Amalia, 2015) the basic seven quality tools include Check Sheets, Pareto Diagram, Cause & Effect Diagram, Histogram, Control Charts, Scatter Diagrams and Graphs. Up to 95 percent of quality-related problems can be solved with the seven QC tools, They are called basic because they are easy to apply or use and because vast majority of quality-related problems can be solved (Shahin, Arabzad, & Ghorbani, 2010). (Neyestani, Behnam, 2017) also suggested that those tools have the significant roles to monitor, gain, analyze data for spot and solving the issues of production processes, in order to promote the accomplishment of performance excellence in the organizations. And Pie chart is the most suitable for illustrating percentage distributions of qualitative variables (Hassan, Marimuthu, & Mahinderjit-singh, 2016).

2.6 Lean Approch

Lean was first invented by Womack, Jones and Roos, (1990) to illustrate the Toyota Production System. This system come forth from the need encountered by the Japanese industry in the period after World War II. Lean provides a fundamental framework for enhancing efficiency, reducing waste (operations that are not needed, excessive setup times, unreliable machines that can be made more reliable, rework that can be eliminated, etc.) and less obvious, reducing variability (in process times, delivery times, yield rates, staffing levels, demand rates, etc.) (Hopp & Spearman, 2004). The causes of waste need to be identified to reduce their negative effects (Hopp & Spearman, 2004), so the manager’s challenge is to find the mix of policies that best minimizes them in each environment. Now adays lean is used as a tool for waste reduction in different industries (Rebecca M. Nunesca and Aile T. Amorado, 2015).

According to Antony, J., Snee, R., & Hoerl, R.,(2017) an apparent limitation of lean is that when problems were not directly related to any of the lean principles, it is difficult to address it using lean thinking and lean is not well suited to resolving complex problems that demand in-depth data analysis and advanced statistical methods. (Chan et al., 2014) also report that lean manufacturing concept would be of not utilized if the execution of the solution has high variation.

An initial conceptual framework of lean tools and principles was developed as shown in Figure 6. A total of 20 tools were identified and these were gathered into six categories: Quality Methods, Visual Management, Policy Deployment, Just-In-Time, Standardized Work and Improvement Methods (Jayaraman, 2015). The focus of all those tools is meeting customer requirements which are the central of the framework.

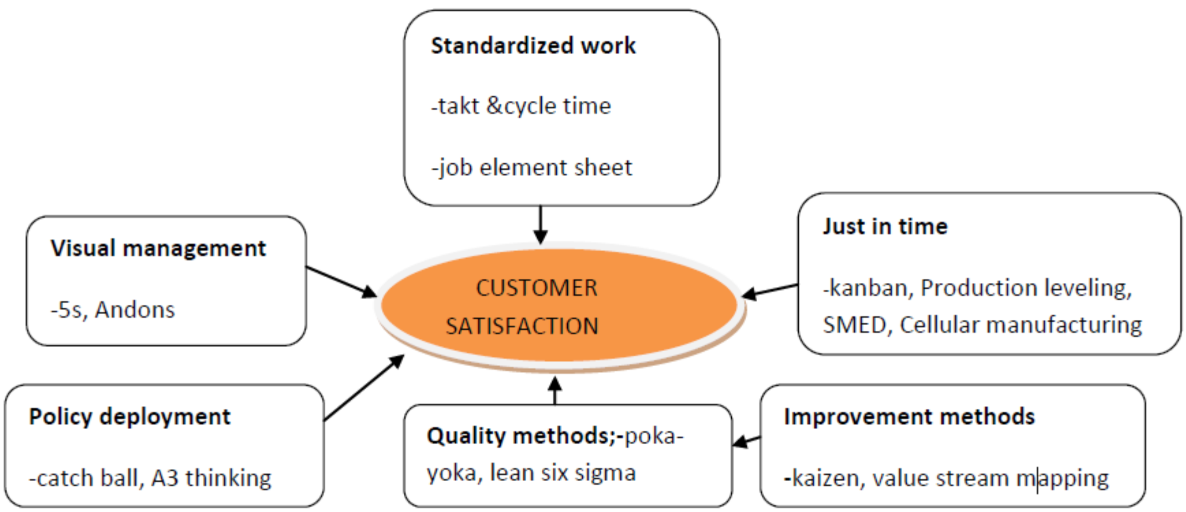


Figure 6 conceptual framework of lean tools and principles (Source: Jeyaraman, 2015).

2.6.1 The Concept of Waste

There are seven commonly identified wastes which are non-value-adding activities in the Toyota production system this are; waste of overproduction, waste of waiting, waste of transportation, waste due to over-processing, waste of unnecessary inventory, waste of unnecessary motion and waste of manufacturing defects (Ajit Kuma, R., K.M. Mithilesh ,N.S. Narahari and Girish Kumar, 2015; Sternberg et al., 2012).

(1) Overproduction: Manufacturing items for which there are no orders, which creates such wastes as overstaffing and storing and transporting costs because of surplus inventory.

(2) Waiting: Workers simply serving to watch a machine or having to stand about waiting for the following processing step, supply tool, part, etc., or just plain having no work because of stockouts, lot processing stays, capacity bottlenecks and equipment stoppage.

(3) Unnecessary transport: Carrying work-in-process (WIP) extended distances, creating wasteful transport, or moving materials, parts, or finished goods into or out of storage or among processes.

(4) Over processing or incorrect processing: Taking unnecessary steps to process the parts. Ineffective processing due to poor tool and product design, causing unnecessary motion and manufacturing defects. Waste is created when providing higher-quality products than is necessary.

(5) Excess inventory: Surplus raw material, WIP and finished goods inventory causing longer lead times, uselessness, damaged goods, transportation and storage costs, and delay. Also, extra inventory hides problems such as production imbalances, late deliveries from suppliers, equipment downtime, defects and long setup times.

(6) Unnecessary movement: Any wasted motion workforces have to make during the sequence of their work, such as searching for tools, reaching for object, or stacking parts etc.

(7) Defects: Manufacture of defective parts or correction. Rework or repair, replacement production, scrap and checkup mean wasteful handling, time, and effort.

2.6.2 Lean Tools and Techniques

The impact of Lean Practices (LP) on business success cannot be neglected. Lean tools and techniques have allowed companies to be more flexible and profitable. Several companies invest in the implementation of LP to remain competitive (Manzouri, M., Ab-Rahman, M., Zain, C., & Jamsari, E., 2014).

All the techniques and tools used to support the Lean paradigm are unique, meaning that all of them have their own method and approach to fulfill a specific goal. The tools and methodologies that contribute to the implementation of Lean are represented on Table 1, all targeting to make companies more efficient and competitive.

Table 1 Lean Tool and Methodology (Source: Bhamu, J., & Singh Sangwan, K. (2014); Manzouri, M., Ab-Rahman, M., Zain, C., & Jamsari, E., 2014).

Techniques	Tools
Kaizen	Standard work,
Just in Time	Value stream mapping (VSM)
5s	Layout configuration
PDCA cycle	5 why technique
Visual control	Poka yoke
Total productive maintenance (TPM)	Brainstorming
	Spaghetti diagram
	Overall equipment effectiveness (OEE)
	Kanban, standard operation & procedure (SOP)
	One-piece production

2.7 Six Sigma Approach

Six Sigma is a driver for business improvement that was developed at Motorola by the engineer Bill Smith within the mid-1980s (Snee, 2010). Sigma (σ) is used by statisticians to measure the variability in any process (Pyzdek & Keller, 2010). Six sigma commit to spot and eliminate causes of defects in business processes by that specialize in outputs that area unit of vital importance to customers (Snee, 2000).

According to Antony & Banuelas, (2012) DIMAC an acronym of define, measure, analyze, improve and control is a roadmap or step-by-step approach for successful implementation of the Six Sigma initiative. DMAIC organizes the use of a large range of tools during Six Sigma projects. As people master these tools and carry out more and more projects, they stand to gain experience in scientific problem solving (Arumugam, Antony, & Linderman, 2014). Six sigma principally concentrates on the processes by identifying issues and gathering and analyzing information to spot and eliminate the foundation causes of those issues (Timans, Ahaus, van Solingen, Kumar, & Antony, 2014).

According to E. Drohomeretskiab, Costaac, Limaac & Rosa Garbuio, (2013) one of the limitations of six sigma is long project duration. And it is very expensive to implement and to apply it to each and every process.

2.7.1 Six Sigma Tools and Techniques

According to Mallikarjun Koripadu, K. Venkata Subbaiah, (2014) few of the most commonly used six sigma tools and techniques are: Ishikawa diagrams (also known as fish bone diagram or cause and effect diagram), Pareto Chart analysis and Why analysis.

There are basically two methodologies in practice for Six Sigma improvement strategy popularly known as DMAIC (define-measure-analyze- improve-control) and another one aiming for design improvement is known as DFSS (design for Six Sigma). For DFSS methodology, there are different approaches in use such as DMADV (define-measure-analyze-design-verify), IDOV (identify-design-optimize-validate) and DIDES (define-initiate-design-execute-sustain) (Zhang, M., Wang, W., Goh, T. N., & He, Z. 2014; Desai, D., & Prajapati, B. N. 2017). Shewhart and Deming’s Plan-Do-Check/Study-Action (P-D-C/S-A) cycle as well as Juran’s ten steps for quality improvement are mirrored in Six Sigma DMAIC implementation (He, Z., & Ngee Goh, T., 2015).

2.7.2 Sigma Level and DPMO Calculation

Measurement of process capability is conducted by using DPMO (Defect Per Million Opportunities) to rate the recent company’s performance, specifically in quality of management and to calculate sigma level from DPMO (Purnama, Shinta, & Helia, 2018).The equation below is well-known to calculate DPMO and to determine the sigma level (Desai & Prajapati, 2016; S. K. Tiwari, R. K. Singh and S. C. Srivastava,2015)

$$DPMO = \frac{numberofdefects \times 10{,}00{,}000}{numberofunits \times noofopportunitiesperunit} \qquad \text{………………. (1)}$$

Gupta, (2013) report that sigma value increases the process performance in a better way. Alternative way of measuring the process capability and performance by the statistical measurements like Cp, Cpk, Pp and Ppk. The Six Sigma means a 3.4 % defects part per million opportunity or yield of 99.9997%. Following is the table 2.2 of comparison of different Sigma values at different defects part per million and capability of process.

Table 2 The Comparison of Different Sigma Values (Gupta, 2013)

SIGMA	DPMO	COPQ	CAPABILITY
6 Sigma	3.4	<10% of sales	World Class
5 Sigma	230	10 to 15% of sales	
4 Sigma	6200	15 to 20% of sales	Industry Average
3 Sigma	67000	20 to 30% of sales	
2 Sigma	310,000	30 to 40% of sales	Noncompetitive
1 Sigma			

2.8 Lean Six Sigma Integration

Lean six sigma is emerged as a hybrid method to maximize shareholder value in the early 2000s to achieve faster rates of improvement in customer satisfaction, cost, quality, process speed and invested capital (George, 2002).

Antony, J., Snee, R., & Hoerl, R., (2017) suggest that because both Six Sigma and Lean had produced enormous results but had limitations, some type of integration of the two was appealing and made intuitive sense. Quality experts use lean principle for achieving immediate benefit from minimum collected data but for the case of complex problem that demand intense data analysis six sigma is utilized.

The most commonly used tools and methods for lean six sigma deployment in different publication were: value stream mapping, cause and effect diagram, 5S, brainstorming, DMAIC, pareto chart, control charts, visual management. Among those tools DMAIC and VSM account the high percent of used by different researchers.

According to (Antony, J., Snee, R., & Hoerl, R.,2017) the integration of Lean and Six Sigma is important as Lean focuses on improving the flow of information and materials between the steps in the process and help to identify the key area of improvements and Six Sigma works to improve the value-adding transformations which occur within the process steps.

An integration or appropriate blend of lean and six sigma can improve, promote, and maintain sustainable development measures and reduce variations in processes to ensure the efficiency of production (Alhuraish I., Robledo C., Kobi A., 2017).

Lately, integration of lean and six sigma increase significantly (Assarlind and Aaboen, 2014). But it is not clear if the first step should be lean or six sigma, or both combined (Albliwi and Antony, 2013). It is preferable a company decided to implement six sigma after having previously implemented lean manufacturing, and this scenario may accelerate the use of six sigma (Bożek and Hamrol, 2012).

The benefit of lean six sigma has been demonstrated by several studies in different sectors (Sri Indrawati and Muhammad Ridwansyah, 2015; Hari Supriyanto and Diesta Iva Maftuhah, 2017; Noor Azam MD Saad, Astuty Amrin and Khairur Rijal Jamaludin, 2017).

The most important issue is that there is no generalized model for LSS implementation for most of the industries and there is no clear picture of the tool usage in various phases of LSS implementation (V. Raja Sreedharan and R. Raju, 2016).

2.8.1 LSS Tools and Techniques

When integrated approach of LSS implemented, it utilizes Define-Measure-Analyze-Improve-Control (DMAIC) methodology for conducting improvement projects (Cudney, Furterer, and Dietrich 2013). This systematic and rigorous implementation structure is one of the characteristics which makes LSS very effective (Garza-Reyes et al. 2014; Harry et al. 2010).

While implementing LSS through the execution of DMAIC phases, lean tools and techniques namely VSM, 5S, Kaizen TPM, SIPOC and 5-whys could be adopted (Murugesh & Devadasan, 2015).

The study of these researches and the emphasis made in papers like (Gupta et al.,2012 ; Chiarini ,2012 ; Salah et al.,2010 ; Hoerl and Gardner, 2010 and Thomas et al., 2009) have indicated that, despite the availability of models like Define, Measure, Analyze, Design and Verify (DMADV), Identify, Design, Optimize and Validate (IDOV), Define, Initiate, Design, Execute and Sustain (DIDES) and Define, measure, Analyze, Redesign, Implement and Control (DMARIC) (Park, 2013; Pyzdek and Keller, 2010), the researchers have preferred to adopt DMAIC as the foundational framework of LSS model, because the researcher scope is to improve the existing system rather than designing from scratch as tools like DMADV and others.

Kumar, Satsangi, and Prajapati, (2013) reported the application of DMAIC methodology for reducing the defects in a foundry result in sigma level improvement. (P. Jirasukprasert, A. Garza-Reyes, V. Kumar and

M. K. Lim, 2014) also mention that lean six sigma DMAIC is used for the reduction of defects in a rubber gloves manufacturing process.

DMAIC methodology consists of five phases namely Define, Measure, Analyze, Improve and Control. In Define phase, project goals and objectives, process and problem are defined. Current process defects are measured in Measure phase. Analyze phase identifies and analyze root causes for the problem, relationships and causality of factors. Optimization or improvement of process takes in Improve phase to streamline the process. Control phase ensure high process performance by eradicating the variations in the process (Soni et al., 2013; Dhamija et al., 2014, Yousaf and Butt, 2013).

According to Gopal Buchade1 and S.N. Teli, (2017) when customers expects quality, speed and low price thus LSS offer these by DMAIC (Define, Measure, Analyze, Improve, and Control) project management methodology and varied lean tools square measure used to contour processes and improve productivity.

E. V. Gijo, Johny Scaria and Jiju Antony, (2011) also suggested that step-by-step application of the DMAIC approach to eliminate the defects in a fine grinding process of an automotive company. This has helped to reduce defects in the process and thereby improve productivity and on time delivery to customer.

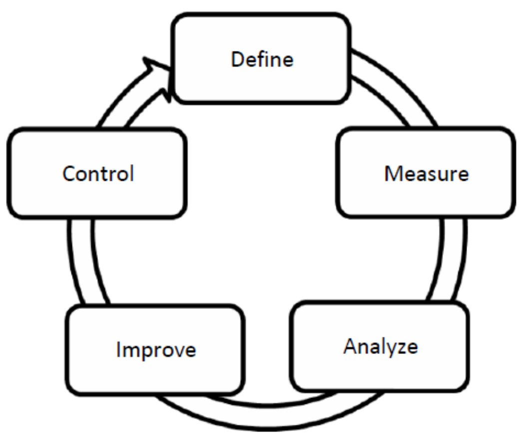


Figure 7 DMAIC Cycle (Source; T. S. Parsana, D. A. Desai, 2014)

According to A. Douglas, J. Douglas and J.Ochiengrs, (2015) the most popular tools in LSS were Pareto Diagram, Scatter Diagram, Histogram, Run Charts, Taguchi Methods, Non-Parametric tests, ANOVA, and SPC Control Charts.

Jie et al. (2014) implemented Lean Six Sigma Framework in a printing company. They followed standard approach of six sigma DMAIC methodology while utilizing lean tools in each phase to determine improvement opportunities and further analyzed the problems. They utilized various LSS tools like VSM, Pareto chart, Fish bone diagram, 5 why analysis, 5S and SIPOC. From those tools VSM, Pareto chart, Fish bone diagram, and SIPOC are used in this paper.

The Supplier, Input, Process, Output and Customer (SIPOC) diagram was drawn to identify the process for achieving improvement (K. Srinivasan, S. Muthu, S. R. Devadasan & C. Sugumaran, 2016). SIPOC diagram is used to categorize how various entities interact with each process, dividing the scope into convenient segments (sharma, 2014). (Tenera & Pinto, 2014) also mention that SIPOC diagram can be very useful, for detailing the involved stakeholders as well as the main project activities to be addressed. And it is used in the define phase of DMAIC roadmap (Tenera & Pinto, 2014; Hassan, Marimuthu, & Mahinderjit-singh, 2016)

SIPOC diagram identifies all elements of a process improvement project before work begins. It provides a deep understanding of the current process, it helps to define and refine a complex project that might not be well scoped (Hassan et al., 2016).

Figure 8 SIPOC diagram (Source: A. Prashar, 2013)

Value stream mapping (VSM), a lean manufacturing tool, which originated from the TPS, is known as material and information flow mapping. VSM is a graphical illustration of the production process representing material and information flow (Singh et al., 2011). It collects all activities in the process including value-added and non-value-added activities starting from the raw material up to the delivery to the customer. Elimination or reduction of the impact of the identified non value- added activities is the purpose of this Lean tools.

Value Stream Mapping is a best way to eliminate wasteful steps and maximize customer value. Most companies looking to transition to a Lean operation will start with a Value Stream Mapping event to startup the change. The current Value Stream Map highlights information that possible hasn't been considered previously. The future state Value Stream Map assists as a goal for future lean actions. These actions can help decrease processing times and advance product quality (Chen et al. 2010).

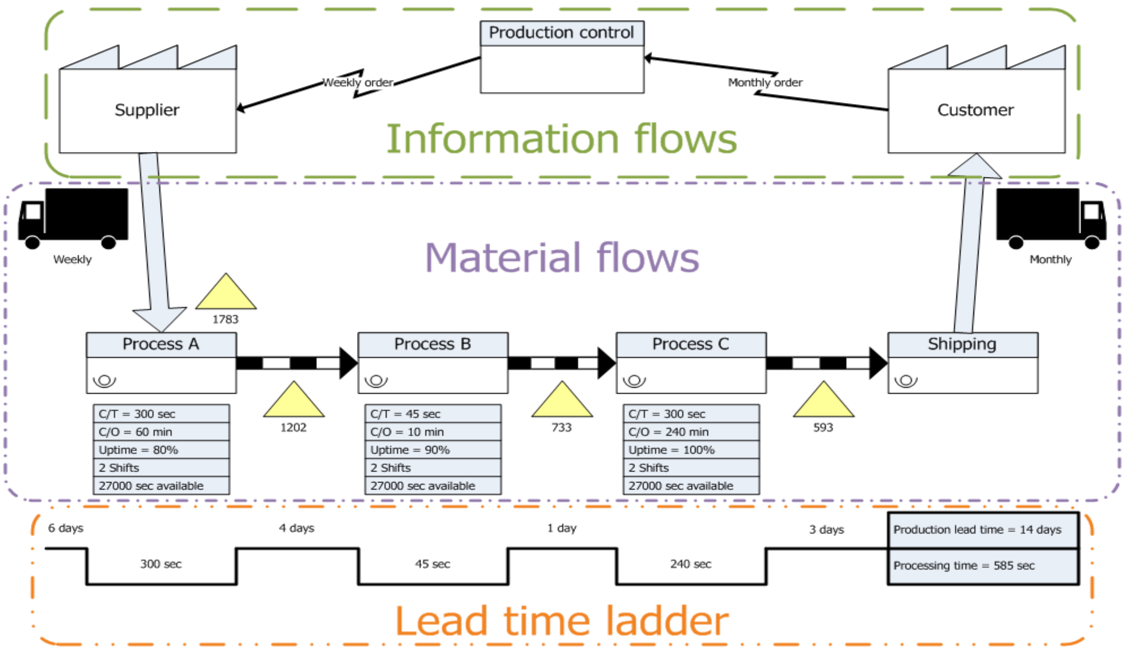


Figure 9 Sample value stream mapping (Source: Austin and Alexis, 2013)

2.8.2 Relation Between Lean and Six Sigma

Lean Six Sigma is a business enhancement practice that has intentions to increase shareholder value by improving quality, speed, customer satisfaction and costs, it attains this by integrating tools and principles from both Lean and Six Sigma concept (A. Laureani and J. Antony, 2018). Lean is a process improvement methodology used to bring products and services improved, faster and at a lower cost. Six Sigma is a data-driven process improvement methodology used to achieve stable and predictable process results by reducing process variations and defects. Both lean and six sigma have been identified as important methodology for achieving sustainable development objectives (Cherrafi et al., 2016).Antony (2011) mention that Lean seeks to reduce the inefficiency of the process and Six Sigma aims to improve the effectiveness of the process.

Table 3 Lean and Six sigma commonalities and differences (Source: Laureani A.& Antony J., 2018))

<table>
<tr><th>Lean</th><th>Six Sigma</th></tr>
<tr><td colspan="2">Both are continuous business process improvement methodologies
Both focus on business needs defined by the customer
Both are practical approaches, demonstrated to work in many organization’s
Both involve a comprehensive tool for undertaking process-related problems</td></tr>
<tr><td>Lean is mainly good for a rapid and at initial stage of improvements</td><td>Six Sigma is suitable for long-term and complex problems where the solutions are either unknown or vaguely known.</td></tr>
<tr><td>Lean places less emphasis on statistical tools and techniques</td><td>Six Sigma demands high investment and is not suitable for fixing common sense problems in the business</td></tr>
<tr><td>No formal organizational infrastructure is required for Lean implementation and deployment</td><td>Six Sigma requires the use of applied statistical methods for understanding and reducing variation in processes</td></tr>
<tr><td>Lean looks into mapping of the end-to-end process and uses value stream exercises to understand the interactions between processes</td><td>System interaction between processes is not considered in a typical Six Sigma problem solving scenario and this would possibly sub-optimize the overall process performance</td></tr>
</table>

2.8.3 Critical Success Factor for LSS Implementation

Critical success factors (CSFs) are elements that are vital for a successful strategy and could affect the performance in either positive or negative direction (Raravi et al., 2013).

According to (A. Laureani & J. Antony, 2018), the important CSFs that highly affect the successful Lean Six Sigma deployment are leadership commitment, organization’s need to make sure they have in place leaders committed to inspiring employees and establishing the right culture for continuous improvement in order to reap the benefits of Lean Six Sigma deployment

J. Douglas, D. Muturi, A. Douglas and J. Ochieng, (2017) survey show that the top three CSFs were identified as management involvement and participation, organizational infrastructure and cultural change respectively.

Based on the combined results of the estimated level of success for implementing lean manufacturing and six sigma, top management commitment was found to be the most important critical success factor for the successful implementation of both lean manufacturing and six sigma (Alhuraish, Robledo, & Kobi, 2017).

Kumar, Sunil Luthra, Abid Haleem and Dixit Garg, (2015) reported that the analytical result shows that, Management involvement and funds allocation (20.3%) has been identified the most important enabler of lean six-sigma concept implementation followed by floor layout and optimization of transportation & material handling (11.0%), and the third one is customer integration. Lean six-sigma implementation process may not be successful in true sense without integration of customer with appropriate feedback mechanism and channels (Albliwi et al., 2014). Consequently, management commitment and customer integration have constructive impact on lean six sigma implementation.

2.9 Synergy between Lean and Six Sigma Approaches

Salah, Rahim, & Carretero, (2010) report that lean and Six Sigma have a complementary relationship is widely approved today and more companies are building lean Six Sigma (LSS) programs, especially after the proven capability of lean and Six Sigma in leading companies.

Thomas Bertels, (2018) survey report show that most companies have deploy either a Lean or Six Sigma program. However, using either one of them only has limitations: Six Sigma will eliminate defects but it will not address the question of how to advance process flow; and the Lean principles eliminate the advanced statistical tools often required to achieve the process capabilities needed to be truly lean. Therefore, most practitioners consider these two methods as complementing each other. And while each approach can result in dramatic improvement, utilizing both methods simultaneously holds the promise of being able to address all types of process problems with the most appropriate tools (Thomas Bertels, 2018). For example, Lean projects are very tangible, visible, and can sometimes be completed within a few days; whereas Six Sigma projects needs long duration. An integrated approach should emphasize Lean projects during the initial phase of the deployment to increase speed. And Lean principles are sometimes incapable to solve some of the more sophisticated problems that require advanced analysis. Therefore, Six Sigma needs to be initiated during the first year of the deployment to ensure that the improvement roadmap includes a generic problem-solving approach.

For implementation of lean Six Sigma previous studies use different type of lean and Six Sigma integration model based on their objective and problems. The following table show the different integration model and qualitative studies that include analysis of strengths and weaknesses.

Table 4 Types of lean and Six sigma integration

Type of Integration	Description of Integration	Strength	Drawback
1**. Lean is parallel to Six Sigma (to tackle different problems)** (Salah, Rahim and Carretero, 2010)	-Work on both methodologies in parallel or applied separately to solve problems.	-Help to decease long project duration. -Each approach can result in dramatic improvement, utilizing both methods simultaneously hold the promise of being able to address all types of process problems with the most appropriate toolkit.	-Conflict of interest between the two tools -Face trouble in prioritizing initiatives, allocating resources, and selecting the right methodology -This does not achieve the integration intended as it still proposes two separate approaches.
2. **Applies One After Another in Series (when applied to the same problem)** (Salah, Rahim and Carretero, 2010; G. Muthukumaran, V.S.K. Venkatachalapathy, K. Pajaniradja,2013)	**I. Apply six sigma then lean** -Six Sigma can first be applied to improve the processes effectiveness followed by lean to improve the system efficiency.	-help to avoid complex problem first and easy to use lean later.	-unable to identify the problem easily - It took long duration
	II. Lean then six sigma -Deploy lean first to eliminate waste and unnecessary steps, and then to introduce Six Sigma after that, in order to focus on certain process steps.	-The aim is to eliminate waste and simplify processes, before starting to tackle the more difficult problems through optimization and process control aimed mainly at process steps. -Smooth flow of improvement	-It took long duration/time
3. **Applying one within the other (as a tool within the other).** (Salah, Rahim and Carretero, 2010; Chan, Jie, Kamaruddin, & Azid, 2014)	**I. Lean is part of Six Sigma** - Six Sigma as an encompassing methodology that forces some lean tools into the DMAIC structure.	The framework utilizes data driven and guided standard approach of the Six Sigma DMAIC methodology while utilizing lean tools in each phase to determine improvement opportunities and further analyses the problem(s). -reduction of error rate, increased productivity and reduced production cost.	-Solutions to the problems are initiated by data
	II. Six Sigma is part of lean -lean as an encompassing methodology that uses Six Sigma as a tool within it,	After the problem is identified from lean tool (VSM) then six sigma tools are applied to solve the issue. -used to control variation	-unable to measure the existing system statically

Source: (Salah, Rahim, & Carretero, (2010); Muthukumaran, V.S.K. Venkatachalapathy, K. Pajaniradja,(2013);(Diego Pacheco Isaac Pergher Guilherme Luís Roehe Vaccaro Carlos Fernando Jung Carla ten Caten, (2015); Chan, Jie, Kamaruddin, & Azid, (2014))

2.10 Summary of the Literature

Vinodh, Gautham, and Ramiya, (2011) suggest that in order to attain effective results, LSS framework must be scientifically and specifically designed to effectively execute and conduct LSS improvement initiatives.

The LSS framework as shown in figure 10 is actually a simplification of the Six Sigma's DMAIC methodology with guided steps on utilizing certain lean tools in each phase. The framework utilizes data driven and guided standard approach of the Six Sigma DMAIC methodology while utilizing lean tools in each phase to determine improvement opportunities and further analyses the problems, this integration is chosen because other integration have limitations of talking long duration, unable to measure the existing system statically and the parallel integration have drawback of conflict of interest between the tools and face trouble in prioritizing initiatives (Salah, Rahim, & Carretero, (2010); G. Muthukumaran, V.S.K. Venkatachalapathy, K. Pajaniradja, (2013)). And also, the framework is based on the quality management system and it took the concept of management commitment and customer focus, because management have basic role for promoting the adaptation of quality management system and identify your customers' desires and expectations are the basics for continuous process improvement (G. Guchu and Z. Mwanaongoro, 2012).Besides from the top critical success factors that affect the successful implementation or deployment of LSS, management commitment and customer focus or integration have a great recognition by different studies. And what makes this research unique is that it use design of experiment-based improvement method and future value stream mapping method to strengthen the improvement method of lean six sigma integration.

The following figure shows the developed framework for LSS implementation.

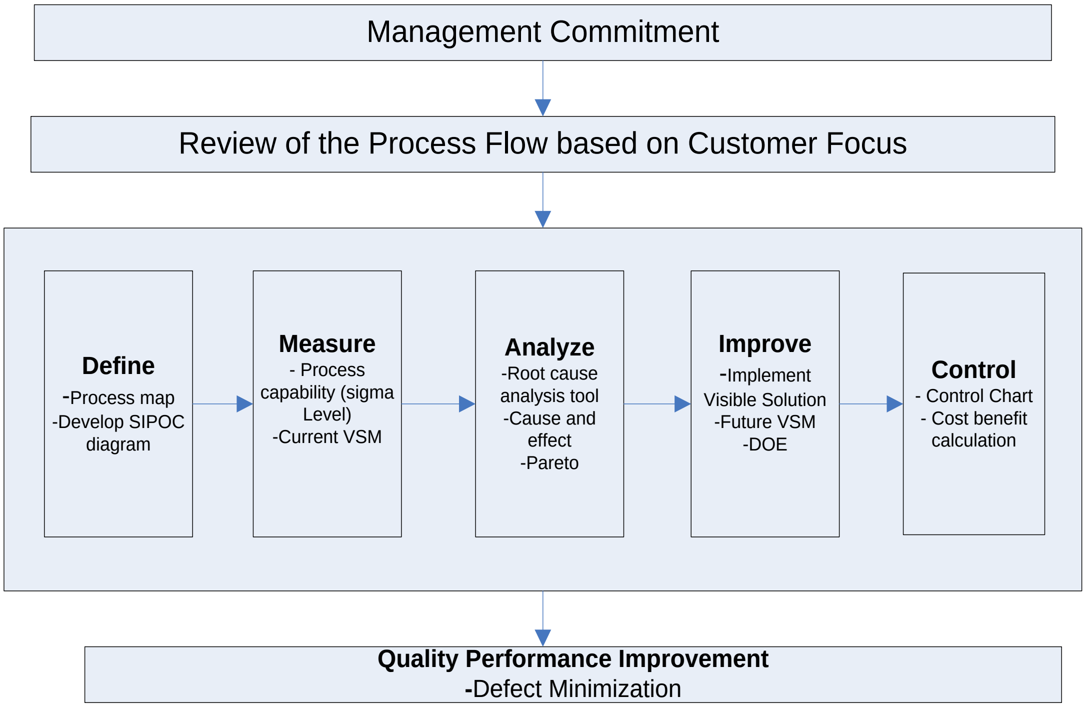


Figure 10 lean six sigma concept map (Source: Author)

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter discusses the methods that were used in the collection and analysis of data to answer the research questions. Both qualitative and quantitative research methods were used in carrying out this research.

3.2 Data Sources

The necessary data for this research were obtained from primary and secondary sources. Primary data is collected through observation and interview. And Secondary data is obtained from articles, books, internet sources and company records.

3.3 Data Collection Methods

3.3.1 Primary Data Collection Method

i) Observation

Observation of the work place were employed to collect primary data for this study. This method is a process of watching or noticing the working environment and existing process flow sequence so as to help us identify the process flow and defect and wastes occurs throughout the process.

ii) Interview

Interview were conducted with company supervisor, production manager, quality control staff, stock controller, sale and purchaser with the semi-structured questions. Data collected by using semi structured interview are root cause of each defects, types of defects occurs in the company, cause of downgrade and how quality is understood by managers, experts, quality controllers, and supporting staffs of the company etc.

3.3.2 Secondary Data Collection Method

i) Recorded data

To show the existing problems of quality in the case company different company documents are reviewed such as production and quality check records, and other related report on the company from external sources.

Recorded data is one of the main sources of data and data's like amount of low-grade level, defect, the frequency of occurrence, their impact, which defect affect the company most and cost encored to treat the defective one etc. are collected. Six-month finished leather production company recorded data is used for forming the Pareto because of defect are occurring on the daily basis.

ii) Literature Review

A review of literature is conducted on the area of defect minimization in tannery industries and studies done before on tannery industries especially in Abyssinia tannery is used as one of the secondary data sources. All available books, journals, case studies, previous research works were surveyed in order to have a clear understanding of the subject matter. Apart from the internet, Leather Industry Development Institute and other available documentations were used.

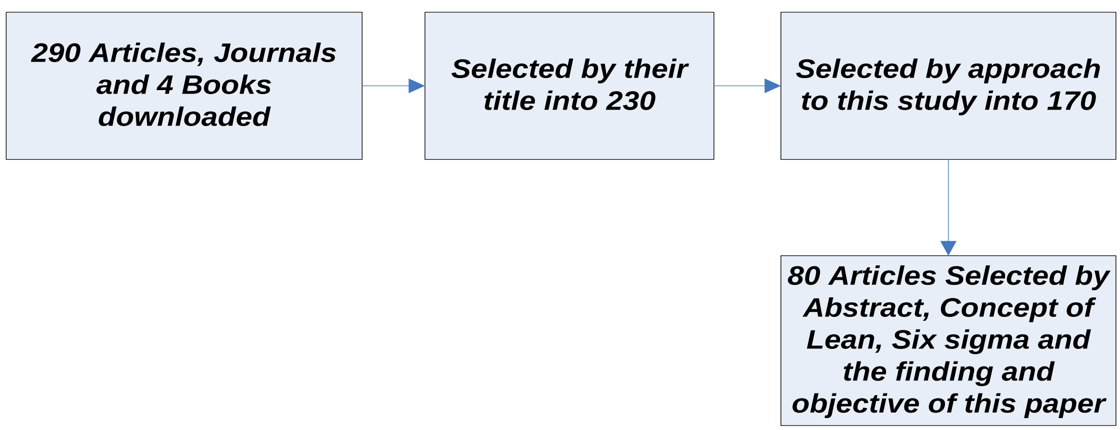


Figure 11 Selection of Articles

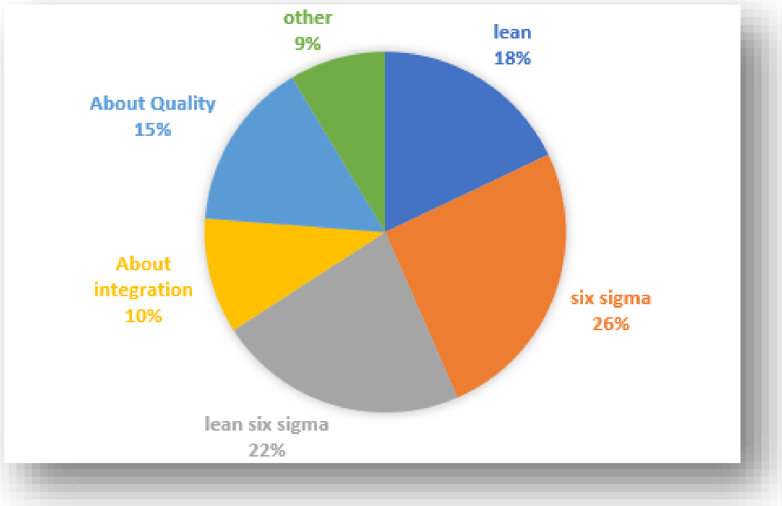


Figure 12 Overall literature main points focused in percent

3.4 Data Analysis and Tools and Methods

Data of the existing condition which is derived from interviews, observations and company's records were analyzed and evaluated qualitatively and quantitatively for the sake of knowing values of percentage of the extent of the defect to determine quality level product in the company using statistical quality control tools such as pareto, cause and effect diagrams (Ishikawa analysis), check sheet etc. and the data will also be analyzed by using statistical quality control tools and software like QI Macros, Minitab and Microsoft Excel.

The analysis follows the DMAIC procedure and lean and other tools were used on the process of DMAIC implementation of lean six sigma.And in the define phase in order to define the process SIPOC, and process flow chart are used to clearly list the processes included and identify where the defect and waste occur in the process. In the second phase the existing system is measured, by calculating the sigma level and by using current value stream mapping. And in the analysis phase the root cause of the critical defect occurs in the process identified by cause and effect diagram and with Pareto chart the identify root causes are prioritized. Finally, future value stream mapping is made and design of experiment is used for improved process and for the purpose of checking the sustainability of the improved process control chart is used.

Formula used:

DPMO=Number of Defects x 1,000,000 ((Number of Defect Opportunities/Unit) x Number of Units) …. (JabeenIffat, 2017)

3.5 Ethical consideration

The respondents were adequately informed that the aim of the study is for academic purpose and Respect for the dignity and privacy of research participants were prioritized. Besides, they were informed that the information or research data they provide in the study is confidential.

3.6 Reseach Design

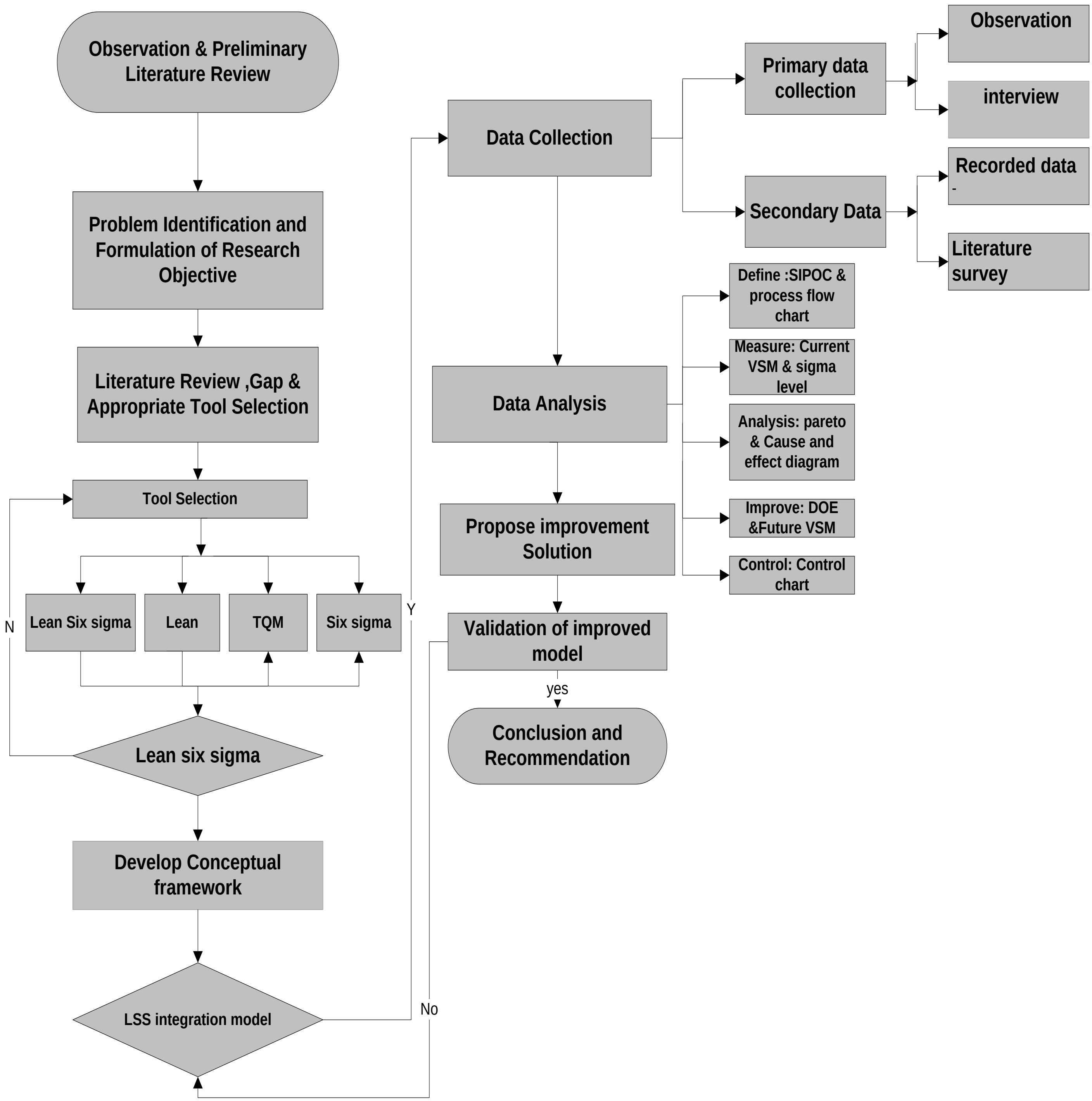


Figure 13 Methodology Framework (Source: Author)

CHAPTER FOUR

QUALITY RELATED PROBLEMS IN ETHIOPIAN TANNERY INDUSTRIES

4.1 Historical Development of Ethiopian Tannery Industries

Ethiopian leather industry has been around for a long time, with its first tannery established in 1918, (Jing Zhao, 2014). Ethiopia has the 8th largest livestock population in the world, and the second largest in Africa (CSA, 2012). Thus, Ethiopia has established its leather industry in the past decades, primarily working in agriculture, exporting raw skins and hides is much easier for the country then developing its manufacturing sector (Jing Zhao, 2014). In 2008, the government levied a 150 percent tax on the export of semi-processed wet blue in order to encourage the development of its leather industry, and capture a larger part of the added value of the sector like a finished leather product, footwear product and Leather garments and goods product (Zakaria, Claire, Anas, Roxane, Narcis and Matthieu, 2016).

The tanning industry in Ethiopia was established with an aim of tanning raw hide and skin to wet blue level though later they advanced to certain levels of finishing operations including the crust and finished leather from hides, sheep skins and goat skins for both export and local markets.

The foundation of current tanning in Ethiopia times back to 1918 and 1927 with the inspiration of the then ASCO, currently Addis Tannery and Darmar/Awash, currently ELICO Tanneries, respectively. Between 1954 and 1976, Dire, Mojo and kombolach tanneries were established (Mohammed Adam, 2019).

Currently, about 30 privately owned tanneries are operating in the country. As a result of privatization, there is no state-owned tannery anymore (Innovision, 2016).

4.2 Quality Related Problems in Ethiopian Tannery Industries

The ones who bear the greatest responsibility in delivering high-quality raw hides and skins to the tanneries are the traders, thus playing a key role in the tanneries' economic viability (Jabbar, Mohammad & Kiruthu, S & Gebremedhin, Berhanu & Ehui, Simeon, 2012).

The traders collect the skins available without paying any particular attention to their quality, and then sell them as bundles to the tanneries, thus managing to exhaust their stock. Low-quality skins are easily sold while there are no incentives for increasing quality upstream. To encourage such incentives, the price signal clearly existing downstream; when selling the finished leather after the tanning process, should be transferred upstream at the input level. This transfer is even more important as analysis highlighted the significance of the quality as a criterion for profit in the tanneries' economic model.

According to **(**Mahmud A., 2016**)** some of the factors that affect the quality of Ethiopian leather industry are; lack of incentive to quality raw material suppliers, quality deterioration and inadequate numbers of slaughterhouses and slabs.

From the study made in different Ethiopian tanneries, on leather quality improvement areas. Most of the problems addressed by the researchers were downgraded and rejected due to deterioration of skin quality, the low performance in Ethiopian tannery industries, and low surface quality and decrease in some key physical properties of the finished leather, (urgesa, 2014; Z. Zemene and M. Addis, 2012; M.albel, 2015; K. Abusabah, Abdalla, M. A. Suliman and Ayoub K. Logmen ,2018).

The researcher tries to review more than thirty literature that are directly related to leather quality. And the proposed solutions for the earlier mentioned problems are summarized in the pie chart below.

Figure 14 Proposed solutions

4.3 The Factors for Incompetence of Ethiopian Tannery Industries

When selling the finished leather, whether directly abroad or to Ethiopian manufacturing plants which then export the finished leather goods, tanneries have to cope with stiff international competition. Indeed, the other market participants (i.e. the other leather or leather goods exporting countries) being in large number and owning large market share determine the selling price for both finished leather or finished leather goods. Since the tannery's profitability is largely based on the share of export or finished leather manufactured into exportable goods in their output, the tanneries' economic model is highly sensitive to the selling price of finished leather.

Due to the availability of abundant indigenous renewable raw material and cheap but easily trainable workforce; potentials of generating employment and earning foreign currency. Ethiopian leather sector has been recognized by the Government as one of its priority sectors. But its low productivity and high unit production cost, two distinctive characteristics have been nullifying its chances of becoming further competitive and thus Ethiopia yet to capitalize its available resources.

Despite the government's initiative to help the Leather Industry, Ethiopian tanneries still have strong difficulties producing finished leather which meets quality standards and that would allow either tannery directly or Ethiopian leather manufacturers to be part of highly competitive international market. Ethiopia has comparative advantages but also faces many obstacles such as the quality issue, low managerial skills, a lack of training, important transportation costs and times, poor infrastructure and a lack of productivity.

Ethiopia is yet to ready to respond to true global competition. Though both external and internal factors are limiting its competitiveness mainly of local firms but low productivity and high cost of production are prime issues at this stage of development. Limited availability of quality workers/managers, use of inappropriate technology or tools, inadequate supply of quality raw hide and skin, weak backward industry, poor inter firm cooperation, limited policy support is causing low competitiveness of the sector.

The vertical disintegration of the leather industry in Ethiopia shed light on various factors that prevent Ethiopia from being a competitive actor in the international leather business.

The lack of official entity able and ready to modernize the agricultural organization has a harmful effect on the Ethiopian leather quality. The location of Ethiopia also extremely prevents the country from being a competitor on the international market due to high transport time and costs. Last, the relatively weak institutional situation of the country adds high transaction costs, thus enabling Ethiopia to be a competitor in terms of prices. Ethiopia's future leather industry therefore highly depends on deeper transformations in the country, including modernized agriculture.

The tanning industry in Ethiopia operates, on average, at two-thirds of its full potential. Though various reasons are provided for this under capacity utilization. Among those the poor quality of their semi-processed leather, which resulted in low export demand, also contributed to this low capacity operation.

According to CSA (2012) report, the livestock population of the country has risen time to time and a large labor resource that pulls many foreign companies are the main comparative advantages. The country is endowed with enormous potential for a cheap supply of skin and hide (Mulat Alubel Abtew, 2015).

According to (A. Abtew,2015), Constraints that affects the Ethiopian tannery industries to deal with international compotators are; seasonality in raw hides and skins supply, dependency on costly imported chemicals, a labor-intensive industry, other logistics and trade facilitation issues and the working capital: a major impediment to growth.

4.4 Quality for finished leather

According to (Elnour K. Abusabah, Abdalla M. A. Suliman and Ayoub K. Logmen, 2018) quality control is the regulatory process measuring actual quality performance, comparing it with standards and rectifying the difference.

The quality evaluation of leathers is fundamental to ensuring their properties. Several physical mechanical tests are performed according to the official methods. However, some of the tests are laborious, time consuming and destructive (A.M. Neiva, M. A. C. Jacinto, M. M. de Alencar, S. N. Esteves and E. R. Pereira-Filho, 2016).

Logmen, Abusabah and. Suliman, (2015) note that animal breed; type; sex, age; nutrition and climate are natural causes affect the quality of finished leather. Poor nutrition causes the skin to produce leather which lacks elasticity and has a dead feel. The skins from male goats and sheep will be heavy with a coarse grain but female skins have better tensile strength. The skin of young animal has fine, compact and tight grain structure. As animals grow older, the grain surface becomes tougher and coarser. The leather originating from Animals raised in warmer climates has superior substance and smoother grain patterns. Leather from Animals rose in colder climates or at higher altitudes will be of poor substance and have a coarse grain.

M. Salehi, I. Kadim, O. Mahgoub, Sh. Negahdari and R. S. Eshraghi Naeeni, (2014) study indicate that the effects of age and sex of goat on the quality of the skins and leather were more important than the type of goat.

The best quality skins have dense uniform structure and usually have surface areas that are small in proportion to their weight (Logmen, Abusabah and. Suliman. (2015).

Onem, E. (2018) mention that Leather manufacturing involves operations like soaking (rehydration), dehairing, liming, de-liming, degreasing, pickling, tanning, post tanning and finishing processes, this all processes also have effect on the quality.

Onem, E. (2018) Suggested that Vegetable tanned leather is very much appreciated and demanded due to its versatility. It is the main material of a wide range of artefacts and adapted to very diverse functional needs such as footwear, book bindings, saddles, harness, liquid vessels, cases and caskets coverings or seating furniture

The measured attributes for checking the quality of leather are leather weight, area, thickness, tensile strength, breaking force, moisture content, water resistance and tear resistance; (Salehi, I. Kadim, O. Mahgoub, Sh. Negahdari and R. S. Eshraghi Naeeni, 2014).

Onem, E. (2018) also indicate that final products were subjected to the tests of tear load, stitch tear resistance and tensile strength. Shimadzu AG-IS brand tensile testing device was used for all tests. For the tests, the measurement of the thickness of the samples was performed in accordance with EN ISO 2589, tensile strength with EN ISO 3376, tear load with EN ISO 3377-2 and measurement of stitch tear resistance with EN ISO 23910. Light fastness analyses were performed by using ATLASXENOTEST ALPHA+ test instrument and according to ISO 105-B02 standard test method.

A finished leather with good water resistance capacity is an important property for different purposes like high quality footwear and clothing making. Finished leather with less than 25%-30% water uptake capacity is highly used for footwear industry (V. Jankauskaitė, I. Jiyembetova, J. Sirvaitytė, K. Beleška and V. Urbelis, 2012).

4.5 Background of Abyssinia Tannery Industry

4.5.1 Company Background

Abyssinia Tannery industry is selected for the study because of the following main reasons:

1. Long time experience in finished leather manufacturing business

2. The large export performance (it’s among the five exporter)

Abyssinia Tannery: is established for production of finished leather under Ethio-Leather Industry PLC (ELICO). It is engaged in the production of superior quality suede upper for the export market as well as

Sheep Napa Upper for the local market. The factory has a unique nature since it is the only suede producer in Ethiopia. The capacity of the factory is 7,140,000 sq. ft finished of Goat and Sheep skins leather.

4.5.2 Vision of the Company

The vision of Abyssinia Tannery is to become world class and branded quality name, by producing quality finished leather and leather products for domestic and export markets. But because of the low grade and quality problem in the company meeting the vision was one of the issues and the research objective help the company to achieve its vision.

4.5.3 Types of Product and Market

Due to the nature of the production operations, the company is categorized under manufacturing industries. Currently the factory produces and distributes a high range of finished leather products like; Goat crust, finished gloving leather, finished Goat Suede Upper, Sheep Napa Upper, and full grain lether etc.The market need this products at agood quality or products that fullfile the quality specification that is accpetable to the buyers but the company had difficulties to fullfill the market need.

Since the company is the largest and most diversified leather industry in the country, its local and mainly the export markets are also highly diversified. The local buyers are shoes manufacturers and the company's garment industries. The export markets are: North America (the buyers are China and Indonesia based American companies), Europe (Italy, UK, and Germany), Japan (Indonesia and Sirlanka based companies) and South Korea.

4.5.4 Organizational Structure

The company have 168 permanent employees working in different division and from those 20 are under administration & human resource division, 5 are under finance & accounting division,110 are in production division, 8 in sales, purchasing & property administration, 18 in technique, 3 in quality assurance and control service and 4 are environmental protection service. The quality control process is conducted by mainly by the three-quality assurance and control staffs and also the production divisions make their own quality check. The quality assurance and control staffs are only three even though the quality problem is significant in the company.

4.5.5 Quality Policy

The quality control strategy carried out in Abyssinia Tannery is Quality Assurance & Control. These include:

- Incoming Inspection
- In-process Inspection
- Final Inspection
- Water & Chemical Analysis
- Calibration Works

➢ **Incoming Inspection**

The key activities undertaken by the quality department is Raw Goat Skin Reselection and associated defect analysis. Besides, Chemical analysis is performed on a regular basis in the Quality Assurance & Control Service. For the raw goat skin 100% inspection has been made on the purchased raw goat skin, to ensuring the quality of the materials meets the standards set. And also, the incoming chemical is inspected for conformity against standard specification.

➢ **In-process Inspection**

The Quality Assurance as part of discharging responsibilities vest to it has carried out an in-process quality control works. In line with this, in process inspection has been performed at different stages of goat production processes.

➢ **Final Inspection**

Before the finished leather hand to the customer, sample is taken and inspected to see whether the produces meet standard or specification. As well, most customers carried out 100% inspection or selection by their own staff and either they approve or reject their order.

Most of the assessment are subjective measurements like Stretch, Softness, Nap (Short & Dense), Feel Handle, Shape (Squareness), Color Fastness (Crocking), Vein, Color Conformation to sample, Spinal line, Thickness, Size, Trimming, Selection/ Grading, % elongation.

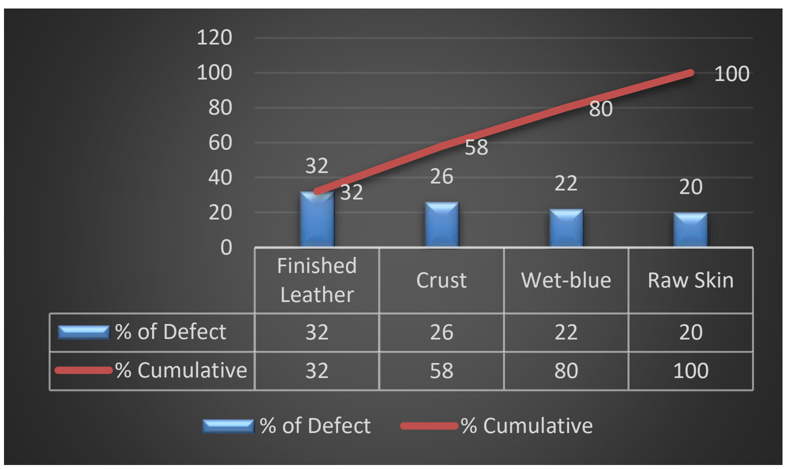
CHAPTER FIVE

DATA COLLECTION AND ANALYSIS

5.1 Introduction

The aim of this work is to propose improvement model for minimizing the defect level in Abyssinia tannery industry. From the companies first quarter of 2018/19 export and local sales performance report, the variance between the planed and actual sale in birr is 50.3% lower. And the significant causes of variance is unable to meet the set quality specification or non-conformity (Appendix-B). In addition, the quality grade classification report shows that the final product that meet I and II grade or the product with low defect level is 0%, III grade account 29.87% and IV to VI grade hold 70.13%. This all show there is a quality problem in the company.

Pareto chart is used to find in which stage of the process that major defect observed (Appendix-D). From the process flow quality check is performed mainly at raw skin receiving, wet blue, crust and finishing stages and from the company recorded data defect is highly observed at the finishing stage.



	Finished Leather	Crust	Wet-blue	Raw Skin
% of Defect	32	26	22	20
% Cumulative	32	58	80	100

Figure 15 Percentage of Defect at different stages in tannery

The analysis follows the DMAIC methodology of Lean Six Sigma and highlight how each step of our project proceeded.

5.2 Define Process

Define is the first phase of the DMAIC methodology of Lean Six Sigma. The purpose of this phase is to define; the problem, the goal of the project and the process that needs to be improved. Flowchart and SIPOC diagram were used for defining the process and spotting the improvement areas. The presence of defect in the product or process variation caused by quality problem is identified as the main cause for the inefficiency of the process.

5.2.1 SIPOC Diagram

In Abyssinia tannery the raw skin is collected from butcheries, municipal abattoirs, middlemen and local skin collectors and pass several steps to get the finished leather. Supplier, input, process, output, and customer (SIPOC) refers to the technique of analyzing a process relative to these parameters to fully understand their impacts. Based on the interview result a SIPOC diagram for the finished leather treatment process is given in Table 5.

Table 5 SIPOC diagram for the finished leather production process

<table>
<tr><th>SUPPLIER</th><th>INPUT</th><th>PROCESS</th><th>OUTPUT</th><th>CUSTOMER</th></tr>
<tr><td>Raw skin supplier</td><td>Raw skin</td><td>Tanning</td><td>Finished Goat Suede Upper</td><td>Local and foreign shoe factories</td></tr>
<tr><td>Chemical supplier</td><td>Chemical</td><td>Re- tanning</td><td>Milled Goat Upper</td><td>Garment industries</td></tr>
<tr><td rowspan="4">Salt supplier</td><td rowspan="4">Salt</td><td rowspan="2">Finishing</td><td>Kamush</td><td>ELICO-Shoe Factory</td></tr>
<tr><td>Finished Goat Lining</td><td rowspan="3">ELICO - Universal</td></tr>
<tr><td>Quality check</td><td rowspan="2">Finished Goat Suede Glove etc.</td></tr>
<tr><td>Packing &shipping</td></tr>
<tr><td colspan="2">Start Boundary:
Raw Materials from Suppliers</td><td>→</td><td colspan="2">End Boundary:
Final Product to End User</td></tr>
</table>

Table 5: shows different suppliers may provide different raw material one may be a raw material with high quality and the other might be poor raw material and this may result high effect on the final product For this purpose the SIPOC will help us in differentiating the variability place whether it comes from supplier, input,

process, output or customer and also it will be very easy for taking corrective action. In this case the variability is arise from the process.

5.2.2. Process Flow

To have a full understanding of the different processes in the finished leather production process and their relationships, the process map as one of the tools of LSS was used. The process map highlights where the waste and defect generate from the process. The finished leather treatment process can be basically divided into three major phases**:** Tanning, Re-tanning and Finishing. From the observation conducted in the company the production process is composed of mainly the following step.

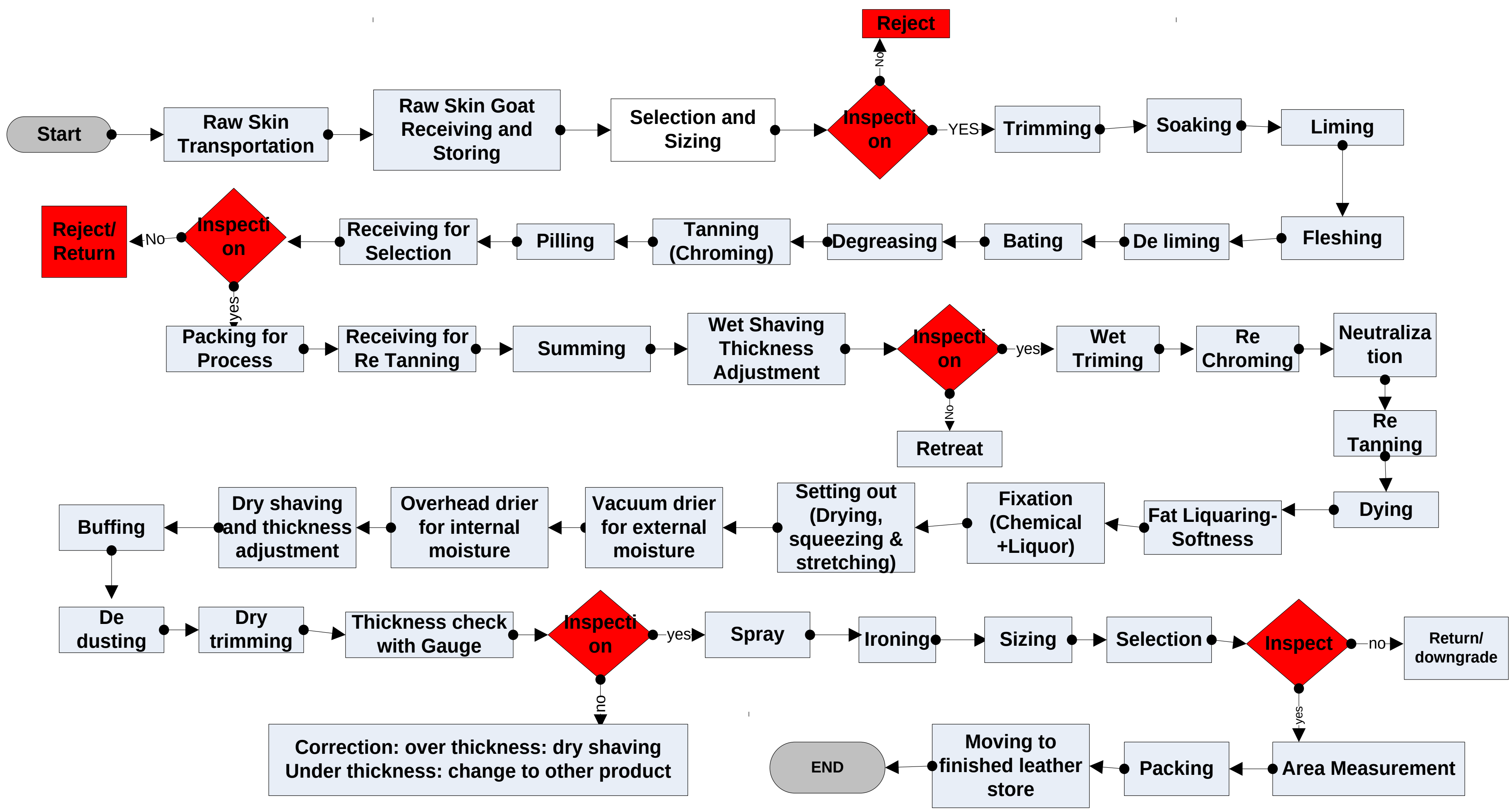


Figure 16 Process flow map (Source: Abyssinia Tannery Process Layout)

From the company recorded data the high percent of defect that is 32% is observed at finished leather stage and some of the defect occur in this stage are namely: Grade Deviation, Size Deviation, Looseness, Open Up/Nap/, Dryness, Non-Uniform color, Folding, Thickness, Roughness, Shape, White Spot, Buffing Shatter mark, Spinal Line, Improper toggling, Penetration, Excess flesh, Vein and Fat spue (Appendix-E).

5.3 Measure

At this stage, percentage of defects, existing Defect per Million Opportunity (DPMO) and Sigma Level of the selected product were calculated for the purpose of understanding the existing system situation. And the current state (baseline) of the process is established using lean tool Value Stream Mapping (VSM). Data regarding defects on finishing stage are collected along with their frequency of occurrence to find critical defects using Pareto chart.

As a part of the measure phase of the Lean Six Sigma methodology, to measure the size and nature of the existing problems data was collected. The records of the defect data in the previous six months from October, 2018 to March, 2019 at finishing stage were collected as given in Table 6.

Table 6 Number of Non-conformities

Month	Production Unit	Number of Defects
October,2018	77,672.00	38,489
November,2018	100,341.00	43,156
December,2018	81,411.00	39,459
January,2019	88,926.00	46,120
February,2019	80,441.00	41,978
March,2019	79,258.00	46,946
Total	427,608	256,148

Table 6, shows the non-conformity rate for recent six-month period and for the month October the non-conformity rate is 49.55%, November 43%, December 48.5%, January 51.9%, February 52.18% and March 59.23%. The trend of the non-conformity is increasing starting from December.

5.3.1 Sigma Level Calculation

To estimate the process capability on producing defect free products, one must properly define and quantify the defects per million opportunities (DPMO). The existing sigma level is calculated from the above data as follows.

DPMO=Number of Defects x 1,000,000 ((Number of Defect Opportunities/Unit) x Number of Units) …. (JabeenIffat, 2017)

DPMO=256,148*1,000,000((8*427,608))

DPMO= 74,878

Sigma Level= 2.9

Sigma level also referred to as process sigma is a degree of process capability and the higher the process sigma, the more capable the process is.

[1]5.3.2 Current State Value Stream Analysis

Value stream mapping (VSM) is a vital tool of the lean approach and is used to recognize value-adding activities and those considered non-value adding activities or wasteful of materials and the flow of information and people (A. J. D. Forno, F. A. Forcellini, F. A. Pereira and L. M. Kipper, 2014).

It is used to optimize the process by eliminating wastes associated with it. A current state value stream is used to know complete door to door flow of inventory in the organization and helps to identify and prioritize areas of improvement. Data required for creating the current state value stream analysis is obtained by discussing with employees involved in the process and observation of the processes during different times of the day, on different days of the week. Information regarding cycle time, number of operators, inventory and daily demand are collected systematically through interview and observation.

Current state of valve stream mapping is shown in the Figure 17 and start and end points of the process are defined. Then materials flow, inventory, cycle time, available time, and other data are depicted in the VSM. Lead time in between process is calculated by dividing inventory between the processes by average daily demand. Then, information lines are drawn and time line is added to the bottom of value stream map. This time line is used to separate value added cycle time and non-value-added time. Finally, all cycle times and inventory times are added up at the end of timeline. From figure 16 value adding activities and non-value

[1]The Measurement is not in metric system because the company uses Sq. Ft measurement system

adding activities are identified from those leather soaking, leather fleshing, unhairing, liming, de liming, bating, degreasing, are included in tanning process and the processes in re tanning process are dry processing, shaving, splitting, dying, stuffing and drying. Polish, iron, embossing, tumbling and spraying are under finishing process of leather treatment process. In the value stream mapping below the main processes are listed and from those the activity that add value to the product and the non-value adding activates are identified from the process flow chart. process flow chart shows that the value adding activities from the process are sizing, trimming, soaking, liming, fleshing, de liming, bating, degreasing, chroming, pilling, summing, wet shaving and thickness adjustment, wet trimming, re chroming, neutralization, re tanning, dying, fat liquoring softness, fixation, setting out, vacuum drier for external moisture, overhead drier for internal moisture, dry shaving and thickness adjustment, buffing, dry trimming, spray, ironing and sizing. And the non-value adding activities identified from the process map are raw material receiving and storing, selection of raw material, receiving for re tanning, inspection, thickness check, area measurement, packing and moving to finished leather store.

Figure 17 shows that total cycle time is 146 hours and total production lead time is 136 days. The non-value adding activities observed from the current VSM are high raw material inventory, waiting between every stage of the process or work in process inventory, unnecessary process are significant.

Cycle time= 20hr+24hr+24hr+18hr+24hr

C/T=146 hr

Lead time=C/T+NVA

L/T=6 day+130day=136 days

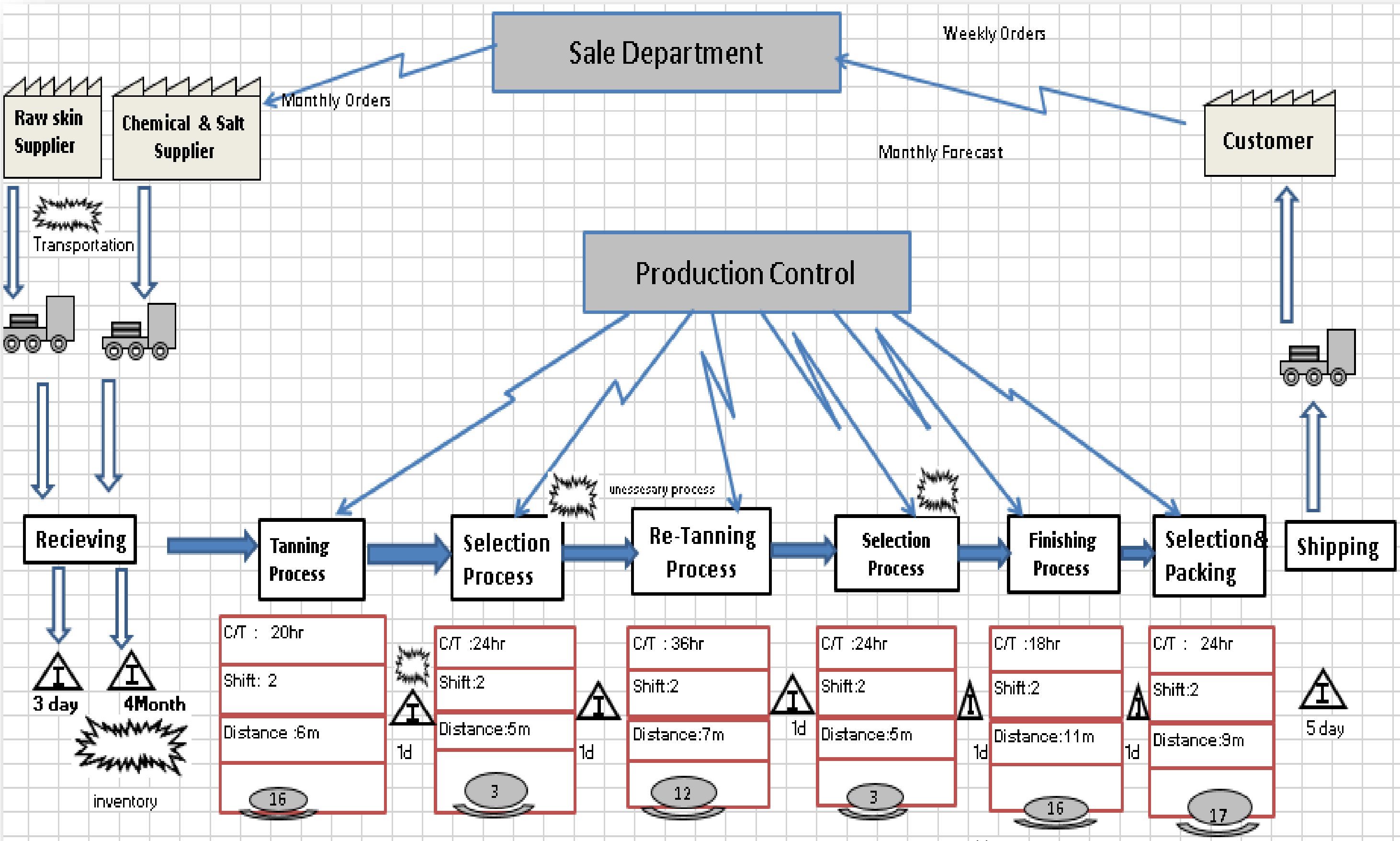


Figure 15 VSM of current state (Source: Author)

5.4 Analyze

The goal of the analyze phase is to go through the data and to find out the root causes of the problems and seek improvement opportunities. At measure phase, the major types of defects were identified and the target of this stage is to find out all the potential causes of those defects. Problems solving lean six sigma tools were used at analysis phase and these were: cause-effect diagram and Pareto diagram. In order to detect the significant causes of the defects and their respective solutions.

Table 7 Type of defect observed at finishing stage (source: company data)

Type of Defect Observed at Finishing Stage	Frequency	% defect	% cumulative defect
Grade Deviation	1986	19.13	19.13
Size variation	1779	17.14	36.27
Looseness	1275	12.28	48.55
Open Up/Nap	1102	10.61	59.16
Dryness	902	8.6	67.84
Non-Uniform color	557	5.37	73.21
Folding	524	5	73.2
Thickness	472	4.55	82.8
Roughness	392	3.78	86.58
Shape	357	3.44	90.02
White Spot	328	3.16	93.18
Buffing Shatter mark	174	1.77	94.9
Spinal Line	122	1.18	96.1
Improper toggling	98	0.94	97
Penetration	86	0.83	97.9
Excess flesh	83	0.8	98.7
Vein	74	0.71	99.4
Fat spue	69	0.66	100
Total Inspected finished leather	10382		

Based on the data presented in Table 7 the significant type of defected observed in finishing stage are prioritized in the Pareto chart below.

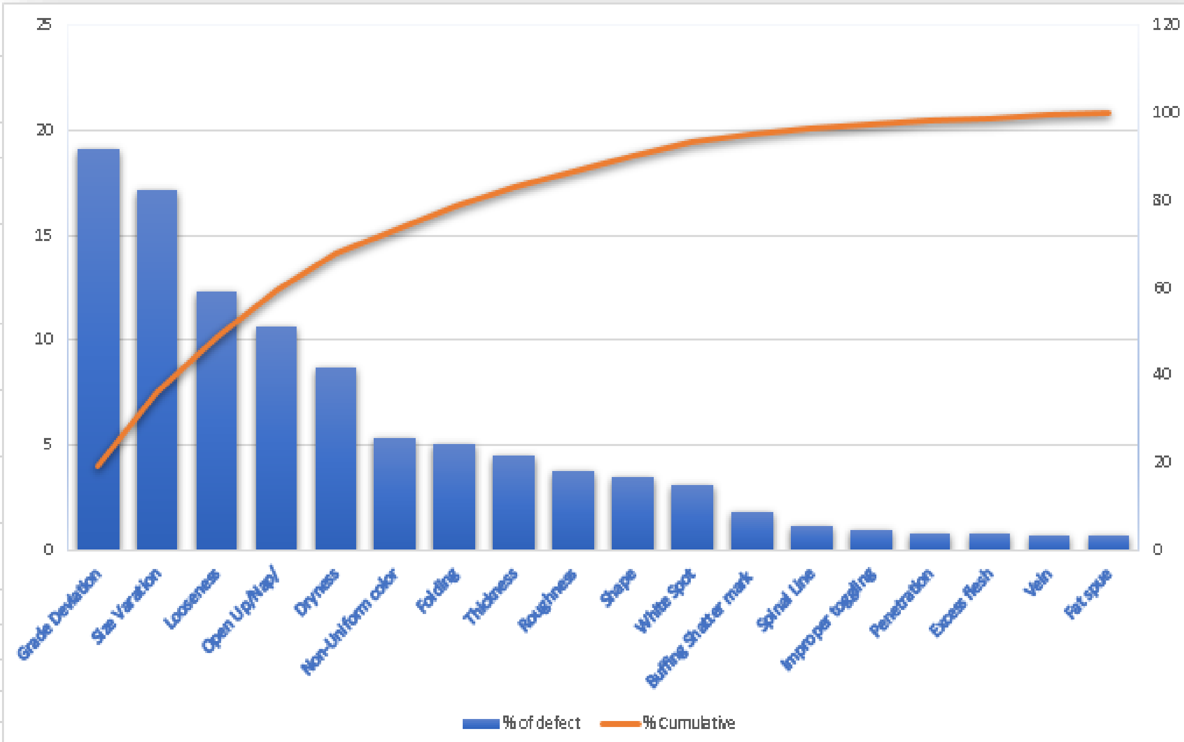


Figure 16 Defect percent observed at finished leather stage

The chart visually shows which defects are more significant on leather product. And from the Pareto Chart major defects were identified. This are i. Grade Variation, ii. Size Variation, iii. Looseness. Among others, the above mentioned three defects are responsible for 48.55% of total defects percentage. Observation from the Pareto Analysis, Grade Deviation is the most frequent occurring defect type with 19.13%. Among other defect types size variation contributes 17.14 % and Looseness is 12.28%. So, these three defect types are responsible for 48.55% of the total defects appear in finished leather stage. In this phase, Cause & Effect diagram is used to analyze root causes for those three major defect types.

5.4.1 Causes for Grade Deviation

The cause and effect diagram below shows the cause and sub-causes for grade deviation on leather product. The following causes are identified by interview of selector or operators in charge of quality check of finished leather.

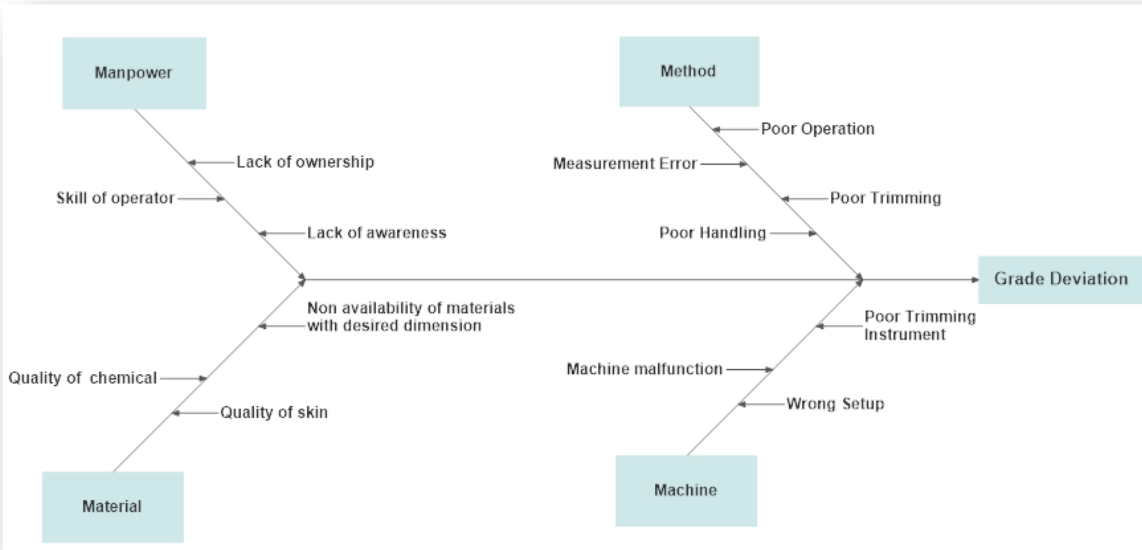


Figure 17 Cause and effect diagram for Grade deviation

Figure 19 shows the cause and effect diagram for Grade Deviation and the potential causes were identified by inspections and root cause analysis of defects. Through observation and data provided by supervisors from production lines through interview the causes for each specific defect types have been identified.

The Pareto Analysis is performed based on defect data from the production section. From this analysis the vital few causes that cause grade deviation was recognized. The analysis is shown in figure 19 represents defect amount and defect percentage and cumulative defect percentage. Then these causes are ordered in a hierarchy according to the frequency of the feedback provided by QC supervisors. Out of all causes the critical root causes were Quality of skin, poor trimming and poor handling. Those defects where coming from the material, method, machine, and manpower.

5.4.2 Causes of Size Variation

The cause and effect diagram below show in detail the cause and sub-causes for size variation on leather product. According to the interview from production line; manpower, method, material and machine errors are responsible for size variation.

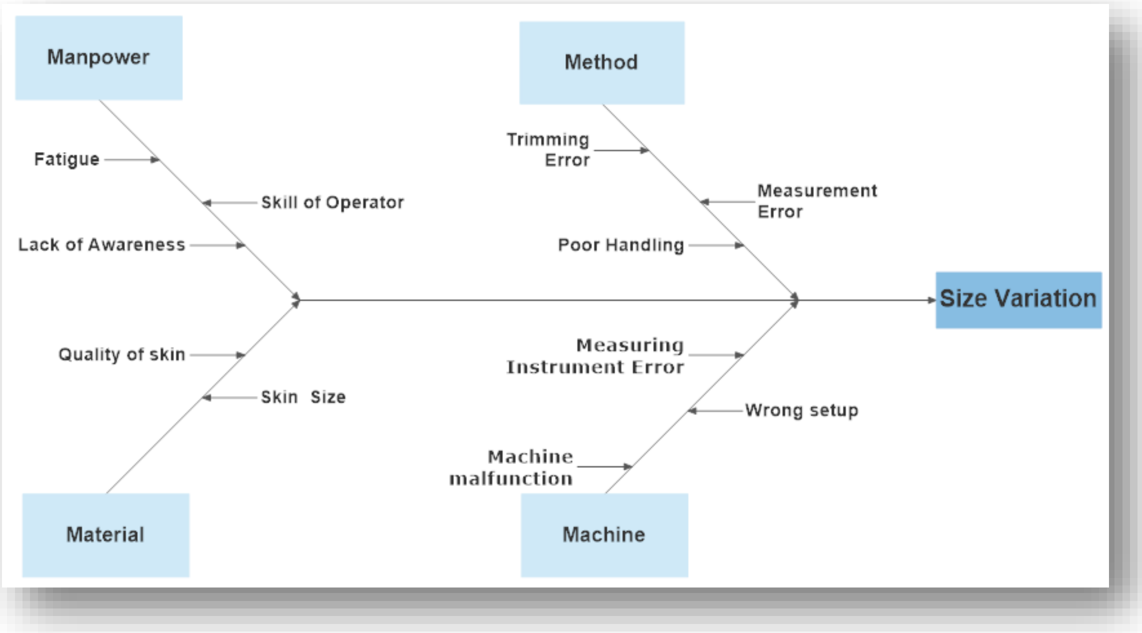


Figure 18 Cause and effect diagram for Size variation

The most frequently occurring machine defects are poor trimming and measuring instrument error, and wrong setup. In case of looseness also material, method of production, manpower and machine has effect. The potential causes that result looseness are skin quality, machine problem, poor handling, wrong setup, chemical mix problem, poor pigmentation and skill of operator etc.

5.5 Improve

The purpose of the DMAIC Improve phase is to discover a solution to the problem that the task aims to address. Future state VSM and design of experiment were used to achieve the improvement and for vital root causes identified through Pareto attain improvement solution.

5.5.1 Grade Deviation, Size Variation and Looseness Improvement Phase

After the root causes were identified in the Analyze stage, the researcher generated solutions along with the help of the production manager and the finishing process workers. The goal was to develop effective improvements by providing such needed improvement plan or actions as listed in the table below.

Table 8 Improvement plan and action for causes of three significant defects (Source: Author)

Areas	Causes	Improvement Plan and Actions
Method	Measurement Error	▪ Measurement error is caused by both measurement taker and instrument error and some of the solution are; use highest precision instrument; multiple check; well-trained measurement taker and measure at good lightning or brightness.
	Poor Trimming	▪ Poor trimming is triggered by trimming instrument and operator fault; use sharp and highest precision instrument and train operator.
Material	Skin Size	▪ For this problem the raw skin purchase should give high attention for size of skin
	Quality of skin	▪ The best solution for skin quality is offer incentive for quality raw skin vendors and company purchasers should give a high consideration to quality.
Manpower	Skill of Operators	▪ Poor skill of operator ruined many operations and leads to occurrence of numerous defects and the company should provide continuous training to its operators
Machine	Measuring Instrument Error	▪ Use advanced instrument like use camera-based area measurement and train the operator who use the instrument help to solve this problem.

From the Table 8 there can be many reasons behind the problems that arise while finishing and knowing the cause of these problems and improvement plan for each particular cause is crucial.

These problems can be minimized by avoiding errors during handing of materials and machines by following the right working methods.

5.5.2 Future State Value Stream Mapping

The non-value adding activities that are identified in current state value stream mapping for improvement are addressed and modified in future VSM. The improved value stream map is shown in Figure 21. Targeted results include reduction in cycle time and lead time, reduction in number of steps and improved quality performance. To achieve the targeted result, for the chemical and salt inventory which is bought from local suppliers, the company hold four month inventory but the company able to hold 15 day inventory since the suppliers can deliver the products in 10 day, the work in process between different stages in the process is one to three days and it is totally non-value adding because of it is caused by waiting since the next process not finished on set time and the finished product inventory also non value adding but it's not possible to avoid that however reduce the number of inventory is important so the 5 to 7 day finished product inventory is reduced to 3 days. Through making the above improvement, the lead time of the total manufacturing process was reduced to 24 days.

Cycle time =146 hr

Lead time =C/T+NVA

L/T=6 day+18 day

L/T=24 day

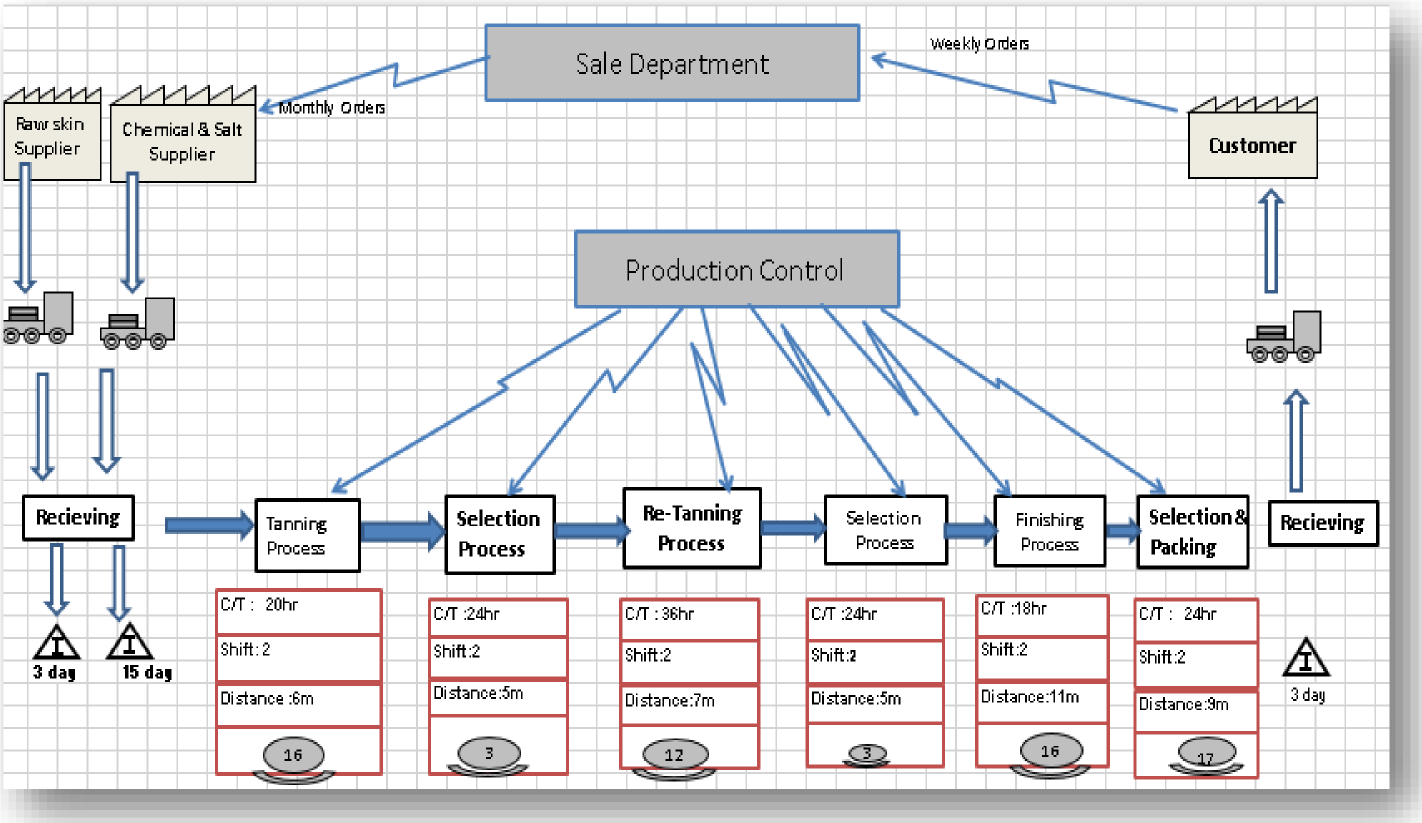


Figure 19 Future state VSM

Comparison of current state VSM and improved future value stream map shown in the table below;

Table 9 Comparison of current versus future VSM (Source: Author)

Variable	Units	Current state	Future state
Lead time	Days	136	24
Cycle time	Hours	146	146
Operators	Numbers	67	67
Distance	Meter	43	33

Table 9 shows a Comparison of the Current state map and the future state map to highlight the improvement in value addition and ultimately throughput**.** The difference between lead time and processing time shows that there are lots of non-value adding activities in the process flow. The data from future VSM indicates that, process lead time reduced from 136 to 24 days.

5.5.3 Design of Experiment

In this research, Taguchi's DOE has been used for the design and modeling of the experiment. It is used to evaluate which process inputs have a significant impact on the process output and to identify optimal tannery process parameters to produce minimum defects. The analysis of factor that influence the quality of finished leather were identified as skin quality factor, PH, Thickness & % of elongation. This helps to determine which variables (Input) are most influential on the response (output) in a study. After identifying the factor, the next task was to fix the level of setting based on the available data and the cost of experimentation. Hence, a two-level setting that is high & low were selected to look their influence in the response variable. Therefore, in order to see their individual & interaction effect of all the four factors, a ½ 2^4=8 experiment i.e. a half factorial experiment was conducted.

The major steps that was followed during DOE experimentation is presented in the following section:

Identified Input Factors

Identified input factors, defining the level or range of operation is the first step DOE experimentation. . The influential factors are selected by brainstorming conducted by quality control staff and production manager. The target range is determined by the company quality engineers. Setting the target has a benefit to fix the experiment point. Hence, the list of level & range is described in Table 10.

Table 10 List of factors, range and level

Parameter No.	The Major Factors or Variables inputs	Range	Level 1	Level 2	Unit
1	Skin Quality	Good-Bad	Good	Bad	no
2	PH	4.2-6.5	4.2	6.5	no
3	Thickness	0.5-1.2	0.5	1.2	mm
4	% Elongation	3.4-5	3.4	5	mm/sec

A. Controllable or Independent Factors: skin quality factor, PH, Thickness & % of elongation

B. Response or Dependent Variables: Defect level

Selection of Design

In this case a two-level half factorial DOE method was selected. The number of combinations or Runs for half factorial design is 8.

Table 11 Evaluation Criteria

No.	Evaluation Criteria	Answer
1	Are the identified variable <6	Yes, they are four in number
2	Are all the variables continuous?	Yes, all of them are continuous & measured in a continuous measurement i.e. for each measurement range
3	Are the process linear?	From the study of all of the four factors effect shows an increment or decrement to the response variable defect level. Therefore, a linear assumption is considered for all the variable.

Design Summary

Taguchi Array L8(2^4)

Factors: 4

Runs: 8

Columns of L8 (2^7) array: 1 2 4 7

Collection of Data Relative to the Identified Outputs

Minitab 18 software was used to find a randomized setting of experiment. Randomization techniques was used for minimizing the effect of uncontrollable factors effect in the process while conducting the experimentation. Since the number of factors are Four, a half factorial experiment was decided to conduct. The test running order is as illustrated in table 12 below.

Table 12 Test order as per the software Randomization method

Std Order	Run Order	Skin Quality	PH	Thickness	% Elongation
6	1	good	4.2	0.5	3.4
7	2	good	4.2	1.2	5
3	3	good	6.5	0.5	5
1	4	good	6.5	1.2	3.4
8	5	bad	4.2	0.5	5
4	6	bad	4.2	1.2	3.4
2	7	bad	6.5	0.5	3.4
5	8	bad	6.5	1.2	5

Analysis of Data and Interpretation

As described in the previous section, the selected setting for finished leather product was governed by the quality target range. Therefore, in this phase based on the given point and experimental order, the experiment for finding the response in finished leather product was determined as per the sequence of experiment as displayed in Table 13.

Table 13 Half factorial experiment and the response

Std Order	Run Order	Skin Quality	PH	Thickness	% Elongation	Trail 1	Trial 2	Trial 3
6	1	Good	4.2	0.5	3.4	11	12.5	9
7	2	Good	4.2	1.2	5	10	8.9	11
3	3	Good	6.5	0.5	5	7.8	9.1	12
1	4	Good	6.5	1.2	3.4	13	12.7	11
8	5	Bad	4.2	0.5	5	14	13.6	12.8
4	6	Bad	4.2	1.2	3.4	14.5	13.2	11.9
2	7	Bad	6.5	0.5	3.4	13.9	14.9	11.6
5	8	Bad	6.5	1.2	5	12	10.9	11.3

Determination of optimal factor levels: The best values of tannery process parameters for the minimum defects are identified from Table 10 and Table 13. The optimal tannery process parameters, within the range of testing values, are chosen as skin quality at level 1 (good), PH at level 2 (6.5), Thickness at level 2 (1.2mm) and % of Elongation at level 2 (5mm/sec).

Minitab factorial regression result & interpretation: defect level versus skin quality, PH, Thickness and % of elongation.

Table 14 Analysis of Variance

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Skin Quality	1	0.037289	0.037289	0.037289	1.96	0.001
PH	1	0.021432	0.021432	0.021432	1.13	0.167
Thickness	1	0.009745	0.009745	0.009745	0.51	0.226
% Elongation	1	0.004637	0.004637	0.004637	0.24	0.255
Residual Error	3	0.057105	0.057105	0.019035		
Total	7	0.130208				

The p value have to be less than α <0.01, for the factor to be significant on the response variable and only skin quality is significant factor in this case.

Significance level α = 0.05

Equal variances were assumed for the analysis.

Table 15 Coded Coefficient

Term	Effect	Coef	T-Value	P-Value	VIF
Constant		11.63	5.17	0.104	
Skin Quality	4.250	2.125	3.79	0.002	8.00
PH	0.2500	0.1250	9.33	0.152	11.00
Thickness	0.2500	0.1250	0.54	0.517	9.00
% Elongation	-0.7500	-0.3750	1.49	0.309	5.00
Skin Quality*PH	0.2500	0.1250	9.33	0.055	10.00
Skin Quality*Thickness	1.2500	0.6250	9.33	0.055	6.00
Skin Quality*% Elongation	1.2500	0.6250	9.33	0.055	7.00

When the VIF is in the range of 4-11 it shows the factors have a good correlation with the response variable and the above result shows the VIF value is in acceptable range.

Regression Equation in Un-coded Units

Defect Level = 12.60 - 3.362 Skin Quality + 0.1250 PH + 0.3571 Thickness - 0.4688 % Elongation + 0.1250 Skin Quality*PH + 1.786 Skin Quality*Thickness + 0.7812 Skin Quality*% Elongation

Analysis of variance (ANOVA) is used to identify factors that are statistically affect response. Hence, from the analysis of variance result in Table 5.11, at significant level of 0.05 (i.e. $\alpha = 0\ .05$) or at the 95 percent confidence level. In this study, the significant independent & interacting factors was determined by comparing the value of P with alpha value. Beside this, the pareto chart as in Figure 22 also shows, factor A is the significant factor since these factors is fall above the red line value called the standardized effect value. In this case, if the value of $p<0.05$, then the factors are significant, otherwise they are categorized as less significant factors. Therefore, A is the significant factors skin quality is significant for the response variable (defect level).

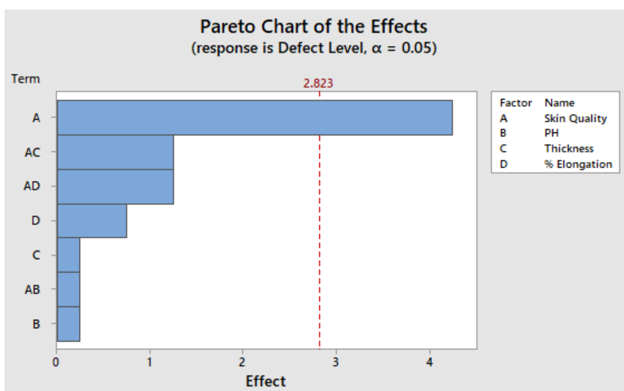


Figure 20 Pareto chart of the Standardize effect plot

From the result, skin quality is statistically significant at the significance level of 0.05. Hence, the change in these variables are associated with changes in the defect level /response variable.

Key Results: S, R-sq., R-sq. (adj), R-sq. (pred)

The model from the above result shows 86.72% R^2 value. In this data, the R^2 value shows the model provides a good fit to the data.

Model Summary

S	R-sq.	R-sq.(adj)	R-sq.(pred)
0.819407	86.72%	85.46%	82.66%

Check the validity of ANOVA assumption

In Figure 23 a Residual plot was used to check the validity of ANOVA assumption. In this plot, there is a normal probability versus fits. The major assumptions are that all the error terms are identically and independently normally distributed with mean 0 and common variance sigma square.

Interpretation of Figure 23:

1. In Figure 23 top left graph, most of the points are found around the line which indicate that the error terms are normally distributed. Hence, the assumption of normality is valid.
2. In Figure 23 top right graph, the error terms versus the fitted values shows that half of the data are above & half of the data are below from the zero line which indicate that the assumption for the error terms mean zero is valid.
3. The bottom left Frequency versus residual bar graph in Figure 23, also re –assure that the validity of the normality assumptions.
4. In the bottom right graph since the order of the data is a time series & important, the cyclic pattern of the graph indicate that the error terms are not dependent on the time variable.

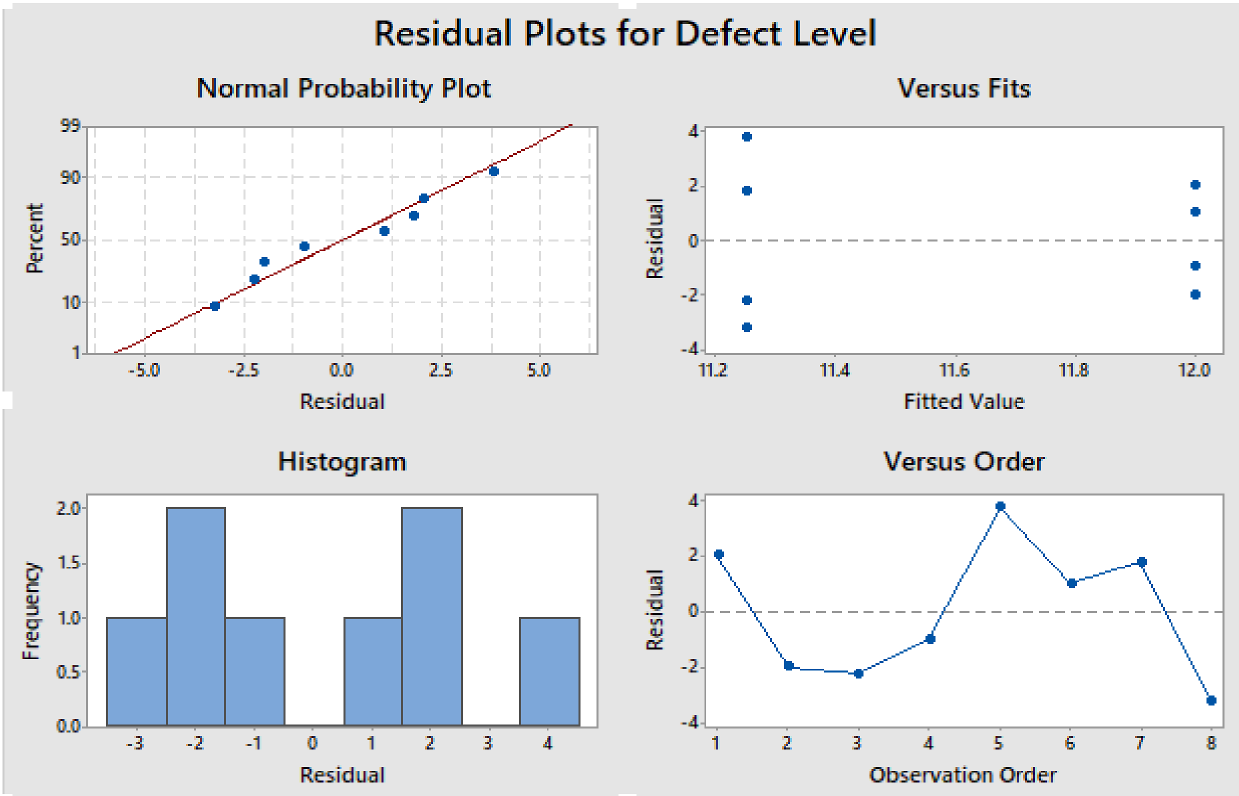


Figure 21 Residual plots for defect level

5.6 Control Phase

The aim of control phase is to sustain the improvements achieved in the improvement phase and gain a sustainable improvement in system. For this purpose, the process requires a measurement system so that it is possible to see the process continue to be both capable and stable. The program used control charts to monitor and control the process metrics.

5.6.1. Control Chart

Attribute control chart p-chart were used for non-conforming or defective products and a sample taken at different time in six-month period has been taken periodically from the production process, and the proportion of defective items in the sample were determined to see the proportion falls within the control limits on the chart.

Table 16 Six-month defect data (Sources: company data)

Days	Checked pcs	Ok pcs	Defective pcs	% Defective
1	275269	260256	11366	4%
2	9016	84775	380	4.2%
3	14976	14050	643	4.3%
4	13376	12524	618	4.6%
5	7107	6620	318	4.5%
6	9913	9253	466	4.7%
7	591	5484	229	38.7%
8	7004	6550	371	5.3%
9	10183	9569	471	4.6%
10	12342	11680	505	4%
11	11087	10380	583	5.3%
12	14307	13674	505	3.5%
13	12329	11745	428	3.5%
14	5215	4939	198	3.8%
15	11088	10419	521	4.7%
16	7297	6699	450	6.2%
17	12281	11673	456	3.7%
18	6869	6543	248	3.6%
19	5782	5529	205	3.5%
20	2550	2450	87	3.4%
21	380	351	24	6.3%
22	12406	11854	459	3.7%
23	11727	11055	523	4.4%
24	13144	12491	515	3.9%
25	14863	14262	452	3%
26	9161	8698	339	3.7%
27	1691	1581	41	2.4%
28	11236	10529	568	5%

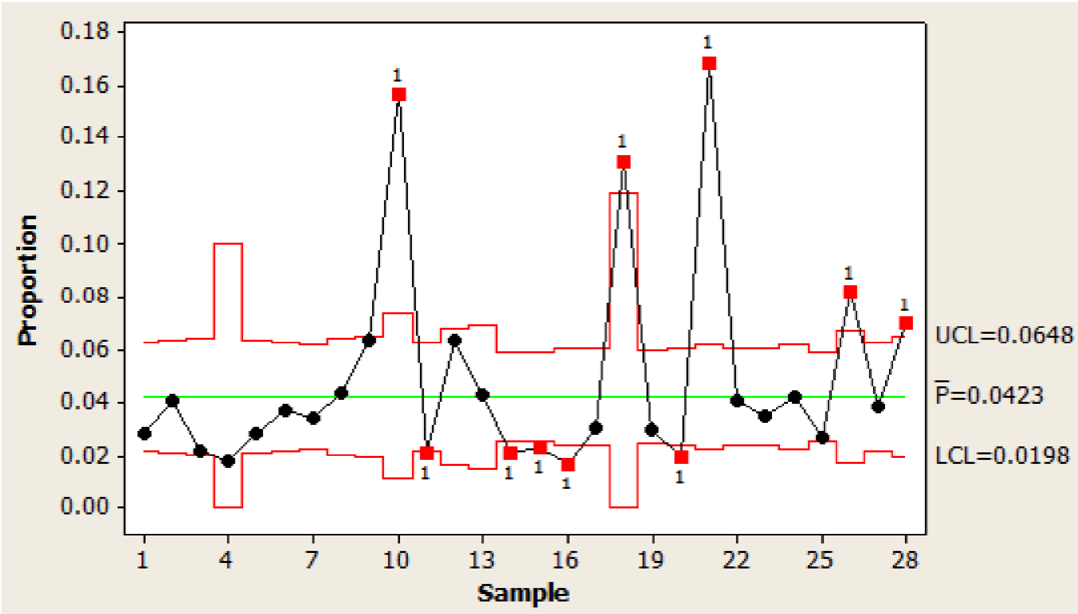


Figure 24 P chart of no. of defective items

From the Figure 25, the processes were out of the upper and lower limit, the process is out of control and the cause has been detected and there was assignable cause of variation that affects the process. process were above the upper control limit during sample taken day 10, 18,20,26,28 the these shows that something was wrong and from the inspection results of the company shows that in day 10 occurrence of non-uniform color, in day 18 PH is out of specification due to usage of new chemical, in day 20 thickness was out of tolerance, in day 26 poor handling problem cause high moisture content and in day 28 there were a deformed problem. Already the nature of the assignable cause of variation has been identified and after counter measures should be taken for making the process stable.

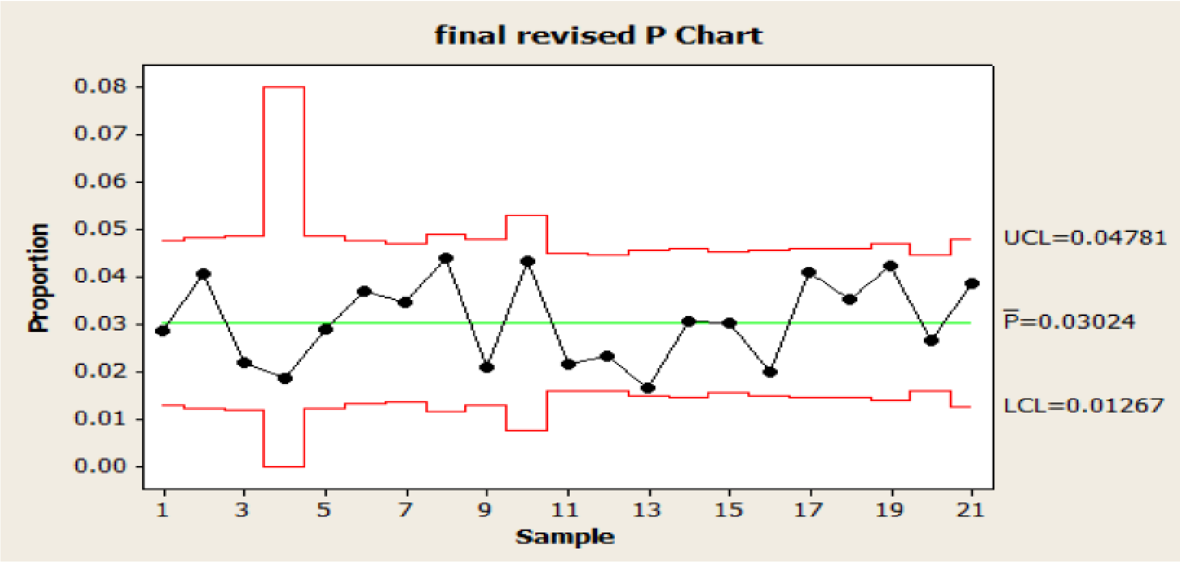


Figure 25 Final revised P-chart

From Figure 26 assuming that actions were taken so that the processes remain in control after the improvement plans have been implemented, out of control state has been quickly detected & associated special causes were determined so that actions can be taken to correct the problem before non-conformities are produced. Now the process is in control and the company needs to sustain the stable process and also control plans should be prepared for specifying process monitoring and corrective actions. To summarize in define phase the problem were identified, in measure phase the current performance were measured, in analyze phase the root cause of the problem were analyzed, in improve phase to eliminate the root causes the process were improved finally in control phase the process to sustain the gains controlling the process due to this reason the methodology so effective.

5.7 Summery of Research Finding and Discussion

In this part the results of findings have been explained and discussed based on the analysis done on the data collected. The results of the study are discussed by triangulating the different sources results i.e. observation, interview and document review results.

- From the document review result, the variance between the planed and actual sale in birr is 50.3% lower. And from the significant causes of variance unable to meet the set quality specification or non-conformity account 58% and the sum of other factors account 42%. In addition, the quality grade classification report shows that the final product that meet I and II quality grade or the product with low defect level is 0%, III grade account 29.87% and IV to VI grade hold 70.13%. This all show there is a significant quality problem in the company.

- Prior to analyzing the system the process is defined to have a better understanding about the system SIPOC diagram and process flow chart is used. The SIPOC diagram used in differentiating the variability place whether it comes from supplier, input, process, output or customer and also very easy for taking corrective action. In this case the variability is arise from the process. And the process map highlights where the waste and defect generate from the process. The finished leather treatment process can be basically divided into three major phases**:** Tanning, Re-tanning and Finishing. Main processes are identified through observation of the production area and from the company recorded data the high percent of defect that is 32% is observed at finished leather stage.
- Then from the data collected from the finishing stage and the existing system is measured using process capability on producing defect free products or sigma level and current VSM. The DPMO is 74,878 and Sigma Level result is 2.9 and after observation of the system current VSM was drawn and it shows that non-value adding activities like high raw material inventory, waiting between every stage of the process or work in process inventory and unnecessary process or over processing are significant in the process.
- The significant type of defects observed in finishing stage are identified and based on the frequency of occurrence prioritized with Pareto chart to find the significant defect occur this stage. And from the Pareto Chart major defects were identified. This are i. Grade Variation, ii. Size Variation, iii. Looseness. Among others, the above mentioned three defects are responsible for 48.55% of total defects percentage. The root causes and sub root causes are identified by cause and effect diagram and the root causes are prioritized by pareto chart over again to get the significant cause of those defects.
- Improvement action were taken for the above defect and their root causes and the non-value adding activities observed in the current VSM. In the future VSM remedial deed are

taken for the identified wastes in the current VSM and The data from future VSM indicates that, process lead time reduced from 136 to 22 days and cycle time also decreased from 146 hr to 98 hrs.

- Design of experiment were used to analyze factors that influence the quality of finished leather i.e. skin quality factor, PH, Thickness & % of elongation. And from those factor the significant factor is identified i.e. skin quality and the optimal factor levels or best values of tannery process parameters for the minimum defects are identified. The optimal tannery process parameters, within the range of testing values, are chosen as skin quality at level 1 (good), PH at level 2 (6.5), Thickness at level 2 (1.2mm) and % of Elongation at level 2 (5mm/sec).
- Finally, to sustain the improvements achieved in the improvement phase and gain a sustainable improvement in system the program used control charts to monitor and control the process metrics.

The capability of lean six sigma improvement approach for defect reduction is checked and it have a good indication for improvement in this lesser time and simple tests eventhogh, the improvement needs time to give practical improvement in the system. Therefore, model development is necessary for the implementation LSS to the company.

CHAPTER SIX

PROPOSED IMPROVEMENT MODEL AND VALIDATION

6.1 Introduction

Customer demand for high quality product at low cost push the manufacturers to reduce their production cost without compromising quality in order to continue in business field. Defect minimization is the first condition of reducing manufacture cost and improving the quality. It will also decrease the cycle time by reducing reworks and finally result higher quality. To minimize the defect there are lots of approaches but integrated models are more preferable because one answer the other questions.

6.2 Model Implementation Procedure

To develop a model, it must satisfy some criteria's according to the literature and the case company problems. And the developed model be easily understandable, addressing the main problems of the company, have continuity for the continuous quality improvement of the production, easily apply for all workers on the company and it must involve all the workers from the top level up to the low-level workers. The model constructed mainly based on six sigma concepts but on each step the lean concepts are added to bring the desired objective of the model to be developed.

1. Preparation: giving awareness to top management up to low level workers, team creation, and providing training.

2. Select: consist selection of work (process), describe function and goal and identify factors.

3. Record: record information about the process and map the flow.

4. **Examine**: measure, find the cause using lean and six sigma concepts and prioritize.

5. **Develop**: develop method under prevailing circumstances that is develop the lean and six sigma integration procedures to identify the intervention option improvement.

6. **Install**: implement improved solution by using the necessary resource.

7. **Maintain**: check whether the developed model is working or not or validation test.

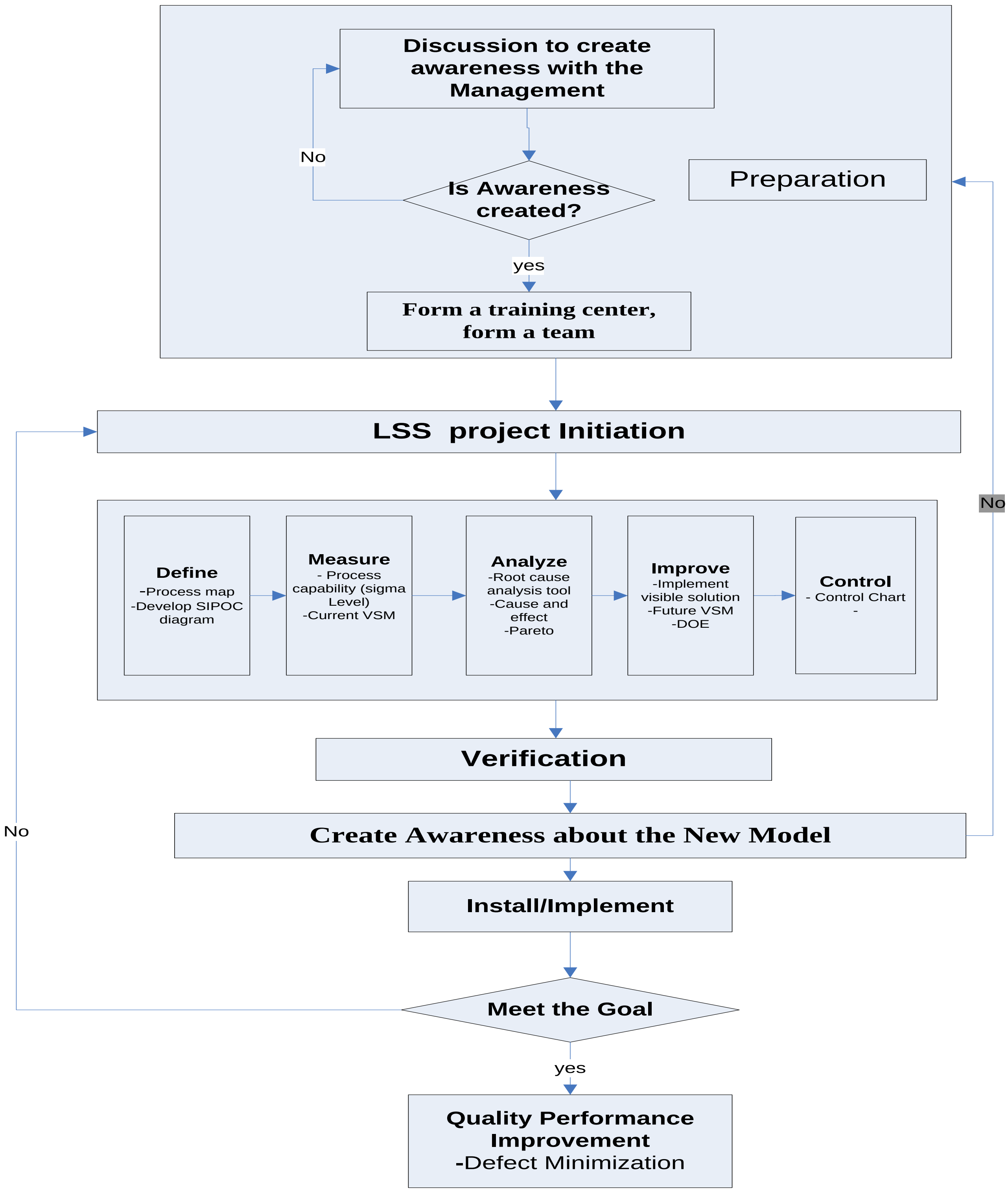


Figure 26 Proposed integrated Model

6.3 Detail of the Proposed Model

6.3.1 Preparation

A. Awareness Creation for Managements

Decision a company took without top management is a waste of time and effort. If the senior management will not take the time to understand, then no one is going to do. Only the top management of the factory can show how important the change is, make people believe in the change and positively influence the factory culture. First discuss with the top managers about the issues and giving awareness about the new integrated ideas (lean and six sigma) and its benefits up to they are recognized.

B. Create a Training Center

Create a center to start a continuous and scheduled training specifically the production line employees. According to a systematic literature review done by (Albliwi and Antony, 2013), training is the most crucial factor to the successful implementation of Lean Six Sigma.

C. Form a Team

Giving awareness about the team work benefits then form a team on the departments. The team is responsible to the management and performs different activities such as establishing sub teams, planning schedules for regular meeting, conducting training to employee regularly, controlling activities, prepare awards for those who show greater achievement.

D. Give Training for the Employees

Give a continuous training start from the managing staff, to share ideas and to improve the staff communications between management and other employees. Train the work process in detail and how to improve quality by decreases defects, deeply about the new model.

6.3.2 Select (Define)

This step of the model includes the following activities: 1-select the process, 2- describe major functions of the process, 3- identify major factors and their specific problem.4-Define in which area did most wastes and defects occur

6.3.3. Record

Attain the facts about the factors affecting the process and record them. In order to improve process or an activity or procedure the fact information is collected from the place where the study is being executed by direct visual observation (Gelan, 2009). This can be done by:

i. Recording defect occur throughout the process.

ii. Recording the waste generated in the process.

iii. Recording the path of movement to improve process.

vii. Recording complains about product quality condition

There are many lean and six sigma tools available which may be used for proper recording and presentation for further analysis as described in the literature. The choice of technique depends on the type of information which is to be recorded. This is a significant step since the improvement in existing process or development of new method be subjected to on how exactly the facts about the existing method have been recorded.

6.3.4 Examine

At this stage critical examination of the process done based on the measurement of sigma level for analysis and improvement. Then effort will be made to find the root cause using different tools such as fishbone diagram and other. Then the causes prioritize by using improvement matrix or Pareto chart based on predefined criteria.

DPMO=Number of Defects x 1,000,000 ((Number of Defect Opportunities/Unit) x Number of Units) ……………………………………………………………………………………... (1)

$$Defect = \frac{total\ number\ of\ Defect}{total\ number\ of\ inspected}.$$ ……………………………………...………...… (2)

$$WIP = \frac{number\ of\ WIP}{total\ number\ of\ input} * 100$$ ……………………………………………………….…. (3)

6.3.5 Develop

At this stage, improvement option developed (DOE based lean six sigma model) after studying all the alternatives presented in response to the causes identified. This improvement should applicable into the changes that eliminate the problem and even its root-causes. To do that tools and techniques provided applied for the reduction or elimination of all the defect and waste problems.

6.3.6 Install/Implement

To install this integrated model all the employees start from the top management have to have the awareness of the integrated model idea, how to install, what materials needed and the benefit for the improvement of quality and defect reduction.

After this model applicable all the workers start from the top managements up to floor level must be committed for the rules and regulations and be Volunteer for the training, participate for all team works and for all what the new models need.

6.3.7 Maintain

Check the validity of the new applicable model, is it reduce the defect level and waste or non-value adding activities. If it fulfills the goal its good if not turn back to the first procedures record or select based on the problems.

6.4 Advantage of the New Integrated Model

The integrated model is used to define the processes, sub-processes and operations to identify main quality factors and also examine the process. The integrated framework can improve quality by minimizing defect rates and avoiding wastes. For academicians and researchers, the framework can be used as guideline how to develop a method that supports continuous quality improvement by minimizing defective product of manufacturing company.

6.5 Proposed Model Validation

Validation is the task of demonstrating that the model is a reasonable representation of the actual system. The model is constructed based on lean within six sigma concept and for achieving this integration quality management concepts and the significant critical factors for lean six sigma deployment management commitment and customer focus are considered in the model. In addition, design of experiment is used in the improvement purpose. The model is developed for the purpose of minimizing defect in Abyssinia tannery industry based the company problem and literature review. For the purpose of validation of the model expert opinion system was used.

Expert Selection

Experts selected are those who have a good knowledge about subject matter. The viability or validity of the proposed model is checked by comment from experts gathered from different area this are from industry consultancy team leader and Abyssinia tannery quality department head.

During discussion, main raised points include can the model solve the existing problem of defect or relevance of the framework, feasibility of framework, in what area may the framework has to be improved. And the feedback collected from experts are include in the implementation procedure of the model.

As per the discussion, framework is relevant and feasible because it addresses practical problems of the company. However, it requires minor modification. The comment that all the experts equally agree is since the model is a new concept for the company continuous training should be provide for the top level management and then to the low level personals.

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATION

7.1 Conclusion

To increase competitiveness in the market manufacturing, companies must deliver quality products on time and economically. In tannery industry, Finishing is one of the major processes. It plays an important role in maintaining the quality of leather. Minimizing defect is very important for ensuring the quality of products. Abyssinia tannery manufactures its products after getting an order from local customers, sister companies and other international customers. As illuminated earlier, the factory is facing a great challenge to satisfy the requirements of its customers. The main problems observed are the problem of return of products due to defective outputs and inability to meet the set quality specification. The most significant defect is recorded in finishing stage and it accounts 32% of the total defect occurs in different stage of the process. The current value stream mapping result indicates there is high raw material inventor, work in process and unnecessary process problem is visualized and after remedial deed taken the lead time reduced from136 day to 24 days. The design of experiment based Lean and Six Sigma integration model is applied as Lean focuses on improving the flow of information and materials between the process and Six Sigma works to improve the value-adding transformations which occur within the process. The integrated model developed is used to improve quality by minimizing defect rate and to increase both internal and external customer satisfaction.

7.2 Recommendation

From the research finding results the following points are worth important to be recommended for the firm;

- The quality assurance department is needed to prepare a formal inspection sheets that can be provided to production personnel at each stages of production. The department must also give fast and accurate inspection services in each production line and use statistical methods to trap any defect which have occurred in production.
- To document all manufacturing processes data in orderly manner.
- To get skilled and qualified manpower for operating on the new proposed model the necessary training should be given. Otherwise the system could not bring meaningful significance for this factory.
- To improve the management communication system between departments.
- To give priority on reducing defect level, long transportation of raw material, lack of skill manpower, work in process and decreasing down time are potentials for quality improvement.
- It is also recommended that the factory will be beneficiary if implement the newly developed model. Because these is an organized and sustainable quality improvement technique.

Finally, since most Ethiopian tannery industries have similar quality related problems, Abyssinia tannery can be a good model to analyze how products can be produced without defects. Thus, the result of the thesis can be applicable to others as well. So, the researcher strongly advice to apply the recommendations given in this thesis.

7.3 Future Study Area

1. Implementing the model on operational level considering specific process in the factory.

2. The study focus on Abyssinia tannery industry due to time constraint, so that it is necessary to see the impact of the model by implementing in other factories.

3. Identifying additional causes of variability like technology, raw material, human action, and environment which are not considered in the study.

REFERENCE

Ahmed, Mohiuddin & Ahmad, Nafis. (2011). An Application of Pareto Analysis and Cause-and-Effect Diagram (CED) for Minimizing Rejection of Raw Materials in Lamp Production Process. 5.

Albliwi, S., Antony, J. (2013). Implementation of a lean six sigma approach in the manufacturing Sector: a systematic literature review. In Proceedings of the 11th International Conference on Manufacturing Research (2013), Cranfield University, UK, pp. 431-436.

Albliwi, S. A., Antony, J., & Lim, S. A. H. (2015). A systematic review of Lean Six Sigma for the manufacturing industry. Business Process Management Journal, 21(3), 665–691.

Alexandros G. Psychogios & Loukas K. Tsironis (2012): Towards an integrated framework for Lean Six Sigma application: Lessons from the airline industry, Total Quality Management & Business Excellence, 23:3-4, 397-415

Alhuraish, I., Robledo, C., & Kobi, A. (2017). A comparative exploration of lean manufacturing and six sigma in terms of their critical success factors. Journal of Cleaner Production, 164, 325–337.

Antony, J., Snee, R., & Hoerl, R. (2017). Lean Six Sigma: yesterday, today and tomorrow. International Journal of Quality & Reliability Management, 34(7), 1073–1093.

Antony, J., & Banuelas, R. (2002). Key ingredients for the effective implementation of Six Sigma 583 program. Measuring Business Excellence, 6(4), 20–27. 584

Antony, Jiju & Snee, Ron & Hoerl, Roger. (2017). International Journal of Quality & Reliability Management Lean Six Sigma: yesterday, today and tomorrow Article information. International Journal of Quality & Reliability Management. 34. 1073-1093

Antony, Jiju. (2011). Six Sigma vs Lean: some perspectives from leading academics and practitioners. International Journal of Productivity and Performance Management, 60 (2). pp. 185-190.

Armand V. Feigenbaum (1983), Total Quality Control, McGraw-Hill Book Company, New York, p. 7

Arumugam, V., Antony, J., & Linderman, K. (2014). A multilevel framework of six sigma: A systematic review of the literature, possible extensions, and future research. The Quality Management Journal, 21(4), 36–61.

Assefa, M & Tesfaye, Dawit & Taye, Mengistie. (2012). A STUDY ON THE PREVALENCE OF SHEEP AND GOAT SKIN DEFECTS IN BAHIR DAR TANNERY, ETHIOPIA. Science line Publication. 2. 384-387.

Abdaziz, Azrilah & Alzhrani, Khadijah & Alotaibi, Bashayer. (2016). Total Quality Management in Saudi Higher Education. International Journal of Computer Applications,135, 6-12.

Assarlind, M., & Aaboen, L. (2014). Forces affecting one lean six sigma adoption process. International Journal of Lean Six Sigma, 5(3), 324-340

Assarlind, Gremyr, & Bäckman. (2013). Multi-faceted views on a Lean Six Sigma application. International Journal of Quality & Reliability Management. 30. 387-402.

AuthoAlexander Douglas Jackie Douglas Jacqueline Ochiengrs, F. (2015). Article information : About Emerald www.emeraldinsight.com Lean Six Sigma in East Africa : Findings from a Pilot Study.

Azizi, A. (2015). Evaluation Improvement of Production Productivity Performance using Statistical Process Control , Overall Equipment Efficiency , and Autonomous Maintenance. Procedia Manufacturing, 2(February), 186–190.

A.Laureani & J. Antony, 2018.Leadership and Lean Six Sigma: a systematic literature review.Total Quality Management and Business Excellence, 30(4):1-29

Badgujar, Rathi. (2014). Taguchi Method Implementation in Abrasive Waterjet Machining Process Optimization.International Journal of Engineering and Advanced Technology, Vol 3-5

Berhanu, Worku & Negussie, Haileleul & Alemu, Sefinew & Mazengia, Hailu. (2011). Assessment on major factors that cause skin rejection at Modjo export tannery, Ethiopia. Tropical animal health and production. 43. 989-93. 10.1007/s11250-011-9796-2.

Bożek, M., Hamrol, A. (2012). Analysis of efficiency of lean manufacturing and six sigma in a production enterprise. Management and Production Engineering Review, 3(4), 14-25

Bonome, L., Costa, M., Filho, M. G., Fredendall, L. D., José, F., & Paredes, G. (2018). Lean, six sigma and lean six sigma in the food industry: A systematic literature review. Trends in Food Science & Technology.

Bereman, R. Johnson, J. Bollinger, Y. Boss, N. Shulman, B. MacLean, N. Hoofnagle, J. MacCoss.(2014).Implementation of statistical process control for proteomic experiments via LC MS/MS. Journal of the American Society for Mass Spectrometry, 25(4), 581–587.

Chan, Jie, Kamaruddin, & Azid.(2014). Implementing the Lean Six Sigma Framework in a Small Medium Enterprise (SME). Proceedings of the 2014 International Conference on Industrial Engineering and Operations Management Bali, Indonesia, January 7 – 9.

Chakravorty, S.S. and Shah, A.D. (2012), "Lean Six Sigma (LSS): an implementation experience", European Journal of Industrial Engineering, Vol. 6 No. 1, pp. 118-137.

Chiarini and Andrea. (2012). From Total Quality Control to Lean Six Sigma: Evolution of the Most Important Management Systems for the Excellence.

Chiarini, Andrea. (2014).Sustainable manufacturing-greening processes using specific Lean Production tools: An empirical observation from European motorcycle component manufacturers, Journal of Cleaner Production, DOI: 10.1016/j.jclepro.2014.07.080.

Costa, Luana & Filho, Moacir. (2016). Lean healthcare: review, classification and analysis of literature. Production Planning & Control, 1-14.

Crosby, P. B. (1979). Quality is free. New York: McGraw-Hill.

Deepak Kumar, Sumit Kumar Singh, Khemchand Sharma. (2014). Implementation of Lean in Continuous Industry: A Case Study (Steel Industry). Int. Journal of Engineering Research and Applications, Vol. 4, pp.05-12.

Deming, W. E. (1986). Out of the crisis. Cambridge, MA: Center for Advanced Engineering Study, Massachusetts Institute of Technology.

Drohomeretski, E., da Costa, S. E. G., de Lima, E. P., & Garbuio, P. A. da R. (2014). Lean, Six Sigma and Lean Six Sigma: an analysis based on operations strategy. International Journal of Production Research, 52(3), 804–824.

Ericson Oberg, Anna & Astrand, Erik. (2017). Improved productivity by reduced variation in gas metal arc welding (GMAW). The International Journal of Advanced Manufacturing Technology,92(1).

FábioA. Fernandes, Sérgio D. Sousa. (2013). On the Use of Quality Tool. Proceedings of the World Congress on Engineering, Vol I

Forno, Ana & Augusto Pereira, Fernando & Forcellini, Fernando & Kipper, Liane. (2014). Value Stream Mapping: a study about the problems and challenges found in the literature from the past 15 years about application of Lean tools. The International Journal of Advanced Manufacturing Technology. 72.

Fujimoto, Takahiro. (2012). the Evolution of Production Systems. Annals of Business Administrative Science. 11. 25-44. 10.7880/abas.11.25.

Filho, Ganga & Gunasekaran. (2016). Lean manufacturing in Brazilian small and medium enterprises: implementation and effect on performance. International Journal of Production Research, 1-23.

George, M. L. (2002). Lean Six Sigma: Combining Six Sigma Quality with Lean Production Speed. New York: McGraw-Hill

Gershon, M. (2010). Choosing Which Process Improvement Methodology to Implement. Journal of Applied Business & Economics, 10(5), 61–69.

Haider, Aftab & Jahanzaib, Mirza. (2015). An implementation of lean scheduling in job shop environment. Advances in Production Engineering & Management. 10.

Hailu, Tabuchi, Ezawa & Jilcha. (2017). Reduction of Excessive Trimming and Reject Leather by Integration of 7 QC Tools and QC Story Formula: The Case Report of Sheba Leather PLC. Industrial Engineering & Management, vol 6

Hari Supriyanto and Diesta Iva Maftuhah. (2017). a lean six-sigma manufacturing process case study. International Journal of Mechanical Engineering and Technology, Volume 8, Issue 7 pp. 498–509.

Hopp, W. J., & Spearman, M. L. (2004). To Pull or Not to Pull: What Is the Question Manufacturing 693 & Service Operations Management, 6(2), 133–148.

Hoerl and Gardner (2010).Lean Six Sigma, creativity, and innovation. International Journal of Lean Six Sigma, Vol. 1 No. 1, pp. 30-38

Hassan, Marimuthu & Mahinderjit-Singh. 2016. Application of Six-Sigma for Process Improvement in Manufacturing Industries: A Case Study. International Business Management, 10: 676-691.

Indrawati, Sri Ridwansyah, Muhammad. (2015). Manufacturing Continuous Improvement Using Lean Six Sigma: An Iron Ores Industry Case Application. Procedia Manufacturing. 4. 528-534. 10.1016/j.promfg.2015.11.072.

Joseph M. Juran and A. Blanton Godfrey.(1974). Juran’s quality handbook,5th ed.

Jackie Douglas, David Muturi, Alexander Douglas and Jacqueline Ochieng.(2017).The role of organisational climate in readiness for change to Lean Six Sigma.The TQM Journal, Vol. 29 No. 5, pp. 666-676

Jirasukprasert, P. , Garza-Reyes, J. A. , Kumar, V. and Lim, M. K. (2014). A Six Sigma and DMAIC application for the reduction of defects in a rubber gloves manufacturing process.International Journal of Lean Six Sigma, volume 5 (1): 2-21

Khadijah Mohammed, Bashayer Ali Alotibie and Azrilah Abdulaziz, (2016). Total Quality Management in Saudi Higher Education. nternational Journal of Computer Applications (0975 – 8887), Volume 135 –No.4

Koloka O and Moreki J C. (2010). Performance of hides and skins subsector in Botswana: A critical review. Livestock Research for Rural Development,Vol 22.

Kumar, A., Kumar, R. G., Narahari, N. S., & Mithilesh, K. M. (2015). Case study on identification and elimination of waste through lean implementation in an automotive part manufacturing industry. International Journal of Lean Enterprise Research, 1(3), 253

Kumar, P.S. Satsangi and D.R. Prajapati (2013) "Improvement of Sigma level of a foundry: a case study", The TQM Journal, Vol. 25 No. 1, pp. 29-43

K. Logmen, K. Abusabah, E. Suliman, Abdalla M. (2018). Application of Process Quality Control in Leather Industry. Gezira Journal of Engineering and Applied Sciences, vol 9

Kumar, Lalit & Prajapati. (2014). Root Cause Analysis of Defectives of A Manufacturing Industry. National Conference on Advancements and Futuristic Trends in Mechanical Engineering, Volume: 64-70.

Kumar, S. Luthra, S.Haleem, A. Garg, Dixit. (2014). Lean six sigma implementation: An analytic hierarchy process approach. Excel India Publishers, pp.269-278

Lavlesh Kumar Sharma, Ravindra Mohan Saxena and Lokesh Bajpai. (2014). Analyzing the Benefits of Lean Techniques: A Manufacturing Process Industry Case Study. Industrial journal of mechanical engineering and information technology, Vol. 2, pp 205-212

Laureani, Alessandro & Antony, Jiju. (2017). Leadership and Lean Six Sigma: a systematic literature review. Total Quality Management & Business Excellence. 30. 1-29.

Lim Sanny and Ria Amalia. 2015. Quality Improvement Strategy to Defect Reduction with Seven Tools Method: Case in Food Field Company in Indonesia. International Business Management, 9: 445-451.

Logmen, Abusabah and. Suliman. (2015). Sampling Technique and Minimization of Inspection Errors in Leather Sorting. Gezira Journal of Engineering and Applied Sciences, vol (01).

Laureani, A., & Antony, J. (2016). Leadership – a critical success factor for the effective implementation of Lean Six Sigma. Total Quality Management & Business Excellence, 29(5-6),

Madanhire, I., & Mbohwa, C. (2016). Application of Statistical Process Control (SPC) in Manufacturing Industry in a Developing Country. Procedia CIRP, 40, 580–583.

Mahmud, A. (2016). Development potential and constraints of hides and skins marketing in Ethiopia. de la Garza Institute for Goat Research, Langston University, Langston, pp. 127-138

Mondal, P. K., Hasan, F., & Islam, Z. (2017). An Approach to Enhance the Sigma Level in Cable Industry by Using QC Tools and DMAIC Methodology

Mohammed Adem. (2019). Production of hide and skin in Ethiopia; marketing opportunities and constraints. Cogent Food &Agriculture.

Moonsamy & Singh. (2012). A 21st Century framework for quality management. African Journal of Business Management. 6. 11231-11242. 10.5897/AJBM11.2655.

Mirko Soković -Jelena Jovanović -Zdravko Krivokapić -Aleksandar Vujović.(2009).Basic Quality Tools in Continuous Improvement Proces. Journal of Mechanical Engineering 55.

Mulat Alubel Abtew. (2015) Revealed Comparative Advantage of Ethiopian Leather Industry with Selected African Economies. International Journal of Business and Economics Research. Vol. 4, No. 5, pp. 229-237.

MuthuKumaran & S K Venkatachalapathy, V & Pajaniradja, K. (2013). Impact on integration of Lean Manufacturing and Six Sigma in various applications -a review. iosr journal of mechanical and civil engineering, 450, 98-101.

Nakhai & Neves. (2009). The challenges of six sigma in improving service quality. International Journal of Quality &Reliability Management Emerald Group Publishing Limited, Vol 26 No. 7, pp. 663-684

Noor Azam Md Saad, Astuty Amrin and Khairur Rijal Jamaludin. (2017). Application of lean six sigma in an electricity distribution company. Journal of Advanced Research in Business and Management Studies, Volume 8, Issue 2 (2017) 28-32

Pearce, A., & Pons, D. (2013). Implementing lean practices: Managing the transformation risks. Journal of Industrial Engineering, 2013, 19 pages. doi: 10.1155/2013/790291

Psychogios, Alexandros & Atanasovski, Jane & Tsironis, Loukas. (2012). Lean Six Sigma in a service context: A multi-factor application approach in the telecommunications industry. International Journal of Quality & Reliability Management. 29.

Pavol Gejdoš.(2015). Continuous Quality Improvement by Statistical Process Control. Elsevier B.V.,pp 565 – 572

Pyzdek, T., & Keller, P. (2010). The Six Sigma handbook. Search (3 rd). McGraw-Hill.

Pratik J. Patel, Sanjay C. Shaz, Sanjay Makwana. (2014). Application of Quality Control Toolsin Taper Shank Drills Manufacturing Industry. Int. Journal of Engineering Research and Applications, Vol. 4, Issue 2 (Version 1), pp.129-134

Rebecca M. Nunesca and Aile T. Amorado. (2015). Application of Lean Manufacturing Tools in a Garment Industry as a Strategy for Productivity Improvement. Asia Pacific Journal of Multidisciplinary Research, Vol. 3, No. 4.

Raravi, P., Bagodi, V., & Mench, R. G. (2013). Critical Success Factors: Service Industries. SCMS Journal of Indian Management, 10(1).

Salah, S., Rahim, A., & Carretero, J. A. (2010). The integration of Six Sigma and lean management

Salehi Kadim, Isam Mahgoub, Osman Negahdari, Sh. Naeeni, R. (2014). Effects of type, sex and age on goat skin and leather characteristics. Animal Production Science. 54. 638-644.

Sandeep Bodke, Snehal Nikam, Yogita Phad, Sayali Katkade, Kiran Kangane.(2017). Quality Improvement in Building Construction Using Six Sigma. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE, PP 01-05.

Saja Albliwi Jiju Antony Sarina Abdul Halim Lim Ton van der Wiele, (2014),"Critical failure factors of Lean Six Sigma: a systematic literature review", International Journal of Quality & Reliability Management, Vol. 31 Iss 9 pp. 1012 – 1030

Snee, R.D. (2010). Lean Six Sigma – getting better all the time. International Journal of Lean SixSigma, Vol. 1 No. 1, pp. 9-29.

Snee, R. D. (2000). Impact of Six Sigma on quality engineering. Quality Engineering, 12(3), 9–14.

Silva, A.P.S., Palermo, J.M., Gibertoni, A., Ferreira, J.A., Almeida, R.M.A. and Marroig, L. (2012). Inventory quality control in clinical engineering: a Lean Six Sigma approach, Pan American Health Care Exchanges (PAHCE), pp. 35-39

Schroeder, Roger & Linderman, Kevin & Liedtke, Charles & Choo, Adrian. (2008). Six Sigma: Definition and Underlying Theory. Journal of Operations Management - J OPER MANAG, 26, 536-554.

Sokovic M., Jovanovic J.,Krivokapic Z. and Vujovic A.(2009). Basic Quality Tools in Continuous Improvement Process. Journal of Mechanical Engineering,

Sousa, Sergio & Fernandes, Fábio. (2013). On the use of Quality Tools: a case study.

Sundar, R., Balaji, A. N., & Kumar, R. M. S. (2014). A review on lean manufacturing implementation techniques. Procedia Engineering, 97, 1875–1885.

Timans, Werner & Antony, Jiju & Ahaus, Kees & Solingen, Rini. (2012). Implementation of Lean Six Sigma in Small- and Medium-Sized Manufacturing Enterprises in the Netherlands. Journal of the Operational Research Society, 63.

Timans, W., Ahaus, K., van Solingen, R., Kumar, M., & Antony, J. (2014). Implementation of continuous improvement based on Lean Six Sigma in small- and medium-sized enterprises. Total Quality Management & Business Excellence, 1–16.

Thomas Bertels. (2018).integration of lean and six sigma. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE, PP 01-05.

Uddin S.M.and Rahman C.M.L. (2014). Minimization of Defects in the Sewing Section of a Garment Factory through DMAIC Methodology of Six Sigma. Research Journal of Engineering Sciences,Vol. 3(9), 21-26

Urgessa, B.G. (2013). Defect assessment of ethiopian hide and skin: The case of tanneries in addis ababa and Modjo, Ethiopia. 11. 395-398. 10.5829/idosi.gv.2013.11.4.75182.

World Bank Group. (2015). Kenya-Leather-Industry. DFID and the Netherlands

W. C. BENTON () Statistical process control and the Taguchi method: a comparative evaluation, International Journal of Production Research, 29:9, 1761-1770,

Womack, Jones and Roos.(1990). The Machine That Changed the World. Free Press,pp

Varsha M. Magar and Vilas B. Shinde. (2014). Application of 7 Quality Control (7QC) Tools for Continuous Improvement of Manufacturing Processes. International Journal of Engineering Research and General Science, Volume 2, Issue 4.

Vikas Swarnakar S. Vinodh, (2016).Deploying Lean Six Sigma framework in an automotive component manufacturing organization. International Journal of Lean Six Sigma, Vol. 7 Iss 3 pp. 267- 293

V. Raja Sreedharan and R. Raju. (2016).A systematic literature review of Lean Six Sigma in different industries. International Journal of Lean Six Sigma, Vol. 7 No. 4, pp. 430-466

V. Jankauskaitė, I. Jiyembetova, J. Sirvaitytė, K. Beleška and V. Urbelis.(2012). Comparable Evaluation of Leather Waterproofing Behaviour upon Hide Quality.materials science (medžiagotyra), vol. 18, no. 2.

Vinodh, Sekar & Gautham, S.G. & Ramiya R, Anesh. (2011). implementing lean sigma framework in an Indian automotive valves manufacturing organisation: A case study. Production Planning & Control. 22. 708-722. 10.1080/09537287.2010.546980.

Zakaria, Claire, Anas, Roxane, Narcis and Matthieu.(2016).Does Ethiopia have a comparative advantage in the leather industry. Mines ParisTech Working Paper.

Zemene, Zenaw & Addis, Mekonnen. (2012). Assessment of Major Factors That Cause Skin Defects at Bahir Dar Tannery, Ethiopia. Advances in Biological Research, 6, 177-181.

Appendix -A Interview Questions (Semi-Structured Interview)

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF MECHANICAL & INDUSTRIAL ENGINEERING GRADUATE PROGRAM IN INDUSTRIAL ENGINEERING

Dear respondents, this interview is conducted for an academic purposed of the fulfillment of master degree. Therefore, your response is very important for the success of the research study. Hence, you are kindly request to give your response and please be informed that your response kept in confidential. I would like to thank you all for your cooperation.

Thesis Title: LEAN AND SIX SIGMA INTEGRATION TO MINIMIZE DEFECTIVE PRODUCTS IN ETHIOPIA TANNERY INDUSTRIES: A CASE OF ABYSSINIA TANNERY

Prepared by: MAHLET ZEBENAY [TEL- 0913761078, E-mail: mahletzebenay12@gmail.com]

Interview Date: ______________________ Time: ____________________

Name: ____________________ Sex______ Position______________________ Educational Level _________________ Experience ___________

Part I: Company Information:

4-Company name: _______________________________________

5-Year of establishment: _______________________ G.C.

6-Market segment: Local ________________________ Export________________________

Local and Export ________________________

7-Number of total employees: Permanent: ___________________,

Temporary: ___________________

8-Average working days per year: _______________________

9-Average working days per month: _______________________

10-Average working days per week: _______________________

11-Number of working shifts per day: _______________________

12-Number of working hours per shift: _______________________

13. What are the suppliers of raw material, input for the process, main outputs and main local and international customers?

Part II

1. Existing production capacity per day/week/ year? (Production)
2. How do you define, and measure quality in the company? (Quality)
3. What are the major problems responsible for the company poor quality problem? (Quality)
4. What are the major quality improvement activities in your company? (Quality)
5. What activities are being done to make the plant to produce quality product and hence competitive in local and the global market?
6. What do you think should be done to improve quality level in general?
7. How much percent did the production fit the standard?
8. How could control the company defect level?
9. Did the company give continue training for the workers? Especially on the quality section?
10. Is there any waste in production process? If it is yes what are they and causes of waste?
11. What kind of system the Company use for waste minimization?
12. Did the company use the lean tools for waste minimization?
13. Did the company have experience shearing program with other exporter companies?
14. What kind of defect occur in leather product?
15. What are the root cause of each defects?
16. Did the company hold stock and for how long?

APPENDIX-B: 2018/2019 Export & Local Sales Performance Report

Product Type	Quantity/Sq. Ft/				Value /Birr/			
	Plan	Actual	%	Variance	Plan	Actual	%	Variance
A/Export Sals								
Finished Goat Suede Upper	365820.00	155483.00	42.50	(57.50)	14,305,170.00	5,955,070.13	41.63	(58.37)
Export Sales	**365,820.00**	**155,483.00**	**42.50**	**(57.50)**	**14,305,170.00**	**5,955,070.13**	**41.63**	**(58.37)**
B/ Local Sales								
Finished Goat Suede Upper	20,100.00	58,566.00	291.37	191.37	683,400.00	2,133,035.57	312.12	212.12
Finished Goat Milled Upper	60,300.00			(-100.00)	1,193,940.00			(100)
Finished Goat Lining	19,500.00	12,096.75	62.03	(37.97)	193,020.00	113,234.25	58.66	(41.34)
Kamush	32,880.00	15,665.00	47.64	(52.36)	614,856.00	344,535.00	56.04	(43.96)
Local Sales	**132780.00**	**86,327.75**	**65.02**	**(34.98)**	**2,685,216.00**	**2,590,804.82**	**96.48**	**(3.52)**
Total Export & Local Sales	**498,600.00**	**241,810.75**	**48.50**	**(51.50)**	**16,990,386.00**	**8,545,874.95**	**50.30**	**(49.70)**

APPENDIX-C: Quality Grade Selection

ELICO Abyssinia Tannery	PRODUCTION	*ISSUE NO. 3* *REVISION NO. 1*
	Title & No. :- Internal Communication Procedure, ELICO/ICP/553 Form 5-4	Page 5 of 8

Form Title:- Production Performance Report	*Form No.553.5-4*

III. Finished leather Selection Result

		SIZE								
		Ex-Small <3.0	Small 3.0 - 3.5	Medium 3.51-4.5	Large 4.51-5.5	Ex-Large 5.51-6.5	XX-Large >6.5	TOTAL	Actual %	Plan in %
GRADE	I	-	-	-	-	-	-	-	-	-
	II	-	-	-	-	-	-	-	-	-
	III	2	1990	4018	1430	189	32	7661	15.99	-
	I-III	**2**	**1990**	**4018**	**1430**	**189**	**32**	**7661**	**15.99**	**14.00**
	IV	2	3345	5549	2211	334	44	11485	23.98	22.00
	V	-	4555	7579	2785	390	63	15372	32.09	28.00
	VIA	-	3521	4089	1510	316	28	9464	19.76	22.00
	VIB	-	987	1332	460	125	45	2949	6.16	11.00
	VIC	-	406	355	150	48	9	968	2.02	3.00
Total		**4**	**14804**	**22922**	**8546**	**1402**	**221**	**47899**	**100**	**100**
Actual %		**0.01**	**30.91**	**47.85**	**17.84**	**2.93**	**0.46**	**100**		
Plan in %		**0.25**	**16.67**	**43.15**	**25.52**	**10.62**	**3.79**	**100**		

APPENDIX-D: Percent of Defect at different stage of the Process

Selection

ISSUE NO. - 4
REVISION NO.- 1
Page 1 of 12

Title & No. :- Internal Communication Procedure, ELICO/ICP/553
Form 5-6

Form Title:- Production Performance Report Form No.:-553-3.6

A) Selection Result

	Quality check at different stage of the process				
Total checked item from four stages	no. of defect observed	Raw skin stage	wet blue stage	crust stage	finished leather stage
41,256	16,195	3,239	3,563	4,211	5,182

APPENDIX-E: DEFECT IN FINISHING STAGE

Selection

ISSUE NO.5
REVISION NO.2
Page 2 of 12

Title & No. :- Internal Communication Procedure,
ELICO/ICP/553 Form 5-6

Form Title:- Production Performance Report

Form No.:-553-3.7

A) Defect in Finishing stage

Period		Types of defect observed																	
		Grade Deviatio	Size Varation	Loosenes s	Open Up/Nap/	Dryness	Non-Uniform	Folding	Thicknes s	Roughne ss	Shape	White Spot	Buffing Shatter	Spinal Line	Improper toggling	Penetrati on	Excess flesh	Vein	Fat spue	Total Inspecte d Skin
6month period	Freq.	1986	1779	1275	1102	902	557	524	472	392	357	328	174	122	98	86	83	74	69	10,382
	% defect	19.13	17.14	12.28	10.61	8.6	5.37	5	4.55	3.78	3.44	3.16	1.77	1.18	0.94	0.83	0.8	0.7	0.7	
	%cum	19.13	36.27	48.55	59.16	68	73.21	73.2	82.8	86.58	90.02	93.18	94.9	96.1	97	97.9	98.7	99	100	