ST. MARY'S UNIVERSITY

SCHOOL OF GRADUATE STUDIES

INSTITUE OF QUALITY & PRODUCTIVITY MANAGEMENT

AN EVALUATION OF STATISTICAL PROCESS CONTROL IMPLEMENTATION FOR QUALITY IMPROVEMENT: THE CASE OF HORIZON ADDIS TYRE COMPANY

DECEMBER, 2020

ADDIS ABABA, ETHIOPIA

AN EVALUATION OF STATISTICAL PROCESS CONTROL IMPLEMENTATION FOR QUALITY IMPROVEMENT: THE CASE OF HORIZON ADDIS TYRE COMPANY

BY

MATIWOS TEREFE

ADVISOR

AMARE MATEBU (PHD)

A THESIS SUBMITTED TO ST.MARY'S UNIVERSITY, SCHOOL OF GRADUATE STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF QUALITY AND PRODUCTIVITY MANAGEMENT

DECEMBER, 2020

ADDIS ABABA, ETHIOPIA

ST. MARY'S UNIVERSITY

SCHOOL OF GRADUATE STUDIES

FACULTY OF QUALITY AND PRODUCTIVITY MANAGEMENT

AN EVALUATION OF STATISTICAL PROCESS CONTROL IMPLEMENTATION FOR QUALITY IMPROVEMENT: THE CASE OF HORIZON ADDIS TYRE COMPANY

APPROVED BY BOARD OF EXAMINERS

Dean, Graduate Studies Institute	**Signature**
Advisor,	**Signature**
External Examiner,	**Signature**
Internal Examiner,	**Signature**

DECLARATION

I, the undersigned, declare that this thesis entitled an evaluation of the effect on Statistical Process Control implementation for Quality improvement: the case of Horizon Addis Tyre Company is my original work, prepared under the guidance of Amare Matabu (PHD) and I further confirm that the thesis has not been submitted earlier either to this university or elsewhere for an award of any other degree and all sources of material used for the thesis have been duly acknowledged.

SIGN: ____________________ DATE: ________________________________

MATIWOS TEREFE SARETA ID NO: SGS\0638\2011A

December, 2020

Addis Ababa, Ethiopia

ENDORSEMENT

This thesis has been submitted to St. Mary's University, School of Graduate studies for examination with my approval as a university advisor.

Advisor, Amare Matebu (PhD)

SIGN: ___________________________

DATE: ___________________________

St. Mary's University,

December, 2020

Addis Ababa, Ethiopia

ACKNOWLEDGMENTS

With all my heart, I would like to thank the LORD, my God who have given me grapples, vigour, courage and success. I would like to express my sincere and heartfelt gratitude to my thesis advisor, Amare Matebu (PhD), without whose pertinent advice, guidance and educating comments from the beginning to the Completion of my Endeavour.

My advisor's important supports have had contributions for successful Completion of the study.

I also extend my sincere appreciation and thanks to my mother W/ro. Welela Gugessa and to my father A/to. Terefe Sareta for their supports and encouragement throughout my study directly or in directly. I would like to warmly acknowledge also the assistance, encouragement and technical supports of all of my Friends which participate in this study.

To the Management and staff Horizon Addis Tyre Company of Product Industrialization and Quality Assurance Department especially for the manager of this Department A/to Alemayahu Emiru and A\to Dawit and W\ro Hiwot. I say "you Deserve big thanks" for opening your doors to me any time. I walked into your Organization's premises. I sincerely appreciate your unreserved support in providing me with the necessary data. Last but not least, my sincere gratitude should also be included to for their cooperation in providing information, which proved to be invaluably helpful towards the realization of this study.

DEDICATION

This work is dedicated to the entire family: my Mother and Father - Madam Welela Gugessa and Mr. Terefe Sareta, respectively, for their being the reason of my coming to this world and getting this level; for their passion, dedication and burning desire to educate their children, even at their sufferings and downs and for their immense contribution towards my studies. Proud of you & this happens because of you.

______________________________ ___________________

Name Signature

Table of Contents

Contents **Page**

LIST OF TABLES

PAGES

LIST OF FIGURES PAGES

LIST OF ACRONYMS AND ABBREVIATIONS

CEA	Cause and effect analysis
CI	Continuous Improvement
CPI	Capability Process Indices
CSF	Critical Success Factors
HATC	Horizon Addis Tyre Company
LCL	Lower Control Limit
OCAP	Out of Control Plan Action
PDCA	Plan- Do- Check-Act
PIQA	Process Inspection Quality Assurance
QC	Quality Control
R & D	Research and Development
SPSS	Scientific Package for Social Science
SQC	Statistical Quality Control
SPC	Statistical Process Control
TQM	Total Quality Management
UCL	Upper Control Limit

ABSTRACT

Quality leads to the improvement of productivity. Quality, productivity and cost of operation are relatively dependent to each other. For making quality products we need some techniques which are named as statistical process control (SPC). The evolution of manufacturing such as tyre went back to early 19th century and matured technologically and automated in the 1980s. Ethiopia joined the tyre industry in 1970sin the name of Addis Tyre SC(currently Horizon Addis Tyre SC); however, the tyre manufacturing stayed stagnant since then owing to various internal and external factors. The main objective of this study is to evaluate the existing Statistical Process Control implementation for Quality improvement approach and to assess and identify the existing quality related problems and identifying the challenges root cause for the implementation of Statistical Process Control implementation and proposed the appropriate solution in the Horizon Addis Tyre Company (HATC) manufacturing organization. Horizon Addis Tyre Company (HATC) has way problems analysis the Production defective Tyre that the company hugely faced those defective Tyre. There were many Quality problems like reject of products, waste of products, and defect of products and because of these Cost of production was high. The approach used in this study is direct observation. The methodology used in this thesis was by using the Control charts following this SPC tools were used to identify the problem areas and find their solutions. In this study, quality control data were collected through the primary source (i.e. directly from the Quality Control Department of the company and Primary data was collected through semi structured interviews and open ended and close ended Questionnaires i.e. using observation and interview). The secondary data was collected from the Web-site and Internet. The design of the research is descriptive since it allows the collection of data through questionnaires on the bases of sample, which helps to find out the view of the population. The study used mixed method of research design employing both quantitative and qualitative study techniques. Though the total number of employees in the factory is more than 770, *the target population or a minimum of sample size is taken for this study is 53. If a statistical process control practices are employed effectively, it could improve the quality of the product and overall organizational performance by knowing the customer requirement and meeting them. From different Quality improvement techniques tools, Horizon Addis Tyre Company used Paratoo Analysis tools for technical department; Control chart for all departments that implemented Statically Process Control and Histogram tools was also used for some sections of the company.*

KEY WORDS: PDCA, PIQA, HATC

CHAPTER ONE

INTODUCTION

This chapter consists of background of the study, statement of the problem, research questions, general and specific objective of the study, significance of the study, limitation of the study, scope of the study and organization of the study.

1.1 Background of the Study

In order to survive in a competitive market, improving quality and productivity of product or process is a must for any company. Quality is considered as the major aspect in this competitive industry. This study is about to apply the statistical process control (SPC) tools in the production processing line and on final product in order to reduce defects by identifying where the highest waste is occur at and to give suggestion for improvement. The approach used in this study is direct observation, thorough examination of production process lines, brain storming session, fishbone diagram, and information has been collected from potential customers and company's workers through interview and questionnaire, Pareto chart/analysis and control chart (p-chart) was constructed.

This research thesis focuses on Statistical Process Control Implementation for quality improvement, and summarizes the evidence about how it has been implemented and the results of this process. It has a focus on the role of industrial quality improvement approaches in this process which is the Statistical Process Control. It also outlines the development of quality from different perspective and the way in which industrial approaches are now being applied in Horizon Addis Tyre Company. The research thesis draws on academic literature as well as other sources, including accounts Published on the web, but recognizes the methodological limitations of accounts of success in quality improvement without any comparative data being made available. Now a day to survive in competitive market, improving productivity and reducing quality defects product is must for any company In today's complex and dynamic business world, organizations are expected to perform well in their line of business in order to stay competent and be profitable. This study shows that how statistical process control can help an organization to improve the quality of their products.

The Lean Production Paradigm is one of the approaches that can be used to achieve productive and quality goals Created by Taichi Ohno, the Lean Manufacturing philosophy, also known as Toyota Production System (TPS) due to the early work developed at Toyota's production plant in the fifties was applied to car engine manufacturing, in the sixties to car assembly and in the seventies to the supply chain. Ever since its success and results fostered a worldwide application in other industries beyond automotive. It aims to identify and remove every activity in design, production and supply chain management-related processes that do not add value from the customer's point of view. It is an approach to the production flow and has waste elimination (cost reduction) as a main goal, through quantity and quality control, using specific tools and techniques from a continuous improvement perspective, producing when needed at the time needed in the quantities needed. Many quality characteristics can be expressed in terms of numerical measurement. A single measure quality characteristic is called a variable.

Statistical Process Control was implemented before four years ago and we are said that Statistical Process Control in Horizon Addis Tyre Company (HATC) was implemented partially because the above reasons. As the research Title says "Evaluation of the effect on Statistical Process Control Implementation for Quality improvement: the case of Horizon Addis Tyre Share Company" means there is a result when Horizon Addis Tyre Share Company was implemented the Tools which is called Statistical Process Control. One of the results was Quality Improvement. There are many Quality dimensions in the implementation of statistical process control. These are the followings: Reduction of Cost, Reduction of Defects, Identification of Hidden loss, Reduction of Compliments and Process Consistence. The implementation of Statistical Process Control in Horizon Addis Tyre Company (HATC) was gave the following results. Cost of Production of Tyre and the number of complained of the customer were decreased in amount that is obtained from the primary data of questionnaires of the employee. The major Quality related problems are the followings:

1. Pulled Bead 2. Soft Bead 3. Side Wall Blester

It has been found that the company has many problems; specifically there is high rejection or waste in the production processing line. The highest waste occurs in melting process line which causes loss due to trickle and in the forming process line which causes loss due to defective product rejection. The vital few problems were identified, it was found that the blisters, double seam, stone, pressure failure and overweight are the vital few problems.

Statistical process control (SPC) is a method of quality control in which statistical methods are employed, in order to monitor and control a process. The eventual goal of Statistical process control is the elimination of variability in the process. It may not be possible to completely eliminate variability, but the control chart is an effective tool in reducing variability as much as possible. In the manufacturing environment, quality improves reliability, increases productivity and customer satisfaction. SPC is one of the most widely applied techniques to control and improve processes in Tyre industry, but very few studies have reported on successful application of SPC in Tyre industry.

A major objective of statistical process control is to quickly detect the occurrence of assignable causes of process shifts so that investigation of the process and corrective action may be undertaken before many nonconforming units are manufactured. The control chart is an on-line process-monitoring technique widely used for this purpose. Control charts may also be used to estimate the parameters of a production process, and, through this information, to determine process capability.

Quality is a concept whose definition has changed overtime. In the past, quality meant “conformance to valid customer requirements”. That is, as long as an output fell within acceptable limits, called specification limits, around a desired value, called the nominal value (denoted by m), or target value, it was deemed conforming, good, or acceptable. We refer to this as the “goalpost” definition of Quality Gitlow and Levin. The definition of statistics according to Deming, is to study and understand variation in processes and populations, interactions among variables in processes and populations, operational definitions (definitions of processes and populations variables that promote effective communication between people), and ultimately, to take action to reduce variation in a process or population. There are many Quality dimensions in the implementation of statistical process control. These are the followings: Reduction of Cost, Reduction of Defects, Identification of Hidden loss, Reduction of Compliments and Process Consistence. The positive changes that observed in the organization since the implementation of Statistical Process Control were to become Cost sensitive, to become Quality sensitive, to identify hidden loss. Quality has a positive and significant relationship to performance measurement for process utilization, process output, product costs, and work-in process inventory levels and on-time delivery. Improvement can be in the form of elimination, correction (repair) of ineffective processing, simplifying the process, optimizing the system.

In the tire manufacturing operation, there are 11 key sub-processes. According to Chavda and Patil (2011) and Grover (2002) and the tire manufacturing process involves the following 11 step:

1. **Mixing** involves weighing and combining various ingredients (natural and synthetic rubbers, oil, carbon black, zinc oxide, sulphur, and other chemicals) to create a homogenous rubber compound that is discharged to a drop mill.

2. **Milling** creates warm malleable sheets that are cooled and coated with an “anti-tack solution.” These sheets are then fed into an extruder.

3. **Extruding** forces the rubber compound through a shaped slot called a die that forms the compound into various shapes.

4. **Calendaring** involves coating fibbers of cloth or steel with a rubber compound, and then curing it in an irradiation oven that bevel cuts it to a desired length, width, and angle.

5. **Bead making** involves the creation of beads that provide a proper seal between the tire and the wheel rim when a Tyre is mounted on the rim and inflated. In the bead building process, bundles of wire are passed through an extrusion die where a coat of rubber is added, and the wires are then wound into a hoop.

6. **Cementing and marking** processes are used at various stages throughout the Tyre building process. **Cements** (adhesives or solvents) are added to improve the adhesion of different components to each other throughout the process. Cement usage can vary significantly among facilities depending on the type of Tyre being manufactured and the process being used. **Marking inks** are used to aid in identifying the components being managed. Typically, they are applied to extruded tread stocks to aid in identifying and handling cured tires. Marking practices can also vary significantly among facilities.

7. The various tire components go through **cooling** and **culture** prior to Tyre building. From the milling and extruding operations, the rubber sheets are placed onto long conveyor a belt that, through the application of cool air or cool water, lowers their temperature.

8. The two main components of the **Tyre-building** process are the tire carcass build up drum and the tread application drum. These drum machines assemble the cut carcass plies and belts plus the extruded tread, sidewall, and beads into tires. The process begins with the application of a thin layer of rubber compound, the inner liner, to the innermost carcass ply. The carcass plies are placed on the drum one at a time, after which the beads are set in place and the plies (reinforcing layers of cord and rubber) are turned up around them. At this stage the belts and tread rubber are added.

9. **Lubricating** involves preparing the uncured (green) tire for curing. The green Tyre may be coated with a lubricant (green tire spray). The function of the green Tyre spray is to ensure the cured tire does not stick to the curing mould during extraction of the tire after curing.

10. **Curing** involves collapsing the drum and loading the green tire into an automatic Tyre press to be cured (vulcanized) at high temperature and pressure. The vulcanization process converts the rubber and also bonds the various parts of the Tyre into a singular unit.

11. **Tire finishing** may involve some of the following processes: trimming, white sidewall grinding, buffing, balancing, blemish painting, whitewall/raised letter protect ant painting, and quality control inspections. Some facilities also apply a puncture sealant during production.

1.2 Statement of the Problem

The company has many problems; specifically there is high rejection or waste in the production processing line and have many quality problems in Horizon Addis Tyre Company (HATC). Horizon Addis Tyre Company (HATC) has many problems analysis the Production defective Tyre that the company hugely faced those defective Tyre due to mainly major reasons of defects. Even if, the company uses SPC as a good practice for quality improvement, in doing this the company faces challenges like lack of experts in SPC field, lack of knowledge in statistical process control (SPC) implementation, including the data collection system for further investigation of the problem, and even in interpretation of the data for quality Improvement analyzing the process quality. Due to these and other reasons the company has still many defective products.

Statistical Process Control (SPC) Implementation has great contribution to Cost reduction and Quality Improvement. Horizon Addis Tyre Company has implemented since four years ago i.e. 2009 E.C then the thesis aims to evaluate the existing Statistical Process Control implementation in the Horizon Addis Tyre Company (HATC) manufacturing organization but unable to achieve the intended goal of Cost reduction and Quality Improvement.

1.3 Objectives of the Study

1.3.1 General objectives

The main objective of this study is to investigate the practices and challenges of implementing Statistical Process Control for Quality Improvement approach in Horizon Addis Tyre Company (HATC).

1.3.2 Specific objectives

The aims of this study can be summarized in the points below

- To evaluate the existing Statistical Process Control implementation in the Horizon Addis Tyre Company (HATC) manufacturing organization.
- To assess and identify the existing quality related problems in Tyre industry and to suggest and to propose the appropriate solutions during Statistical Process Control implementation in the Horizon Addis Tyre Company (HATC) manufacturing organization.
- Identifying the challenges or root cause for the implementation of Statistical Process Control implementation and proposed the appropriate solution.
- To recommend a possible solution for the identified causes of variation for achieving quality improvement.

1.4 Significance of the Study

There is no ample research on the topic of "Evaluation of the Effect of Statistical Process Control for Quality Improvement." So, the study focused on A Critical Assessment on Statistical Process Control Implementation in Quality improvement. So, this research help to other manufacturing companies that begins to implement SPC Tools by addressing the success factor of Horizon Addis Tyre Company factory. The benefits of improving Quality with SPC tools could be translated to Tire Manufacturing companies that have little expertise that are trained on SPC and lack access to the advanced technologies that drive Quality gains in the top firms. By taking random samples of output, variability in a process could be evaluated objectively by managers, as opposed to using subjective techniques to identify activity inefficiencies. Purpose of this study is to find an objective way to spot inefficiency and fix the problem using the combined expertise of the personnel involved. Finally, the research would create awareness about the usefulness of the Statistical Process Control implementation to enhance the Quality Improvement and the significant prior research on the organizational effects of increased technological sophistication.

1.5 Scope of the Study

This research report was limited and focuses on "Evaluation of the Effect of Statistical Process Control for Quality Improvement. This research is conducted with the factory department called PIQA and some selected section of production department such as Bead Wire and Steal Coating section, Laboratory, Textile- Rubberizing Cord, and Tread, Building machine and Mixing or Compounding Section. There is PIQA department who control the quality controls parameters and ensuring the quality assurance. In terms of time dimension, the study employed a five year operational data coupled with cross-sectional survey data that was run both for primary customers (individuals), organizations, and distributing agencies. This study focused on a single manufacturing industry in order to provide increased depth of analysis. The field study directly measured the effects of SPC implementation on product quality, consistency, material cost, employee attitudes, and the organization structure.

There is a very few researches was done as the title of SPC implementation in Tyres industry and there was limited resource in this section.

1.6 Basic Research Questions

Following the research objectives, the research has following specific research questions to be answered.

1. What is the Quality related problems and possible reasons to Quality related problems in Horizon Addis Tyre Company?
2. How to evaluate Quality improvement with respect defect and scrap rate reduction in the case of the Horizon Addis Tyre Company?
3. What are the common possible Defective types and their possible causes for those Defective Tyres for Statistical Process Control in Horizon Addis Tyre Company?
4. What are the key ingredients for, results of the successful implementation of Statistical Process Control and advantages of Statistical Process Control implementation?

1.7 Organization of the Study

Chapter one is the Introduction of the study. It consists of background of the study, statement of the problem, research questions, general and specific objective of the study, significance of the study, limitation of the study, scope of the study and organization of the study.

Chapter two is Theoretical Frame Work of References or Literature Review of the Study. It provides an overview of literature that is related to the research problem presented in the previous Section. This section contains the following topics. These are: previously published research relating to the effects of implementing statistical process control (SPC). Since little has been written in this area, published research into the effects of implementing other related participatory processes are also reviewed or examined, Quality and Economic Effects of the implementation of SPC ,The evolution of Quality, Methods of Quality and Profitability improvement, Effects on Organization Structure, to effects on employee attitudes and behaviour, Theoretical Reviews about SPC, Theoretical concepts of Statistical Process Control, Theoretical framework in Statistical Process Control (SPC), a conceptual framework for the effective implementation of statistical process control**,** Quality and Quality Improvement and Application of SPC Tools in the Manufacturing Company.

Chapter three is Research Design and Methods of the Study. This chapter outlines the methodology on how data and information relevant to the research were gathered and analyzed in order to achieve the objectives of the study. It discusses the description of study procedures and the methods employed in the study. Areas covered include the research design, sources of data, instruments of data collection, population and sampling procedures, methods of data analysis, and ethical consideration.

Chapter four is Data Presentation, Analysis and Interpretation. It consists or presents of Quantitative and Qualitative Data were collected persistent observation and documentary analysis of Statistical Process Control implementation research framework. The first section is on demographic characteristics of the respondents. Section two presents and describes about the data on the implementation of Statistical Process Control. The third section examines the challenges encountered in the implementation of Statistical Process Control and finally Background of the Organization.

Chapter Five is consists of Summary of Major Finding, Conclusion and Recommendations.

CHAPTER TWO

LITERATURE REVIEW

This chapter provides an overview of literature that is related to the research problem presented in the previous Section. This section contains the following topics. These are: previously published research relating to the effects of implementing statistical process control (SPC). Since little has been written in this area, published research into the effects of implementing other related participatory processes are also reviewed or examined, Application of SPC Tools in the Manufacturing Company ,Quality and Economic Effects of the implementation of SPC and Effects on Organization Structure to effects on employee attitudes and behaviour, Common and special causes of variation, Theoretical concepts of Statistical Process Control, Theoretical framework in Statistical Process Control (SPC),a conceptual framework for the effective implementation of statistical process control**,** The evolution of Quality, Quality and Quality Improvement, Methods of Quality and Profitability improvement.

2.1 Quality

2.1.1Definitions of Quality in Manufacturing Company

The definition of quality at the From Corporation Distribution Centre (Martin 1985) is to have zero errors in all of their shipments. Such a definition can lead to excess inspection and wasteful work practices.

Therefore, it is important first of all that an organization adopt a unified quality policy; and secondly, that this policy be ground-A in the correct definition of quality. The correct definition of quality will open the way for continuous, never-ending improvements in both quality and productivity; and this translates into an improved competitive position for profit making organizations and sound fiscal responsibility for non-profit organizations. The different viewpoints can be assessed using Garvin's (Garvin, 1987) dimensions of Quality. Modern businesses define specific strategic guidelines to assure successful implementation of their Quality Management System (QMS). Quality is a concept whose definition has changed overtime. In the past, quality meant "conformance to valid customer requirements". That is, as long as an output fell within acceptable limits, called specification limits, around a desired value, called the nominal value, or target value, it was deemed conforming, good, or acceptable.

We refer to this as the “goalpost” definition of quality (Deming, 1950). According to Montgomery (2005), quality is one of the most important decision factors in the selection of products and services. Therefore, quality leads to business success, growth, and increases competitiveness, as well as improves the work environment. Additionally, it involves the employee in achieving the corporate goals and brings a substantial return of investment. The study and the analysis of quality must be aimed at understanding, meeting, exceed and surpassing customer needs and expectations (Kolarik, 1995). Statistical tools allow measurement and evaluation of the performance in a process to improve its quality. The tools frequently used to support decision making. According to Montgomery (2005), statistical tools can be helpful in developing activities previous to manufacturing, in measuring process variability, in analyzing this variability relative to product requirements or specifications, and in eliminating or greatly reducing variability in process.

These tools allow the interpretation of the process by detecting when the variables change and experimentation by knowing how the variables can change by experimental designs (Ott*et al*., 2000).One of the key processes performed in organizations is to minimize the re-works and increase profitability of the tire building. This review will include the process of reducing the re-works or alteration happening in the various departments of tire industry. After that, some of the popular methodologies and approaches are discussed. The current literature published by Md. Mazedul Islam, Adnan Maroof Khan and Md. Mashiur Rahman Khan, and January 2013 gives great emphasis to the importance of decreasing the amount of rework, which meets the overall productivity of the industry. Generally in an industry more focus is given on profit margin, customer demand for high quality product and improved profitability.

Thus the review deals with an application of methodology in an industry which provides a framework to identify quantify and eliminate sources of variation in an operational process, to optimize the operation variables, improve and sustain process performance with well -executed control plans. The above-mentioned viewpoints and dimensions are all aspects that an organization will aim to achieve at the lowest cost. The association between improvement of quality and the cost involved should be clearly defined (Arabian, Mehdi Jourabchi, Leman & Ismail, 2013).

The application of this paper improves the process performance of the critical operational process, leading to better utilization of resources, decreases variations & maintains consistent quality of the process output. The outcome of this review reflected that an industry may gain higher profitability with improved quality product by minimizing reworks activities. It also minimizes cost and improves internal throughput time.

Quality improvement of the product is the key to keep the Tyre sector on the track of global competition. At this critical point, manufacturers should give top priority to reduce defects in their products and become competitive. As the world financial situation is changing quickly, industries are now giving more focus on customer demand for superior quality product, turnover and enhanced profitability. Effective quality improvement can be instrumental in increasing Productivity and reducing cost. This amounts to an increase in production capacity of almost 10%, without any additional investment in equipment, workforce, or overhead. Efforts to improve this process by other methods (such as Just-in-Time, lean manufacturing, etc.) are likely to be completely ineffective until the basic problem of excessive variability is solved. The objective of continuous improvement is not only to meet customer satisfaction but also to do it at the lowest possible cost (Hung & Sung, 2011b; Vaxevanidis & Petropoulos, 2008).

Given this, a corporation should adapt a framework to classify the cost associated with quality (Grigg & Walls, 2007; Vaxevanidis & Petropoulos, 2008). From (An Implementation Framework for Statistical Process Control in Small to Medium-sized Enterprises: A South African Context December 2019 by Logan-Lee Miché Appollis). According to the definition of ISO 9000 quality is defined as 'The totality of characteristics of an entity that bear on its ability to satisfy stated or implied needs'. Armand Feigenbaum explains Quality as "A customer determination based upon a customer's actual experience with a product or service, measured against his or her requirements – stated or unstated, conscious or merely sensed, technically operational or entirely subjective and always representing a moving target in a competitive market".

American Society for Quality (ASQ) opines that quality denotes an excellence in goods and services, especially to the degree they conform to requirements and satisfy the customers. Quality is a concept whose definition has changed overtime. In the past, quality meant "conformance to valid customer requirements". That is, as long as an output fell within acceptable limits, called specification limits, around a desired value, called the nominal value, or target value, it was deemed conforming, good, or acceptable. We refer to this as the “goalpost” definition of quality (Deming, 1950). According to Montgomery (2005), quality is one of the most important decision factors in the selection of products and services. Therefore, quality leads to business success, growth, and increases competitiveness, as well as improves the work environment. Additionally, it involves the employee in achieving the corporate goals and brings a substantial return of investment. Quality is inversely proportional to variability.

Quality improvements the reduction of variability in processes and products. Quality refers to the combination of characteristics of a product, process, or service that determines the Products ability to satisfy specific needs.

Some definitions are given below:

- ❖ Quality is fitness for purpose or use. Or quality is customer satisfaction. Juran J. M. (1998).
- ❖ Quality is conformance to requirements. Crosby Phillip, (1979).

2.1.2 Dimensions of Quality

From the eight dimensions of Quality, the Tyre manufacturing industry was expressed by the followings list of quality’s dimensions. These are the followings:

1. Durability:

(How long does the product last?) This is the effective service life of the product. Customers obviously want products that perform satisfactorily over a long period of time. The automobile and major appliance industries are examples of businesses where this dimension of quality is very important to most customers. Durability of Tyre was the basic one from the eight dimensions of quality.

2. Performance:

(Will the product do the intended job?) Potential customers usually evaluate a product to determine if it will perform certain specific functions and determine how well it performs them. The Performance of Tyre was also the basic one for the property and the parameters of Tyre.

There are different criteria of performances. E.g. Speed of Tyre, Load chain capacity and steering actions of Tyre.

3. Aesthetics:

(What does the product look like?) This is the visual appeal of the product, often taking into account factors such as style, colour, shape, packaging alternatives, tactile characteristics, and other sensory features Aesthetics value of Tyre was also the basic one from eight dimensions of quality. It means Vision perceived and elegancy.

4. Life

Tyre has associated with the life of the truck driver and the passengers because most of the car accident was related with the quality of the Tyre.

5. Strength:

The strength of the Tyre rubber was associated with the raw material that was produced and the capacity to carry the load of the truck that the tension forces of the truck. If the raw material of the Tyre has a good quality then the strength to carry the truck was a good enough.

2.2 The Evolution of Tyre Production

According Radder.F (2017) on his 'Tire Recappers News', the first use of pneumatic tyres for automobiles was pioneered by the Michelin brothers, André and Édouard. They equipped a car with pneumatic tyres and drove it in the 1895 Paris-Bordeaux road race. Though André and Édouard didn't win the race, they generated popular interest in pneumatic tyres, and Michelin & CST became a leading producer of tyres in Europe. At the same time, solid rubber tyres disappeared from the highways, mostly because of legislation that discouraged their use because they were hard on the roads In 1898 Goodyear Tyre and Rubber Company─named after George Goodyear, the discoverer of vulcanized rubber─was formed **in America by Frank Seiberling.** Then Firestone Tyre & Rubber Company was started by Harvey Firestone in 1900. Thereafter, other tyre makers followed. For the next fifty years automobile tyres were made up of an inner tube that contained compressed air and an outer casing that protected the inner tube and provided traction. The rubber that made up the casing was reinforced by layers or "plys" of rubberized fabric cords embedded in the rubber. The tyres made during this period were known as bias-ply tyres because the plys ran across the tyre in alternating diagonal layers at about a 55 degree angle to the wheel rim. Bias-ply tyres continue to be made and are sold as authentic equipment for antique and collector cars that were made during this period. Michelin first introduced steel-belted radial tyres in Europe in 1948. Radial tires are so named because the ply cords radiate at a 90 degree angle from the wheel rim, and the casing is strengthened by a belt of steel fabric that runs around the circumference of the tyre. In radial tyres the ply cords are made of nylon, rayon, or polyester. The advantages of radial tyres include longer tread life, better steering characteristics, and less rolling resistance, which increases gas mileage. Again, radials have a harder riding quality, and since they are technologically more complex than bias-ply tires, they are about 45 percent more expensive to make. Because of their construction, radial tyres require a different suspension system from that used by cars designed for bias-ply tyres. It is however, recommended that radial tyres not be used on cars designed for bias-ply tyres (Radder 2017).

These days' radial tyres became standard on new cars outside of America. Michelin in France, Bridgestone in Japan, Pirelli in Italy, and Continental in Germany became powerful radial tyre manufacturers. Automobile tyres everywhere became tubeless as tyre technology improved. Both the American automobile manufacturers and the tyre companies sought the radial tyre. Detroit, home of the American automobile, was afraid of how much it would cost to redesign automobile suspensions to accept radial tyres. The tyre industry was afraid of how much it would cost to retool the entire American tyre industry to make the more costly radial tyres. Not happy with the threat of having to make tremendous investments, most American automobile makers and tyre manufacturers wrote off the radial tyre as a freak product that isn't going anywhere (Ernst 2013). With the notable exception of B.F. Goodrich, the American tire companies decided that the American public wasn't ready to pay a lot more for the harder ride that radials produced, and they stuck to making bias ply tyres. Goodrich bucked this trend by investing heavily in radial tyre technology, only to have their tyre—the Silvertown Radial 900, introduced in 1965— snubbed by the American automobile industry. Eventually Goodrich sold its tyre operations and got out of the tyre business (Ernst 2013).

In 1967, Goodyear, the world's largest tyre company, introduced their response to the radial, a bias-belt product called the Custom Super wide Poly-glass. The bias-belted tyre simply added a Fibber glass belt to the bias-ply tyre. The bias-belted tyre would last 30,000 miles compared to 40,000 for radial and 23,000 for bias-ply tyres. It could be used on cars designed for bias-ply tyres. Best of all, it could be made on existing bias-ply tyre-making machines, which made its cost not much more than a bias-ply tyre (Ernst 2013).

Fuelled by a Goodyear advertising blitz, bias-belted tyre sales rose from 2 percent of the original equipment market in 1968 to 87 percent by the early 1970s. In advertisements touting their bias belted tyres, Goodyear ridiculed radials for their hard ride and their high cost. The American tyre and automobile industry was confident that the bias-belted tire would keep the radial tyre wolf from the door for a while and expected to have plenty of time to develop their own radial tyre expertise at their own pace. Then in 1973 came the gasoline crisis. Gas went from 30 cents to a dollar a gallon. Americans demanded more economical cars. That year, imported cars represented 15% of American auto sales, but by the early 1980s imports were 28 percent. Of course, each foreign car came equipped with radial tyres. Americans clamoured for radial tyres when they found that they improved gas mileage. Companies like Michelin and Bridgestone were only too happy to supply the American market.

Alas, in the mid-seventies Firestone Tyre decided to get into radials on the cheap, fabricating radial tyres on machines made for building bias tyres. The tyres came apart in a spectacular manner. Firestone recalled close to 9 million of its Firestone 500 steel-belted radial tyres. From 1977 to 1980, Firestone's tyre business dropped 25 percent, resulting in the layoff of 25,000 workers. The company went from a $110 million profit to $106 million loss, and its stock dropped from $15 down to $10 a share. Firestone was rescued when Bridgestone Tyre bought them in 1988. Goodyear finally produced a radial tyre in 1977 by investing billions of dollars in radial technology. Other American Brand Finance tire companies either merged or were bought out. All American new cars came with radial tyres by 1983. Currently Goodyear holds about 20 percent of the global market share in radial tires, both original equipment and replacement; Michelin, 19 percent; Bridgestone, 17 percent; Continental, 9 percent; Pirelli, 5 percent; and the others, 30 percent (Ernst 2013).

According to Workman (2016), there are 102 countries that export various types of tyres across the globe. A report shows that a ranking of the 10 most valuable Tyre Brands in the World are Bridgestone, Michelin, Continental, Goodyear, Pirelli, Sumitomo, Hankook, Dunlop, Yokohama,
and CST in descending order. Each brand has been assigned a brand rating based on a benchmark study of the strength, risk and future potential of a brand relative to its competitor set,
as well as a Brand Value- a summary measure of the financial strength of the brand. Today the global industry encompasses around 400 factories worldwide producing more than one billion units per annum. The peak of the industry's dynamics in the modern era was reached in the late 1980s when a series of dramatic restructuring occurred. Currently, the world tire industry is led with nine ultimate parent companies that have annual sales in excess of $1 billion each. These nine companies account for 80 percent of world tire sales (Ita and Gross, 1995). Four of the nine companies have their headquarters in Japan (Bridgestone Corporation, Sumitomo Rubber Industries Ltd., Yokohama Rubber Co. Ltd., and Toyo Tire and Rubber Co. Ltd.), three are based in Europe (Groupe Michelin, Continental A.G., and Pirelli), and two are headquartered in the United States (Goodyear and Cooper) (Bradley, 2000)

2.3 Statistical Process Control

Statistical process control (SPC) tools charts are widely used in industries to assess and control industrial processes , being referred to as the most popular method used for the productive process in systems quality assurance, SPC involves statistical techniques to measure and analyze the variation of the process to check*B. Barbosa et al. / Procedia Manufacturing*product quality and maintain processes to Deming cycle (Plan-Do-Check-Act) problem using tools as Histograms, Pareto Charts, SPC and analysis of Variance (ANOVA). The production process quality output can be measured by the joint level of several correlated characteristics, supported by modern data-acquisition equipment. In automotive and parts industries, considering the standards' specifications used for quality assurance, the commonly quality tools used are charts *X*-*R* and *X*-*S* as parameters control. Traditional control charts *X*-*R* are used to analyze the process critical points. The order of action to implement *X*-*R* is Analysis of production process; Choice of estimation features of the product; settlement of the size sample and as well the frequency of taking sample size, at least four; Project of form to assembling dates; Designing of control charts according to references.

2.3.1 Types and Causes of Variation in SPC

When looking at bottles of a soft drink in a store carefully, it will be notice that no two bottles are filled to exactly the same level. Some are filled slightly higher and some slightly lower. This type of difference is completely normal. Wiley et al (2007), says no two products are exactly alike because of slight differences in materials, workers, machines, tools, and other factors‟. These are called common, or random, causes of variation (Wiley et al, 2007). Wiley further say that common cause of variation are based on random causes that cannot be identify. These types of variation are unavoidable and are due to slight differences in processing. An important task in quality control is to find out the range of natural random variation in a process when all the data falls within the predetermined range of control, i.e. Lower Control Limit (LCL) and Upper Control Limit (UCL) it is regarded as random or normal causes of variation. This normal or random cause of variation cannot be identified because the data falls within the present limits. Wiley et al (2007) further says the other type of variation that can be observed involves variations where the causes can be precisely identified and eliminated. These are called assignable causes of variation. Examples of this type of variation are poor quality in raw materials, an employee who needs more training, or a machine in need of repair. In each of these examples the problem can be identified and corrected.

Also, if the problem is allowed to persist, it will continue to create a problem in the quality of the product where data falls above and below the present control limits (LCL and UCL) indicating that a variation due to assignable causes has been developed and can be identified and also be corrected.

Shewhart (1931, 1980) defined ―control‖ as follows: A phenomenon will be said to be controlled when, through the use of past experience, we can predict, at least within limits, how the phenomenon may be expected to vary in the future. Here it is understood that prediction within limits means that we can state, at least approximately, the probability that the observed phenomenon will fall within the given limits. The critical point in this definition is that control is not defined as the complete absence of variation. Control is simply a state where all variation is predictable variation. A controlled process isn‘t necessarily a sign of good management, nor is an out-of-control process necessarily producing non-conforming product. (Pyzdek, 2003). In any production process a certain amount of inherent or natural variability will always exist. This natural variability or ―background noise" is the cumulative effect of many small, essentially unavoidable causes. In the framework of statistical quality control, this natural variability is often called a "stable system of chance causes." (Montgomery, 2005) Where Dr. Shewhart used the term chance cause, Dr. W. Edwards Deming coined the term common cause to describe the same phenomenon. (Pyzdek, 2003). A process that is operating with only chance causes of variation present is said to be in statistical control. In other words, the chance causes are an inherent part of the process. (Montgomery, 2005) Needless to say, not all phenomena arise from constant systems of common causes. At times, the variation is caused by a source of variation that is not part of the constant system. These sources of variation were called assignable causes by Shewhart, special causes of variation by Deming. (Pyzdek, 2003). This variability in key quality characteristics usually arises from three sources: improperly adjusted or controlled machines, operator errors, or defective raw material. Such variability is generally large when compared to the background noise, and it usually represents an unacceptable level of process performance. (Montgomery, 2005). The basic rule of statistical process control is: Variation from common-cause systems should be left to chance, but special causes of variation should be identified and eliminated. This is Shewhart‘s original rule. However, the rule should not be misinterpreted as meaning that variation from common causes should be ignored. Rather, common-cause variation is explored ―off-line. That is, we look for long-term process improvements to address common-cause variation. The answer to the question ―should these variations are left to chance? Can only be obtained through the use of statistical methods. In short, variation between the two ―control limits will be deemed as variation from the common-cause system.

Any variability beyond these fixed limits will be assumed to have come from special causes of variation. We will call any system exhibiting only common-cause variation, ―statistically controlled. It must be noted that the control limits are not simply pulled out of the air. They are calculated from actual process data using valid statistical methods. Without statistical guidance there could be endless debate over whether special or common causes were to blame for variability. (Pyzdek, 2003) Variations are two types**:** - Random or chance variation - Variations with assignable causes.

2.3.2 CAUSES OF DEFECTS

Defects may happen in any stage of the transforming process, input, process, and also output. The causes of defects can be simply categorized into three types: there are materials, human and machinery. To lowest the defective, firstly need to know well about the cause factor. By utilized different method of way to overcome the different cause will be more effective and efficiently. Defects results from allowing a mistake to reach at the customer end, therefore the organization reputation will be ruin because of the defect product. Quality control department play a main role to checking the products carefully and have a good cooperation with production department.

1 Material

The variability of each batch of material is dependent variable, which is uncontrollable. In principle it is not possible to improve on the variability in either mass or unit area properties or fiber straightness, so the variability in the incoming materials sets the minimum variability (Potteret al., 2006). Because of the material is dependent variable that cannot be change and no possible to be improved, therefore the only thing can do is adjust machinery setting to fit to the variability of the material rather than using the same setting to produce defect product. Any solution will be tried to reduce defects and also minimized the cost. Defect and quality of the material have a strong relationship between each other. The higher quality of the materials, the lower defective happened. Otherwise, the low quality materials will cause high defective. Production line operator should look-out when using different batch of material, if there is variability operator must report to production manger. Then, production manager have to discuss with the organization engineer either doing adjustment in the machinery or forgo that batch of material, leaving until suitable chance to use it.

2 Man: Employee, human is the main assets of an organization. They able to used their intelligent to help organization generate wealth by using their strength to get wage. Normally, the defects caused by human resources because they are lack of skill and related knowledge, especially in this modern era. Using high-tech machines require related professional knowledge, without the knowledge, workers may not manage well in the production process and it may causes defects happened. Training can be given by organization to enhance their require skill in order to manage the machinery well. Sometimes, the defects caused by humanity are because of human fatigue, carelessness, forgetfulness and errors due to the misunderstanding, mis-interpretation and mis-communication and so on. Mistakes are in evitable; people are human beings and cannot be expected to concentrate all the time on the work or to understand completely the instructions. To overcome the humanity causes, sign board or memo board can be built to remind worker for the important issue. Tolerance should be given because humanity is not perfect. Communication and teamwork are to avoid mis-understanding, mis-interpretation, miscommunication also vital in producing low defect products.

3. Machinery

While the machine runs for 24 hours every day, defects might happen because of non-stop producing products. So, the maintenance of the machinery is important to an organization. The maintenance should be executed regularly like monthly, semi-year or yearly, to maintain the machinery is in the top performance and lowest defects. Quality control department have to inform to the mechanic if defects are happened frequently, that might because some of the machinery setting or parts goes wrong. Skilful technician and operator are required in producing high quality finished goods.

4. Method

Methods means the system that the company used when the defects was occurred at the process because of the methods used by the company. So, it is controllable parameters of quality control.

2.3.3 The Concepts Of Statistical Process Control (SPC) Tools

SPC is defined as a powerful collection of problem-solving tools useful in achieving process stability and improving capability through the reduction of variability (Montgomery, 2012). Attempts have been made to expand the concept of SPC beyond the process monitoring technique. SPC is categorized into several types of topics such as:

- Technological innovation (Bushe, 1988, Roberts et al., 1989)
- Process management technique (Bissell, 1994)
- control algorithm (O, H ,1997)
- A component of total quality management (TQM) (Barker, 1990)
- One of the quality management systems in the food industry (Caswell etal., 1998).

Wallace et al. (2012) and Davis and Ryan (2005) viewed SPC as a participatory management system — teamwork efforts, employee involvement and enable real-time decisions were made (Deming, 1986, et al., 2008).

The focus of SPC is understanding the variation in values of quality characteristic (Woodall, 2000). The process stability refers to the stability of the underlying probability distribution of a process over time and these very often can be described as the stability of the distribution parameters overtime (Mahalik and Nambiar, 2010). The process stability extremely crucial as it is one of the pre-requirement condition prior to the process capability indices determination (Brannstrom-Stenberg, 1999, Motorcu and Gullu, 2006, Sharma and Kharub, 2014). There is no standard set of tools within SPC, however, Gaafar and Keats (1992) and Duffuaa and Ben-Daya (1995) argue that there is a general agreement on the seven tools which includes data gathering, Histogram, Pareto chart, cause and effect analysis (CEA)/fishbone diagram, scatter diagram, check sheets and control charts. However, it is generally agreed that control chart is a primary tool within SPC. SPC is arguably involved more than its mathematical literacy issues. According to Rungtusanatham et al. (1997), the term SPC implementation requires a clear understanding of the procedures to be adopted and activities to be performed using a set of tools ─ indicating participatory management. Therefore, such argument is seconded with the implications from the dual concepts of SPC — "the operation of statistical control" and "the state of statistical control" suggested by Shewhart (1939).According to Pena-Rodriguez (2013), Lim et al. (2014), Grigg (1998), there is a crucial need to develop customize guideline for the food industry to apply and integrating all these tools in a systematic manner at the correct problem. PARETO CHART

Main purpose: Prioritization by ranks the data, in descending order, from the highest frequency of occurrences to do laws frequency of occurrences. Principle 8020: Emphasise the need to focus first on the 20% of the causes that matter, without totally ignoring the remaining 80%. Question: which are the big problems?.(Cravener 1993, Varzakas and Arvanitoyannis, 2007, Dalgiç et al., 2011, Fotopoulos et al., 2011).

SCATTER DIAGRAMS

Main purpose: to illustrate the relationship or correlation between different variables. Principle: demonstrates the results of a series of experiments applied to document the relationship between the variables. Question: what are the relationships between factors? Knowels et al., 2004, Grigg, 1998, Pluta, 2014).

CEA/ ISHIKAWA DIAGRAMS

Main purpose: to identify possible causes for problem, uncover bottlenecks in the processes, identify where and why the process is working Principle: Identify all possible relationships among input and output variables, there is, five or six categories of the following skeleton (machines, methods, materials, manpower, measurements, environments) Question: What are the relationships between factors? Why does this happen? (Varzakas and Arvanitoyannis, 2007, Saini et al., 2011, Hubbard, 2013, Desai et al., 2015)

HISTOGRAMS

Main purpose: To illustrate and identify the distribution of the observations from a set of data. Principle: A graphical representation of the frequency of occurrence process that the points or a class that represents a set of data points. Question: what does the observation look like? Ooi and McFarlane, 1998, Srikaeo et al., 2005, Mertens et al., 2009, Mataragas et al., 2012, Dalgiç et al., 2011, RábagoRemy et al., 2014)

FLOW CHARTS

Main purpose: to Endeavour understanding of the process flow, a process for improvement, to communicate to others on how the process is done and to document the process. Principle: brainstorming activities (arranged activities in the process in proper sequence).

Question: what are the steps and process involved? Dalgic,et al.,2011, Mertens et al., 2009, Cinar and Schlesser, 2005, Srikaeo and Hourigan, 2002)

CHECK SHEETS

Main purpose: To provide a simple means for recording data and enable the analyst to determine the relative frequency of occurrence of the various categories of the data. Principle: brainstorming activities (arranged activities in the process in proper sequence) Question: how often is it done? (Bidder, 1990, Hubbard, 2013)

CONTROL CHARTS

Main purpose: To study process changes over time, control on-going processes by finding and correcting problems as the current, to predict the expected range of outcomes from a process, to determine whether a process is table, to analyse evidence of process variation from special causes or common causes, whether the quality improvement project should be to prevent spastic problems or to make fundamental changes to the process. Principle: The graft of process characteristics plotted in sequence, it includes the calculated process mean of statistical control limits. Question: Which variations to control and how? ((Grigg, 1999, Grigg and Walls, 2007a, Ittzes, 2001, Hayes et al., 1997).

2.3.4 Aim of Statistical Process Control

The seven quality control tools are simple statistical tools used for: - problem solving, collecting data, analysing data, identifying root causes and measuring the results. The primary main function of statistical quality control tools is to effectively collect quality data like various product quality including defect data, retry rate of machines, operating rate. Compute the fraction defective based on data collected to create a chart with plotting such fraction defective in time sequence, so that the chart may be used as a poster in the office space. Further, it is important for them to confirm that product quality is remaining within a manageable range. If the quality would be out of the range, every worker should discuss about any possible counter measures. These data should be analysed by certain method to examine counter measure. For example: stratify defect cause to find the defection fracture by each phenomenon, take countermeasure toward defect caused by a group with high defection fracture in order to decrease it below the manageable range. If the fraction defective improved to that level, narrow down the manageable range to repeat the procedure (Hansen B.I and Gahere P.M 1987).

2.3.5 SPC implementations

In SPC application, it is important to understand and identify key product characteristics which are critical to customers or key process variation. Successful implementation of SPC depends on the approach to the work being structured. This applies to all organizations, whatever their size, technology or product/service range. Unsuccessful SPC implementation programmers usually show weaknesses within either the structure of the project or commitment to it. Any procedure adopted requires commitment from senior management to the objectives of the work and an in-house co-coordinator to be made available. The selection of a specific project to launch the introduction of SPC should take account of the knowledge available and the improvement of the process being:

- Highly desirable; Measurable;
- Possible within a reasonable time period; Possible by the use of techniques requiring, at most, simple training for their introduction.

The first barrier which usually has to be overcome is that organizations still pay insufficient attention to good training, outside the technological requirements of their processes. With a few notable exceptions, they are often unsympathetic to the devotion of anything beyond minimal effort and time for training in the wider techniques of management.

This exacerbates the basic lack of knowledge about processes and derives from lack of real support from the senior management. Lame excuses such as ‘the operators will never understand it’, ‘it seems like a lot of extra work’ or ‘we lack the necessary facilities’ should not be tolerated. A further frequently occurring source of difficulty, related to knowledge and training, is the absence from the management team of a knowledgeable enthusiast. The impact of the intervention of a third party here can be remarkable. The third party’s views will seldom be different from those of some of the management but are simply more willingly received. The expertise of the 'consultant', whilst indispensable, may well be incidental to the wider impact of their presence.

In SPC application, it is important to understand and identify key product characteristics which are critical to customers or key process variation. The key steps for implementing SPC are:

- Identify defined processes
- Identify measurable attributes of the process
- Characterize natural variation of attributes
- Track process variation
- If the process is in control, continue to track
- If the process is not in control
- Identify assignable cause
- Remove assignable cause
- Return to 'Track process variation'

The Statistical Process Control - SPC is a set of statistical techniques focused on process control, monitoring and analyzing the variation causes in the quality characteristics and/or in the process parameters. A control chart (also called process chart or quality control chart) is a graph that shows whether a sample of data falls within the common or normal range of variation. A control chart has upper and lower control limits that separate common from assignable causes of variation. We say that a process is out of control when a plot of data reveals that one or more samples fall outside the control limits. Statistical process control (SPC) is generally regarded as a set of tools that are meant to increase the quality of a process by reducing variability in the process, thus making each individual product produced conform to a certain same set of standards. There are both technical and philosophical aspects of SPC (Bo Bergman, 2010). The philosophical aspect consists of a consistent will and motivation in the organizations continuously to improve the process, as well as management strategies to achieve continuous improvement, while the technical aspect is a set of statistical methods which in various ways can monitor and observe the variability and alert the possibility of a defect in process (Bo Bergman, 2010).

The Pareto's 80/20 rule is used to identify the vital few processes, which control manufacture, and then build the planning around these key processes and products for quality control activities. Statistical Process Control is the application of statistical techniques to control a process and eliminate process variations due to assignable causes. Statistical process control requires operators to do periodically sampling of the quality of their own output, enter data into control charts, analyze the trend, and decide for themselves when to shut down the process and when to make adjustments / corrections to the process to prevent defects. SPC was pioneered by W. A. Shewhart in the early 1920s. In 1939, he created the basis for the control chart and the concept of a state of statistical control, through carefully designed experiments. He discovered that some process variation in manufacturing data is natural to the process, while others display uncontrolled variation that is not present in the process causal system. W. E. Deming later applied SPC methods in the US during the World War II, thereby, successfully improving the quality in the manufacturing of munitions and other strategically important products. Deming also introduced SPC methods to Japanese industries after the war.

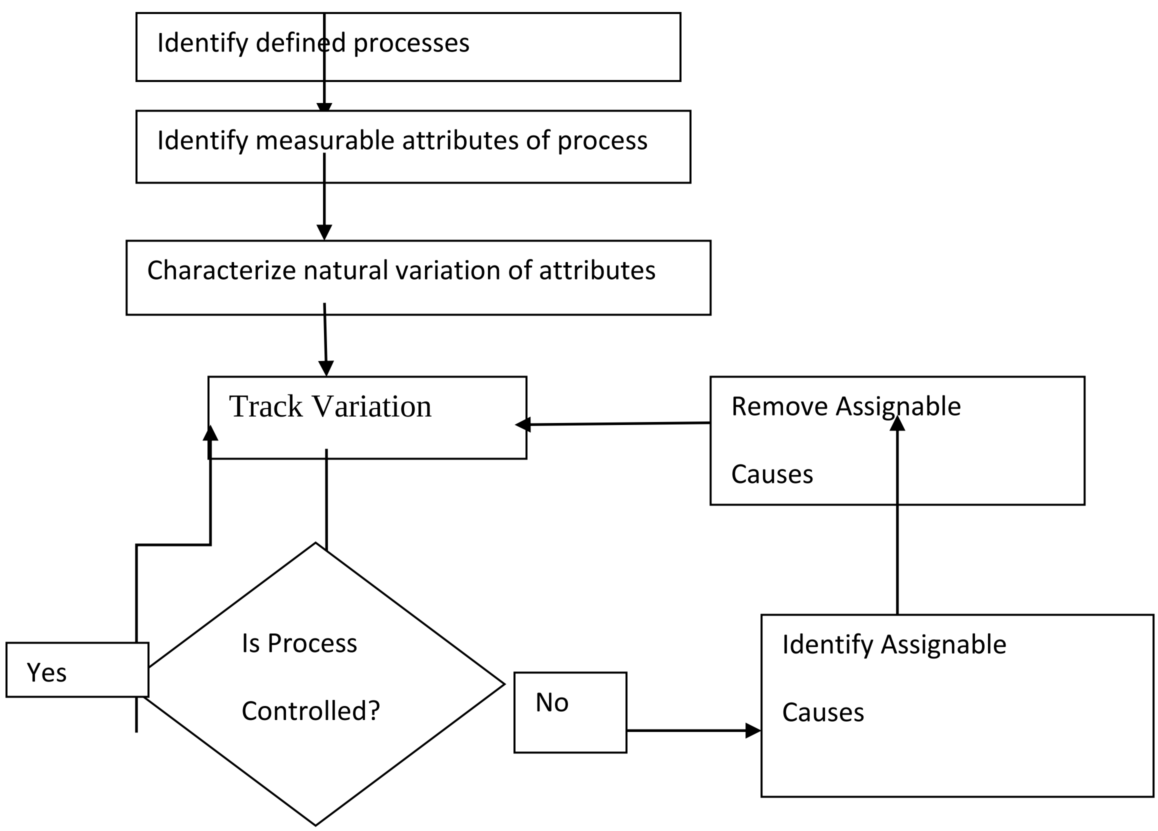


Fig 2.1 Steps in SPC Implementation

The methods were practiced by many manufacturing and service organizations. Sultana F. et al. tried to show machine breakdown frequencies and time duration of making cigarettes, as well as the major causes of those breakdowns by using SPC. Semel F. J. et al. indicated implications, not only to manufacturing and quality but also to research programs and product development. Statistical Process Control (SPC) is the application of statistical methods to monitoring and control of a process to ensure that it operates at its full potential to produce a conforming product. Under SPC, a process is monitored so that it behaves predictably to produce as much conforming product as possible with least possible waste. Key tools in SPC are control charts, continuous improvement and design experiments.

Variations in the process that may affect the quality of the product can be detected and corrected, thus reducing waste as well as the likelihood that problems will be passed on to the customer. .When a process is considered out of control, an alarm is raised, so that engineers look for assignable causes of variation and try to eliminate them. It is more effective to take a proactive approach to prevent the occurrence of out of control situations allowing the process to be adjusted in a preventive way so that fewer non-conforming items will be produced.

2.3.6Application of Statistical Process Control Implementations Tools in the Manufacturing Company

B. Barbosa, M. T. Pereira, F. J. G. Silva, R. D. S. G. Campilho (27-30 June 2017) Solving quality problems in Tyre production preparation process: a practical approach,: This work was carried out at Continental Tyre factory in Portugal, regarding the APEX machines production process, with the main goal of improving of their performance and product quality rate. Main possible causes of defect generation were identified and proposals to enhance the functioning of the bead APEX production process were also carried out. By applying Six Sigma, variables that influence the quality of the production were identified. DMAIC cycle (Define, Measure, Analyze, Improve and Control) was applied in the process analysis, enabling a structured analysis and the identification of different causes that negatively affect the process studied and consequently allowed the identification of opportunities for improvement. With the help of the DMAIC method, a series of experiments were developed in order to achieve improvements in product quality rate and process control and stabilization.

Harsimran Singh, Harsimran Jeet Singh Sidhu , Amandeep singh Bains**,** May-2016: Implementation of Statistical Process Control Tool in an Automobile Manufacturing unit. In this paper, an attempt has been made to implement the some statistical process control (SPC) techniques in the industry that is offering its customers the widest and latest range of sealing solutions for various applications in the automotive industry. The power of SPC lies in the ability to examine a process and the sources of variation in that process, using tools that give weight age to objective analysis over subjective opinions and that allow the strength of each source to be determined numerically. Only two main techniques i.e. cause and effect diagram and control charts are implemented in this industry out of seven SPC techniques. It is found that after implementing tools to remove the root causes, the percentage rejection is reduced from 9.1% to 5% and reduction in cost is achieved.

Tesfaye Gebrehanna Anfwatte (June 2018 Addis Ababa, Ethiopia), ORGANIZATIONAL PERFORMANCE AND CHALLENGES OF TYRE MANUFACTURING IN ETHIOPIA: THE CASE OF HORIZON ADDIS TYRE FACTORY: The general objective of the study is to investigate its performance and challenges through mapping its value chain for better understanding of the process and evaluate the performance as well as bottlenecks. Data is collected using a multiple of approaches. Desktop data was mined, survey was conducted on 385 respondents, observation was made to understand and map out the tyre production process, seven detailed key informant interviews were carried out. Data were analyzed both in descriptive and econometric applications, i.e., descriptive analyses were made about performance and performance measurements while econometric analysis (i.e., ordinal logistic regression) is used to identify the determinants of customers' satisfaction. In terms of results, the production value-chain map was developed where three grand stages and ten-specific sub processes were indentified. The company is extremely dependent on the imported raw materials where about 98% raw materials and technology were imported with a value of 317 million - 716 million Birr annually. In terms of capacity utilization, in all three production process sections, the company is performing below 40% which is much below the target due to foreign currency scarcity. In terms of financial performance indicators, it is performing with 12.1-33.4% (ROI), 11.4-23.3% (ROS), and 14.1-29.8 (GPM). In terms of market share, it covers 14.97% and of customer satisfaction, the result depicted that 35.4% and 58.7% were very satisfied and satisfied respectively. With regard to the determinants of customer satisfaction, the product related attributes (i.e. 'important'), such as design, raw material, price, sales and after sales services and most importantly price significantly contribute to the satisfaction of customers at

5% level of significance. Moreover, customers' level of education has a significantly positive relationship with level of customer satisfaction at 5% level of significance. Finally, durability of the product has a strong positive effect upon the satisfaction level of customers with 5% level of significance. To conclude, although Horizon Addis is producing strategically vital product, its operational performance is far much below both from its target and from the demand of the product at domestic market. The company is under a number of operational and managerial intricacies which require serious attention both from the owners and government so that the company plays its role both in fulfilling the domestic tyre demand and in saving the country's economy which is already struck by the most serious hard currency deficit in the economic history of Ethiopia.

Yonatan Mengesha Awaj, Ajit Pal Singh and WassihunYimer Amedie (January 2013) QUALITY IMPROVEMENT USING STATISTICAL PROCESS CONTROL TOOLS IN GLASS BOTTLES MANUFACTURING COMPANY: **(2013)** has been investigated SPC tools in the production processing in order to reduce defects by identifying occurrence of highest waste in the bottle and glass manufacturing industry established in 1973 located in Addis Ababa, Ethiopia, Africa. Through SPC tools monitoring of the process centre can be done by collecting data from samples at various points within the process. Thus, SPC will be able to reduce the probability of passing problems to the customers. Pareto charts helps to prioritize efforts and pays attention on most pressing problems and Fish bone diagram leads to the root cause of the problem. Five major defects have been identified but focus is given only on pressure failure and blister defects. Through these techniques 572 glass bottles were saved per month from pressure failure and 11 glass bottles were saved from blister defects. These various SPC tools like Brainstorming, control chart, Pareto chart and fish bone diagram provided. Useful information in identifying major defects which can be categorized in to material, machine, human factor machine setup and operation. The company also lacks the ongoing education and training of management and line staff on SPC tools. The furnace is being bottle neck for the individual section machine, moulds overused and get worn out and operates need training to skill-ful in machine setting and operation control. Company should effectively use SPC tools or productivity improvement.

The principal aim of the study is to create awareness to quality team how to use SPC tools in the problem analysis, especially to train quality team on how to held an effective brainstorming session, and exploit these data in cause-and-effect diagram construction, Pareto analysis and control chart construction. The major causes of nonconformities and root causes of the quality problems were specified, and possible remedies were proposed. Although the company has many constraints to implement all suggestion for improvement within short period of time, the company recognized that the suggestion will provide significant productivity improvement in the long run Farzana Sultana, Nahid Islam Razive and Abdullahil Azeem (IMPLEMENTATION OF STATISTICAL PROCESS CONTROL (SPC) FOR MANUFACTURING PERFORMANCE IMPROVEMENT):This paper intends to combine the Hourly Data System (HDS) and Statistical Process Control (SPC) practices to improve manufacturing performances in manufacturing companies.

Maruf Ariyo Raheem, Aramide Titilayo Gbolahan and Itohowo Eseme Udoada (2016) Application of Statistical Process Control in a Production Process: This study evaluates the process of production of Champion Breweries Plc., located at Aka Offot, Uyo, and Akwa Ibom State Nigeria. The information on the following measurable characteristics used during production were obtained; Brilliance (Haze), pH, Original Gravity (O.G) and Alcohol Percentage. Information on the number of defective crates recorded for the period of fifteen (15) days on Amstel Malta were also obtained from the bottling section. Mean (X) and Range (*R)* control charts for variable were adopted to ascertain if the process with respect to each quality characteristics is statistically in control.

Đorđe Vukelić et al (2008), quotes that Statistical methods for quality evaluation provide analyses of production processes which can serve as the basis for undertaking adequate preventive and correction measures in order to increase the total production quality. In this paper, importance is emphasized for applying statistical quality control methods to evaluation of process stability and capability. There is a preview of structure and functioning of the developed applicative software for statistical process control. The author used X-bar and R chart to see the process stability (whether the manufacturing process is under control). The authors concludes that in order to achieve zero rejects it is necessary to continually monitor all process parameters, which, among other things, imply monitoring process stability, that is, measuring process capability.

Raj Kumar et al (2009) analyze the various factors important for total quality management implementation in various manufacturing organizations and to assess their relevance for Indian manufacturing organizations. For improving productivity and quality in any organization, the key techniques are based on quantitative data. The paper used statistical process control to check quality in the organizations and the author suggests employees trained in SQC to improve quality.

Maurizio Bevilacqua et al (2011), in their paper presents the application of a procedure for the quality control of stainless steel tubes produced for automotive exhaust systems from a leading company in the steel sector, based on the Delphi method. Statistical methods were used to monitor process compliance and capacity. The statistical methods used to monitor the process were mainly control charts. Dimensional data were acquired by non-destructive testing on diameters and X Bar-R charts were used to graphically represent the process state of control. Destructive tests were performed to monitor the welding quality and P-chart was used to assess the proportion of nonconforming units.

Rallabandi Srinivasu, Satyan arayana Reddy & Srikanth Reddy Rikkula (2011), discussed about the use of control chart techniques to improve the productivity and quality in an industry. Statistical Process Control (SPC) methods have been widely recognized as effective approaches for process monitoring and diagnosis. Statistical process control provides use of the statistical principals and techniques at every stage of the production. Statistical Process Control (SPC) aims to control quality characteristics on the methods, machine, products, equipment both for the company and operators with magnificent seven. Some simple techniques like the seven basic quality control (QC) tools provide a very valuable and cost effective way to meet these objectives. However, to make them successful as cost effective and problem solving tools, strong commitment from top management is required.

Laurence, Utama & Hanafi (2011), presented the application of statistical quality control technique in a furniture manufacturing company. This company produces a variety of wooden furniture, such as tables and chairs, to cater local and overseas customers. Based on initial observation, it was found that the product with the highest percentage of defects is the folding chairs. Statistical quality control technique was applied to ensure that the products meet the standard specified. This research identified five major defects based on the Pareto rules. Those defects are pin holes (26.03%), heart wood (22.5%), breakage (17.57%), cracks (17.57%) and discoloration (8.7%).

Fabio A. Fernandes, Sergio D. Sousa and Isabel Lopes (2013) has been studied to improve the level of quality through use of quality tools in a company producing leather components located in Portuguese for leather goods and is being installed. In this case a PDCA cycle is applied to trigger the use of quality tools in problem solving. The application of the Taguchi method to determine the optimum combination of factors of a station (together with other improvement actions) caused a 50% decrease of the most critical defective component and an overall reduction of 29% in the level of nonconformities in the preparation section. PDCA (Plan-Do-Check-Act). It is a four step management method use for controlling and improving processes and products. Quality tools and methods were applied at various stages for the reduction of non confirming components in the IG station. Through this technique helped to identify priority area to increase its quality level by putting the process under statistical control which resulted in reduction of non conformities to 50%. PDCA cycle showed that it is effective support for continuous improvement. Finally the methodology presented in detail can contribute for companies to start using quality tools efficiently.

According to Cao Jian (2004), Statistical Process Control (SPC) in the manufacture of injection mould consists of two main parts – SPC planning and SPC implementation. SPC planning involves defining and identifying SPC processes, forming and identifying part families, selecting data transformation methods, and selecting control charts with the main objective of develop a framework consisting of methods and procedures on SPC application in the manufacture of injection mould and the second objective is to analyze, summarize and generalize the characteristics of different mould parts and the different machining features on the parts and the manufacturing processes of the mould parts. SPC implementation involves collecting data, transforming data, plotting transformed data on control charts, analyzing and interpreting the charts and suggesting possible causes for out-of-control situations. As SPC implementation in the manufacture of mould is similar to other those used in manufacturing industries, which have been studied by other researchers.

Rallabandi Srinivasu, Satyan arayana Reddy & Srikanth Reddy Rikkula (2011), discussed about the use of control chart techniques to improve the productivity and quality in an industry. Statistical Process Control (SPC) methods have been widely recognized as effective approaches for process monitoring and diagnosis. Statistical process control provides use of the statistical principals and techniques at every stage of the production.

Ignatio Madanhire and Charles Mbohwa (2016) attempted to address in the literature of SPC implementation with the emphasis on early detection and prevention of the problems in the manufacturing industry based in Harare, Zimbabwe and investigated that there was need for the apparatus to be trained, gauges and machines. To achieve the purpose 7 SPC quality tools were utilized as a way to explore the natural variability of processes so that assignable causes can be eliminated such as Pareto analysis and Brainstorming are applied. After conducting detail study by applying SPC techniques which indicated that some of benefits of SPC include increase understanding between employee and processes. Employees ability to do trouble shooting and process diagnosis was improved which ultimately resulting in reduced cost of per unit of production and work efficiency.

Ľubica Simanová and Pavol Gejdos (2015) has been investigated that use of tools of operative quality management to prevent decrease in quality during operational processes and adhesive applications as well in the furniture manufacturing units. In addition to other tools they also use histogram and Ishikawa diagram frequently used to achieve quality. For evaluation of capability of processes, a list of process capability indexes was developed. The basic condition is that evaluated process must be in a statistically managed state. The information obtained from histogram and Ishikawa diagram played a vital role. From histogram an estimate of the position of the monitored quality feature, division shape, process changes and feasibility of processes can be determined a suitable method for finding positive factors i.e. Brainstorming. From the results obtained it can be concluded that illustration of using specific tools of various process of furniture production and implementation in the identification process capability resulted in improve quality, competitiveness and performance of businesses.

B. Krishn akumar, the Hindu Business line (2003) presented that the pick-up in the automobile production and the improvement in economic fundamentals has had a positive impact on the financial performance of the Tyre companies. Taking into account the recent developments such as cut in excise duty, soft trend in input cost and the appreciation of the rupee, Goodyear's performance could improve in the near term. Risk-seeking investors with a slightly long-term orientation could take limited equity exposure in the company at the current level of `42. Goodyear India has a strong presence in the passenger car and tractor Tyre segments.

A bulk of its income flows from the original equipment market. It has also taken efforts to gain a better presence in the replacement market. The slowdown in the automobile sector, in general, and the tractor segment, in particular, has affected the company's financial performance in the past few years.

Rallabandi Srinivasu, Satyan arayana Reddy & Srikanth Reddy Rikkula (2011), discussed about the use of control chart techniques to improve the productivity and quality in an industry. Statistical Process Control (SPC) methods have been widely recognized as effective approaches for process monitoring and diagnosis. Statistical process control provides use of the statistical principals and techniques at every stage of the production. Statistical Process Control (SPC) aims to control quality characteristics on the methods, machine, products, equipment both for the company and operators with magnificent seven. Some simple techniques like the seven basic quality control (QC) tools provide a very valuable and cost effective way to meet these objectives. However, to make them successful as cost effective and problem solving tools, strong commitment from top management is required.

Madanhire and C Mbohwa (2016): Statistical Process Control (SPC) Application in a Manufacturing Firm to Improve Cost Effectiveness. This study investigated the use of the statistical process control (SPC) as a tool in a manufacturing firm to improve quality and cost effectiveness. With emphasis on early detection and prevention of the problems, SPC was shown to have a distinct advantage over other quality methods such as inspection of final products. There was need to check gauges and machines, and determine need for some maintenance or overhaul work to be carried out as faulty machines could not produce expected quality products. There was need for operators to be trained, new documents to be produced and actions for the future to be agreed on. There was a need for reviewing the operations and monitoring key equipment for retooling or adjustment to achieve required levels of plant performance.

Pranay S. Parmar, Vivek A. Deshpande (Nov 2014), Implementation of Statistical Process Control Techniques in Industry: Excessive variability in process performance often results in waste and rework. For improvement in quality and productivity process variation needs to be reduced. For this Statistical Process Control techniques are used. SPC uses statistics to detect variations in the process so that it can be controlled. Control charts are used in SPC for measuring the variation in the process and that can be continuously improved by the different techniques used in the SPC such as 7 QC tools. This paper shows applicability of the statistical process control techniques in different manufacturing industries. In this research paper various research articles and the case studies on the implementation of the Statistical Process Control Techniques in the manufacturing industries are selected for the review.

Logan-Lee Miché Appollis (December 2019) An Implementation Framework for Statistical Process Control in Small to Medium-sized Enterprises: A South African Context: The implementation of Statistical Process Control (SPC) is driven by the desire to be more proactive as the re-activeness of an inspection-based quality control system is unreliable, costly and time-consuming. SPC is commonly overlooked due to a lack of awareness of the potential benefits and it commonly fails due to an unclear objective and ill-constructed implementation plan. This study is an intervention which surveys existing SPC implementation publications. The study identifies strengths and weaknesses of existing published literature, highlighting key areas of SPC implementation. The study further focuses on the organizational and methodological critical success factors (CSFs), which would be relevant to South African small to medium-sized enterprises (SMEs), utilizing the identified CSFs and deficiencies to develop a framework for the sustainable and effective implementation of SPC in manufacturing SMEs. The research methodology consists of three phases, which are the literature review, framework development and the validation of the framework as a case study using participatory action research. The literature survey was performed as a random literature survey coupled with a systematic literature review of SPC implementation frameworks. The research branches into implementation strategies and methodologies used for other continuous improvement initiatives. According to the reviewed frameworks the most commonly identified gaps are a lack of focus on: (1) measurement system capability; (2) process prioritization; (3) Identification of critical to quality characteristics; (4) training and education; (5) validation of the framework; (6) step-by-step procedure with a logical flow and (7) problem-solving.

A total of 81% of the articles mentioned training and education as a critical success factor, and 69% of the same reviewed articles also mentioned management commitment as a critical success factor, in contrast to the 13% which mentioned statistical thinking. This study contributes to the domain of quality management and continuous improvement by addressing a tangible issue in a specific manufacturing organization in which a previous attempt on implementing SPC failed. The study addresses the lack of substance, which current literature offers regarding strategic approaches on the implementation of SPC in smaller organizations with limited resources. The application of SPC demands organizational and behavioural changes and it is important the dialogue and integration between management and operators aiming exchange of information and learning for the successful use of control charts. It indicates the need for consideration of factors that transcend the technical aspects of implementation (Grigg & Walls, 2007a). The application of statistical quality control techniques have widely been applied in all the manufacturing industries.

However, the research felt that not much work has been carried out in paper industry where there is a possibility of applying statistical techniques to control quality at the time production itself. Also the researcher felt that the statistical quality control tools were deployed at primary level and not much application has been carried out with techniques like cumulative sum chart and multivariate chart. Hence the researcher decided to carry out a research in paper industry on the application of these tools to control quality at the time of production.

Quality improvement using statistical process control tools in glass bottling manufacturing company (Awaj et al., 2013)Awaj, Singh and Amedie (2013) pursued the implementation of SPC in a glass bottle manufacturing company. The focus on waste reduction by minimizing the manufacturing of defective products. The study also aimed at raising awareness and coaching employees in problem-solving and SPC tools. The study entailed the observation and evaluation of the production line and its employees. The product of this study does not have a clear cut implementation Framework; however the steps applied in order to reduce process variation and eliminate unnecessary manufacturing waste were clearly explained. The company implemented three SPC tools in order to reduce the manufacturing of defective material. A case of implementing SPC In a pulp mill (Rantamäki et al., 2013) Rantamaki, Tianinen and Kässie (2013) developed a guideline to operation-aliz SPC in a pulp mill production unit. The aim of the study was to highlight special SPC requirements in this specific industry. The SPC initiative was implemented as a case study in a pulp manufacturing company.

The initiative was pursued as part of the company's strategic plan to change from focusing on internal efficiency to being customer-driven, therefore the significance of manufacturing consistent compliant products. The control philosophy of the pulp mill was supported by a fully automated control system. The plant is operational for twenty-four hours a day, seven days a week and only shuts down for maintenance at planned intervals during the year. The automated control system could however not recognize assignable cause variation nor address the variation. Human intervention was required to restore the process back to its natural state.

2.3.7 Key ingredients for the successful introduction of SPC

Mason, Ben & Jiju Antony (2000), attempts to remove the myth that SPC is concerned only with control charting of processes. The engineers should be made fully aware of the necessary ingredients mentioned for successful SPC implementation. A suggestion for the teaching of such quality improvement techniques is to review the successful case studies of SPC implementation. A major issue addressed by this paper is the need for a systematic and practical methodology (i.e. where to start and how to perform an SPC study in an organized manner) for the implementation of SPC in industry. William Woodall (2000), states that Statistical process control (SPC) methods are widely used to monitor and improve manufacturing processes and service operations. Disputes over the theory and application of these methods are frequent and often very intense. In order to effectively apply SPC in any organization, it is important to understand the essential ingredients that will make the application successful. Bird and Dale (1994) have identified three key factors for the successful introduction of SPC: a capable measurement system, proper training and management commitment. Xie and Goh (1999) recently identified three important aspects of SPC as a technique for continuous improvement.

These are management aspects (such as management commitment, team working, training, etc.), human aspects (such as resistance to change, conflict between the operator and computer) and operational aspects (such as tools of SPC, process prioritizations, corrective action procedures, etc.). However, a recent study carried out by one of the authors of this paper (Mason and Antony, 2000) found that the only thing taught to engineering students within many UK academic institutions in relation to SPC is control charting of processes. Very little, if any, time is spent on management and implementation aspects of SPC. It is important to teach engineers and managers the key ingredients which will make SPC successful. These key ingredients are as follows.

1. Management commitment and support

Management commitment and support are essential for the resolution of common and special causes of variation. SPC cannot succeed unless management is prepared to establish a responsive environment (i.e. an ability to take corrective action). According to Robinson et al. (2000), until it becomes apparent to all employees that the SPC project is important to the management, it is very difficult to achieve coordinated efforts. It is highly desirable for managers to understand the importance of SPC as a variation reduction technique and therefore the concept and the underlying principles of SPC must be taught to senior managers within the organization.

Management should provide adequate budget and resources for improvement actions which lead to continuous improvement of product/process quality. They should also be prepared to address any resistance to change that might be present within the organization, plus any fear of training or reluctance to embrace the SPC technique.

2. Training and education for SPC

All relevant members of the organization should go through training and education programmed on SPC from an SPC facilitator. The facilitator should play a vital role in the establishment and continuous success of SPC in the organization. According to Dale and Shaw (1989), companies who appoint an SPC facilitator are less likely to experience difficulties with the introduction and application of SPC. The facilitator should be able to provide guidance and advice on all technical and statistical aspects of SPC. Training should start with the senior management team and it should then be cascaded down through the organizational hierarchy.

Training should include exposure to relevant statistics, creation of control charts, interpretation of control charts, and the appreciation of the reasons and benefits of SPC (using successful case studies from similar organizations). Companies engaged in a Six Sigma implementation programmed (e.g. Motorola, Allied Signal and General Electric) allocate to the Master Black-Belt the initial facilitation of SPC involving top management (usually the process' champions), middle management (usually the process' owners) and the implementation teams (usually the supporting functions and/or the shop-floor operators) (Harry, 1994). It is important to note that training should not just be short term but on a long-term basis, with regular training follow-ups and briefings (Oakland, 1999).

3. Teamwork

Teamwork plays a vital role in SPC and can be fostered through better communication across various departments. This is because inputs from all relevant parts of the process are necessary in order to implement changes on complex systems. Moreover, teams contain diverse talents, experience, skills and knowledge from various participants, which is an added advantage in any problem solving activity. For the effective application of SPC in organizations, it is good practice to have an SPC steering committee and process action teams (Does et al., 1997). Top management should delegate to the steering committee (consisting, say, of the SPC facilitator (who may be an external SPC consultant), quality manager, production manager, process manager, maintenance manager and purchasing manager) the initiation, control and management of the implementation process of SPC.

A process action team (consisting of operators, their supervisor, a process engineer, quality, engineer production engineer and maintenance engineer) is responsible for bringing their specific process into a state of statistical control by eliminating assignable causes of variation present in the process. The process engineer with technical responsibility for the process can lead the process action team.

4. Process prioritization and definition

It is important to prioritize all processes according to their importance with respect to the quality of the finished product. Goh et al. (1998) recommend a very powerful approach for prioritizing processes in complicated production systems prior to implementing SPC.

They suggest a preliminary selection of key processes from a larger number of processes based on statistical and technical criticality. This should be followed by the use of a powerful method called analytic hierarchy process (AHP) based on pair-wise comparisons between several factors in deciding the relative criticality of the processes in a hierarchy structure. The pair wise comparison judgments are finally translated into numbers using Saaty’s eigenvector weighting methods (Saaty, 1980). Process prioritization will assist management in identifying processes with higher priority and provide guidance on where to allocate the limited economic resources and manpower for continuous improvement of process and product quality.

Once a process which needs to be studied is identified, the next immediate step is to define the process in terms of its relationship with other operations, both upstream and downstream, in terms of process elements (people, machines, materials, equipment and environment) that affect it at each stage. It is advisable to use process flow charts and cause and effect diagrams to make these relationships more visible.

5. Selection of appropriate quality characteristics (or process variables)

It is important to select the most critical characteristics of the process which are most promising for process improvement. It is good practice to select quality characteristics that can be measured precisely, accurately and with stability (Antony, 1997). Quality characteristics can be any of the following types (Antony and Kaye, 1999): smaller-the-better quality characteristics (e.g. tool wear, surface roughness, response time to customer complaints, etc.); larger-the-better quality characteristics (e.g. pull strength, life of components, engine efficiency, etc.); Target-the-best quality characteristics (e.g. dimensions such as diameter, thickness, width, weight, density, etc.); attribute quality characteristics (defective/non-defective, good/bad, pass/ fail, etc.). It is also possible to take advantage of relationships between quality characteristics.

If a particular characteristic is difficult to measure (say, volume), then it is often possible to identify a correlated characteristic that is easier to measure (e.g. weight)

6. Define the measurement system

In some, even simple, measurement processes, there can be a great deal of variation. This may be due to the effect of the operator (and his/her skills and experience), the part being measured, the measuring instrument used and also the interactions among them.

It is essential to ensure the accuracy of measurement to minimize the potential errors in the data. Gauge repeatability and reproducibility (GRR) studies are a recognized means of measuring the variation gauge (Wheeler and Lyday, 1989). Here gauge repeatability is the variation in measurements obtained when one operator uses the same gauge several times to measure the identical characteristic on the same part. Reproducibility, on the other hand, is the variation in measurements. Obtained when several operators use the same gauge to measure the identical characteristic on the same part. If measurement is not found to be within acceptable limits, SPC should then be deferred.

7. Selection of control charts

A control chart is a powerful tool for identifying out-of-control situations in the presence of assignable or special causes of variation. It is a simple graph with two axes, the horizontal axis represents time; the vertical axis represents the quality characteristic of interest (Caulcutt, 1996a; 1996b). The selection of a control chart depends on the type of data we collect from the process. For example, if the data are variable, it is appropriate to use variable control charts (e.g. X-bar and R chart, X-bar and S chart, etc.). On the other hand, if the data are of an attribute nature, it is appropriate to use attribute charts (p-chart, c chart, Np-chart, etc.). It is generally advisable to choose variable measurements over attribute, as variable data provide more information and a better estimate of process capability than attribute data.

8. Cultural change

Use of SPC involves cultural change in the working environment. Human behavioural issues and resistance to change are crucial here. Operators, engineers and managers need to be aware of the benefits of SPC for continuous improvement of the quality of products and processes. Operators, who know their processes better than anybody, should be empowered to take corrective actions that are within their capability and authority. Here empowerment and ownership mean that workers have the opportunity to be recognized for their contribution and feel that they are an important part of the organization.

If a problem is out of the operator's capability and authority, then the process action team will be responsible for tackling it with the full support of management.

9. Use of pilot study

Organizations should not fall into the trap of trying to apply SPC in all departments (or processes) at the same time. Before any SPC implementation takes place, it is a good idea to carry out a pilot implementation. This gives an appreciation of the power of SPC to everyone in the organization, and helps the refinement of tools, techniques, training and the overall approach. SPC should therefore be applied in a prioritized manner, often starting with a single process.

Once SPC has been used successfully in one process, it is then easier to extend its use to other processes and areas. (Of course, it may be worthwhile to carry out a cost-benefit analysis to determine if it is actually financially beneficial to implement SPC.) Does et al. (1997) propose that, depending on the complexity and size of a process, a typical pilot implementation can take from three months to more than a year.

10. Use of computers and software packages

The use of computers in SPC has received much attention recently and will be extremely useful and helpful in the near future. The use of familiar and user-friendly computer software packages (e.g. companies can use Microsoft Excel to construct and analyze control charts) offers many advantages such as less time spent on mathematical calculations, easier storage and retrieval of data, and so on. Computer-based training schemes may be a promising and effective way of presenting SPC training material (Hewson et al., 1996). However, the application of computer software packages should only be allowed after the essential principles of SPC are understood and those involved have acquired control chart interpretation skills (Owen, 1993).(Key ingredients for the effective implementation of statistical process control Jiju Antony Alejandro Balbontin Tolga Taner 24 September 2014).

2.3.8 Results of Successful implementation of SPC

This research attempts to close the gap by developing an operator friendly system. The system is coordinated by a single SPC Champion. The coordinator will define the critical control metrics using statistics. The research will attempt to bridge the gap between practical implementation and theory by providing a step-by-step implementation framework for the implementation and support of SPC. Therefore, emphasis is placed on the steps leading up to the implementation of SPC.

If implemented successfully, SPC may:

- Increase process stability
- Minimize process variability
- Improve process performance

So, the results of successful implementation of SPC are:

Increase process stability, Minimize process variability and Improve process performance

The Pareto's 80/20 rule is used to identify the vital few processes, which control manufacture, and then build the planning around these key processes and products for quality control activities.

2.3.9 Advantages of SPC Implementation

SPC implementation is important as it could improve process performance by reducing product variability and improves production efficiency by decreasing scarp and rework. According to Attaran (2000), in their attempts to remain competitive, US business had embarked on TQM techniques such as SPC that leads to higher quality product by reducing-variability and defects; rework, failure, scrap, warranty claims and product recall costs, thus improving their overall business competitiveness (Booker, 2003). Most of the production and quality cost that SPC aims to minimize such as rework, lost of sales and litigation are measurable. The success and failure in SPC implementation does not depend on company size or resources, but it relies on appropriate planning and immediate actions taken by workers with regards to problem solving.

According to Benton (1991) and Talbot (2003), the advantages of implementing SPC could be Categorize into the following categories; maintain a desired degree of conformance to design, increase product quality, eliminate any unnecessary quality checks, reduce the percentage of defective parts purchased from vendors, reduce returns from customers, reduce scrap and rework rates, provide evidence of quality, enable trends to be spotted, ability to reduce costs and lead-times. In other words, SPC implementation can also help to accomplish and attain a consistency of products that meet customer's specifications and thus fulfil their expectations. In general, SPC can be used to monitor the natural variation of a process and minimize the deviation from a target value and thus play a major role in process improvement.

2.3.10 Critical Success Factors for SPC implementation

One key and often mentioned reason for lack of success and failed SPC implementation program is lack of proper implementation. The implementation aspects are not only cover the technical side of SPC, but, it must also focus on management aspects as well. Gordon et. al. (1994) argued that managers must be able to identify the technological and management factors that are linked to the success of a quality improvement program. Xie and Goh (1999) identified three main aspects as a holistic approach for effective SPC initiatives: The management side, the human side and operational side of SPC. Mason and Antony (2001) identified four essential areas that will make SPC program successful: management issues, engineering skills, statistical skills and teamwork skills. A review of literature revealed that most studies are focused mainly on identifying factors that affect the success of SPC program. This study attempts to fill the gap by examining the relationship between the implementation factors and quality and firm performance.

By identifying the significant critical factors that influence the quality and firm performance, this study will enable the SPC practitioners to focus on limited resources to the SPC initiatives for the maximum benefits.

There are complex and numerous factors affecting the SPC implementation. These factors are prerequisites for the creation of an environment favourable for the SPC use. The CSF conduction failure may lead to issues associated with the implementation, maintenance and continuity of the program (Antony et al., 2000; Lim et al., 2014; Rohani et al., 2010; Woodall & Montgomery, 1999). There are two important aspects associated with SPC implementation: the managerial aspect, also called organizational; and the technical or operational aspects (Does et al., 1997; Mason & Antony, 2000; Elg et al., 2008; Putri & Yusuf, 2008; Rohani et al., 2009; Rohani et al., 2010; Xie & Goh, 1999). These two aspects of SPC implementation were taken into consideration in the analysis conducted in the current study. The CSF can be classified as a managerial or technical factor, and it enables analyzing these two aspects. The technical impairments prevent the application of statistical concepts and tools. The greatest challenge is to eliminate the barriers people face when they deal with such tools. This goal can be achieved through continuous SPC training (Elg et al., 2008; Lim et al., 2014; Mason & Antony, 2000).

From an organizational viewpoint, it is quite difficult to have the whole organization committed with the program, but such commitment is accomplished through top management support (Elg et al., 2008; Lim et al., 2014).Many studies (Fryer et al., 2007; Lee, 2004; Marin-Garcia at al., 2008) have focused on identifying CSF through Continuous Improvement (CI) activities. The authors also emphasize the importance of management aspects such as senior management support and of technical aspects, such as training for CI implementation and maintenance.

Despite the fact that SPC is considered a CI form (Mason & Antony, 2000; Grigg & Walls, 2007b).

A Systematic Literature Review (SLR) was conducted to define the procedures in order to impartially identify, analyze and interpret the available evidences related to a particular topic, research question or phenomenon of interest, which can be replicable and evidence-based to create generalizations (Biolchini et al., 2007; Brereton et al., 2007; Tranfield et al., 2003). The following search string was adopted to identify critical factors in the literature: "statistical process control" or "SPC" or "control chart", and "critical success factors" or "success factors".

The factors that affect the implementation of the SPC are complex and numerous (Rohani et al., 2010) and can be called Critical Success Factors (CSF). If there is a better control over these factors, the chance of success in the implementation of SPC is higher (Gordon et al., 1994; Elg et al., 2008; Rohani et al., 2010).

The implementation of the SPC involves technical factors and organizational factors, both are considered critical for successful implementation (Does et al., 1997; Elg et al., 2008). Xie & Goh (1999) emphasize an holistic approach to the implementation of SPC, based on three basis: the first, related to the SPC Management, which involves issues such as the role of senior management, focus on Continuous Improvement, training and teamwork; the second, related to the human factor, which presents resistance to change issues, difficulties with the use of computer technologies and the need for incentives; the third, focuses on the implementation of the SPC, including the use of appropriate tools for monitoring the process.

Although SPC is superficially a simple technique, the application is a more complex issue (Antony et al., 2000). The main reasons for failures in implementing are related to: organizational and social factors (Does et al., 1997); lack of senior management commitment (Antony et al., 2000); lack of training and understanding of SPC (Does et al., 1997; Antony et al., 2000); decreased attention after the introduction (Does et al., 1997) and the lack of understanding of the potential benefits of the SPC (Mason & Antony, 2000).

SPC implementation does not only refer to the sequence of actions to build the control charts and interpret the process is under control. The implementation is also related to social, environmental, technical and cultural factors that will make sure that the use of these charts is integrated into the routine process. For the analysis of critical success factors for SPC, a Systematic Literature Review (SLR) was held to identify the publications that address these factors.

The three most cited factors are related to SPC management, the first one is the "Commitment and senior management responsibility". Which is related to support the implementation with financial, human resources and training and is related to the second factor, "Education and training in SPC", the training in concepts and techniques needs resources and senior management support, and it was appointed as CSF.

The third CSF is "Team work", for SPC implementation is important to have a specific working group with leaders, a board of directors committee and an operational team to lead, coordinate and carry out the implementation.

The fourth and fifth CSF is related to technical aspects of the SPC implementation; "Identification and measurement of critical product characteristics", which involves identification and measurement of characteristics that impact the client and generate significant quality problems.

The sixth CSF is "Cultural change and communication", this factor considers that behavioural and resistance to change issues must be considered; operators, engineers and managers need to be aware of the benefits of the SPC for the continuous improvement of products and processes and to base its actions on facts and data.

The seventh and eighth factors are also technical: "Measurement system analysis in relation to its capability and applicability" (process of measuring the quality characteristics must be analyzed considering the effect of the inspector, the measuring instrument and the interactions between these factors).

The problems faced in implementation are also related to CSF: it needs to invest time, money and training in the implementation of the SPC (Does et al., 1997); it needs constant attention and Senior Management support.

It is important the effective use and correct interpretation of control charts; it must overcome the difficulties in the use of statistics to build the chart, understanding and identification of corrective actions; it is important to plan for the implementation of the SPC and the management after implementation. (From Success factors in the implementation of statistical process control: action research in a chemical plant by Jose Carlos de Toledo, Fabiane Letícia Lizarelli, and Manoel Bispo Santana Junior)

Critical Success Factors (CSF), also known as key success factors, were first proposed by Daniel (1961) and popularized by Rockart (1979) in the study of the information systems. The CSF approach has been widely adopted and used in a variety of field of study to determine key factors which are essential to the success of any program or technique.

In SPC study, Rungasamyet. al. (2002) was among the pioneer to use the word to identify CSF for SPC implementation in UK small and medium enterprises.

Gordon et. al. (1994) was among the first researcher to study the SPC implementation issues. They identified specific management factors or activities associated with successful implementation of SPC such as higher management commitment, the structure of SPC training, the involvement of workers in decision making process and job security issues.

Rungfusanathart. al. (1997) described the process and outcome of developing a measurement instrument that operation-alize the 14 dimensions underlying the SPC implementation/practice construct. The results of their study provided some evidence and insights into how the SPC implementation/practice construct might be measured in organizational setting. Rungtusnathart's 14 dimensions included managerial action, control chart usage, critical measurement, measurement technology, operator visibility, verification of control charting, control chart information, sampling ,strategy, training, technical support, quality improvement team, absence of final Inspection, update process knowledge and audit and revision. The missing components identified in their 14 dimensions are culture issue, pilot project and use of computer. Xie and Goh (1999) identified three main aspects, namely, management aspects, human aspects and operational aspects to be very crucial for the successful implementation of SPC. Bird and Dale (1994) identified three key factors, namely, capable measurement systems, training and management commitment for effective SPC implementation. In their empirical investigation of defining and operation-alzing the questions of “what does the implementation and practice of SPC entail [within organizations]?".

Delerydet. al. (1999a; 1999b) conducted process capability implementation at nine Swedish organizations. They identified factors such as management support, show potential of process capability study, conscious data gathering, educational efforts, and cross-functional teams, routine of process capability study awareness and willing to change, pilot projects and use of computer can lead to successful implementation. Although this research is focused on SPC implementation, the authors felt that some of the factors are really very much relevant to any statistical based quality improvement methods such as SPC. They also suggested process capability successful implementation model or approach includes factors, deployment and results.

The most comprehensive and detail studies of identifying SPC critical success factors for SPC implementation was done by Antony et. al. (2001), Antony et. al. (2000), Rungasamyet. al. Q002) and Antony and Taner (2003). Antony identified and discussed the key ingredients for the successful implementation of SPC in both manufacturing and service organizations.

They identified 10 key ingredients which are as follows: management commitment and support, process prioritization and definition, selection of appropriate characteristics, define system devices, selection of control charts, training and education, team work cultural change and use of computer and software packages. In their continuing study on the deployment of SPC, Antony and Taner (2003) reviewed and compared four existing SPC implementation frameworks and proposed their conceptual framework for the successful introduction and application of SPC program in organization.

Grigg QO04) described and categorized the success of SPC implementation will depend upon a number of factors, both external and internal to organizations. He defined the external factors as the factors that organizations could obtain from various outside sources such as available advice and information, external bench marking, network participation, customer support and competitive pressure experienced by the supplier. He then defined the internal factors that are essential to SPC success which include technical/quality manager, quality systems, management commitment, training, teams, and self-assessment against an excellence model, facility size, and technology level and process/product relevance.

Phtynthhanilkumaran and Zailani (2008) studied the factors influencing the success of SPC projects in the Malaysian firms in the northern region. Most of their factors are adopted based on the study done by Mason and Antony (2000), but included additional factors such as role of quality department communication and culture.

Success factors are as follows:

l. Top management commitment 2. Teamwork 3. SPC Training and Education

4. Control charts 5. Identification of process/product characteristics

6. Process prioritization and identification 7. Measurement systems analysis

8. Pilot project 9. Use of SPC facilitators 10. Cultural change

11. Deployment. Most of these factors are adopted and adapted based on the study by Antony et. al. (2001), Antony et. al.(2000), Rungasarny et. al. Q002) and Delerydet. al. (1999).Jose Carlos de Toledo, Fabiane Letícia Lizarelli, Manoel Bispo Santana Junior, Success factors in the implementation of statistical process control: action research in a chemical plant: Despite the Statistical Process Control (SPC) be extensively explored in the literature, there are still difficulties in the implementation and maintenance, usually due to lack of attention to Critical Success Factors (CSF). This paper identified by literature review, critical factors that contribute to the success of the SPC and through an action research was implemented a control chart in a chemical plant using these factors. The attention to CSF during planning, implementation and the discussion with the process team resulted in the implementation and acceptance of control charts by the operational teams of the company, with continuing indications of use.(From Success factors in the implementation of statistical process control: action research in a chemical plant by Jose Carlos de Toledo, Fabiane Letícia Lizarelli, and Manoel Bispo Santana Junior)

CHAPTER THREE

RESARCH DESIGN AND METHODS OF THE STUDY

This chapter outlines the methodology on how data and information relevant to the research were gathered and analysed in order to achieve the objectives of the study. It discusses the description of study procedures and the methods employed in the study. Areas covered include the research design, sources of data, instruments of data collection, population and sampling procedures, methods of data analysis, and ethical consideration. The variable of this research is quality improvement, in which the quality control problem is a problem that can't be measured directly and need detailed indicators to be measure clearly. Thus the problem of quality control is a latent variable. Latent variable is a formation variable or hidden variables that must be declared by using an indicator. Another name for the latent variable is a factor, construct, or unobserved variable. The indicators regarding quality control in this study is the number of defective products, the number of samples. In this study, data related to the process of the product and the main reason that makes the defects would be collected. The research is descriptive by its nature since different defect can be counted and recorded for further analysis.

3.1 Research Approach or Instruments of data collection

Literature Studies, Questionnaires, interviews and direct observations are mentioned as the most important means of data collection tools (Kothari, 1985). In this study, Primary data will be collected through semi structured interviews and open ended and close ended Questionnaires. Secondary data will be collected through Internet and different Web-site. In this study, basic questions like to what are the success factors are present in successful implementation of Statistical Process Control in achieving quality and profitability? Be raised and analyzed to understand whether there is a gap between the target value and the planned process output. To asses and identify the role of Statistical Process Control in achieving Quality and Cost, a descriptive research design will be employed and hence both qualitative and quantitative methods will be applied in collection and analysis of data. The source of data will be primary and secondary through designing open ended, five point linker scale questioners and structured and unstructured interview question. Results of the findings will be presented both in qualitative and quantitative manner. The researcher collected data by administering a questionnaire and semi-structured interview questions. The questionnaire used structured questions, divided into three parts. Part I consisted of the demographical background of respondents.

Part II discusses about respondents' opinion on Statistical Process Control Implementation and Quality Improvement based on key dimensions questions to answer the research questions. Part Щ about the practice of Statistical Process Control. The Semi- structured interview questions were prepared for the researcher to collect the data through interview. Most of the structured questions were the open –ended and closed- ended type and respondents were asked to mark the appropriate box matching the correct answer. So as to collect the reliable and relevant data this research used open (oral) semi structured interview, self administered close ended questionnaires, direct observation of the industry, documentation review of previously recorded data and reviewing related literatures. These data collecting tools are chosen intentionally on the basis of their applicability to this research and considering their advantages and limitations as well. Therefore, reasons that the research intended to employ the above mentioned tools discussed clearly as follows.

3.1.1 Literature Studies

There was a need for a literature study since it was a necessity as a starting point of every research as a deductive approach. Reference books, E-Books, E-journals and Articles were our guidance to walk through that way.

3.1.2 Direct Observations

This method is used for collecting the required data and information from the selected industry. During direct observation, the researcher observed how the process was preceded and took the actual data directly from the observation. This was a means to evaluate the use of appropriate quality. The researcher conducted observation on factory production and production related departments' general environment.

3.1.3 Interview

Most information would be gathered by interviewing different employees. Quality manager, Production and Processing manager and responsible person will be participated in my thesis Questioning from the appropriate operators was really helpful since they were pretty familiar with the machine‘s details, parameters and problems.

For example, I interview with M/r Alemayahu Emiru, manager of Product Industrialization and Quality Assurance Department for answering some questions with interview about Horizon Addis Tyre Company and the topic that I was choose. It is verbal form of data gathering instrument. “Interview is a form of verbal questioning and it is a principal means of data gathering.

It is one of the most popular techniques in survey research” Robson, A, (1993).The research has used unstructured interviews to collect more detail information about the topic. It was employed to technical managers, quality department, production managers, to the operators, supervisors and with the others who were working in the area of production to evaluate the existing quality considerations and the practices and challenges faced in the implementation of quality improvement tools. And also the interview helped to determine the overall perception about the application of statistical process control.

3.1.4 Questionnaire

The researcher used opened and closed - ended questions prepared and presented for Statistical Process Control Supervisors and Quality Assurance manager, since they are able to read and understand the questions and reply in rating form. This is believed to produce quick and consistent result.

The questionnaires helped the researcher to gather the required data enabling the respondents to complete anonymously. In addition to this questionnaire was inexpensive to administer to many people, easy to compare and analyse and the researcher could get lots of data. The Questionnaire addressed the level of awareness, usage and experience of the selected manufacturing industry on quality control tools such as SPC methods as well as constraints/challenges of industry for introducing quality improvement tools. Accordingly the questionnaire was distributed for 55sample respondents but only 53 of them were returned.

3.2 Research Design

The design of the research is descriptive since it allows the collection of data through questionnaires on the bases of sample, which helps to find out the view of the population. The study will use mixed method of research design employing both quantitative and qualitative study techniques. According to Mark et al. (2009:101) mixing qualitative and quantitative approaches gives the potential to cover each method's weaknesses with strengths from the other method. It helps to collect data that could not be obtained by adopting a single method. Therefore, survey with questionnaires and semi-structured interview was employed so as to address the SPC implementation practices and challenges in respect to quality improvement. The semi structured interview was used to gather some information about the views of the quality managers and managing directors of the company.

3.3 Source of Data

The main sources of data for this research were both primary and secondary data. The choice of particular method of collecting data depends upon the purpose of collecting data, the information being collected, and the resources available for the researcher and the skills of the researcher (Kumar, 1996). Accordingly, the data for this study were collected from both primary and secondary sources. Self administered close ended questionnaire, semi structured interview, and focus group discussion was held to technical managers, quality department, production managers, and supervisors and with the others who are working in the area of production process and a direct observation were employed as a primary source of data gathering tools. Whereas the different work pieces such as; a company previous recorded data related to the proposed research title and other relevant literatures were considered as a secondary source of data and were reviewed.

3.3.1 Primary Data

In relation to this, Trochim (2003:179) argues that alternative forms are designed to be equivalent to the types of questions … that leads to the outcome. Likewise, Kothari (2006:266) describes that the collection of primary data is either through questionnaire or through interviews. For this study, the primary data have been collected directly from the sample respondents through the selected instruments discussed in the following sub-sections.

3.3.2 Secondary sources

Besides primary data, **s**econdary data were obtained from different books, newspapers, magazines, academic papers, reports, etc. In addition to these, authentic and reliable online scholarly written literatures were used to supplement the information.

3.4 Method of data Analysis and presentation

The study used both primary and secondary data. The primary data will be collected by using observation and interview. The secondary data will be collected from the Web-site and Internet. In this study, Primary data will be collected through semi structured interviews and open ended and close ended Questionnaires.

Both qualitative and quantitative data analysis techniques were used in the study for the understanding of the complete picture of the implementation of Statistical Process Control Implementation and Quality Improvement in Horizon Addis Tyre Company.

With respect to this, (Kumar,1999) stated that employing multiple data collection instruments help the researcher to combine, strengthen and amend some of inadequacies of the data. For quantitative analysis, Control Chart was used, and also for qualitative analysis descriptive statistics such as frequency and percentage were used to analyse the data obtained from questionnaire and interview. Accordingly, questionnaires were used as the main data gathering instruments whereas structure interview and document analysis were used to enrich the data obtained through questionnaire.

The PIQA department will be investigated by means of telephone and personal interviews with industry leaders and employees, and more site visits follow. The secondary data source will be brochures, internet, relevant books, work procedures and other documents.

When identifying the problems presence as implementing SPC Tools, I used different data analysis methods as gathering the important data. Since SPC Tools was one of the data analysis techniques. Then the data will be analysed using descriptive statistical methods like mean, median and percentages.

As long as the quantitative and qualitative data were required to be gathered, presented, analysed and interpreted, different ways of presenting data were used. For the presentation of the quantitative data control charts, tables and/ or diagrams were used. Whereas for presenting qualitative data the researchers summarize comments or responses in to X number of people commented that. In order to make the analysis and interpretation, the researcher explored key themes – what answers does it give to the research question? And identified what is surprising about the information, are there any ‘unplanned’ issues! Then discussed the interpretation of the finding sand linked it back to the terms of reference, the project objectives and the literature review.

3.5 Population and Sampling Technique

Employing convenient sampling technique, all the production staffs were chosen as respondents. So as per the information obtained from Horizon Addis Tyre Company implementing SPC Tools are a total of 55 employees are working mainly in the area of the production process. Therefore the researcher employed purposive convenient sampling method and all the production staffs were taken for the research. The study was used purposefully select population of professionals and management from Horizon Addis Tyre Company specially PIQA department. The selected professionals will include experts from management, senior technical staffs, production, quality control, logistics/ procurement, and research and development (R&D) departments. Proportional stratified random sampling technique will be employed to ensure representation from different functional departments. The study will include workers who can provide the expected information by using stratified sampling technique for data collection.Employing convenient sampling technique, all the production staffs were chosen as respondents. So as per the information obtained from Horizon Addis Tyre Company a total of 55 employees are working mainly in the area of the production process.

3.6 Sample size determination

A minimum of sample size 53 is needed for this study. Population refers to the group about whom the researcher wants to know more and from whom a sample will be drawn. This is often defined in terms of demography, geography, occasion time, etc. Though the total number of employees in the factory is more than **770,** the target population taken for this study is 55. This is because of SPC in Horizon Addis Tyre Company has implemented partially that means it is implemented for some sections of the factory such as in Bend wire and Steal lactic section, in Laboratory department, in Textile – Rubberizing cord, in Thread section, in Mixer or Compounding section and finally in the Building section. So, there is lack or shortage of experts and employees and then I take small size of population of samples.

CHAPTER FOUR:

DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.1 Introduction

The quantitative and qualitative data were collected and analysed using descriptive statistics and inferential statistics, as well as thematic and content analysis techniques, respectively. This chapter presents data from quantitative, qualitative, persistent observation and documentary analysis of Statistical Process Control implementation research framework. The first section is on demographic characteristics of the respondents. Section two presents and describes about the data on the implementation of Statistical Process Control. The third section examines the challenges encountered in the implementation of Statistical Process Control.

4.2 Background of the Organization

The Horizon Addis Tyre Company has used some of the "seven basic quality control tools" in their quality related problem solving technique. These are Pareto Chart and SPC tools. SPC seeks to maximize profit by the improving product quality, customer value and productivity, reducing waste and defects. Horizon Addis Tyre Company was established in 1970 G.C as state owned company with the help of the then Czechoslovakia government. It started production in 1972 G.C and produced 200 diagonal tires per day with the help of 7 Czechoslovakia experts. The company sold its 30% share to Japanese Yokohama Rubber Company in 1973 G.C and replaced 7 Czechoslovakia experts with 13 Japanese experts. The company incurred continuous loses in the following years and the government of Ethiopia suggested that the debt of the company has to be covered by Yokohama Rubber Company and the Ethiopian government. But Yokohama Rubber Company refused to cover the debt; therefore, the Ethiopian government covered all the debt so that the share of Yokohama Rubber Company decreased to 6%. July 8, 2004 G.C 61% of the share of the company is sold to Horizon Group. Horizon Group was composed of Horizon plantation and Matador Group. In January 2011 Horizon Plantation bought Matador Group's share and the name of the company has been changed to Horizon Addis Tyre Company. There are two types of tire in factory:

a. Diagonal tire b. Radial tire

Horizon Addis Tyre Product Ranges are:

1. Truck Bias Tyres 2. Light Truck Bias Tyres 3. Light Truck Radial Tyres 4. Passenger Car Bias Tyres 5 Passenger Car Radial Tyres.

4.2.1 Raw Materials

Rubber is the main raw material used in manufacturing Tyres, and both natural and synthetic rubbers are used. The other primary ingredients in tire rubber are carbon black, Zinc Oxide, Stearic acid, process aids, anti-ozone, anti-oxidants, curing accelerators and curing agent like Sulfur and others are also used.

As reinforcing fabric to support carrying load, nylon or polyester fabrics or steel cord is used. For anchoring the tire with the rim, bead wire which is made of copper coated steel is used. The company has defined procedure and specification for accepting of raw materials. As set standard, before purchase of raw material started, the suppliers is supposed to send its specification both product and technical specification for the review of Horizon Quality assurance team. Once spec is compared and confirmed compatible with the company standard, the supplier is requested to send adequate sample qty, which is also predefined one, for further laboratory test and analysis. After this approval process, supplier will be communicated to supply raw materials for further process test with purchase volume of 15days production run. It is after such long process that any supplier is shortlisted for future supply.

4.2.2 The Tyre Manufacturing Production Processes or Tyre Manufacturing Process in HATSC (Horizon Addis Tyre Company).

A Tyre is a strong, flexible rubber casing attached to the rim of a wheel. Tyres provide a gripping surface for traction and serve as a cushion for the wheels of a moving vehicle. Tyres are found on automobiles, trucks, buses, aircraft landing gear, tractors and other farm equipment, industrial vehicles such as forklifts, and common conveyances such as baby carriages, shopping carts, wheel chairs, bicycles, and motorcycles.

For the specific case **Horizon Addis Tyre manufacturing** operation is taken as an example and following descriptions of the process are derived from this company's context.

Horizon Addis Tire manufacturing plc is the sole tire producing in the nation which is certified both QMS and EMS in the 2015 new versions.

The company produces variety of Tyres from the range of three wheelers (Bajaj tires -8") to 38" big farm tires. It is established in 1972.Tyres for most vehicles are pneumatic; air is held under pressure inside the Tyre. Until recently, pneumatic tires had an inner tube to hold the air pressure, but now pneumatic Tyres are designed to form a pressure seal with the rim of the wheel.

The production of Tyre starts with the inspection and preparation of raw materials for the process. Once the raw materials are approved by the responsible department, after conducting of the required tests per the already agreed "**entry check**" test requirements for each item, materials will be released for production to the subsequent process operations. The first step in the tire manufacturing process is the mixing of raw materials—rubber, carbon black, sulfur, and other materials—to form the rubber compound.

After the rubber is prepared, it is sent to laboratory for test to ensure that mix has met the present standards both for process ability and product. Once these compounds are stamped ok, then they will be released to further process units such as tread extruding line for the making of tire tread, base tread and sidewalls, fabric coating both for the bead wires and reinforcing fabrics such as steel and nylon/or polyester. After having the required tests in these semi products, the items are transferred to the assembly line called tire-building operation and this operation is taking place using Tyre building machines dedicated for such purpose. Here a worker builds up the rubber layers to form the Tyre.

At this point, the tire is called a "green Tyre". Following operation is Tyre curing, which is technically named as vulcanization process; here chemical reaction is taking place using temperature, pressure and time as reaction media. Finishing this process, the Tyre is inspected for conforming set standards and released for warehouse for sale. In between of this sample are taken to verify and validate the performance of Tyres as random check.

The processes mainly consist of mix formulation, compounding, extruding, calendaring, moulding (building), vulcanization (curing), and finishing, accompanied by the processes of manufacturing Tyre cords and bead wires.

The rubber Tyre manufacturing process consists of 11 steps in detail here in horizon:

1. **Mixing** involves weighing and combining various ingredients (natural and synthetic rubbers,

oil, carbon black, zinc oxide, sulphur, and other chemicals) to create a homogenous rubber compound that is discharged to a drop mill.

2. **Milling** creates warm malleable sheets that are cooled and coated with an “anti-tack solution.” These sheets are then fed into an extruder.

3. **Extruding** forces the rubber compound through a shaped slot called a die that forms the compound into various shapes.

4. **Calendaring** involves coating fibbers of cloth or steel with a rubber compound, and then curing it in an irradiation oven that bevel cuts it to a desired length, width, and angle.

5. **Bead making** involves the creation of beads that provide a proper seal between the tire and the wheel rim when a Tyre is mounted on the rim and inflated. In the bead building process, bundles of wire are passed through an extrusion die where a coat of rubber is added, and the wires are then wound into a hoop.

6. **Cementing and marking** processes are used at various stages throughout the Tyre building process. **Cements** (adhesives or solvents) are added to improve the adhesion of different components to each other throughout the process. Cement usage can vary significantly among facilities depending on the type of Tyre being manufactured and the process being used. **Marking inks** are used to aid in identifying the components being managed. Typically, they are applied to extruded tread stocks to aid in identifying and handling cured tires. Marking practices can also vary significantly among facilities.

7. The various tire components go through **cooling** and **culture** prior to Tyre building. From the milling and extruding operations, the rubber sheets are placed onto long conveyor a belt that, through the application of cool air or cool water, lowers their temperature.

8. The two main components of the **Tyre-building** process are the tire carcass build up drum and the tread application drum. These drum machines assemble the cut carcass plies and belts plus the extruded tread, sidewall, and beads into tires. The process begins with the application of a thin layer of rubber compound, the inner liner, to the innermost carcass ply. The carcass plies are placed on the drum one at a time, after which the beads are set in place and the plies (reinforcing layers of cord and rubber) are turned up around them. At this stage the belts and tread rubber are added.

9. **Lubricating** involves preparing the uncured (green) tire for curing. The green Tyre may be coated with a lubricant (green tire spray). The function of the green Tyre spray is to ensure the cured tire does not stick to the curing mould during extraction of the tire after curing.

10. **Curing** involves collapsing the drum and loading the green tire into an automatic Tyre press to be cured (vulcanized) at high temperature and pressure. The vulcanization process converts the rubber and also bonds the various parts of the Tyre into a singular unit.

11. **Tire finishing** may involve some of the following processes: trimming, white sidewall grinding, buffing, balancing, blemish painting, whitewall/raised letter protect ant painting, and quality control inspections. Some facilities also apply a puncture sealant during production.

4.2.3 Process Flow Diagram

The overall production process is narrated concisely in the sub title "Production process" The detail process flows and check points in each process is described in the flow sheet below

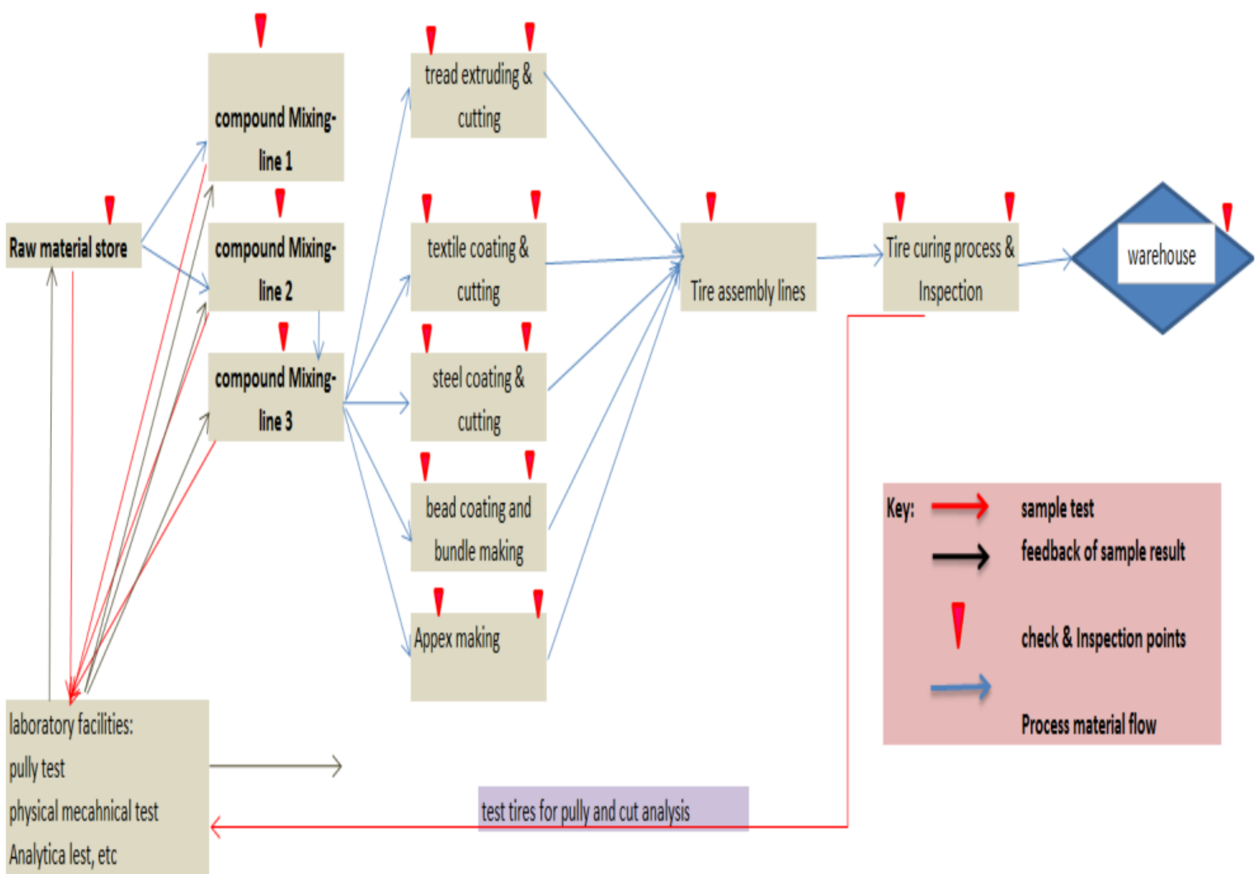


Figure 4.1 Process flow diagram of Horizon Addis Tyre Company.

The Horizon Addis Tyre Company implemented SPC before five years ago specially at the PIQA department. Statically Process Control was implemented before five years from now in Horizon Addis Tyre Company (HATC) and it is implemented partially not completely in the factory that means in selected section and employees. As the Flow Diagram showed, Statically Process Control was implemented at Check points in the followings sections. These sections are: Tire Assembly lines, Apex making, bundle making, bead coating and bundle making, steel coating and cutting and textile coating and cutting from 12 sections of the productions processes.

4.4 Demographic Variables of the Respondents

The first analysis of data involves profiling the background characteristics of the respondents Figure 4.1 indicates the demographic characteristics of the respondents. A total of 44 (88%) of the respondents were males and 6 (12%) were females. The majority of the respondents are males. Apart from the social/cultural influence and restriction, the prevailing low level of technology by manufacturing related to sectors, which involves much more physical work, might have contributed to the less number of female workers in the study. Notwithstanding, efforts should be made to encourage female workers, as well as possible means need to be sought and put in place for better technology utilization, including love of hard work. On the other hand, The Education background or Education Qualification of the respondents was as follow:

- University Degree……………………..5
- Undergraduate………………………….24
- Masters………………………………….5
- College Diploma……………………….15
- Completed High school………………….1

Thus, the majority of the respondents were Undergraduate in their Education Qualification. Tables, charts and descriptive explanations have been employed to illustrate the demographic variables of the respondents such as gender, age, years of experience and educational background of the 50 respondents.

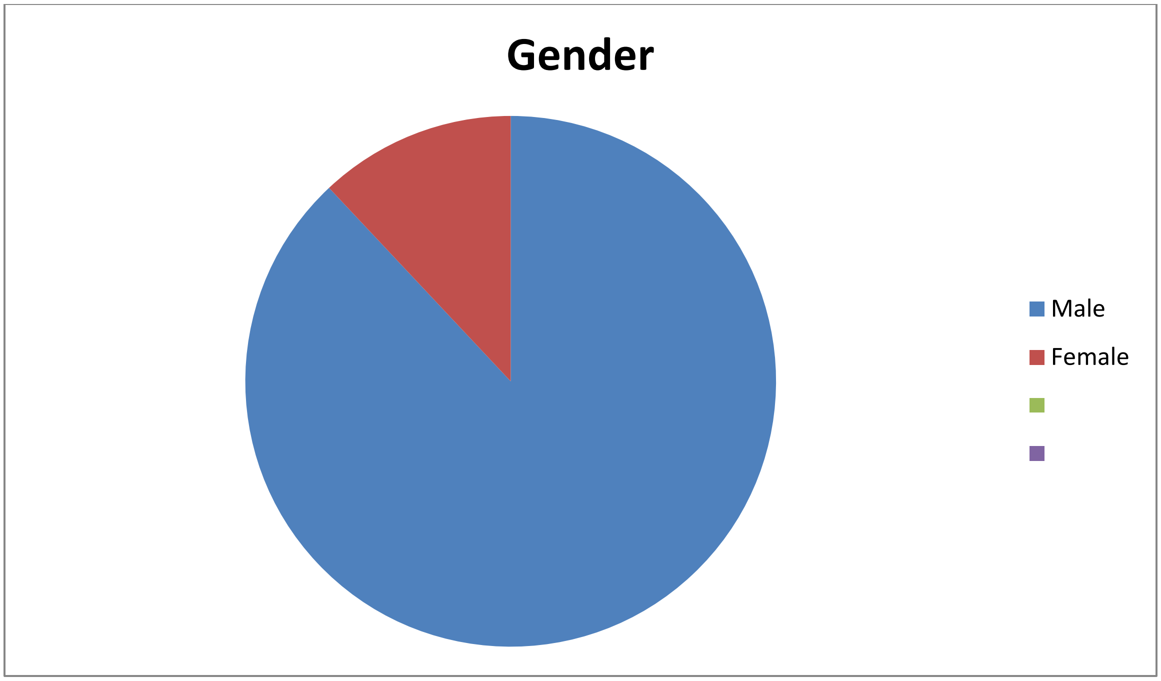
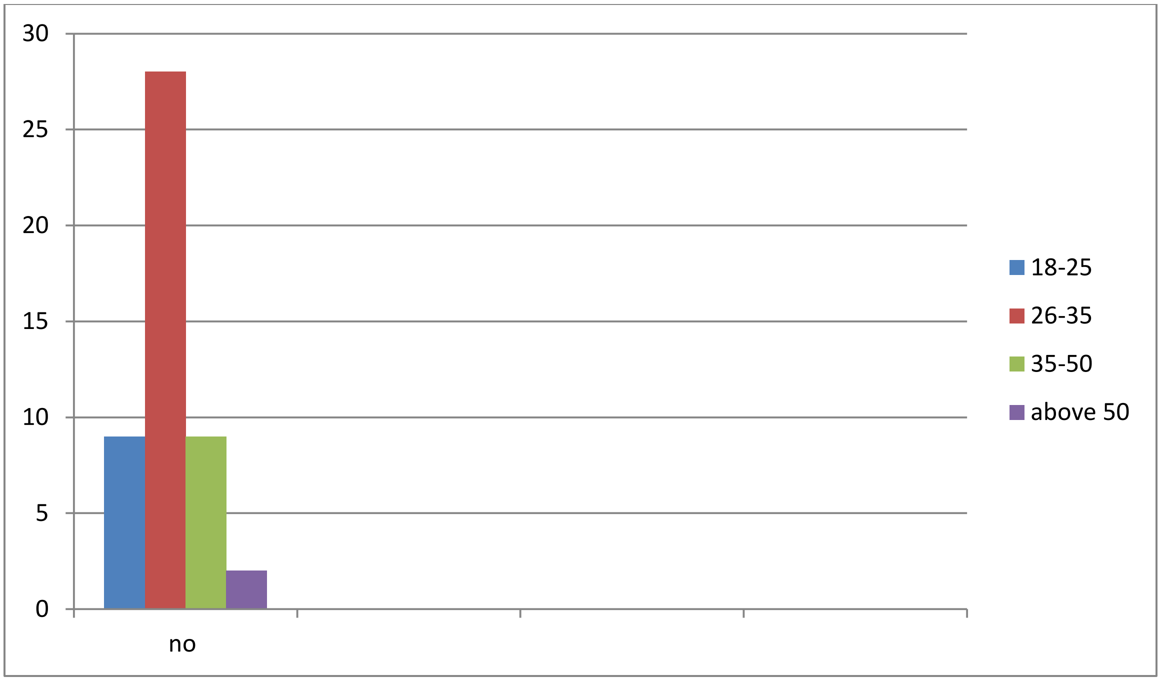


Figure 4.2 Genders of Respondents

Figure 4.1, indicate that 88% of the respondent of Horizon Addis Tyre S.C staff was males and 12% of them were females. This is an indication of a slightly high male composition of the respondent staff of Horizon Addis Tyre S.C.



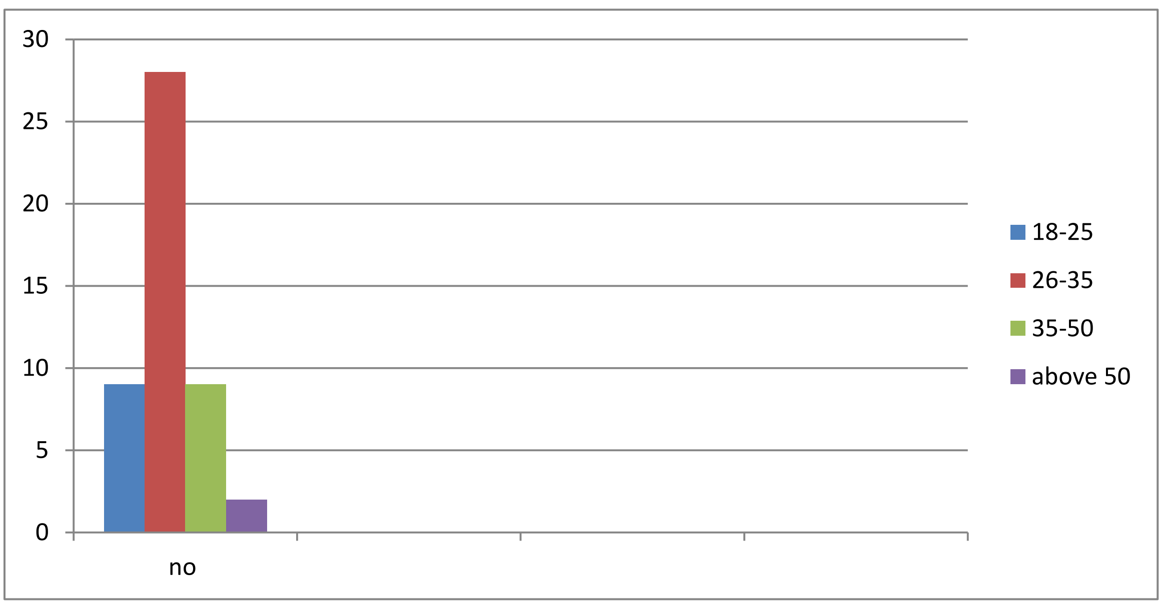


Figure 4.3 Age group of the Respondents

Figure 4.2 indicate that 18% of the staff respondents were in the age bracket of 18 - 25 years. 56% and 22% of the Respondents were in the age bracketing of 26- 35and 36 - 50, respectively, while 4% of the respondents were 50+.

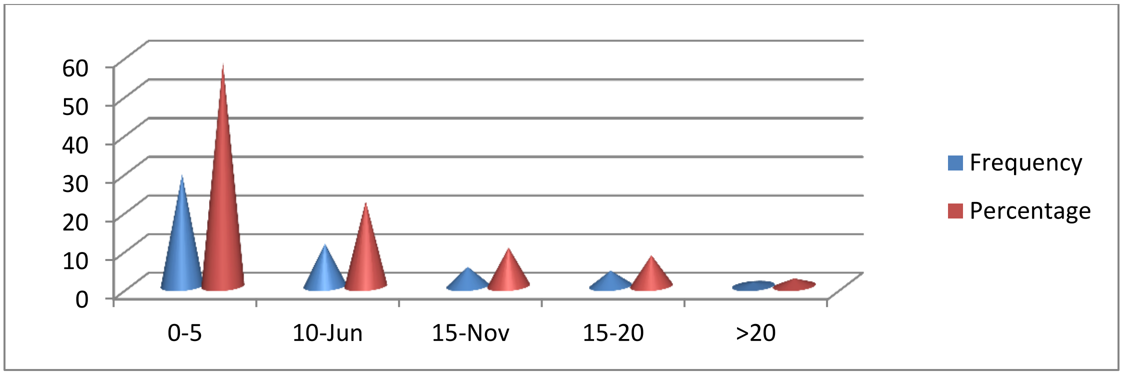


Figure 4.4: Years of Service of the Respondents

Figure 4.3 indicate that 58% of the respondents have served in the factory for 0 to 5 years, 22% of the respondents for 6 - 10 years. 10% of the respondents have served the factory for 11- 15 years while 8 % have served the Factory for more than 15-20 years. The research revealed that two of the respondents the Factory were in the age bracket above twenty years.

Figure 4.5: Educational background of staff respondents

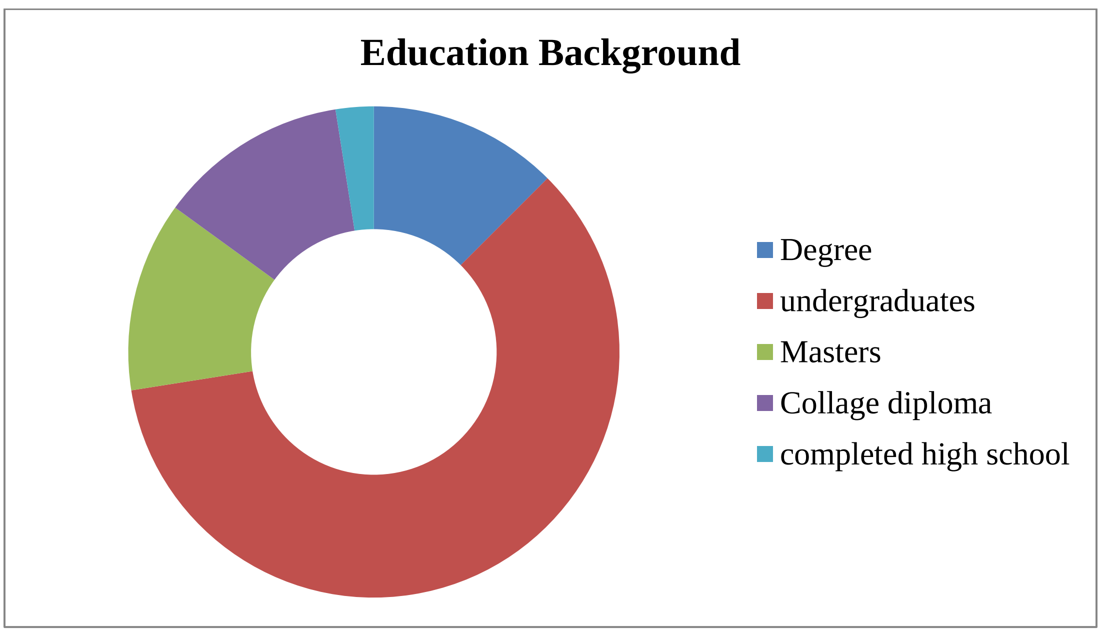


Figure 4.4 indicate that majority (48%) of the respondents were Undergraduates , the second huge number of respondents were collage diploma as 30% of them, however, while 10% and 10% have first degree and second degree holders, respectively. Only one respondent was below High School complete.

4.5 Data Analysis and Interpretation

As the research Title says “Evaluation of the effect on Statistical Process Control Implementation for Quality improvement: the case of Horizon Addis Tyre Company” means there is a result when Horizon Addis Tyre Share Company was implemented the Tools which is called Statistical Process Control. One of the results was Quality Improvement. There are many Quality dimensions in the implementation of statistical process control. These are the followings: Reduction of Cost, Reduction of Defects, Identification of Hidden loss, Reduction of Compliments and Process Consistence.

4.5.1 Evaluation of the Quality of the Tyre

From the questions from the questionnaire, there are some questions that discussed the main idea of the title. For example:

1. What is the company level of Quality and Cost improvement because of implementing Statistical Process Control?

- Highly Satisfied ………………..18 of respondent are Highly Satisfied
- Satisfied………………………..25 of respondent are Satisfied
- Neutral…………………………3 of respondent are Neutral.
- Dissatisfied……………………..1 of respondent are Dissatisfied.
- Highly dissatisfied……………..1 of respondent are Highly Dissatisfied.

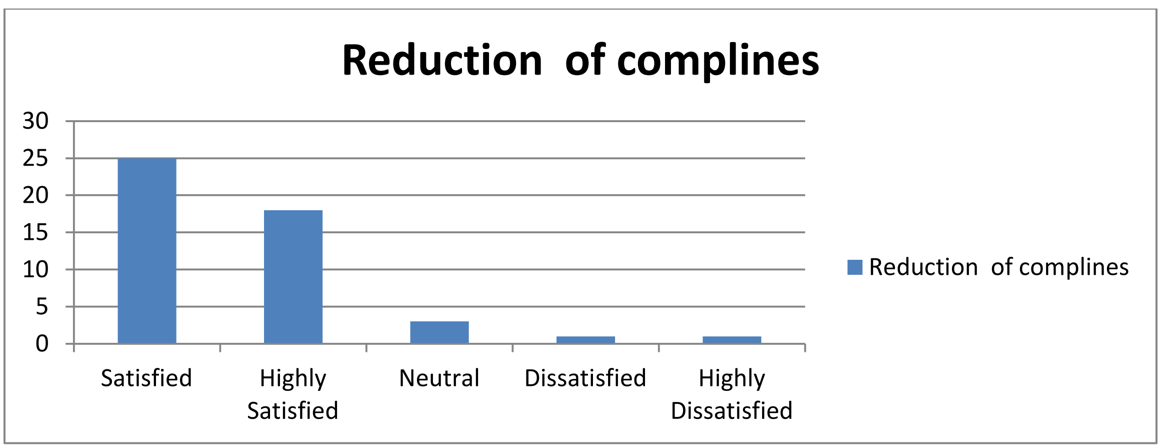
This refers to the problem of adequate skill, technology and power problem.

Table 4.1 Evaluation of the Quality of the Tyre

	Frequency	Per-sent	Valid per-sent	Cumulative per-sent
Very High	18	37.5	37.5	37.5
High	25	52	52	89.5
Medium	3	6.3	6.3	95.8
Low	1	2.1	2.1	97.9
Very Low	1	2.1	2.1	100
Total	48	100	100	

Source: Own Customer Satisfaction Survey

Figure 4.6 No of Complained Vs No of Respondents



The application of Statically Process Control in Horizon Addis Tyre Company was applied in the selected section and it is implemented partially. These sections are the followings:

1.Bead Wire and Steal Coating section**:** The parameter used to check was Weight of Bead. It must control using the usage of SPC chart. It is done monthly report.

2.Laboratory: The parameter used to check were Max-torque, Specific gravity and physical mechanical property. E.g. T2L-M1-mosture batch and T2L-FM modules@ 300

3**.** Textile- Rubberizing Cord: The parameter used to check was Thickness of Cord.

4. Tread: The parameter used to check was Weight of tread.

5. Building machine: The parameter used to check was Weight.

6. Mixing or Compounding Section: The parameter used to check was Temperature.

The raw material used to produce Tyre is the followings:

- Different Chemicals. 6 types of Carbon Black. D types of Different Oil
- Natural and Synthetic Rubber

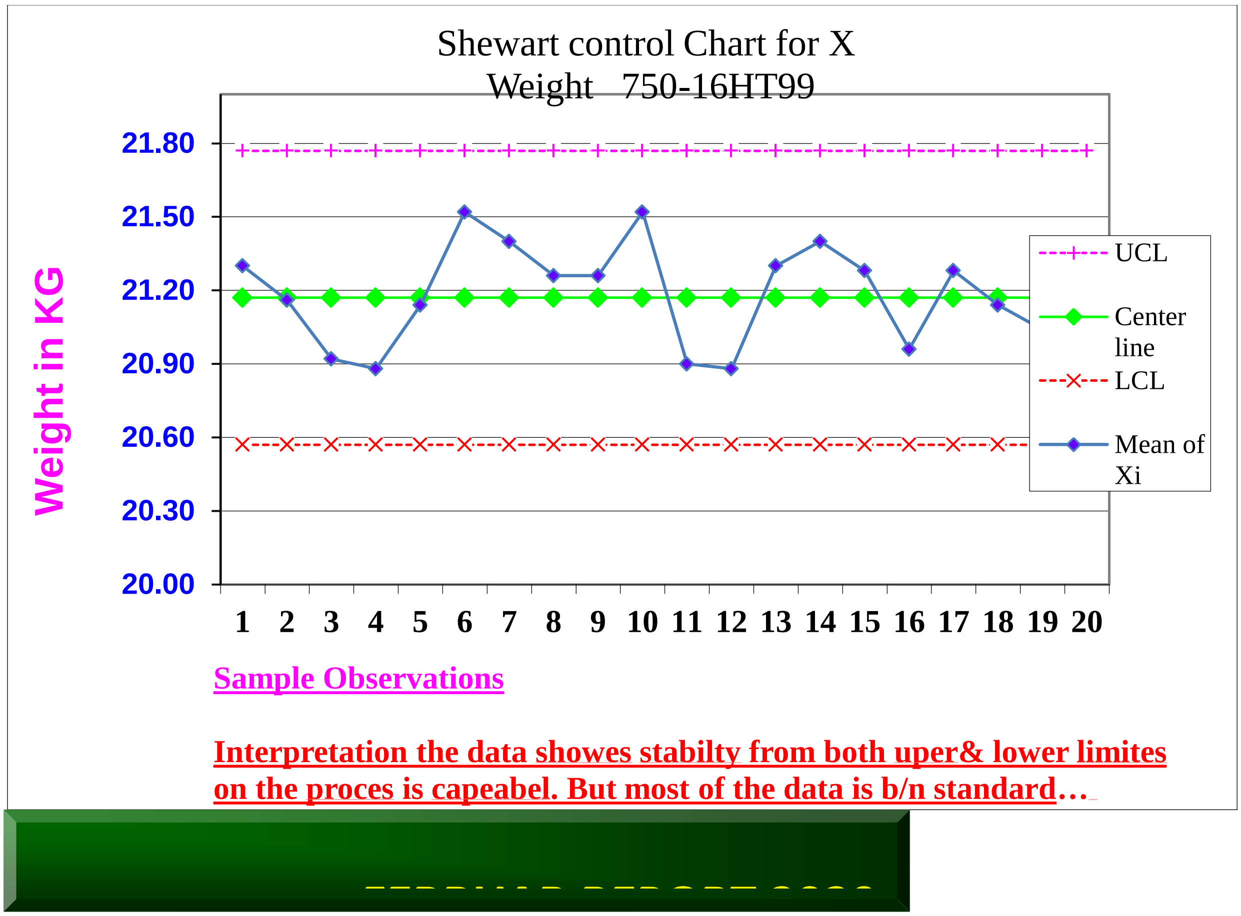


Figure 4.7 SAMPLES OF CONTROL CHART

4.5.2 Actual Data of Annual Tyre Production from 2008-2012 E.C

The Horizon Addis Tyre Share Company implemented SPC before four years i.e. 2009 E.C ago especially at the PIQA department. Statically Process Control was implemented before four years from now in Horizon Addis Tyre Company (HATC) and it is implemented partially not completely in the factory that means in selected section and employees.

YEARS	**TOTAL ANNUAL TYRE PRODUCTION**
2008	**259699**
2009	**344,318**
2010	**375084**
2011	**447863**
2012	**489514**

Table 4.2 2008- 2012E.C Annual Tyre Production

N.B

The above Tables are Data of Actual Tyre Production from 2008-2012 E.C after and before SPC implementation in the HATC since SPC implementation has a direct effect on the Cost of Production and if the annual revenue of the case company is increased then it means SPC has a positive impact on Cost production and if the annual revenue of the case company is decreased then it means SPC has a negative impact on Cost production.

So, the Table which found above is used to compare SPC implementation and their effect on Cost of Productions. After and before SPC implementation in the HATC in order to show whether SPC implementation has a positive or negative impact on the Cost of Production or the revenue that the case company got.

4.5.3 Data of Annual Defective & Scrap Tyre from 2006-2011 E.C

Table 4.3 2006- 2011E.C Annual Defective Tyre

YEARS	TOTAL ANNUAL DEFECTIVE TYRE
2006	**3563**
2007	**5203**
2008	**7633**
2009	**8859**
2010	**6289**
2011	**5354**

N.B

The above Tables are Data of Annual amount of defective Tyre from 2006-2011 E.C after and before SPC implementation in the HATC since amount of defective Tyre has indicate the impact of SPC implementation on the Quality of the Tyre if defective Tyre has increased, the it has a negative impact or if defective Tyre has decreased then it has a positive impact on Quality when after and before SPC implementation in the HATC.

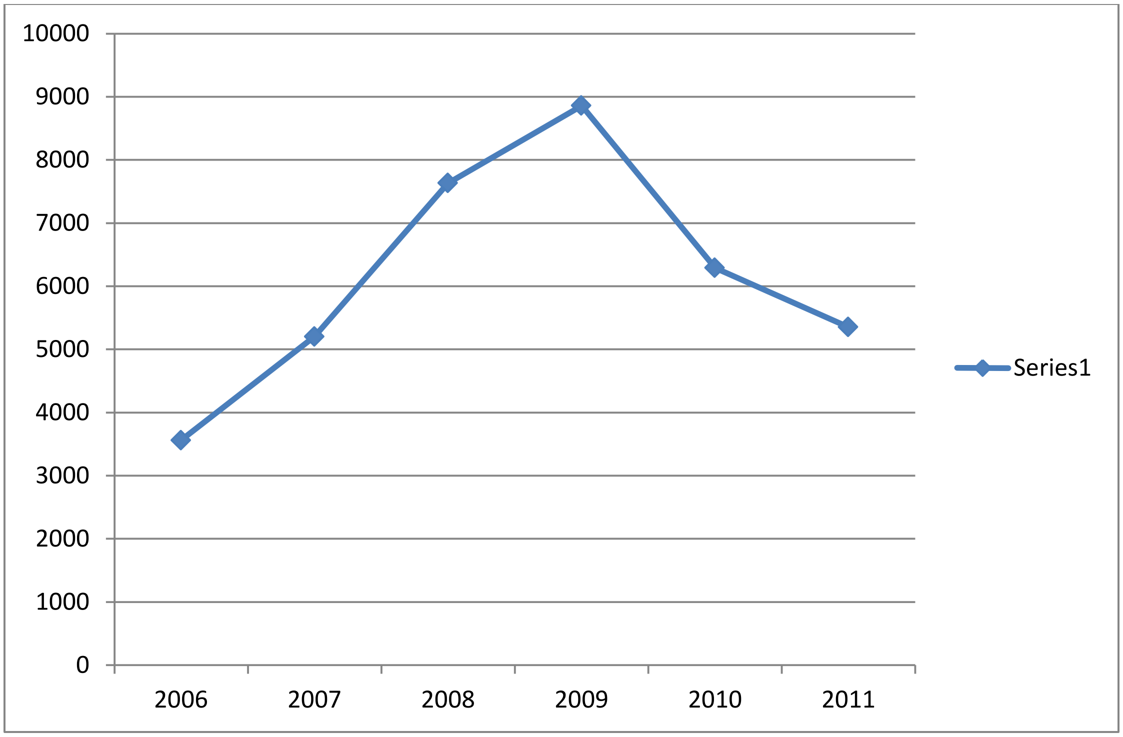
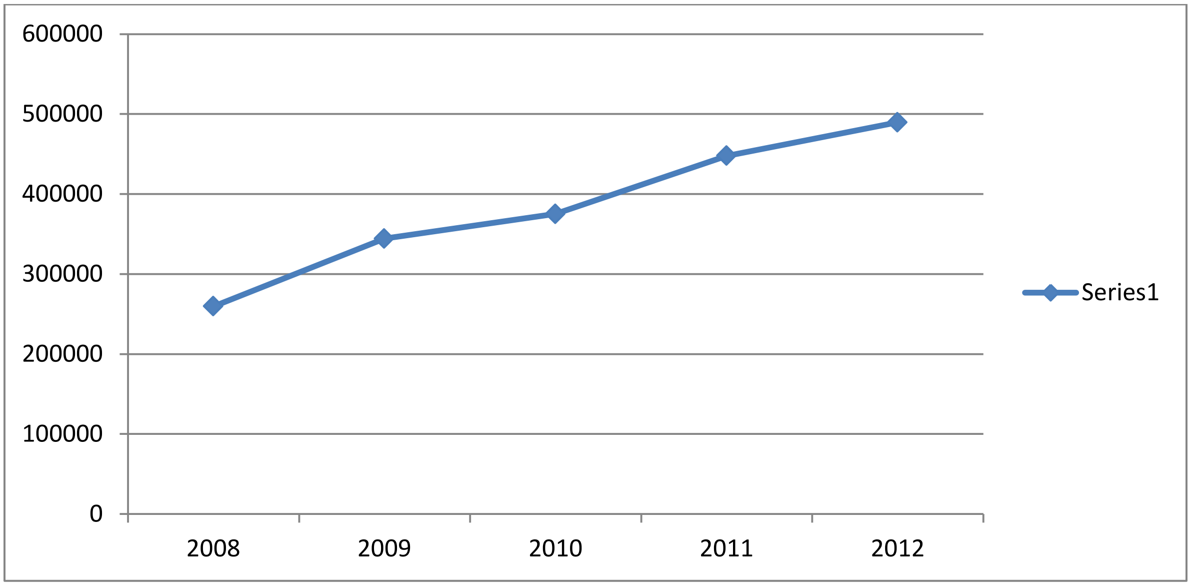


Figure 4.8 Graph of Annual Defective Tyre VS. 2006- 2011E.C Years

The Horizon Addis Tyre Company implemented SPC before four years i.e. 2009 E.C ago especially at the PIQA department. Statically Process Control was implemented before four years from now in Horizon Addis Tyre Company (HATC) and it is implemented partially not completely in the factory that means in selected section and employees.

The Graphs shows the above consecutives Tables that are the annual amount of Defective Tyres from 2006-2011 E.C years in HATC.

Figure 4.9 Graphs of Annual Data of Tyre Production VS. 2008-2012E.C Years



N.B

The above Graph is shows that the graph of Annual Tyre Production from 2008-2012 E.C after and before SPC implementation in the HATC since SPC implementation has a direct effect on the Cost of Production and if the annual revenue of the case company is increased then it means SPC has a positive impact on Cost production and if the annual revenue of the case company is decreased then it means SPC has a negative impact on Cost production.

So, the Graph which found above is used to compare SPC implementation and their effect on Cost of Productions.

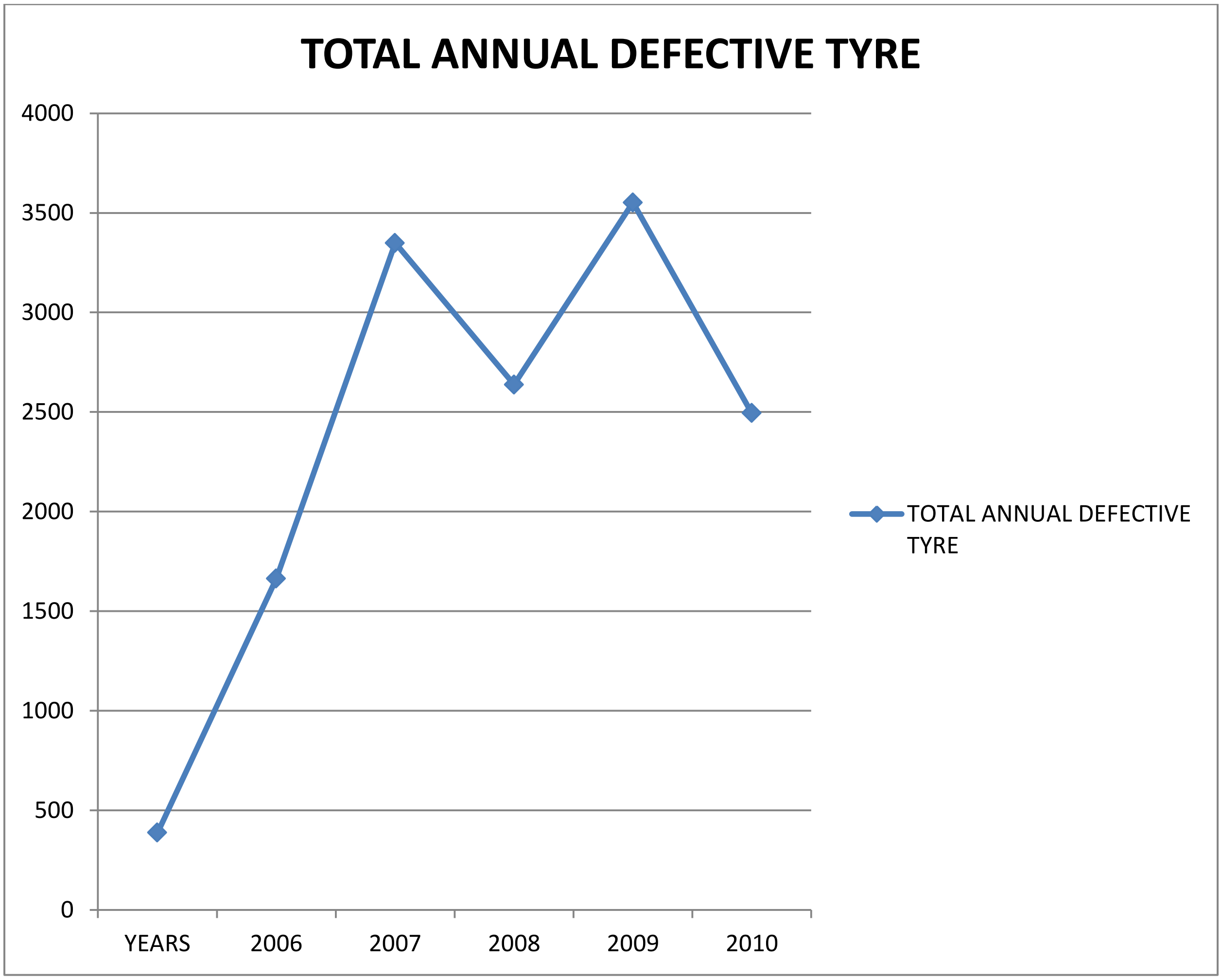
Table 4.4 2006- 2011E.C Annual Scrap Tyre Summary Report

YEARS	TOTAL ANNUAL SCRAP TYRE
2006	388
2007	1664
2008	3349
2009	2638
2010	3552
2011	2495

N.B

The above Table shows that the annual scrap Tyre production from 2006-2011 E.C that indicate the impact of after and before SPC implementation with the Quality since the amount of annual scrap Tyre production is increased then it has a negative impact with Quality and if the amount of annual scrap Tyre production is decreased then it has a positive impact with Quality.

Figure 4.10 Graph of Annual Scrap Tyre VS. 2006- 2011E.C Years



The Graphs is the same as the above Table that indicates the impact of after and before SPC implementation with the Quality.

The following research questions are answered from the data that I collect from the company.

1. What are the Common Possible Defective types and their possible causes for those Defective Tyres?
2. What is the most commonly cause for Defective Tyres?

Types of Defects in Tyres	Causes of Defective Tyres	Quantity
CS-O	GOP	985
	Alen Losse	8
	GOP-U= Side	45
	Silicon	38
	GOP-U= 1000-20	26
	GOP-U=16PR	31
	GOP-U= Tire	49
	GIP	64
	Leakage	30
	GOP-L= AT-20	25
	GOP-B= Side	9
	GOP-U= Addis	43
	GOP-L=16PR	12
	GOP-U= HT-40	20
	MOISTURE	10
	GIP-L=SIDE	10
	GOP-L=900-20	10
BWB-O	Bladder FM	12
	Bladder Bilister	7
BS-O	Pricking- L= AT-20	10
	Pricking Problem	180
	Pricking-L= Addis	10
LS-T	Leakage	233
	Moisture due to mould cleaning	800

SB-O	GOP	24
	Silicon	10
FM-O	GIP	9
FM-O	Cord-L= Tire	11
	Rubber	20
	OIL	9
	S\NO	13
S\No	Without S\No	15
LS-O	Silicon	15
	GOP	20
BRC-O	Pricking	25
CS-T	Leakage	700
	Loss Alen	25

Table 4.5 2006 E.C Common possible Defective types and their possible causes for those Defective Tyres.

Sum or Cumulative total = 3563

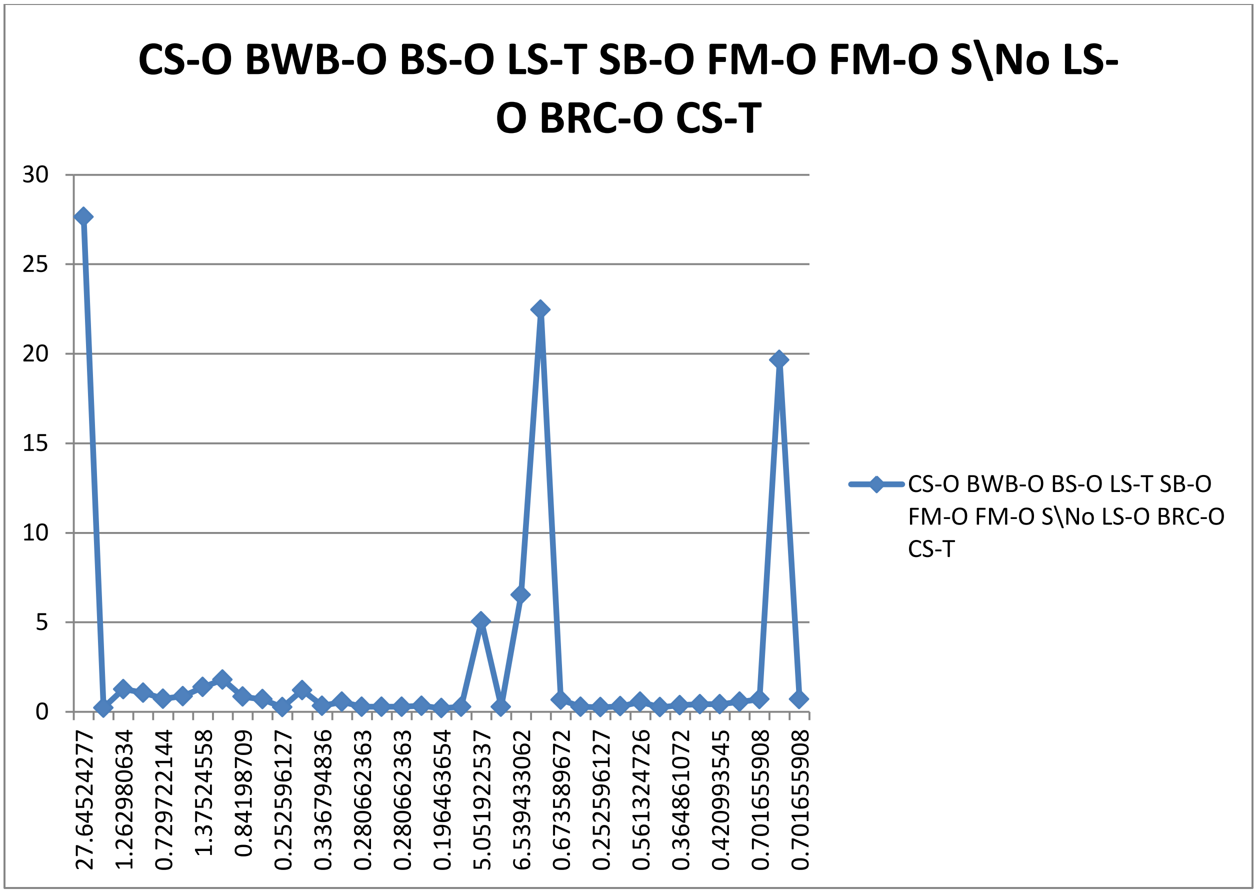


Figure 4.11 Percentage or Ratio of Types of Defectives in 2006 E.C Annual Year

From the data analysis the above fig, we conclude and answered the following questions.

1. What are the Common Possible Defective Tires and their possible causes for those Defective Tires?

Answer

Common types of defects:	Causes of defects
CS-O	GOP
LS-T	Leakage
	Moisture due to mould cleaning
BS-O	Pricking Problem
CS-T	Leakage

2. What is the most commonly cause for Defective Tires?

Answer: GOP, Leakage, Moisture due to mould cleaning and Pricking Problem.

4.5.4 Major Quality Related Problems/obstacles

For the purpose of answering research question No 2 which is found at this research thesis. The research question is said that: What major SPC related problems did you observe and the main roots causes of quality problems in Tyre Industry in case of the Horizon Addis Tyre Company.

From the Horizon Addis Tyre Company data source in PIQA departments, I was got this quantitative data. There are many major Quality related Problems/obstacles that are list in the above table at the Tyre Curing production Area and having possible reasons and check points. The Quality related problems are the following:

Quality related problems	Quantity of possible Reasons	Percentage
1. No\Less Internal	10	7.87%
2. Soft Bead	12	9.45%
3. Tread\ Ply Blow	10	7.87%
4. Side Wall Flow Crack	8	6.3%
5. Side Wall Blester	11	8.66%
6. Kink Bead \ Bent Bead	8	6.3%
7. Pulled Bead	16	12.63%
8. Turn Up Blow	6	4.72%
9. Light Heel	6	4.72%
10. Light Shoulder	4	3.15%
11. Carcass Crack	4	3.15%
12. Lug Chipping	3	2.36%
13. Inner Paint Flaking \ FM	3	2.36%
14. Cord Lifting	6	4.72%
15. Spread Cords	10	7.87%
16. Carcass Buckle	10	7.87%
Total	127	100%

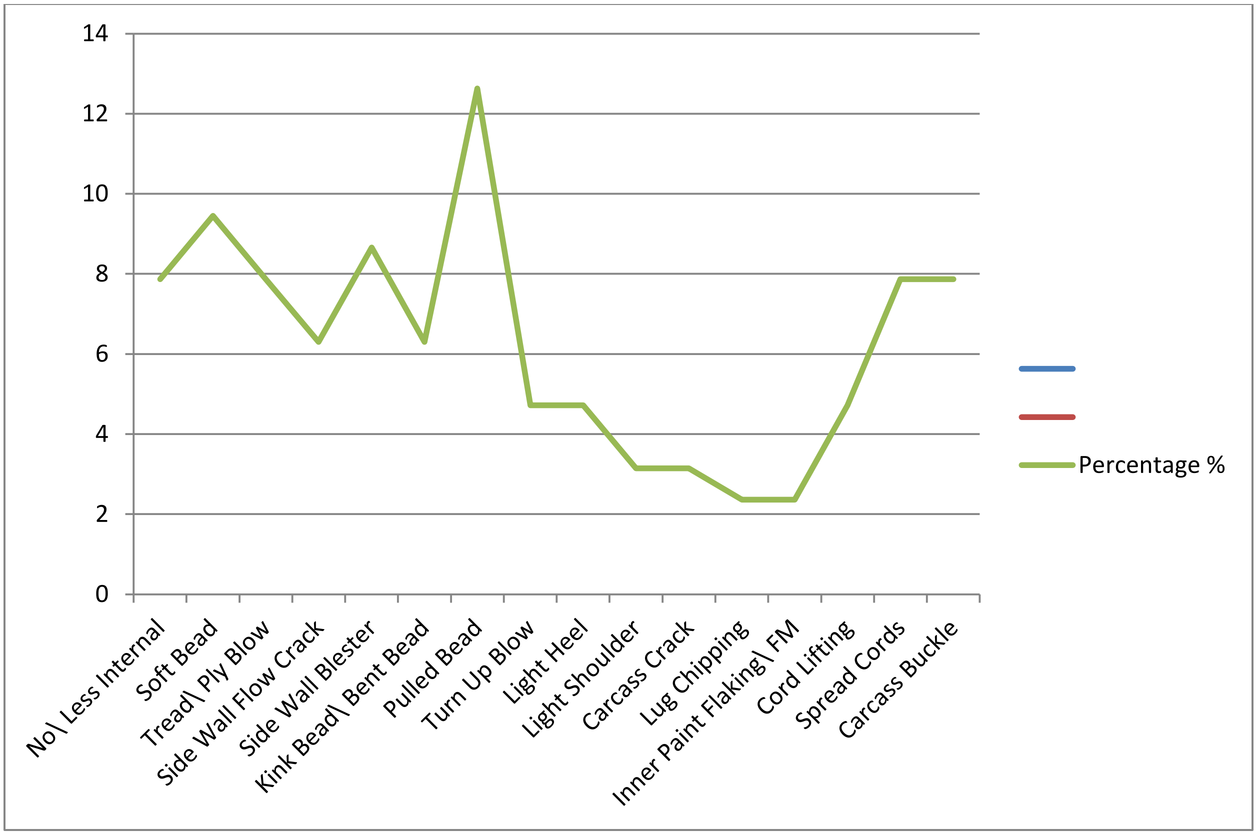


Figure 4.12 Graph of Percentage of Major Quality related Problems

For each Quality related Problems or Obstacles, There are many possible reasons and check points at the Tyre Curing production area.

According to the above data analysis, the major Quality related problems are the followings:

1. Pulled Bead
2. Soft Bead
3. Side Wall Blester

So concern with the above major Quality related problems in order to tackle the major Quality related problems.

```
CORRELATIONS
  /VARIABLES=DEFECTIVE_TYRE TYRE_PRODUCTION
  /PRINT=TWOTAIL NOSIG
  /MISSING=PAIRWISE.
```

Correlations

		Annual Defective Tyre	Annual Tyre Production
Annual Defective Tyre	Pearson Correlation	1	-.813
	Sig. (2-tailed)		.094
	N	5	5
Annual Tyre Production	Pearson Correlation	-.813	1
	Sig. (2-tailed)	.094	
	N	5	5

```
CORRELATIONS
  /VARIABLES=SCRAP_TYRE TYRE_PRODUCTION
  /PRINT=TWOTAIL NOSIG
  /MISSING=PAIRWISE.
```

Correlations

		Annual Scrap Tyre	Annual Tyre Production
Annual Scrap Tyre	Pearson Correlation	1	-.731
	Sig. (2-tailed)		.160
	N	5	5
Annual Tyre Production	Pearson Correlation	-.731	1
	Sig. (2-tailed)	.160	
	N	5	5

Table 4.6 Correlations Relations Quality and Cost Using SPSS Software

N.B. Quality has a negative correlation with respect to Cost Effectiveness or Annual Tyre Productions.

4.6 Summary of Chapter Four

In chapter four, the background of the Organization is comes at the beginning of the chapter. It includes the Tyre manufacturing production processes or Tyre manufacturing process in HATSC (Horizon Addis Tyre Company), raw materials and process flow diagram**.** The Horizon Addis Tyre Company has used some of the "seven basic quality control tools" in their quality related problem solving technique. These are Pareto Chart and SPC tools. The rubber Tyre manufacturing process consists of 11 steps. These are: Mixing, Milling, Extruding, Calendaring, Bead making, Cementing and marking, cooling and culture, Tyre-building, Lubricating, Curing and Tyre finishing. In Demographic variables of the respondents, I collect 53 respondents of the data, 88% of the respondent of Horizon Addis Tyre S.C staff was males and 12% of them were females. This is an indication of a slightly high male composition of the respondent staff of Horizon Addis Tyre S.C. The parameters that are conducted in the laboratory are i.e. The max-torque of 1243-FM, the specific gravity of T_{2L}-M1 and the physical mechanical property of T_{2L}-FM were within the control limit of the process that is between the Upper and Lower control limit. The Weight of Bead in the Bead Wire and Steal Coating section was within the control limit of the process that is between the Upper and Lower control limit. The Weight of the Tyre in the Building machine section was within the control limit of the process that is between the Upper and Lower control limit. The Thickness of Cord in the Textile- Rubberizing Cord was out of the control limit of the process. The Weight of tread in the Tread section was also within the control limit of the process that is between the Upper and Lower control limit.

From 53 respondents, 18% of the staff respondents were in the age bracket of 18 - 25 years. 56% and 22% of the Respondents were in the age bracketing of 26- 35and 36 - 50, respectively, while 4% of the respondents were 50+, 58% of the respondents have served in the factory for 0 to 5 years, 22% of the respondents for 6 - 10 years. 10% of the respondents have served the factory for 11- 15 years while 8 % have served the Factory for more than 15-20 years. The research revealed that two of the respondents the Factory were in the age bracket above twenty years. The majority (48%) of the respondents were Undergraduates, the second huge number of respondents were collage diploma as 30% of them, however, while 10% and 10% have first degree and second degree holders, respectively. Only one respondent was below High School complete. I collect the data from 53 respondents with respect to the company level of Quality improvement because of implementing of Statistical Process Control, 25 of the respondents are satisfied, 18 of the respondents are highly satisfied and 3 of respondents are neutral.

From the data of Actual Tyre Production from 2008-2012 E.C after and before SPC implementation in the HATC since SPC implementation has a direct effect on the Cost of Production and if the annual revenue of the case company is increased then it means SPC has a positive impact on Cost production and if the annual revenue of the case company is decreased then it means SPC has a negative impact on Cost production. So, the data of chapter four is used to compare SPC implementation and their effect on Cost of Productions.

From the data of Annual amount of defective and scrap Tyre from 2006-2011 E.C after and before SPC implementation in the HATC since amount of defective and scrap Tyre has indicate the impact of SPC implementation on the Quality of the Tyre if defective Tyre has increased, the it has a negative impact on Quality of the Tyre or if defective and scrapTyre has decreased then it has a positive impact on Quality of the Tyre when after and before SPC implementation in the HATC. The graph of Annual Tyre Production from 2008-2012 E.C after and before SPC implementation in the HATC since SPC implementation has a direct effect on the Cost of Production and if the annual revenue of the case company is increased then it means SPC has a positive impact on Cost production and if the annual revenue of the case company is decreased then it means SPC has a negative impact on Cost production. The Table 4.4 shows that the annual scrap Tyre production from 2006-2011 E.C that indicate the impact of after and before SPC implementation with the Quality of the Tyre since the amount of annual scrap Tyre production is increased then it has a negative impact with Quality of the Tyre and if the amount of annual scrap Tyre production is decreased then it has a positive impact with Quality of the Tyre.

From the Data analysis, I answered the research questions, what are the common possible Defectives Tyres and their possible causes and what are the most commonly cause for Defectives Tyres. The common types of defects of Tyres are CS-O, LS-T, BS-O, and CS-T and their respectively cause of defects are GOP, Leakage, Moisture due to mould cleaning and Pricking Problem. I was listed the major Quality related problems or obstacles. These are No\Less Internal, Soft Bead, Tread\ Ply Blow, Side Wall Flow Crack, Side Wall Blester, Kink Bead \ Bent Bead, Pulled Bead, Turn Up Blow, Spread Cords, Cord Lifting and Spread Cords.

From the analysis of the data, it has been found that the company has many practices like usage of control charts, Usage of computerized technology for data recording, usage of calibrated measuring devices, Planning for quality improvement, Presence of in house technical staff experts and setting definition for quality are in use in the organization etc. and challenges specifically like there is lack of higher management support, lack of team working, lack training etc. If a statistical process control practices are employed effectively, it could improve the quality of the product and overall organizational performance by knowing the customer requirement and meeting them. Even if the company has many constraints to implement all suggestion for improvement within short period of time, but it is important to give training for employs and management commitment is important and the company recognized that the suggestion will provide significant productivity improvement in the long run.

The result of this research to know the effect of Statistical Process Control implementation with respect to total annual production of Tyre during 2008-2012 E.C and annual defective and scrap during 2006-2011 E.C Tyre i.e. after and before SPC implementation in the HATC in order to show whether SPC implementation has a positive or negative impact on the Cost of Production or the revenue that the case company got in Horizon Addis Tyre Company (HATC). Horizon Addis Tyre Company (HATC) has many quality related problems and to tackle these problems, the company takes counter measures like implementing Statistical Process Control.

I was doing data analysis using SPSS software to correlates Annual Defective Tyre vs. Annual Tyre production and Annual Scrap Tyre vs. Annual Tyre production. I conclude that Quality has a negative correlation with respect to Cost effectiveness or Annual Tyre productions.

There are many problems and difficulties in the Implementation of SPC in Organization of Horizon Addis Tyre Company. These are the followings:

- Lack of commitment and involvement of top management
- Lack of training and education in SPC
- Failure to interpret control charts and take any necessary actions.
- Lack of knowledge of which product characteristics or process parameters to measure and monitor within a process.

I was listed the application of Statically Process Control in Horizon Addis Tyre Company that are applied in the selected section and it is implemented partially. These sections are the followings: Bead Wire and Steal Coating section, Laboratory, Textile- Rubberizing Cord, Tread, Building machine and Mixing or Compounding Section.

From different Quality improvement techniques tools, Horizon Addis Tyre Company used Paratoo Analysis tools for technical department; Control chart for all departments that implemented Statically Process Control and Histogram tools was also used for some sections of the company.

Even if the company has many constraints to implement all suggestion for improvement within short period of time, but it is important to give training for employs and management commitment is important and the company recognized that the suggestion will provide significant productivity improvement in the long run.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSTION AND RECOMMENDATIONS

5.1Summary of Findings

In Demographic variables of the respondents, I collect 53 respondents of the data, 88% of the respondent of Horizon Addis Tyre S.C staff was males and 12% of them were females. This is an indication of a slightly high male composition of the respondent staff of Horizon Addis Tyre S.C, from 53 respondents, 18% of the staff respondents were in the age bracket of 18 - 25 years. 56% and 22% of the Respondents were in the age bracketing of 26- 35and 36 - 50, respectively, while 4% of the respondents were 50+, 58% of the respondents have served in the factory for 0 to 5 years, 22% of the respondents for 6 - 10 years. 10% of the respondents have served the factory for 11- 15 years while 8 % have served the Factory for more than 15-20 years. The research revealed that two of the respondents the Factory were in the age bracket above twenty years. The majority (48%) of the respondents were Undergraduates, the second huge number of respondents were collage diploma as 30% of them, however, while 10% and 10% have first degree and second degree holders, respectively. Only one respondent was below High School complete. I collect the data from 53 respondents with respect to the company level of Quality improvement and Cost effectiveness because of implementing of Statistical Process Control, 25 of the respondents are satisfied, 18 of the respondents are highly satisfied and 3 of respondents are neutral.

From the data of Actual Tyre Production from 2008-2012 E.C after and before SPC implementation in the HATC since SPC implementation has a direct effect on the Cost of Production and if the annual revenue of the case company is increased then it means SPC has a positive impact on Cost production and if the annual revenue of the case company is decreased then it means SPC has a negative impact on Cost production. So, the data of chapter four is used to compare SPC implementation and their effect on Cost of Productions.

From the data of Annual amount of defective and scrap Tyre from 2006-2011 E.C after and before SPC implementation in the HATC since amount of defective and scrap Tyre has indicate the impact of SPC implementation on the Quality of the Tyre if defective Tyre has increased, the it has a negative impact on Quality of the Tyre or if defective and scrap Tyre has decreased then it has a positive impact on Quality of the Tyre when after and before SPC implementation in the HATC.

The graph of Annual Tyre Production from 2008-2012 E.C after and before SPC implementation in the HATC since SPC implementation has a direct effect on the Cost of Production and if the annual revenue of the case company is increased then it means SPC has a positive impact on Cost production and if the annual revenue of the case company is decreased then it means SPC has a negative impact on Cost production. The Table 4.4 shows that the annual scrap Tyre production from 2006-2011 E.C that indicate the impact of after and before SPC implementation with the Quality of the Tyre since the amount of annual scrap Tyre production is increased then it has a negative impact with Quality of the Tyre and if the amount of annual scrap Tyre production is decreased then it has a positive impact with Quality of the Tyre.

From the Data analysis, I answered the research questions, what are the common possible Defectives Tyres and their possible causes and what are the most commonly cause for Defectives Tyres. The common types of defects of Tyres are CS-O, LS-T, BS-O, and CS-T and their respectively cause of defects are GOP, Leakage, Moisture due to mould cleaning and Pricking Problem. I was listed the major Quality related problems or obstacles. These are No\Less Internal, Soft Bead, Tread\ Ply Blow, Side Wall Flow Crack, Side Wall Blester, Kink Bead \ Bent Bead, Pulled Bead, Turn Up Blow, Spread Cords, Cord Lifting and Spread Cords. I was doing data analysis using SPSS software to correlates Annual Defective Tyre vs. Annual Tyre production and Annual Scrap Tyre vs. Annual Tyre production. I conclude that Quality has a negative correlation with respect to Cost effectiveness or Annual Tyre productions.

From the analysis of the data, it has been found that the company has many practices like usage of control charts, Usage of computerized technology for data recording, usage of calibrated measuring devices, Planning for quality improvement, Presence of in house technical staff experts and setting definition for quality are in use in the organization etc. and challenges specifically like there is lack of higher management support, lack of team working, lack training etc. If a statistical process control practices are employed effectively, it could improve the quality of the product and overall organizational performance by knowing the customer requirement and meeting them. Even if the company has many constraints to implement all suggestion for improvement within short period of time, but it is important to give training for employs and management commitment is important and the company recognized that the suggestion will provide significant productivity improvement in the long run.

The result of this research to know the effect of Statistical Process Control implementation with respect to total annual production of Tyre during 2008-2012 E.C and annual defective and scrap during 2006-2011 E.C Tyre i.e. after and before SPC implementation in the HATC in order to show whether SPC implementation has a positive or negative impact on the Cost of Production or the revenue that the case company got in Horizon Addis Tyre Company (HATC). Horizon Addis Tyre Company (HATC) has many quality related problems and to tackle these problems, the company takes counter measures like implementing Statistical Process Control. I was doing data analysis using SPSS software to correlates Annual Defective Tyre vs. Annual Tyre production and Annual Scrap Tyre vs. Annual Tyre production. I conclude that Quality has a negative correlation with respect to Cost effectiveness or Annual Tyre productions.

Quality has a negative correlation with respect to Cost Effectiveness or Annual Tyre Productions. It can be concluded that by applying statistical Quality control techniques the cost of the product manufactured can be reduced and that to without compromising with Quality. While making quality products, the manufacturers should take care of operations done at lesser cost. However, in most control activities, cost saving are real and they remain a principle objective of quality control for most organizations. Thus by analysing it can be concluded that by applying statistical Quality control techniques the cost of the product manufactured can be reduced and that to without compromising with Quality. Based on the findings of the study, the company has been benefited from implementation of SPC in terms of minimizing the risk of product recalls, non conforming products, product giveaways or under fills or over fills. This implies SPC has a power to improve the quality of the product.

There are many problems and difficulties in the Implementation of SPC in Organization of Horizon Addis Tyre Company. These are the followings:

- Lack of commitment and involvement of top management
- Lack of training and education in SPC
- Failure to interpret control charts and take any necessary actions.

- Lack of knowledge of which product characteristics or process parameters to measure and monitor within a process.

From different Quality improvement techniques tools, Horizon Addis Tyre Company used Paratoo Analysis tools for technical department; Control chart for all departments that implemented Statically Process Control and Histogram tools was also used for some sections of the company

5.2 Conclusion

Based on the findings of the study, the following conclusions are drawn by the researcher. From 53 respondents of Horizon Addis Tyre Company (HATC) in the questioner, 25 respondents are satisfied and 18 respondents are highly satisfied with respect to Cost and Number of complains reduction with respect to after and before implementation of Statistical Process Control since four years ago.

From the data analysis of total annual Tyre production, there is an increasing tread of Annual Tyre Production in Horizon Addis Tyre Company (HATC) with respect to after and before implementation of Statistical Process Control since four years ago. So, it has a positive impact to implementation of Statistical Process Control.

From the data analysis of total annual defective Tyre i.e. 2006-2011 E.C, there is Up and Down tread of Annual Defective Tyre in Horizon Addis Tyre Company (HATC) with respect to after and before implementation of Statistical Process Control since four years ago. So, it has a positive impact to implementation of Statistical Process Control with respect to Quality Improvement. Now the defect rate was 1%.

From the data analysis, the Annual Scrap Tyre i.e. 2006-2011 E.C, years has an increasing tread of Annual Scrap Tyre and it has a negative impact with respect to after and before implementation of Statistical Process Control since four years ago. So, from this I am concluding that, Statistical Process Control in Horizon Addis Tyre Company (HATC) was implemented partially in achieving Quality and Cost improvement and implication..

The positive changes that observed in the organization since the implementation of Statistical Process Control were to become Cost sensitive, Quality sensitive, to identify hidden loss and to get process constancy. There is much huge difference between the defects before and after implementation of Statistical Process Control implementation. Before Statistical Process Control (SPC) Implementation was occurred i.e. before four years ago, the defect rate of the final product of Tyre was 10%. But now a day, it was reduced to 1%.

From 53 respondents, 18% of the staff respondents were in the age bracket of 18 - 25 years. 56% and 22% of the Respondents were in the age bracketing of 26- 35and 36 - 50, respectively, while 4% of the respondents were 50+, 58% of the respondents have served in the factory for 0 to 5 years, 22% of the respondents for 6 - 10 years. 10% of the respondents have served the factory for 11- 15 years while 8 % have served the Factory for more than 15-20 years.

The research revealed that two of the respondents the Factory were in the age bracket above twenty years. The majority (48%) of the respondents were Undergraduates, the second huge number of respondents were collage diploma as 30% of them, however, while 10% and 10% have first degree and second degree holders, respectively. Only one respondent was below High School complete. I collect the data from 53 respondents with respect to the company level of Quality improvement and Cost effectiveness because of implementing of Statistical Process Control, 25 of the respondents are satisfied, 18 of the respondents are highly satisfied and 3 of respondents are neutral.

From the data of Actual Tyre Production from 2008-2012 E.C after and before SPC implementation in the HATC since SPC implementation has a direct effect on the Cost of Production and if the annual revenue of the case company is increased then it means SPC has a positive impact on Cost production and if the annual revenue of the case company is decreased then it means SPC has a negative impact on Cost production. So, the data of chapter four is used to compare SPC implementation and their effect on Cost of Productions.

From the data of Annual amount of defective and scrap Tyre from 2006-2011 E.C after and before SPC implementation in the HATC since amount of defective and scrap Tyre has indicate the impact of SPC implementation on the Quality of the Tyre if defective Tyre has increased, the it has a negative impact on Quality of the Tyre or if defective and scrap Tyre has decreased then it has a positive impact on Quality of the Tyre when after and before SPC implementation in the HATC. The graph of Annual Tyre Production from 2008-2012 E.C after and before SPC implementation in the HATC since SPC implementation has a direct effect on the Cost of

Production and if the annual revenue of the case company is increased then it means SPC has a positive impact on Cost production and if the annual revenue of the case company is decreased then it means SPC has a negative impact on Cost production. The Table 4.4 shows that the annual scrap Tyre production from 2006-2011 E.C that indicate the impact of after and before SPC implementation with the Quality of the Tyre since the amount of annual scrap Tyre production is increased then it has a negative impact with Quality of the Tyre and if the amount of annual scrap Tyre production is decreased then it has a positive impact with Quality of the Tyre.

5.3Recommendations

As concluding remark, we would like to forward some recommendations on Horizon Addis Tyre Company on the implementation of Statistical Process Control.

- Due to lack of Experts, the company has not implemented the Tool completely and this leads to not achieve the maximum benefits of implementing Statically Process Control in Horizon Addis Tyre Company.
- Hence it is highly recommended the Company to implement Statically Process Control completely by having Experts and by giving adequate training to the Employee.
- I recommended that the Horizon Addis Tyre Company must giving training to the employees and recognizing and rewarding the employee after the benefits of implementation of Statistical Process Control.
- The management of Horizon Addis Tyre Company must facilitate the implementation of Statistical Process Control by the acceptance of it.
- Educating employees to aware on the values for SPC implementation in the company.
- Top level management be supposed to be convinced that SPC has the ability to improve the company‘s bottom-line.
- Quality control research work should be extended to other section or department of the organization aside PIQA department and the production process.
- The operators and personnel should be well trained, educated and sensitized so as to sustain the quality of their products.
- Management, staff and individual of the organization should be sensitize, enlighten on how important is the concept of quality to their organization performance in the competitive market by taking quality control courses on scheduling bases.

- The study apply Quality improvement and methods of SPC to solve problems to reduce defects, improve the yield of acceptable products, increase customer satisfaction, continuous cost reductions and deliver best in-class organizational performance.

To answer all of these, decisions must be made on facts, not just opinions; consequently, data must be gathered and analyzed in order to help the decision making process and as such statistical process control (SPC) technique would help in the Company. To achieve the benefits for the implementation of Statistical Process Control, The Statistical Process Control in Horizon Addis Tyre Company (HATC) must implement in all sections. This will be achieved by getting many Experts in that field. Horizon Addis Tyre Company has taken short-term training for Quality and Production Employee but there is no long-term training In order to achieve the above, the factory must take short and long- term training to the Employees.

The assessment done on Horizon Addis Tyre Company regarding the Statically Process Control implementation has come up with major findings discussed in previous sections. Based on these findings the following conclusion can be drawn. To achieve the benefits for the implementation of Statistical Process Control, The Statistical Process Control in Horizon Addis Tyre Company (HATC) must implement in all sections. This will be achieved by getting many Experts in that field.

6. References

A case of implementing industrial practice in designing for quality. International Journal of Quality and Reliability Management, 20(3), 288-303.

An Implementation Framework for Statistical Process Control in Small to Medium-sized Enterprises: A South African Context by Logan-Lee Miché Appollis, December 2019 .

An Implementation Framework for Statistical Process Control in Small to Medium-sized Enterprises: Logan-Lee Miché Appollis (December 2019).

Application of Statistical Process Control (SPC) in Manufacturing Industry in a Developing Country, Ignatio Madanhire, Charles Mbohwa, 2006..

Application of Statistical Process Control in a Production Process: Maruf Ariyo Raheem, Aramide Titilayo Gbolahan and Itohowo Eseme Udoada (2016)

Bruce Davis, (2017) World Top Exports Rubber tyre exports by country http://www. Worldtopexports.com-tires-exports-country *Tire Business Global tire rankings* http://www. Tire business. com/ articles /20170905/ News/global-tire-rankings

Chavda, A., Patil, MY. 2011. Increased Productivity of Tyre Manufacturing Process using Lean Methodology. Institute of Technology, Nirma University, Ahmed Abad-382 481, 08-10

Cranfield University *International Journal Business Performance Management* Vol 5, No. 1, 2003 implementing performance measurement systems.

Chauda, A., Patil, Y. 2011. Rubber processing industries in Asia. Spiceland Cengage Learning Services, p. 27.

Freddy Radder 2017 the evolution of tyre, tire recappers news https://www. Hemmings. Com/blog/2013/12/10/this-day-in-history Economic Analysis of the Rubber Tyre Manufacturing.

Implementation of Statistical Process Control Techniques in Industry: Pranay S. Parmar, Vivek A. Deshpande (Nov 2014),

Improving quality with basic statistical process control tools by Jafri Mohd. Rohani & Chan Kok Teng, Jurnal Teknologi, 2001.

International Journal of Emerging Technology and Advanced Engineering, Shock Absorbers/ Rod SealsDr. D. R. Prajapati, 2012.

M. Islam, A. Khan, & M. Khan Minimization of reworks in quality and productivity improvement in the apparel industry (2013).

Quality improvement using Statistical Process Control Tools in Glass Bottles manufacturing company, Yonatan Mengesha Awaj, Ajit Pal Singh and WassihunYimer Amedie (January 2013) (2013).

Quality improvement using statistical process control tools in glass bottles manufacturing company, International Journal of Quality Research, 103-112. R.E. Devor, T. Chang and J.W. Sutherland. 2007.

Solving quality problems in Tyre production preparation process: a practical approach, B. Barbosa, M. T. Pereira, F. J. G. Silva, R. D. S. G. Campilho (27-30 June 2017).

SPC in a pulp mill International Journal of SPC Techniques in Automotive Industry: of Lean Six Sigma, Jukka Rantama ¨ki,Eeva Liisa Tiainen,Tuomo Ka¨ss 2013

Statistical quality design and control: Contemporary concepts and methods (2nd ed., Pearson Prentice Hall). E.L. Grant and R.S. Leavenworth. 1972.

Tesfaye Gebrehanna Anfwatte (June 2018 Addis Ababa, Ethiopia), ORGANIZATIONAL PERFORMANCE AND CHALLENGES OF TYRE MANUFACTURING IN ETHIOPIA: THE CASE OF HORIZON ADDIS TYRE FACTORY.

Appendix I

St. Mary's University

School of Graduate Studies

Institute of quality and productivity management

Dear Respondents, I am postgraduate student of the above institution mentioned and now I am undertaking a research by using your company as case company. This questionnaire is designed based on the Topic: "An Evaluation of the Effect on Statistical Process Control Implementation for Quality Improvement: The Case of the Horizon Addis Tyre Share Company". The main purpose of this questionnaire is to obtain information about overall experience with Statistical Process Control Implementation in your Organization.

The quality of the result of this research is based on the accuracy of the information you provide. In order to be useful, all responses to the items contained in this questionnaire must accurately reflect your true opinions. Please take a few minutes to provide your honest opinion about each statement. Your honest opinion is very valuable to the success of this study.

Any information you give would be kept confidential and it is for academic purpose only.

Your kind cooperation is very much appreciated.

With best regards,

Note

- You are not required to write your name.
- Questions, related to your opinion, please write shortly and precisely on the space provided.

The questionnaires are employee and managerial type, framed into three parts: part one deals with overall profile of the respondents, part two focuses on general Statistical Process Control Implementation issues. Finally, part three tried to shed light on achievements (the managerial type questionnaires have special emphasis on the social and technical system outcomes gained).

1. General Instruction:
    - No need of writing your name
    - In answering the questions, please answer by making tick (√)

I: QUESTIONNARIES FOR EMPLOYEES

Part I Demographic Information

1. Gender: Male □ Female □

2. Age; 18-25 □ 26-35 □ 35-50 □ above 50 □

3. Kindly indicate the level of your education or Educational Qualification

a) Basic Education □ b) Completed Elementary School □ c) Completed High school □
d) College Diploma □ e) Undergraduate □ f) Masters □ g) Doctor □

4. For how long have you been working in the current Company or years of employment in HATMPLs?

a) 0 – 5 years □ b) 6 – 10 years' □ c) 11 – 15 years' □ d) 15 – 20 years' □

e) Above 20 years □

5. How long has your company been using Statistical Process Control management?

a) 1 year □ b) 2 years □ c) 3 years□ d) 4 years □

e) 5 years □ f) above 5years □

6. Your Statistical Process Control practice positions ____________________________

7. Your work area / position/ level in the Organization

i. Department manager □
ii. Head/ Division □
iii. Team leader □
iv. Foreman □
v. Operator □
vi. Technical team □
vii. Supervisor □
viii. Other □

8. Occupation / Professional Qualification

i. Engineering
ii. Quality Assurance
iii. Product Industrialization
iv. Production
v. Accountant
vi. Administration

Part II. Please put a tick mark (√) in the brackets that best describe your answer.

1. Do you think you and your colleagues have adequate knowledge of Quality improvement tools**?**

a) Yes □ b) No □ c) I am not sure □

2. Do you think your company has a consecutive employee training program on Statistical Process Control**?**

a) Not really. □ b) Not quite enough. □ C) Reasonable training program □

d) Enough training program □ e) More than enough training program □

3. To what extent the worker involvement in Statistical Process Control programs in your workplace can be explained? a) Very good □ b) good □ c) Fair □ d) Poor □e) Very poor □

4. Do you think the employees' opinions and suggestions are given due consideration in your company?

a) Not at all. Supervisors and managers don't care employees' opinions □

b) Maybe in special cases, supervisors listen to front-line workers' opinions. □

c) Sometimes Supervisors and managers listen to their subordinates' opinions. □

d) Supervisors and managers in many cases listen to opinions of employees. □

e) Supervisors and managers always listen to opinions of employees from some employees. □

f) Supervisors and managers always listen to opinions of employees from all levels and they are responsive. □

5. What type ofStatistical Process Control tools/ techniques/practices have you applied on your workplace?

6. As an employee what is your company level of Quality and Cost improvement because of implementing Statistical Process Control?

a) Highly Satisfied □ b) Satisfied □ c) Neutral □

d) Dissatisfied □ e) Highly Dissatisfied □

7. Do you like being part of Statistical Process Control activity in your work station?

a) Yes □ b) No □ c) I don't care □

8. If your answer for question number seven (7) is "No" please specify the Reason.

____

____

9. Are you involved in problem identification & improvement of the production process of the company?

a) Yes □ b) No□

10. If your answer is "Yes" for question number 9, how do you involve in problem identification & improvement of the production process of your company?

____

____

____

11. The feedback you get from the management of the company while you identify problem & come up with solutions is

a) Highly encouraging □ b) Encouraging □ c) Neutral □ d) Discouraging □

e) Highly Discouraging

12. Do you believe Statistical Process Control has improved your productivity?

a) Yes to a very great extent □ c) Yes to some extent □

b) Yes to a great extent □

d) No, Statistical Process Control are not related for our case □

14. If your answer is "Yes" for question number (12) how do you think Statistical Process Controlhas improved your productivity?

____

____

Part III. Please rate your agreement or disagreement with the statements below by putting a tick (√)mark.

The rating scale: which presented during observation in theHorizon Addis Tyre Share Company,**5=strongly agree, 4=Agree, 3=Neutral, 2=Disagree, 1=strongly disagree**. Study the statements and tick √**)** one box to reflect the level to which the statement is true for your business, unit or organization.

Table 1. Views on the practice of Statistical Process Control

No	Statements	5	4	3	2	1
1	There is an established system for training and education in the organization.					
2	Top management commitment, visionary leadership and support are weak					
3	There is coordination, communication and integration within departments that foster Statistical Process Control implementation					
4	I am willing to put efforts beyond that is normally expected in order to help this organization to be successful					
5	The Statistical Process Control technique increased employees'/team members' interest (voluntarily) in the work area.					

St. Mary’s University

School of Graduate Studies

Institute of quality and productivity management

Interview (Management)

This interview is designed to be made with the managers of Horizon Addis Tyre Share Company in light of assessing the company’s Statistical Process Control implementation practice.

Introduction

Thank you for your willingness to respond to my questions. The following questions are not meant for testing your knowledge.

The aim of this study to assess the implementation of Statistical Process Control in the company and its impact on productivity of the organization.

The questions that will be raised during the interview are;

1. Do you have taken short-term training or long term training on implementing the Statistical Process Control as a management system?
2. Have you evaluate the effect on Statistical Process Control implementation for Quality Improvement.?
3. How did the management of Horizon Addis Tyre Share Company facilitate Statistical Process Control implementation?
4. To what extent does Statistical Process Control theory related with practical at work place?
5. What positive changes have you observed in your organization since the introduction of Statistical Process Control strategy?
6. Do you think that the implementation of Statistical Process Control helped to improve the productivity of your organization? If so, what improvement has the training brought about in your organization? Like on working area and production time improvements.
7. Do you think your organization Use Statistical Process Control effectively today by applying reducing Variation and defects and Controlling the Process?
8. Based on your experience implementing Statistical Process Control in your organization and the sustainability today, how likely are you to recommend Statistical Process Control implementation to a similar business enterprise?
9. Does the case company implement Statistical Process Control before?

10. Does Statistical Process Control has role on Quality, Cost and Productivity improvement?

11. What major Statistical Process Control related problem did you observe in the case company?

12. What are the critical factors for a successful SPC implementation?

13. Do you think your organization use Statistical Process Control for Maximize the production and Cost reduction and Rejection reduction of the product?

14. What is the level of Rework or Scrap after and before Statistical Process Control Implementation?

Thank you for your participation!

You have been very helpful.

St. Mary's University

School of Graduate Studies

Institute of quality and productivity management

Interview guiding questions for Supervisors

1. What is your role in Statistical Process Control implementation at the case company?
2. Have you ever provided trainings and education on Statistical Process Control implementation to performers so far and how frequently was the event conducted?
3. How was Statistical Process Control as a management system organized and conducted in the factory?
4. How do you compare the defects before and after implementation of Statistical Process Control at the company?
5. Is there any employee's motivational change towards their job as a result of Statistical Process Control implementation?
6. How do you compare the Quality, Cost or Profitability, customer satisfaction andemployee's motivational change towards their job as a result of Statistical Process Control implementation?

Thank you for your participation!

You have been very helpful

St. Mary's University

School of Graduate Studies

Institute of quality and productivity management

Interview Guiding Questions for Horizon Addis Tyre Share Company officer

1. What were the steps of program Statistical Process Control implementation taking place particularly in Horizon Addis Tyre Share Company**?**

2. Is the company effective in Statistical Process Control implementing management philosophy in Horizon Addis Tyre Share Company**?** If no, what are the challenges of the Statistical Process Control program implementation in the factory?

3. What benefits have you got from Statistical Process Control program implementation over the traditional management system? (Measureable and non measureable achievements)

4. Is the company effective in coordination, monitoring and evaluation of Statistical Process Control intervention? If yes, what are the outcomes registered and gaps identified so far?

5. Is the company effective in Statistical Process Control management philosophy intervention and altering the attitude of employees towards the new work culture? If yes, what are the perceived new work cultures due to Kaizen intervention?

6. How do you see the implementation of Statistical Process Control events in the factory increasing, decreasing or staying the same over the years?

7. What mechanisms do you have in place to sustain Statistical Process Control outcomes?

Thank you for your participation!

You have been very helpful

The Statistical Process Control technique increased employees'/team members' interest (voluntarily) in the work area.

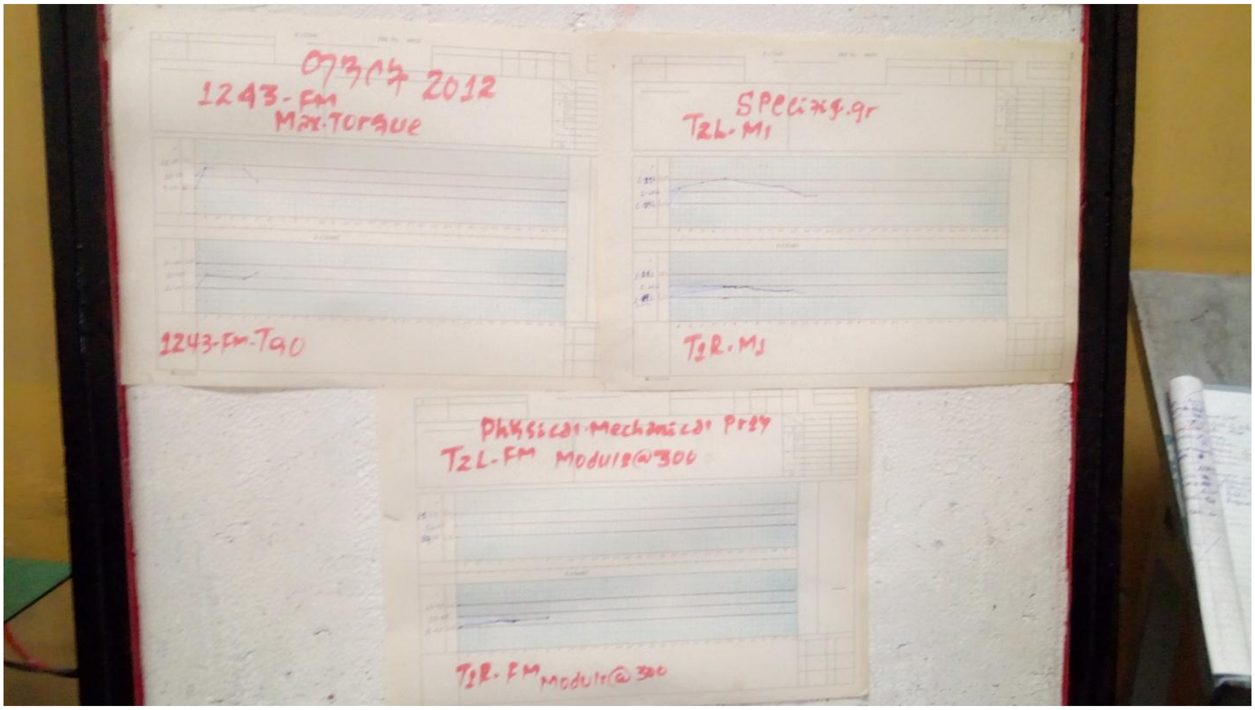


Figure 4.8 Sample SPC Charts of Laboratory

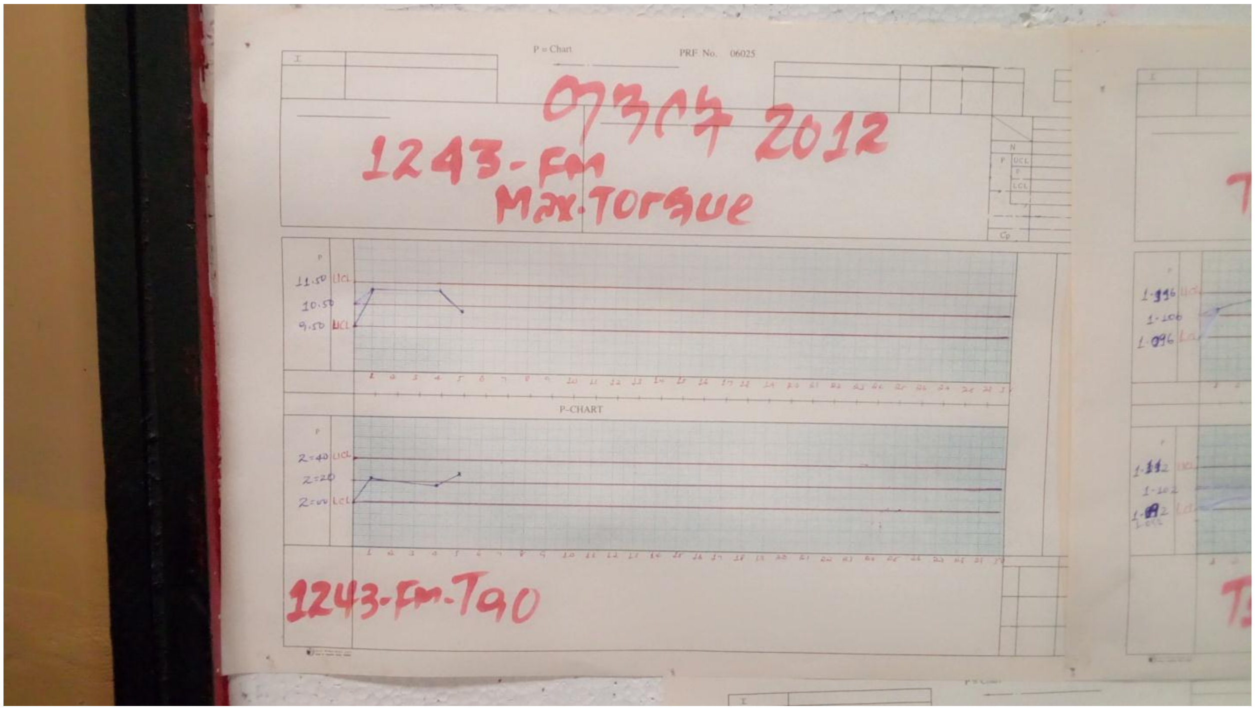


Figure 4.9 Sample SPC Charts of Laboratory

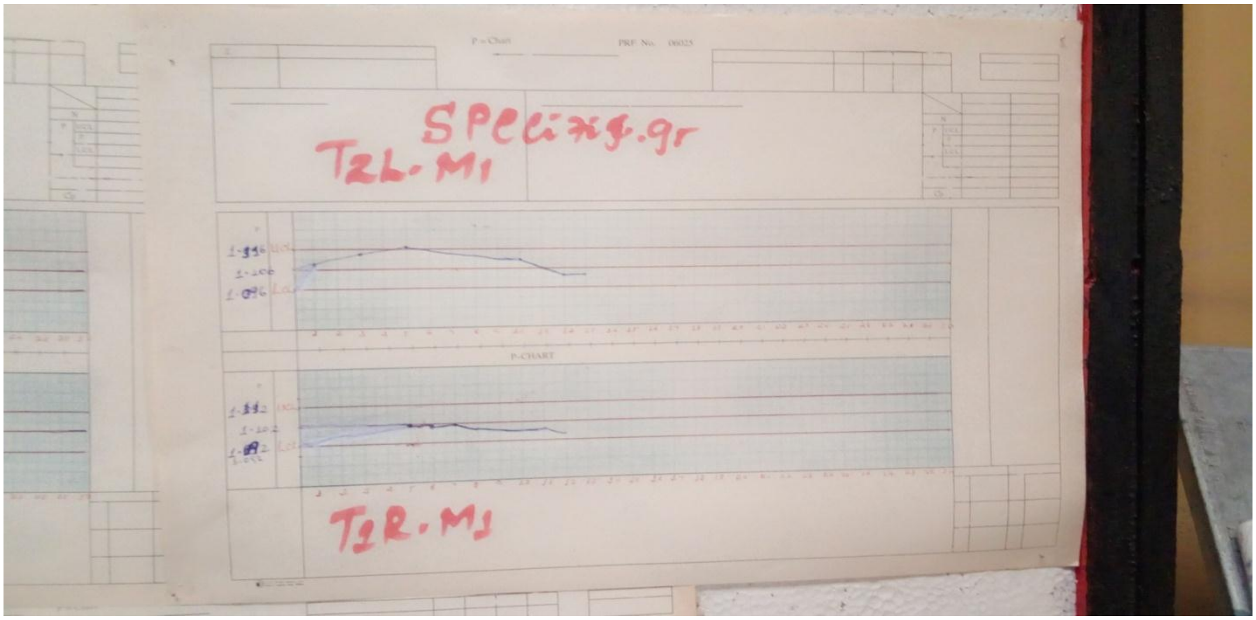


Figure 4.10 Sample SPC Charts of Laboratory

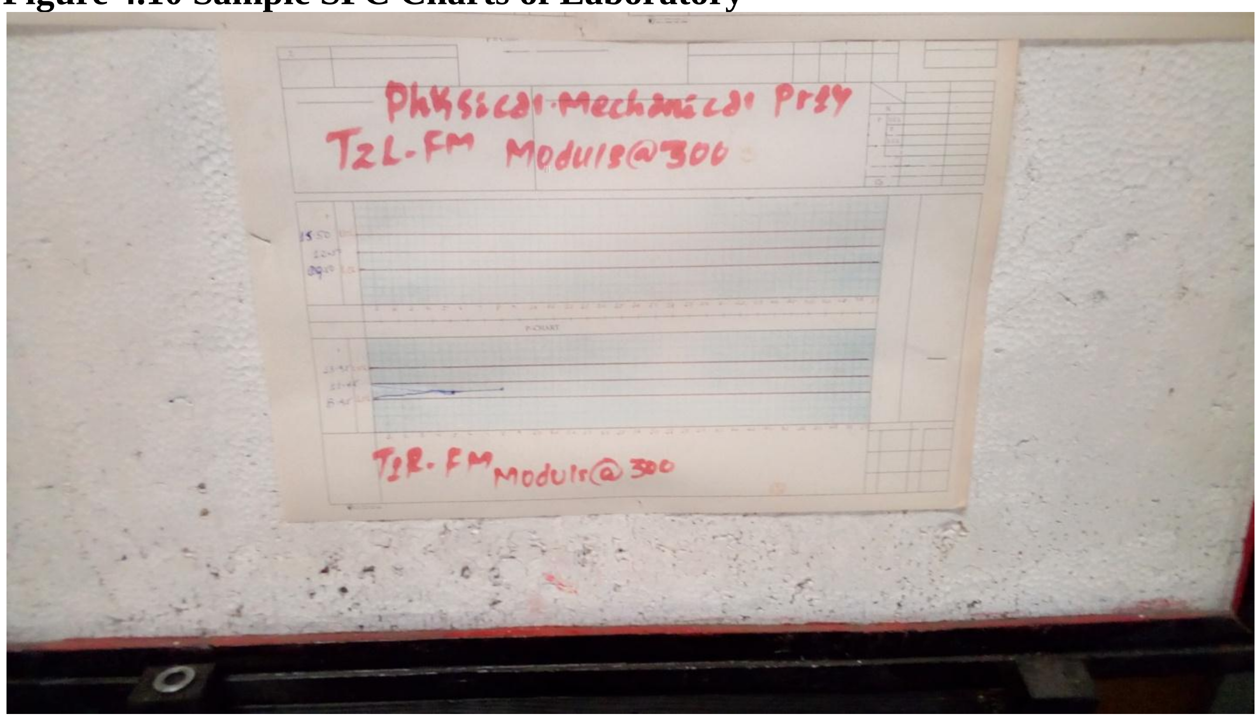


Figure 4.11 Sample SPC Charts of Laboratory

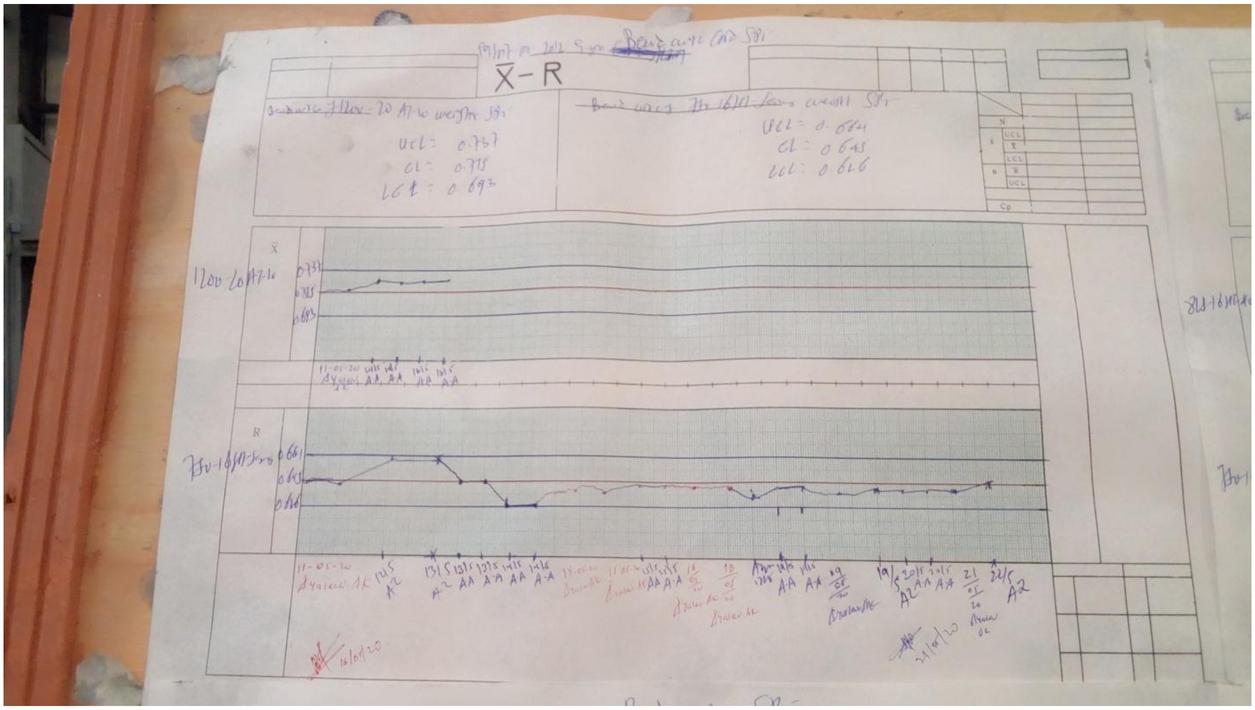


Figure 4.12 Sample SPC Charts of Bead Wire and Steal Coating

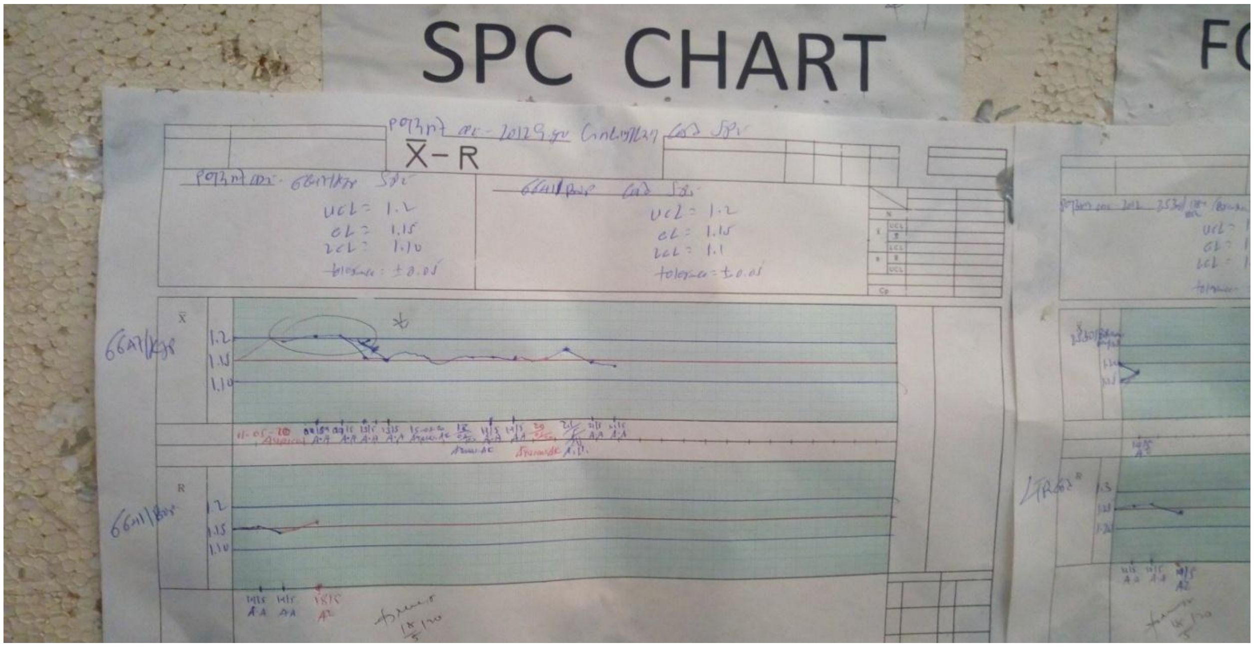


Figure 4.13 Sample SPC Charts of Textile- Rubberizing Cord

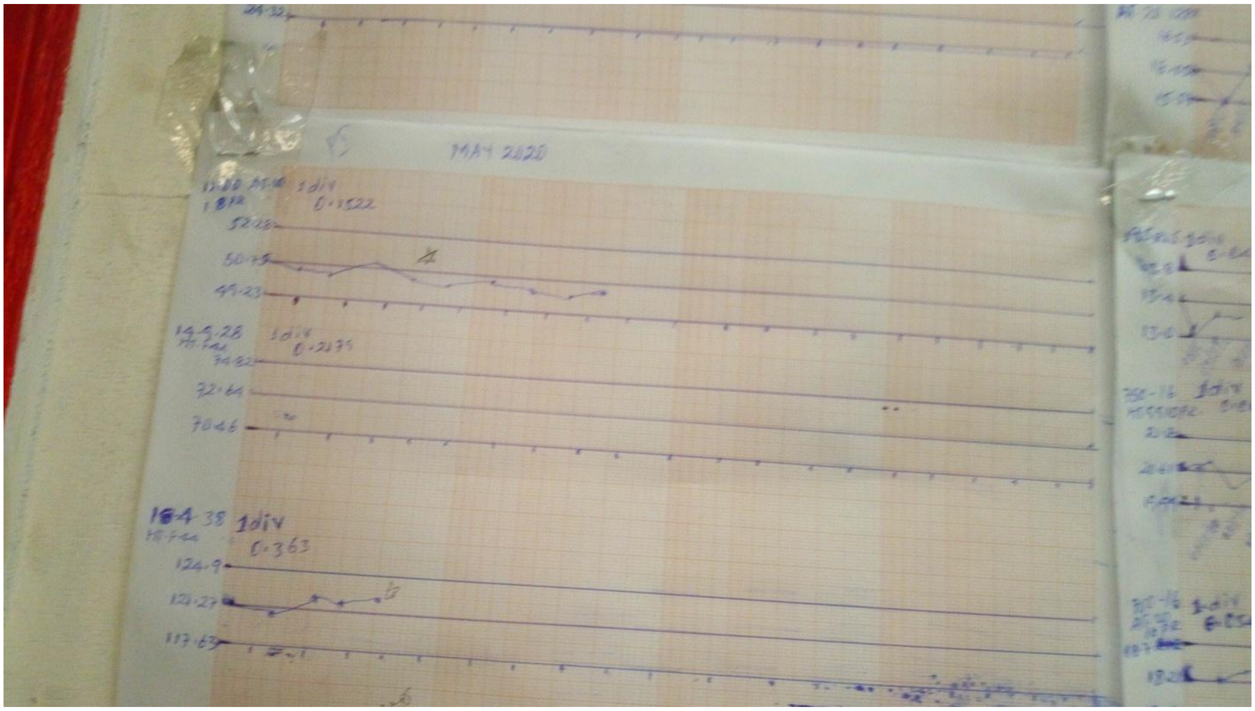


Figure 4.14 Sample SPC Charts of Building Machine

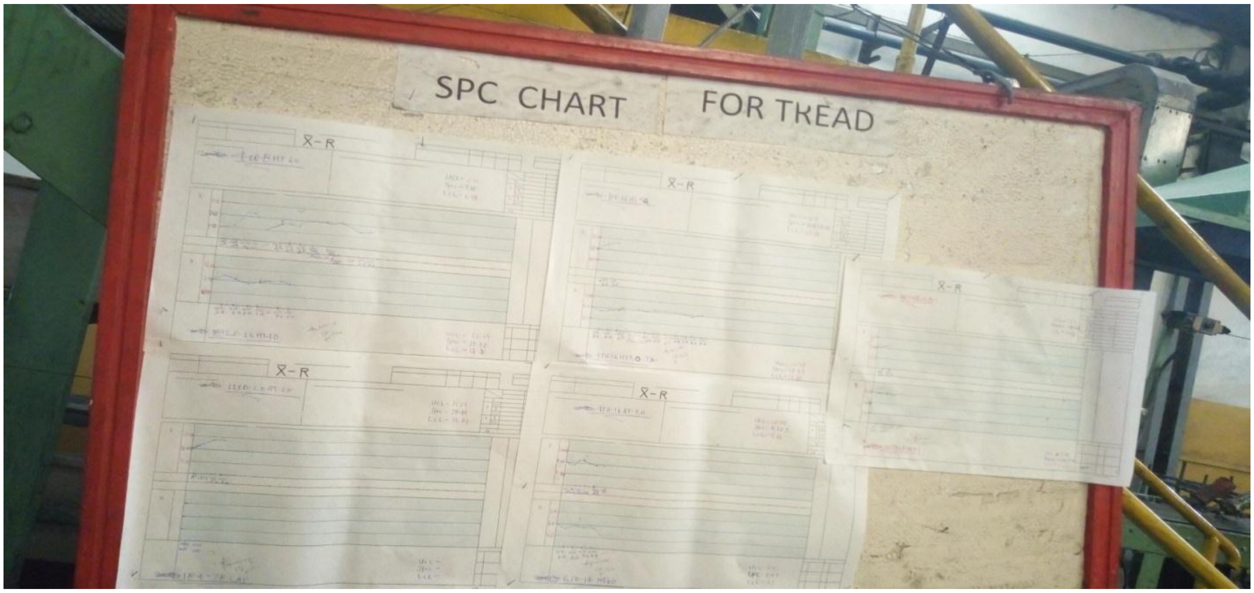


Figure 4.15 Sample SPC Charts of Tread