ST. MARY'S UNIVERSITY

SCHOOL OF GRADUATE STUDIES

INSTITUTE OF QUALITY AND PRODUCTIVITY MANAGEMENT

APPLICATION OF STATISTICAL PROCESSCONTROL TOOLS IN MANUFACTURING INDUSTRIES: THE CASE OF TIKUR ABBAY SHOE FACTORY

BY: GASHAW GOJE

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Declaration

I, GASHAW GOJEhereby declare that the thesis entitled "APPLICATION OF STATISTICAL PROCESS CONTROL TOOLS IN MANUFACTURING INDUSTRIES: THE CASE OF TIKUR ABBAY SHOE FACTORY" submitted by me for the award of master's Degree in quality and productivity management is my original work and it has not been presented for the award of any other Degree, Diploma, Fellowship or any other similar titles of any other university or institutions.

Signature________________

Name: GASHAW GOJE

Date: June, 2020

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 Signature

St. Mary's University

Addis Ababa, Ethiopia

June, 2020

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Finally, my thanks are go to all product process Stuffs Tikur Abay Shoe Factory SC. for their honestly collaboration by providing important data to build this master thesis.

LIST OF ACRONYMS AND ABREVIATIONS

CL - Centrallimits

Cp - Central Point

ISO - International Organization for Standards

LCL - Lower control limits

PC - Process Capability

SPC - Statistical process control

SQC- Statistical Quality Control

TASF- Tikur Abbay Shoe Factory

UCL- Upper control limits

Abstract

In the era of quality, working with specified standards is not the ultimate goal of business companies. Executing significant tasks below the standard and delivering products to customers may out the firm from the game truck. Process-out products and delivering services above quality standards, definitely satisfy all types of customers. To deliver quality products and to reach clients'need and satisfaction, improving the process is an ambiguous task of any company. In order to improve the product process, applying statistical process control tools is significant and widely used. The aim of this study is introducing statistical process control tools to the selected company, to identify, control and manage its process related problems. The application initially started after identifying common defect during proposal stage of this research. Direct observation, adaptation time to investigate how the process is going on, interviewing stake holders such as technicians, product managers and quality assurance teams were thoroughly used to apply the most related SPC tools. Primarily, Pareto chart is used to prioritize the defect types, next the cause and effect diagram applied to identify the likely causes of the selected product. From the control chat p chart is calculated and drawn to determine where the process is Cp is calculated to indicate the process capability. After data analyzed by the indicated tools, during the product process, common process problems, such as outdated machine, unused test laboratory machine due to lack of skilled lab technician and unused quality manuals and other problems has been found and frequently causing defect product. Eliminating or reducing such problems through applying the steps of SPC tools, the process may stay in the control limit, become excellent and will provide products which satisfy and excite the needs of customers. The tools also employ visualized data and help the top managers to pass numeric based decisions.

Key words: - Process, statistical process control, process improvement, control charts

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CHAPTER ONE

1. Introduction

Chapter one addresses background of the study, statement of the problem, research questions, both general and specific objective of the study, scope of the study,organization of the study and company background.

1.1 Background of the study

According to ISO 9000:2015, the term quality means a degree to which a set of inherent characteristics of an object fulfils requirements. This sentence consist three major concepts such as 1. Inherent: means existing in something, especially as a permanent characteristic 2. Characteristic: distinguishing feature 3. Requirement: need or expectation that is stated, generally implied or obligatory. Based on its significance and current situation Sujeong Seo (2017) notes that quality is the most important factor in research, development and robust design within the manufacturing industry since customer needs and product satisfaction is rapidly changing through globalization. Many companies look upon quality management as a way by which to maintain competitive benefit. During the last few decades the interest and industrial use of quality-related system, tools and methodologies has grown significantly. Modern quality management is based on the idea that to remain competitive an organization has to incessantly upgrade the way it fulfills the needs of its customers. It is not enough to focus on the finished products that customers receive. How these products are produced, i.e. the processes, also needs to be addressed. (Azad & Reza et. al. 2009)

No production process produces exactly identical items, one after the other. (Russel & Taylor 7th edition, 2011) All processes contain a certain amount of variability that makes some variation between units inevitable. Variation has been a problem since beginning of industrialization, perhaps even earlier. The introduction of mass production, assembly lines and exchangeable parts required consistency and high precision. This problem was initially handled by setting specification limits for important product characteristics. Most of the statistical quality control techniques used now have been developed during the last century. One of the most commonly used statistical tools, control charts, was introduced by Dr. Walter Shewhart in 1924 at Bell Laboratories. (Chandra, 2001) Advancements in the field of mathematical statistics resulted in the development of problem-solving techniques such as statistical process control, design of experiments and process capability studies (Montgomery, 2009) As time passed, focus moved away from the finished products towards improving the capability of production process. (Azad & Reza et. al. 2009)

Statistical process control is a statistical procedure using control charts to see if any part of a production process is not functioning properly and could cause poor quality. It is used to inspect and measure the production process to see if it is varying from what it is supposed to be doing. (Russel & Taylor)

Process control is achieved by taking periodic samples from the process and plotting these sample points on a chart, to see if the process is within statistical control limits. A sample can be a single item or a group of items. If a sample point is outside the limits, the process may be out of control, and the cause is sought so that the problem can be corrected. If the sample is within the control limits, the process continues without interference but with continued monitoring. In this way, SPC prevents quality problems by correcting the process before it starts producing defects. (Russell & Taylor,2011)

Wu, Pearn and Kotz notes that understanding the structure of process and quantifying capability performance no doubt is essential for successful quality improvement initiatives. For the last 20 years, the idea and application of process capability analysis has become significantly growing A well defined tool in applications of statistical process control (SPC) to a continuous improvement of quality and productivity. They reviewed that the relationship between the actual process performance and the specification limits (or tolerance) may be quantified using suitable process capability indices. Process capability indices (PCIs), in particular Cp, Ca, Cpk, Cpm and Cpmk, which provide numerical measures of whether or not a manufacturing process is capable to meet a predetermined level of production tolerance, have received substantial attention in research activities as well as an increased usage in process assessments and purchasing decisions during last two decades.

Footwear leather industry is one of the manufacturing industries that produce shoes and shoe related products to satisfy individuals' needs and wants. In Ethiopia, the sector is given major emphasis in the growth and transformation plan II (GTP II). The Quality improvement of the leather products is very important on the growth of the sectors. Measuring and reducing Quality problems related to leather and leather products at the national level enhance the national goods and products acceptance level in the international markets (Nebyuo and Tesfahun 2015).

Tikur Abbay shoe factory is one of the leather manufacturing industries in Ethiopia. It was established in 1948 in the capital city- Addis Ababa. It was nationalized in 1975 by the former government and was run by the National Leather and Shoes Corporation under the Ministry of Industry. It was re-established in 1992 as an autonomous Public Enterprise with a capital of 4,416,000. Transforming the previous public enterprise, the factory has been incorporated as a share company on Oct. 1, 1999 having 22,053 authorized and paid shares with a par value of birr 1000 each, fully owned by government. In view of its eventual privatization, all fixed assets were revalued and financial restructuring made.

The company primarily processed-out different types of products for different purpose such as, foot wears (safety shoes, military shoes, working shoes, causal shoes ladies' shoes and children shoes) and glues for internal use and for local market. It was providing its out puts to internal market and external market areas such as Sudan, South Africa, Uganda, Rwanda, Italy, USA and Canada. But currently, the company international market limited with in Africa and Middle East. TASF is working with international standards in recent years and engaged with ISO 900: 2015 and has only one quality control team which work multiple quality related tasks.

However, in recent years the level of customer complain has increased and the company is collecting defected products from its customers. This became a critical quality issue of the company.

In applying statistical process control tools, the most related and appropriate tools are applied in order to have possible solutions for the quality related problems. In addition, other issues are assessed within the manufacturing industry, if there is any trend in the application of statistical process tools.

1.2 Statement of the problem

Reducing or eliminating defects from process to produce and deliver quality products to customers is critical for manufacturing industries. The pivotal quality principles in production are to prevent, improve and control. (Bergman, 2003) In recent years using Statistical process control and Six

Sigma has grown in popularity especially in the US and companies like General Electric and Motorola have obtained significant improvement in their performance. (Pande & S., 2000 et al)

According Beshah and Kitaw(2014), quality management practices in Ethiopia was found to be low in all the tenets including leadership, policy and strategy, resources management, process management, customer satisfaction, business performance and impact on society. This means there is process management problem in Ethiopian manufacturing industries and service sectors.

TASF producing and delivering heavy duty military shoes and civilian shoes for: gents, ladies and kids in large number of models in its three independent factories within a compound.

However, monthly performance reports of quality control team show that TAFS faced quality related problems during sewing, lasting and finishing stages of the process such as improper setting during toe lasting, Side lasting problems due to feather edge stitching, wrongly shaped rubber, needle thread breakage, skipped stitches, inefficient ironing, Seam pucker on some model shoes and this lead the company for frequent rework and delay on delivering finished products to customers on the contracted time. According to the last quarterly report of model 927 heavy duty shoe frequently recorded as abnormal rate of defects and created a situation for rework and delay.

This study specifically focuses on the process of those model shoes which have frequent defect rates, investigating the root causes of the process variation and finding possible solution based on statistical process control tools.

1.3 Research questions

In order to minimize the quality related problems, this thesis will reach to address the following fundamental research questions.

I. What are the causes of process variation that influenced finished and semi-finished products in TASF?

II. Which SPC tools are compatible for the identified problem in the case company?

III. Which process element need improvement to minimize defects?

1.4 Objectives of the study

1.4.1 General objective

The general objective of the thesis is to identify the root causes of quality related problems and recommending possible solutions to boost in order to maximize the profit of the case company-Tikur Abbay shoe factory.

1.4.2 Specific objectives

Specifically, this research aims the following objectives:

I. To assess the existing quality related problems in the company;
II. To have thorough understanding the basics of statistical process control and its effective application in the company.
III. To develop a better solution and to take a counter measure for achieving quality improvement.
IV. To develop a frame work for the application of SPC tools in the case company.

1.5. Scope of the study

The research had been conducted in Addis Ababa city Tikur Abbay shoe factory. In this share company there are three process sub stations and the research had studied only one substation, in order to accomplish the research objective. Specifically, it closely focused on Model 927 products and solutions.

1.6 Definition of Basic Terms

Statistical process controls: is defined as the application of statistical and engineering methods in measuring, monitoring, controlling, and improving quality.

Variations: is the degree of variation, more than its presence, which varies.

Control charts: a run chart with statistically determined upper and lower control limits.

Process capability: is capable of producing products which conforms to specifications.

Quality Improvement:the reduction of variability in processes and products.

1.7 Organization of the research paper

This thesis paper is organized in five chapters. The first chapter introduces the research background, statement of the problem, the objective of this study where and what to be studied within it. Chapter two encompass the theoretical part, statistical process control tools, of the study bases to run. Chapter three shows the research design and how and where data gathered. Chapter four describes the interaction of problems and SPC tools and discussion part. Chapter five concludes the research main findings and states recommendations as a solution.

CHAPTER TWO

2. Theoretical frame of reference

In this part, theoretical background of reference is discussed. Areas such as variation, statistical process control and the seven SPC quality tools.

2.1. Statistical process control

As D. Montgomery described in his fifth edition, statistical process control (SPC) is a powerful collection of problem-solving tools useful in achieving process stability and improving capability through the reduction of variability.

In the production processes, due to the machine equipment, material, environment, operator, and so on reasons, it causes that no product is created quite the same as the others. In quality control, variations are divided into chance and assignable variations. Chance variation, also named random variation, is caused under the natural condition, is inevitable, and its influence is small. But assignable variations should not occur in the regular production processes. Once it occurs, it causes the system conspicuous losses. The statistical process control (SPC) identifies whether the production processes have changed or not, or the occurrence of assignable variations, by the analysis of quality characteristic data in order to improve the production processes before the irregular products created.

2.2The Aim SPC tools in manufacturing industries

SPC tools are used for continuous improvement of the production volume as well as quality which leads to achieve manufacturing excellence. The major goal of any company is to beer profit by achieving the customers' satisfaction. This can be done by proper execution of the SPC tools. SPC can be used as quality control tool or it can contribute to increase the total volume of production. By this tool, the production manager can easily identify the causes responsible for poor product quality, machine breakdowns and also huge wastage. (F.Sultana, N.I. Razive & A. Azeem, 2009)

They found in their investigation that the critical problems of product machine break down through SPC tools. They also discovered possible solutions for all types of process related problems. It is a statistical technique in decision making that is used for selection of a limited number of tasks that produce significant overall effect. SPC techniques have been widely recognized as effectiveapproaches for process monitoring and diagnosis. It providesuse of the statistical principals and techniques at every stage ofthe production. SPC aims to control quality characteristics onthe methods, machine, products and equipment, both for thecompany and operators with the **magnificent seven**(Abtew,Hong, Kopi&PU, 2018).

2.3 The Seven Basic Quality Tools

Russell and Tailor (7th edition, 2011) notes that the seven quality tools are popular and became the basis for the quality management programs developed by many companies. Once the basic problem-solving or quality improvement process is understood, the addition of quality tools can make the process proceed more quickly and systematically.

2.3.1 Flow chart

Flow chart is a pictorial representation showing steps of a process. We apply flow chart tools because it uses easily recognizable symbols to represent the process and used in problem identification in a process called Imagineering. In order to find the condition of the process we first draw flowchart of what steps the process actually follows. Next, we draw a flowchart of what steps the process should follow. Then, compare the two charts to find where they are different b/c this is where the problem arises.

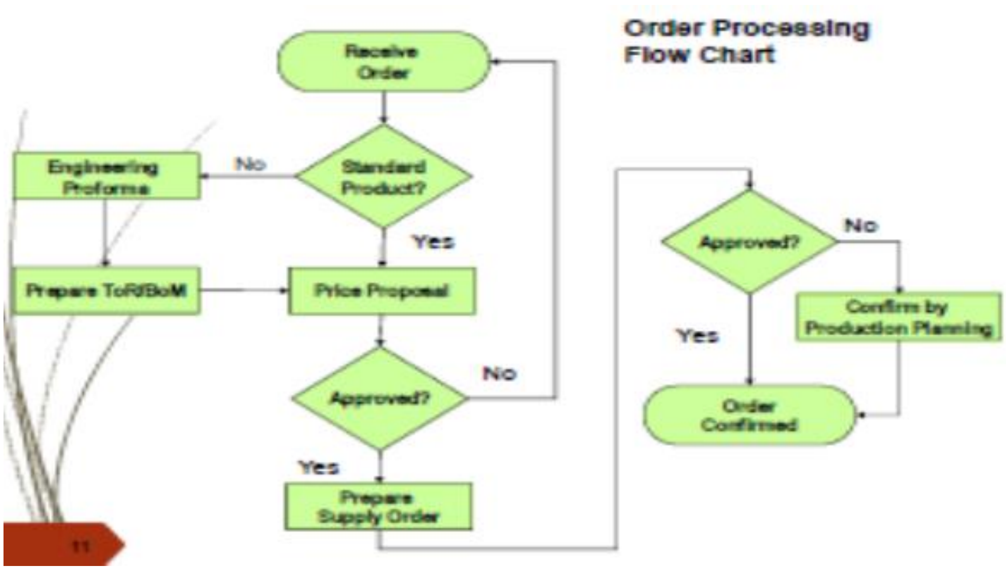


Fig.1.1 a compete view of flow chart

2.3.2. Check Sheet

Check sheets are the simplest and easily understandable SPC tools. We use this tool to answer the question like “How often are certain events happening?” It starts the process of translating “opinions” into “facts.”

Part No.: TAX-41
Location: Bellevue
Study Date: 6/5/03
Analyst: TCB

	2002												2003					
Defect	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	Total
Parts damaged		1		3	1	2		1		10	3		2	2	7	2		34
Machining problems			3	3				1	8		3		8	3				29
Supplied parts rusted			1	1		2	9											13
Masking insufficient		3	6	4	3	1												17
Misaligned weld	2																	2
Processing out of order	2															2		4
Wrong part issued		1						2										3
Unfinished fairing			3															3
Adhesive failure				1							1		2			1	1	6
Powdery alodine					1													1
Paint out of limits						1								1				2
Paint damaged by etching			1															1
Film on parts						3		1	1									5
Primer cans damaged								1										1
Voids in casting									1	1								2
Delaminated composite										2								2
Incorrect dimensions											13	7	13	1		1	1	36
Improper test procedure										1								1
Salt-spray failure													4			2		4
TOTAL	4	5	14	12	5	9	9	6	10	14	20	7	29	7	7	6	2	166

Fig. 1.2 a cheek sheet

2.3.3 Histogram

Histogram shows a picture of the variation in a process or a product. It shows the capability of a process and helps us to understand and analyze what is happening. Histograms are used as a check on specific process parameters to determine where the greatest amount of variation occurs in the process or to determine if process specifications are exceeded. Three questions can be answered by a quick look at the pattern of the histogram.

1. Is the process operating to the bell-shaped curve?
2. Where is the process centered?
3. Is the process capable of meeting the specifications?

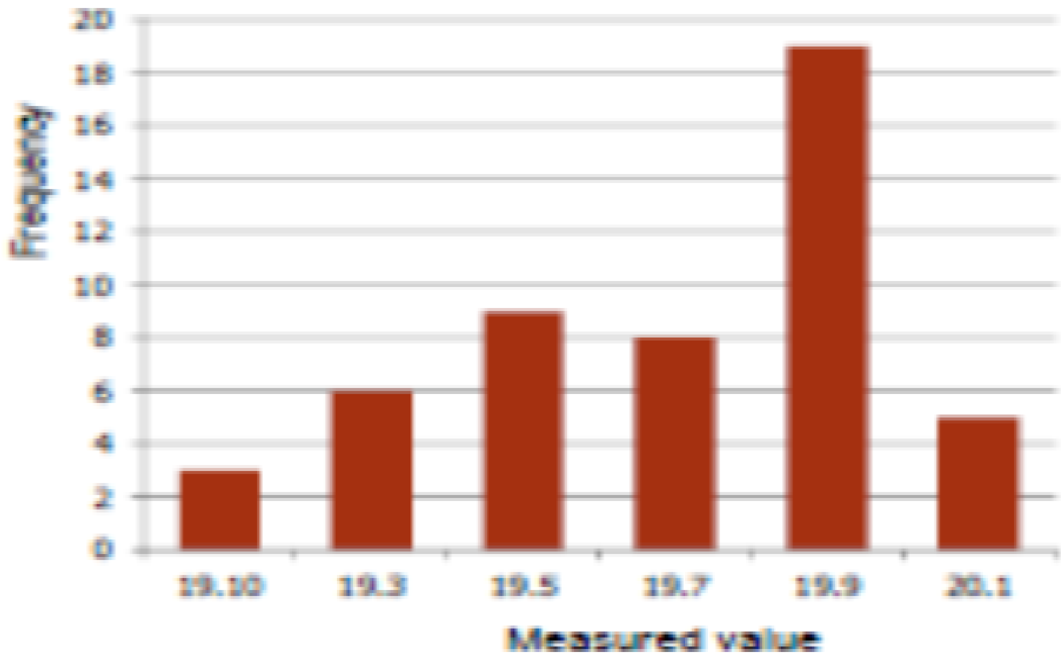


Fig. 1.3 Histogram

2.3.4 Pareto chart

Pareto chart is a simple bar graph ranking in order of importance the causes, sources, types or reasons for problems and/or opportunities. The chart is similar to the histogram or bar chart, except that the bars arranged in decreasing order from left to right along the abscissa.

In his words Juran describes “vital few, trivial many”. He noted that 20% of the quality problems caused 80% of the revenue loss. The fundamental idea that we get this diagram for quality improvement that the first few contributing causes to a problem usually account for the majority of the result. Pareto or ABC analysis is an investigatory tool that enables the quality assurance service to assign priorities to the possible sources of quality defects - examination of rejects, for example, is the most expensive action.

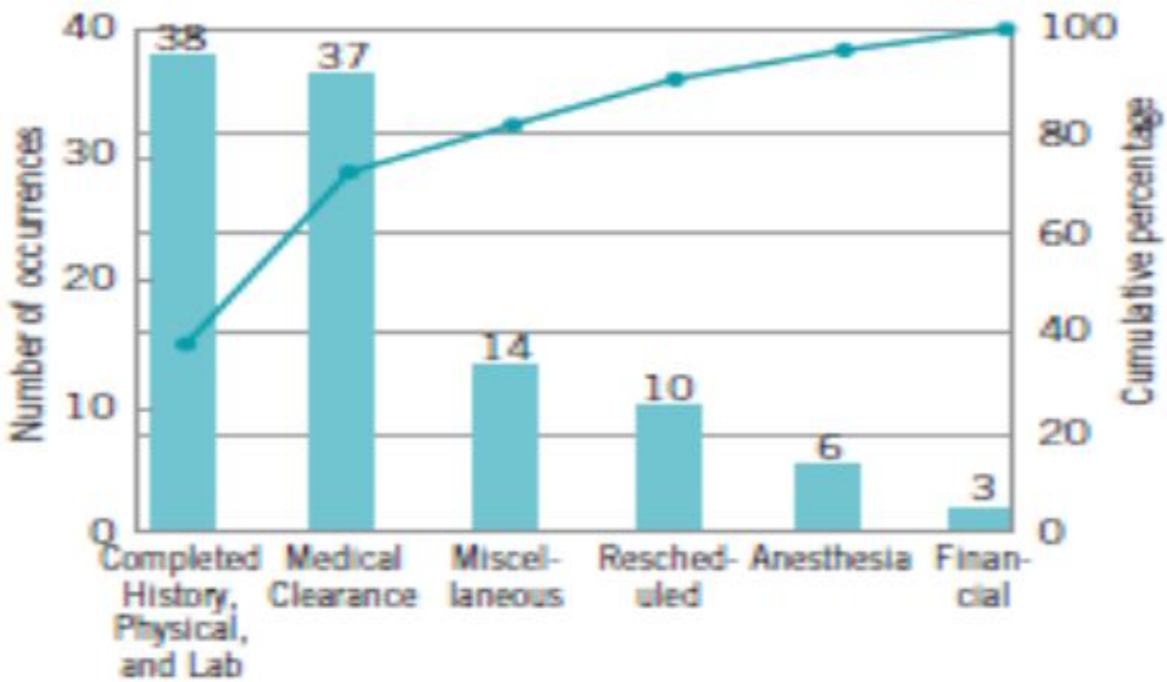


Fig. 1.4 Pareto diagram

2.3.5 Cause and effect Diagram

This tool was proposed by a Japanese professor named Kawuru Ishikawa. His tool is used to develop to represent the relationship between some "effect" and all possible "causes" influencing it. The major categories of causes contributing to the effect are assigned to the major branches of the diagram. A well-detailed Cause and Effect Diagram will take on the shape of fish bones.

We apply the Cause and Effect diagram to:

- Focus attention on one specific issue or problem.
- Organize and display graphically the various theories about what the root causes of a problem are.
- Reveal r/n among various variables & possible causes.
- Provide additional insight into process behaviors.
- Focus the team on the causes, not the symptoms.

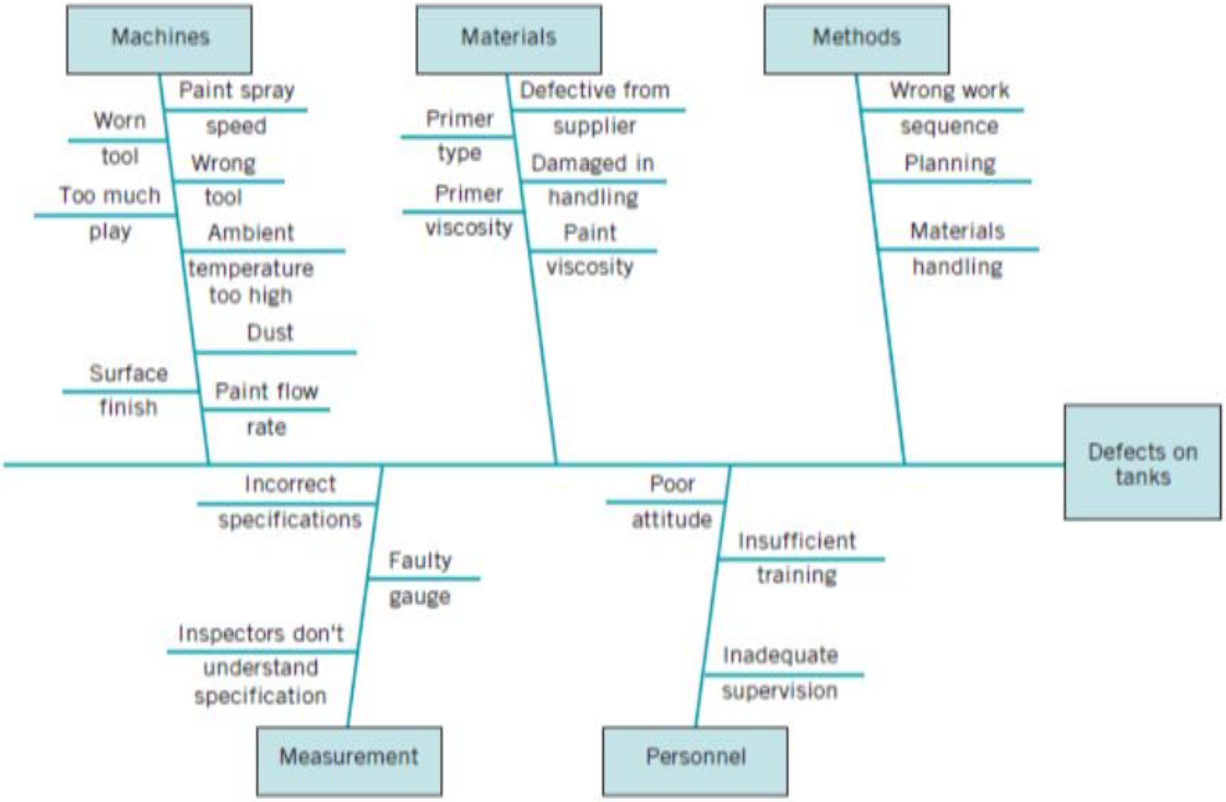
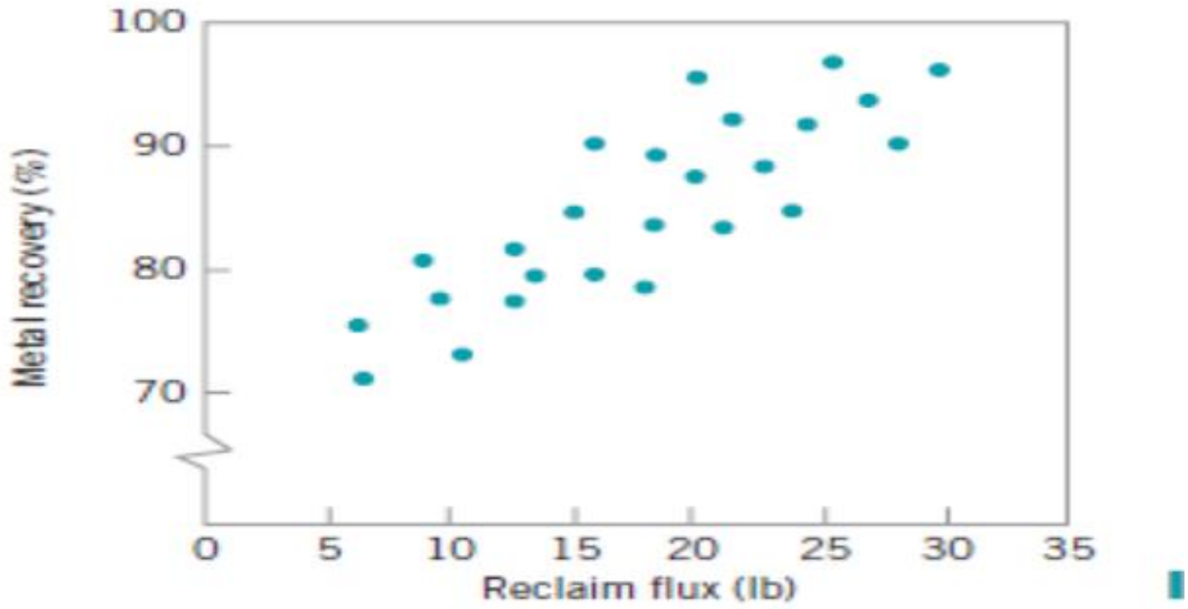


Fig. 1.5 cause and effect diagram

2.3.6 Scatter diagram

Scatter Diagram is a diagram where the relationship between two characteristic values is plotted and analyzed as to whether a correlation exists between the two set of data. They are a natural extension to cause and effect charts and should be used to get the best result. The item plotted on the horizontal axis: independent variable. The item plotted on the vertical axis: dependent variable. This diagram answers the question: "Is Y in some way dependent on X?" or "Does X Affect Y?"



1.6 Scatter diagram

2.3.7 Control chart

D. Montgomery described the control chart as 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. The control chart may also provide information useful in improving the 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. The details of above method may refer to Montgomery fifth edition. A control chart has three significant parts:

I. Center line (CL)
II. Control limits (CLs) and
III. Monitoring statistic by sample dots

Main functions of Control Charts:

- to analyze a process
- to stabilize a process
- to control a process and

- to improve a process

Halima Elfaghihe (2016) illustrated that the components of this three items of control chart as Let *M* be a sample statistic which is a measure of quality. Suppose that M has a normal distribution with mean μM and the standard deviation σM. The mean of M is equal to the target value μM=μ0, when the process is in control. Then the central line is CL=μM, the upper control limit is UCL=μM+σM, and the lower control limit is LSL=μM−σM. Shewarts control chart is shown in Figure (1.1). The quantity kσM represents the distance of the control limits from the central line. Parameters of the control chart are the following: the sample size n and the control limit width k. It should be noticed that Shewarts control charts actually represent tests corresponding to hypothesis testing. Null hypothesis H0(μM=μ0) corresponds let M is (Based on the inspection or measurement of quality characteristics from the obtained sample,to the situation when the production process is in control, while the alternative hypothesis H1(μM≠μ0) corresponds to the situation when the production process is out of control.

For each sample she notes that i, i=1, 2, m we calculate the value of sample statistic M and we denote it by Mi. If the point Mi is within limits UCL and LCL, then the process is in-control state and this leads to the acceptance of the hypothesis(H0:μM=μ0). But if the point Mi is out of the interval (UCL, LCL), this means that the process is out of control, and we reject the hypothesis (H0:μM ≠μ0). The result is an acceptance of the alternative hypothesis and it becomes necessary to discover the causes that led to this out-of-control state, and to correct them.

Control charts have two broad classifications: when the quality nature can be quantified, then we use the

1. Variable control chart: we use when the quality nature can be quantified, then we use the
2. Attribute control charts: we use when the quality characteristic is qualitative in nature

Variable control chart

X- Bar R control chart is the most widely used control chart especially in manufacturing industries. D. Montgomery stated about process variability, can be monitored with either a control chart for the standard deviation, called the s control chart, or a control chart for the range, and called an R control chart. The R chart is more widely used. Usually, separate and R charts are maintained for each quality characteristic of interest.

To calculate the UCL and the LCL of the mean is we use the formula:

$$UCL_{\bar{X}} = \bar{\bar{X}} + A_2\bar{R} \qquad LCL_{\bar{X}} = \bar{\bar{X}} - A_2\bar{R}$$

To calculate the range, we use the formula:

$$UCL_R = D_4\bar{R} \qquad LCL_{\bar{R}} = D_3\bar{R}$$

Reinhart (1960) elaborates E. Shewhart's X-bar R control chart as, core consideration in the using of X and R charts, the type of data needs to be variable and should be analyzed. This variable must be something that can be measured and expressed in numbers, such as a dimension, hardness number, or compressive strength. It is important that the variable chosen depict a pertinent characteristic of the product's quality.

The X-bar chart is used for monitoring the process mean. On this chart, we plot the sample mean. For monitoring the process variability, we use S-chart and R-chart. If we have a sample (x1, x2, xn) of the size n, then on S-chart we represent the sample standard deviation.

To calculate X- bar S chart we use the formula:

$$S = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n-1}}.$$

X-bar S chart is used when the sample size is small (n<10).

Attribute charts

The most frequently used attribute charts are: np-chart, c-chart, u-chart and p-chart.

We use np-chart to plot the number of defectives (per batch, per day, per machine). The control limits in this chart are calculated from binominal distribution. On the c-chart, the number of defects (per batch, per day, per machine, per 100 feet of pipe, etc.) is plotted. It is presumed that the quality defects are not frequent and the control limits are computed using Poisson distribution. A defect per unit chart (u-chart) is used to plot the rate of defects. We divide the number of defects by the number of inspected units (the n; e.g., feet of pipe, number of batches). The differences between u-chart and c-chart is that u-chart does not need a constant number of units, and we can use it, for example, when the batches (samples) are not of the same size. We use proportion defective chart (p-chart) in order to plot the fraction of defectives (per any unit of measure, per day, per machine, etc.) just like in the u-chart. The control limits are based on binominal distribution of proportions. To construct the control limits, we need an estimate of the standard deviation σ. We may estimate σ from either the standard deviations or the ranges of the m samples.

P chart: We use this chart when:

- ✓ only when variable data cannot be obtained;
- ✓ charting fraction rejected as nonconforming from a varying sample size;
- ✓ screening multiple characteristics for potential monitoring on variable control charts and
- ✓ tracking the quality level of a process before any rework is performed

To calculate the UCL and LCL of this chart are we use:

$$UCL = P_0 + \frac{3\sqrt{P_0(1-P_0)}}{\sqrt{n_i}} \qquad LCL = P_0 - \frac{3\sqrt{P_0(1-P_0)}}{\sqrt{n_i}}$$

np chart: we use it when: -

- used when subgroup size is constant (n)
- the actual number of defects is represented by pn (or np)

To calculate the UCL and LCL of this chart is we use:

$$UCL_{np} = n\overline{p} + 3\sqrt{n\overline{p}(1-\overline{p})}$$

$$UCL_{np} = n\overline{p} - 3\sqrt{n\overline{p}(1-\overline{p})}$$

C chart: used to monitor the number of nonconformities on a unit of a process based on units taken from the process at given times (hours, shifts, days, weeks, months, etc.)

The lower and upper control limits for the C chart are calculated using the formulas:

$$LCL = \overline{c} - m\sqrt{\overline{c}} \quad UCL = \overline{c} + m\sqrt{\overline{c}}$$

2.3Process Capability

Russell and Tailor (7^{th} edition) described about process capability as, refers to the natural variation of a process relative to the variation allowed by the design specifications. In other words, how capable is the process of producing acceptable units according to the design specifications? Process control charts are used for process capability to determine if an existing process is capable of meeting design specifications. They point out three main elements related with process capability such as: Process variability (the natural range of variation of the process), Process center (mean) and Design specifications.

Measure of process capability

According to the book of Russell and Tailor, one measure of the capability of a process to meet design specifications is the process capability ratio (Cp). It is defined as the ratio of the range of the design specifications (the tolerance range) to the range of the process variation, which for most firms is typically:

$$C_p = \frac{\text{tolerance range}}{\text{process range}} = \frac{\text{upper specification limit} - \text{lower specification limit}}{6\sigma}$$

They notify the second measurement as process capability index (Cpk). The Cpk differs from the Cp in that it indicates if the process mean has shifted away from the design target, and in which direction it has shifted—that is, if it is off center.

$$C_{pk} = \text{minimum}\left[\frac{\bar{\bar{x}} - \text{lower specification}}{3\sigma}, \frac{\text{upper specification} - \bar{\bar{x}}}{3\sigma}\right]$$

CHAPTER THREE

3.Research Design and Methodology

3.1. Research Design

To investigate the problems thoroughly and to obtain answers to research questions as well as to identify the root causes of processes variation in the case company based on the research problem and stated objectives, statistical process control trends areemployed. Thenature of the research isqualitative, because of the data are more attributive than variable.

3.2. Data Collection methods and procedures

To obtain valid and reliable data for the study, both primary and secondary data collection methods will be used. Primary data is collected by using direct observation, interviews and focused group discussion methods. Secondary data is also considered to apply some tools of statistical process control tools. To Secondary had been be gathered through documentation such as weekly, monthly and quarterly reports of quality assurance team of TAFS.

Direct Observation

To understand the process deeply and toughly, observation is used as a primary data gathering tool. During the observation process stations identified, major process problems detected and concerned individual distinguished. All the four product process stations such as cutting, stitching, vulcanization and finishing rooms are observed for better understanding on how footwear process is going on.

Interview

Interviews are the most widely used and valuable tool in all steps of this study. During the interview concerned bodies such as quality assurance and quality control team, technicians, supervisors and managers of the case company are conducted. The interview has made in two forms: Initially it was made face to face with individuals and in group. Individuals from all substations such as quality checkers, supervisors are interviewed. Individuals from quality assurance team also responded significant data. Technician from selected sub process stations interviewed in group and delivered the expected information. Later, telephone call is used up to the end of the research.

Secondary sources of data

As a secondary data, a monthly and weakly product performance report are involved as an initial study to identify the most likely defects. It was obtained through documentation such as weekly, monthly and quarterly reports of quality assurance team of TAFS.

3.3. Data processing and analyzing method

Data were processed and analyzed based on the rule of statistical process control tool as of explained in the literature part. A monthly company report was an initial phase to study this research model 927 has recorded high level of defects and defective items. Check sheets were used to identify the frequent problems and prioritized by Pareto diagram. Then, the prioritized defect causes filtered by cause and defect diagram. Data for control charts were obtained from quality inspection team, after the recommendation of this research paper owner. For calculating data and drawing graphs and charts, Microsoft office software was used.

CHPTER FOUR

4.1. Results and Discussion

4.1. Results

Tikur Abay shoe factory has three independent factories in a compound. As per information from quality assurance team product performance quarterly report, the company is producing and will produce for the next 13 months four major model shoes such as, model 1031, 7025, 927, 929, 1001 SA0l etc. Among these, model 927, heavy dutyshoe, has recorded abnormal number of defects.

Because of a mass production on model 927, only a one-month data has conducted. The quality control team recorded product defects and the nature of the defects are attributive in variable. The following table shows types of the process, quantity of product and number of defects which is reported by quality assurance team for the month December, 2019.

Model 927 in the four categorized process

Table 1 Product performance monthly report from 01/12/19 31/12/19

No.	Model 927 Types of the process	Quantity of product	No of defects	No. of defect product %
1	Cutting	78993	337.4	2.0
2	Stitching	72710	523	1.4
3	Vulcanization	70507	5226	4.0
4	Finishing	63630	2792	3.0

According to the monthly quality performance report, there is high number of defect product in the third and fourth process units. Further reports and interview results show there is high no. of defect rate in vulcanization room.

Table 2 shows major quality related issues in each process which happen frequently.

Process stages	Name of the process	✓ Major quality related problem
1	Cutting	✓ Fly cuts ✓ Hole
2	stitching	✓ Broken stitches ✓ Without eyelet ✓ Wrong assembling
3	Lasting	✓ Crack ✓ Improper heel lasting ✓ Wrong toe lasting
	vulcanization	✓ Misplaced toe puff ✓ Improper sole used ✓ Poor adhesive of heel
4	Finishing	✓ Without eyelet ✓ Rubber sole not cleaned ✓ Leather type difference ✓ Hole

After identifying the monthly major product defects during process, the next step is finding the root cause of the problem. In this case SPC tools are must to indicate a better solution to the business company. Secondary data from company quality assurance record and primary data via observation conducted to construct the following tally full check sheet.

Table 3 Defective items check sheet

Types of defects	Checked						Sub total
	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	
Fly cuts during design	//	///	//	/	//	/	11
Unbalanced or Variable stitches	///	/	//		//		8
Hole	/	///	///	///	///	//	16
Without eyelet	//////	/////////	/////	////	///////////	//////	41
Rubber sole defect	////////	////////	//////////	/////////////	/////////	//////////////	63
Wrinkles on toe puff part	/////////	///////	//////////	/////////	////////	////////	51

4.1.1. Application of Pareto diagram

Pareto diagram is critically used to identify and analyze about 20% significant causes which affect 80% process performance and product quality. Table 4 shows the collected data in descending order.

Table 4: Defects in descending order

Types of defects	**No. defects**
Rubber sole defect	63
Wrinkles on toe puff part	51
Without eyelet	41
Hole	18
Fly cuts during design	11
Unbalanced or Variable stitches	8
	Total 192

Since the collected data prioritized, it is easy to calculate the cumulative totals. The following table and chart show the prioritized defects in processing model 927 shoes.

Table 5 chart show the prioritized defects in processing model 927 shoes.

Number of Non-Conformance			
Types of defects	No. defects	cumulative count	Cumulative %
Rubber sole not cleaned	63	63	32.81%
Wrinkles on toe puff part	51	114	59.38%
Without eyelet	41	155	80.73%
Hole	18	173	90.10%
Fly cuts during design	11	184	95.83%
Unbalanced or Variable stitches	8	192	100.00%

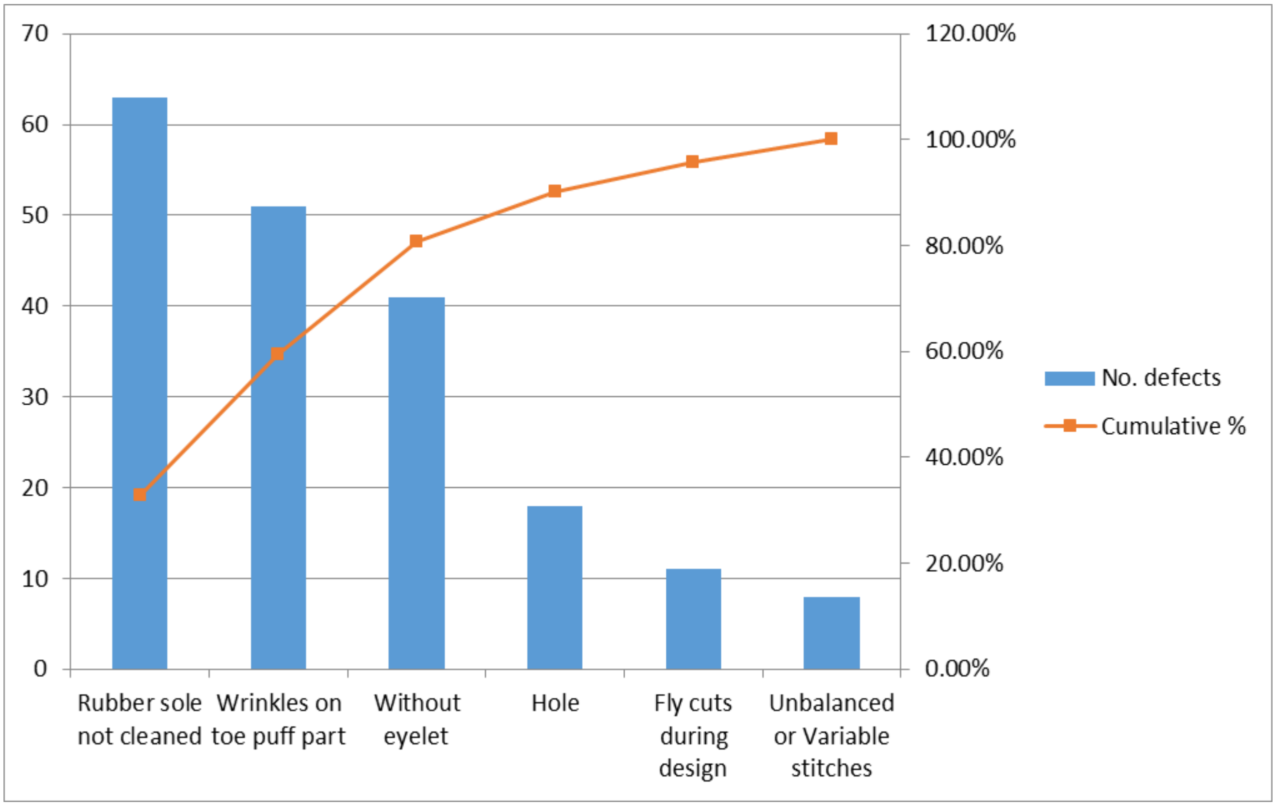


Fig. 1 Pareto Diagram

Interpretation

Based Pareto 80/20 principle, sole problem in vulcanization room, gouges and lasting defect are vital few quality related defects that frequently determine the standard of model 927 shoe. Rubber sole not cleaned, wrinkles on toe puff part and without eyelet are causes have the largest percent which needed greater attention by the company to reduce defect products of model 927. Since the major problem is identified through this figurative principle, it's common to apply Cause and Effect (Ishikawa diagram) principle to reach on its root cause.

4.1.2. Application Cause and effect diagram

Primarily, brainstorm causes were prepared as interview questions. First hand interview had been directly conducted for process men who are engaged within cutting, stitching, vulcanization and finishing process stations and quality control-oriented individuals.

List of common possible problems in manufacturing industries used as interview questions and focused group discussion.

- ✓ No quality manuals
- ✓ No maintenance manual
- ✓ Unavailability of skilled operators
- ✓ Lack of continual training
- ✓ Absence of qualified quality checkers
- ✓ Availability of old machineries
- ✓ No Latest machineries
- ✓ No maintenance schedule
- ✓ Shortage of spare parts
- ✓ Un Skilled mechanics
- ✓ Limited communication between departments
- ✓ No Team work
- ✓ No continuous improvement tools
- ✓ Defected raw materials
- ✓ No quality in station
- ✓ Employees turn over
- ✓ Work load
- ✓ No operation standardization
- ✓ No workplace standardization
- ✓ Unsafe work environment

After interview and discussion the following list of possible types of causes had been identified and determined under the six pillars.

Table 6: Categorized causes

Machinery	Material	Man	Procedure	Communication	Environment
The presence of outdated machine	Scraped raw material	Inadequate periodic training	An implemented standardization	Absence of teamwork to solve immediate problem in between process	Unused sanitation schedule
Not computerized	Defected Parts	Inadequate quality checker	Ineffective work standard	Dalliance in between Work stations	Not cleaned work station
Unavailable spare part		No laboratory technician	Repetitive rework		
Continuous machine break			No laboratory test		

In order toreach the root causes of defected rubber Sole of model 927, the possible likely causes are sorted in the Fish bone diagram. The following fish bone diagram upholds the result of the interview questions.

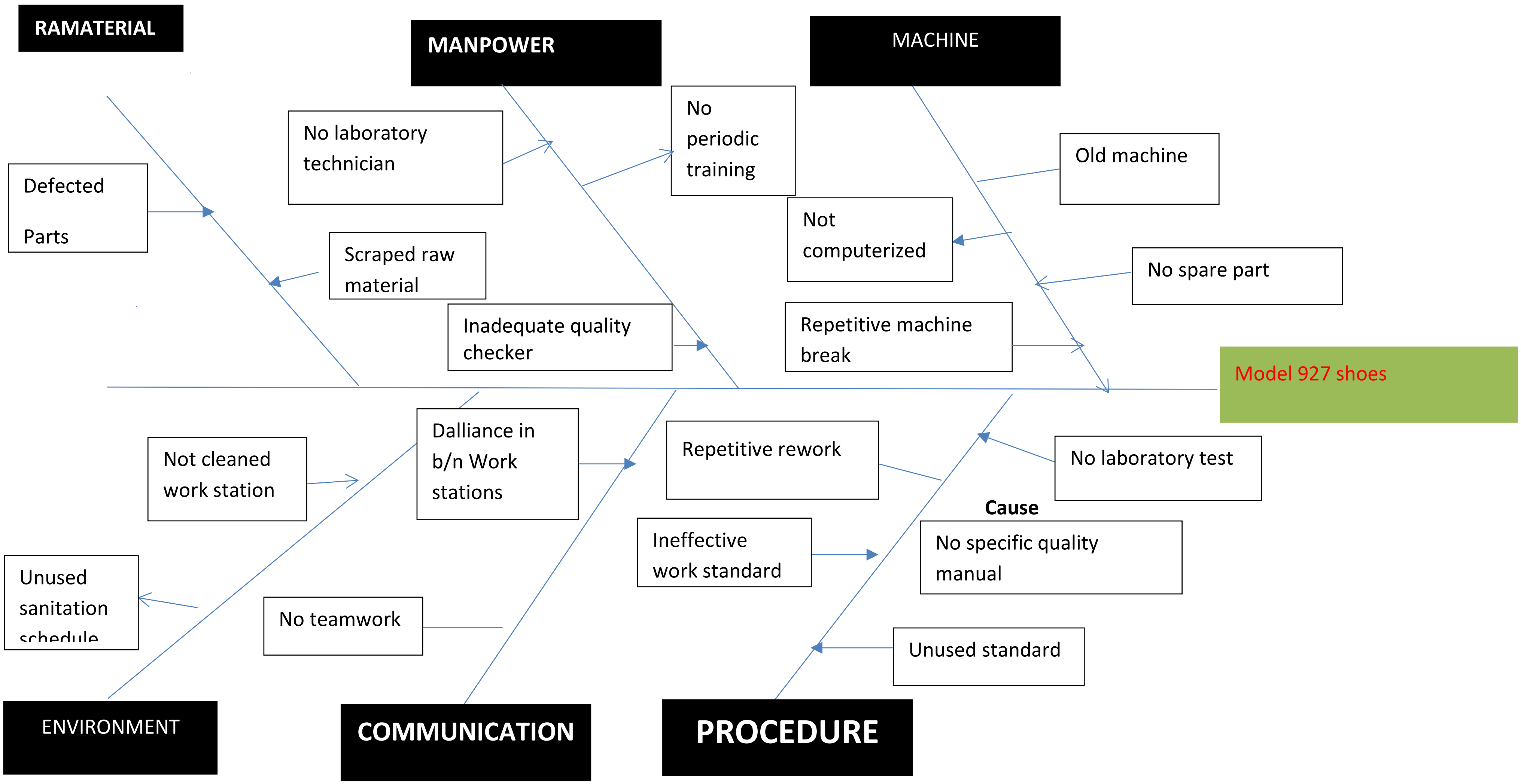


Fig.2 Fishbone Diagram

Cause and effect diagram

Interpretation

- ✓ Procedure: Under procedure pillar the root cause for rubber sole frequent defect is no laboratory taste of mixed or prepared raw material before vulcanization in order to produce shoe's sole part.

- ✓ Machinery: the outdated machine called Calendar for shoe sole production has no spare part on the international market. It shrinks and burns product materials during process. Also creates long machine down time.

- ✓ Material: unused laboratory devise followed by absence of laboratory technician to taste spare parts and products.

4.1.3. Application Control Chart

It's common in statistical process control world to check and determine the process itself whether it is controlled or not under specified standards. Data had been gathered with the collaboration of quality inspection team to determine the process of model 927 shoe if it's under control limit or upper control limit. Attributive nature of data excides variable data in time of collection, P chart was used. Influential reasons to choose and include p chart in this investigation:

- ❖ Inaccessible to collect variable data
- ❖ Data had a list of full of pass or fell, checked by quality inspectors
- ❖ Has fixed amount of observation in each sample
- ❖ Single product process was selected for Applying SPC tools

Table 7: Source of data to calculate and construct p chart

No.	No. of sample	Sample n	np
1	S1	50	9
2	S2	50	2
3	S3	50	7
4	S4	50	12
5	S5	50	5
6	S6	50	15
7	S7	50	9
8	S8	50	6
9	S9	50	9
10	S10	50	13
11	S11	50	3
12	S12	50	5
13	S13	50	3
14	S14	50	7
15	S15	50	10
16	S16	50	5
17	S17	50	11
18	S18	50	8
19	S19	50	1
20	S20	50	6
21	S21	50	12
22	S22	50	16
23	S23	50	17
24	S24	50	12
25	S25	50	4
26	S26	50	8
27	S27	50	8
28	S28	50	5
29	S29	50	2
30	S30	50	10

$$P = \frac{x(i)}{n}$$

Proportional defective

$$\overline{P} = \frac{Total\ number\ of\ rejects}{Total\ number\ of\ inspections}$$

$$\overline{P} = \frac{240}{30 \times 50}$$

$$\overline{P} = 0.16$$

CL= $\overline{P}$ **=** 0.16

Where,

240 is number of rejected shoes

30 is number of sample and

50 is the number of observed samples.

Therefore, upper control limit and lower control limit calculated as follows:

Upper Control limit:

$$UCL = \overline{P} + 3\sqrt{\frac{\overline{P}(1-\overline{P})}{n_i}}$$

UCL=0.315

Lower Control Limit

$$LCL = \overline{P} - 3\sqrt{\frac{\overline{P}(1-\overline{P})}{n_i}}$$

LCL=0

Therefore, all the calculated significant elements sorted in excel sheet (2010) to draw the needed chart**.**

Table 8: Calculated data of p chart (Excel sheet 2010

No. of sample	Sample n	p	np	$\bar{P}$	UCL	LCL
S1	50	9	0.18	0.16	0.315	0.004
S2	50	2	0.04	0.16	0.315	0.004
S3	50	7	0.14	0.16	0.315	0.004
S4	50	12	0.24	0.16	0.315	0.004
S5	50	5	0.1	0.16	0.315	0.004
S6	50	15	0.3	0.16	0.315	0.004
S7	50	9	0.18	0.16	0.315	0.004
S8	50	6	0.12	0.16	0.315	0.004
S9	50	9	0.18	0.16	0.315	0.004
S10	50	13	0.26	0.16	0.315	0.004
S11	50	3	0.06	0.16	0.315	0.004
S12	50	5	0.1	0.16	0.315	0.004
S13	50	3	0.06	0.16	0.315	0.004
S14	50	7	0.14	0.16	0.315	0.004
S15	50	10	0.2	0.16	0.315	0.004
S16	50	5	0.1	0.16	0.315	0.004
S17	50	11	0.22	0.16	0.315	0.004
S18	50	8	0.16	0.16	0.315	0.004
S19	50	1	0.02	0.16	0.315	0.004
S20	50	6	0.12	0.16	0.315	0.004
S21	50	12	0.24	0.16	0.315	0.004
S22	50	16	0.32	0.16	0.315	0.004
S23	50	17	0.34	0.16	0.315	0.004
S24	50	12	0.24	0.16	0.315	0.004
S25	50	4	0.08	0.16	0.315	0.004
S26	50	8	0.16	0.16	0.315	0.004
S27	50	8	0.16	0.16	0.315	0.004
S28	50	5	0.1	0.16	0.315	0.004
S29	50	2	0.04	0.16	0.315	0.004
S30	50	10	0.2	0.16	0.315	0.004
	1500	240				

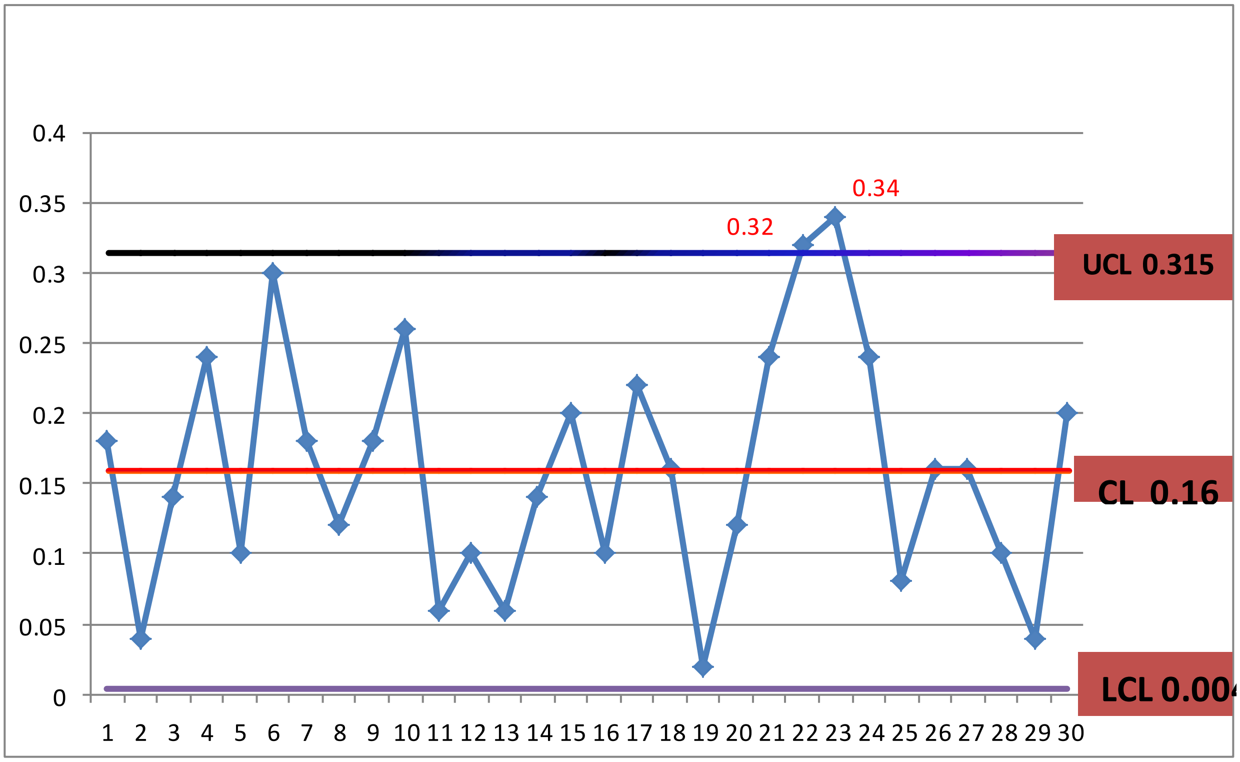


Fig. 3: P chart

Interpretation

From the diagram, three points laid on the central line, 11 points put under upper control limit, 14 points run under lower control limit zone. However, two points such as 0.32 and 0.34 from the sample 22nd and 23rd respectively run abnormally from the central line and out of upper control limit. None of points are out of the lower control limit. Therefore, the process is out of statistical process control if the problems are non-assignable.

After investigation the data shows that there was high level of rejection of model 927 shoe because of rubber sole problem which caused by vulcanization. Shrunken and burnt rubber sole by machine.

Possible counter majors were taken and the p chart was revised to check and determine again weather the process is under in statistical control limit or not.

The revised P chart calculated as:

$$\bar{P} = CL = \frac{207}{28 \times 50}$$

CL=0.147

Upper control limit and lower control limit were recalculated as:

$$UCL = 0.147 + 3\sqrt{\frac{0.147(1 - 0.147)}{50}}$$

UCL=0.23

$$LCL = 0.147 - 3\sqrt{\frac{0.147(1 - 0.147)}{50}}$$

LCL=0

Table 9: Revised data of excel sheet

No. of sample	Sample, n	Np	P	$\overline{P}$	UCL
S1	50	9	0.18	0.147	0.297
S2	50	2	0.04	0.147	0.297
S3	50	7	0.14	0.147	0.297
S4	50	12	0.24	0.147	0.297
S5	50	5	0.1	0.147	0.297
S6	50	15	0.3	0.147	0.297
S7	50	9	0.18	0.147	0.297
S8	50	6	0.12	0.147	0.297
S9	50	9	0.18	0.147	0.297
S10	50	13	0.26	0.147	0.297
S11	50	3	0.06	0.147	0.297
S12	50	5	0.1	0.147	0.297
S13	50	3	0.06	0.147	0.297
S14	50	7	0.14	0.147	0.297
S15	50	10	0.2	0.147	0.297
S16	50	5	0.1	0.147	0.297
S17	50	11	0.22	0.147	0.297
S18	50	8	0.16	0.147	0.297
S19	50	1	0.02	0.147	0.297
S20	50	6	0.12	0.147	0.297
S21	50	12	0.24	0.147	0.297
S24	50	12	0.24	0.147	0.297
S25	50	4	0.08	0.147	0.297
S26	50	8	0.16	0.147	0.297
S27	50	8	0.16	0.147	0.297
S28	50	5	0.1	0.147	0.297
S29	50	2	0.04	0.147	0.297
S30	50	10	0.2	0.147	0.297
	1400	207			

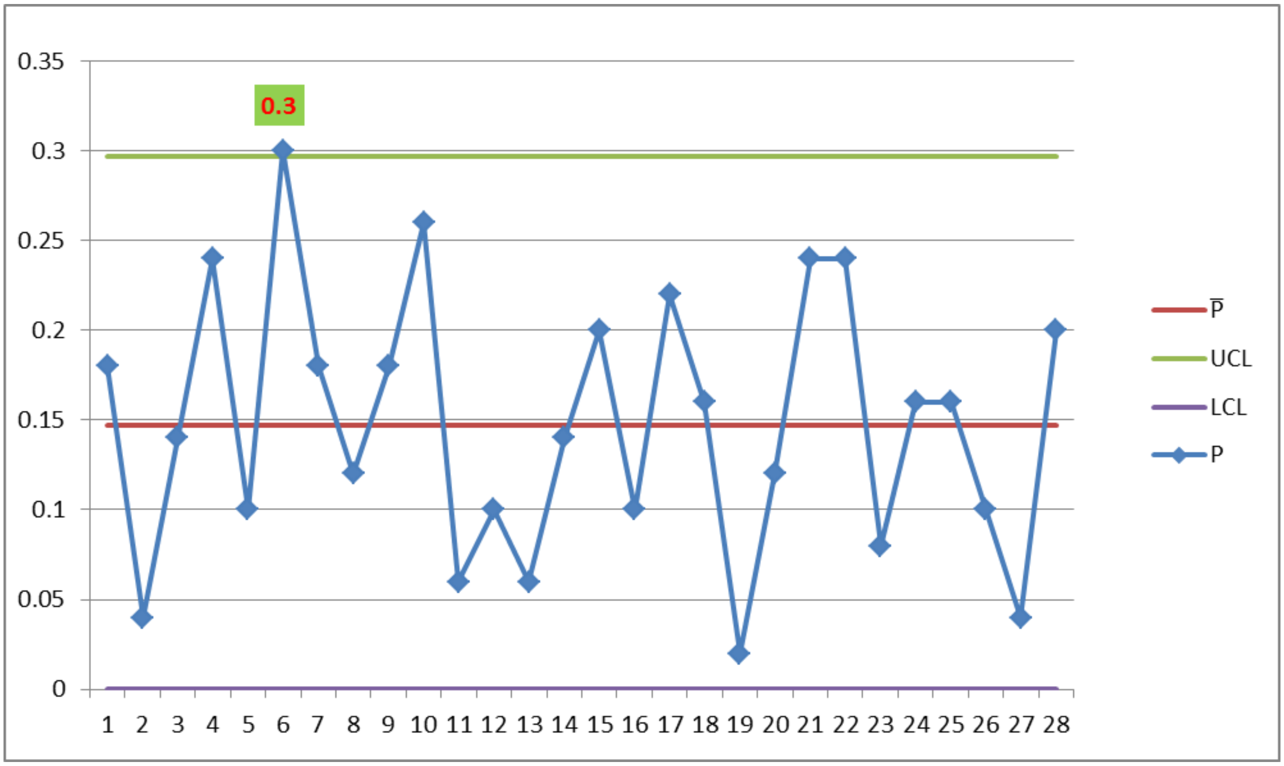


Fig.4: The revised p chart

Interpretation

The revised diagram also shows that the 6th point still out of the upper control limit. Therefore, the process was still not under the statistical control limit.

Investigated data indicated that the first problems that seen in points 22 and 23 still exist affected the process not to be normal. The old machine interrupted the process and producing defected rubber sole.

In order to determine and know where the process is getting normal under the rule of statistical process control, point 6 had been removed from the data and another control p chart calculated and drawn.

In this case, sum total of sample size would be reduced to 192 and number of samples became 27.Therefore, the value of $\bar{P}$ calculated as:

$$\bar{P} = CL = \frac{192}{27 \times 50}$$

$\bar{P}$**=0.142**

Upper control limit and lower control limit were recalculated as:

$$UCL = 0.142 + 3\sqrt{\frac{0.142(1-0.142)}{50}}$$

UCL=0.297

$$LCL = 0.142 - 3\sqrt{\frac{0.142(1-0.142)}{50}}$$

UCL=0.006

Table 10: The calculated data sheet

No. of sample	Sample, n	np	P	$\overline{P}$	UCL	LCL
S1	50	9	0.18	0.142	0.29	0.006
S2	50	2	0.04	0.142	0.29	0.006
S3	50	7	0.14	0.142	0.29	0.006
S4	50	12	0.24	0.142	0.29	0.006
S5	50	5	0.1	0.142	0.29	0.006
S7	50	9	0.18	0.142	0.29	0.006
S8	50	6	0.12	0.142	0.29	0.006
S9	50	9	0.18	0.142	0.29	0.006
S10	50	13	0.26	0.142	0.29	0.006
S11	50	3	0.06	0.142	0.29	0.006
S12	50	5	0.1	0.142	0.29	0.006
S13	50	3	0.06	0.142	0.29	0.006
S14	50	7	0.14	0.142	0.29	0.006
S15	50	10	0.2	0.142	0.29	0.006
S16	50	5	0.1	0.142	0.29	0.006
S17	50	11	0.22	0.142	0.29	0.006
S18	50	8	0.16	0.142	0.29	0.006
S19	50	1	0.02	0.142	0.29	0.006
S20	50	6	0.12	0.142	0.29	0.006
S21	50	12	0.24	0.142	0.29	0.006
S24	50	12	0.24	0.142	0.29	0.006
S25	50	4	0.08	0.142	0.29	0.006
S26	50	8	0.16	0.142	0.29	0.006
S27	50	8	0.16	0.142	0.29	0.006
S28	50	5	0.1	0.142	0.29	0.006
S29	50	2	0.04	0.142	0.29	0.006
S30	50	10	0.2	0.142	0.29	0.006
	1350	192				

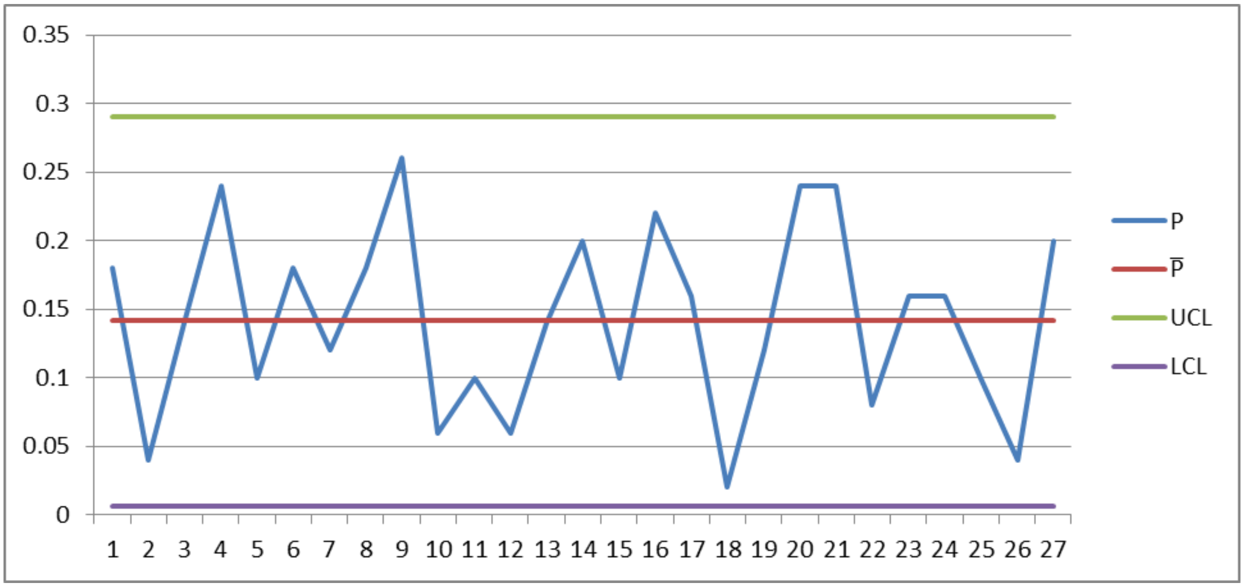


Fig. 5 secondly revised p chart

Interpretation

After eliminating the abnormal sample point 6, none of the points were flow out from the two control limits and run around the central line. Therefore, data without the three random causes became under statistical process control.

4.1.4. Process Capability (PC)

It's normal in SPC studying and determining the process capability weather it is poor, fair, acceptable or excellent. The leading data had been conducted from the third p chart calculate values such as:

UCL 0.29, LCL 0 and standard deviation also conducted to calculate Cp

$$Cp = \frac{USL - LSL}{6\sigma}$$

$$p = \frac{0.290 - 0.006}{6 \times 3.423}$$

C*p* = 1.38

Interpretation

Since the Cp value is 1.38, the process is capable. According to Shewhart's control limits, it falls in-between***$1.33 \leq Cp < 2$*****acceptable range** process status. However, range indicates the process is running in basic standard conditions. Therefore, there is always a situation of process variation and producing a handful defect products.

4.2 Analysis of the data

Initially, the problem was identified during the proposal phase of this research. Problem on Product model 927 in the case company was identified; defined and possible solutions were indicated in the whole process of this study. Findings based on statistical process control tools such as check sheet and Pareto diagram, cause and effect diagram, control chart and process capability discussed and analyzed as follows.

A check sheet: data onthe frequencydefects such as, fly cutes, variable stiches whole, without eyelet, rubber sole defect and wrinkles on the toe puff were collected and rated through the application of a check sheet. It used as a prerequisite tool for the application of the next SPC tool Pareto diagram.

Pareto diagram: Rubber sole problem, wrinkles on toe puff part and without eyelet were found as the most frequent defects of shoe model 927 products. They possessed around 80% of defects of the selected model product. They strongly need primary consideration immediately by Product Company to minimize and eliminate their rates which are causing defective product.

Cause and defect diagram: After applying this tool likely root causes have been discovered. Under the pillar of **machinery**, a very old machine followed by lack of spare parts on market is one of the root causes of the problem in the product process of TASF. With unfixed time interval the outdated colander machine become overheated continuously and interrupts the sole production process. As a solution modern and computerized machine can fix the problem on sole production process. Unused test manual, under the pillar of **procedure**, followed by unused laboratory (material) and lack of laboratory technician (**man power**) were found as the root causes which are making defects frequently. Supervisors or any concerned body should have follow up process men tasks weather they are running the process with test manuals or not. However, the better solution is accessing the already bought laboratory machines for some spare parts to reduce manual work and human assignable and random mistakes.

Control charts: Through applying this SPC tool, the p chart visualized that the process is not under the statistical control limits, due to the indicated problems. Repetitively, machine breakdown created rubber sole type of defect and this made the process running abnormally. According to the chart, simply, avoiding machinery problem replacing it by the latest and computerized one can keep the process under the statistical control limits.

Process capability: Cp calculation finds the process is capable of to produce. The result shows the process is moving with standard condition. However, the process situation is acceptable under Shewarts width, but this means that the process is always not running without product variation. To increase process capability at excellent level, the company should focus on random and assignable causes of its process.

The company should always strive to minimize variations through detecting, determining and getting possible solutions to defects. Counter majors as a general solution to solve or to minimize the problems are: changing the outdated calendar machine in vulcanization room by the latest computerized devices, have to start the unused laboratory test machine, recruiting laboratory technicians from the market, implementing quality manuals and procedures, assigning or employing additional individuals who have skilled in quality control sector, improving substation communication through planned training. Preparing quality related training for all departments. Properly applying scientific process control methods, such as statistical process control tool

Chapter Five

Conclusion and Recommendation

5.1 Conclusion

Tikur Abbay shoe factory has experience in producing different shoe models and huge customer desire in the market. The company has skilled man power and experienced technicians. However, there are limitations in applying standardizations and quality manuals. Based on this study, it can be concluding that the company is not applying SPC tools, to study the process or to manage defects with possible solutions. Because of this, way of processing products and handling problems are highly depended on traditional way than scientific. This has been seen in applying SPC tools to the process of product shoe Model 927. Model 927 is the primary product of TASF and which is processing in large amount and found with different types of defects. After employing the most common SPC tools, such as check sheets, Pareto diagram, fish bone diagram, control chart and process capability indices, different types of defects and problems were detected, identified, determined and possible solutions are recommended. According to this study, the major defects of product model shoes 927 is sole problem, wrinkles on toe puff and without eyelet. And the root causes for the indicated problems also found as old machine, not following procedures and unused material especially the test laboratory device. Due to these, especially, sole parts of the shoe becoming shrink and burn during the process in the vulcanization room. Lacks of commitment in applying test manual, using laboratory test machine to test spare parts and employing skilled laboratory technicians are also critically disturbing the process. As a conclusion, there is lack of quality related awareness to implement ISO standards and other continuous improvement manuals: no sign to solve process related problems through statistical process control: inability to set up laboratory for testing parts and products, problem in recruiting laboratory technician for the already bought laboratory machine and lack of training on quality related awareness. If the company using and applying SPC tools, the identified defects would be reduced or eliminated and the process become capable in an excellent manner.

5.2 Recommendation

In order to minimize quality related problems and defect shoe products, the researcher suggested the following quality and process related facts as a recommendation.

Quality as a Basement has to be given the place of a lion share and should be the philosophy of the company and its workers. Because it helps all departments of the company together see in the glass of quality principles to achieve their goal.

Effective Training: Effective training should be given in a continuous manner about quality related thoughts and process and process related issues for all departments of TASF. This would empower internal clients to be process focused workers and can easily detect process related defects and problems.

Commitments: Company managers should be committed in applying quality standards and manuals to improve the product process of footwear. Implementing continuous improvement procedures also strongly needs all departments' commitment to find problems, to find possible solutions and to enhance workers' performance in a better way.

Facilities: I strongly recommend that TASF should quickly replace the old machine by the new and modernize one to reduce the great risk of sole production problems. It would be better to think about quality product after setting up standardized machineries. The new laboratory machine which is used to taste spare parts need to be set up and accessed.

Applying statistical process control tools: TASF should be applying SPC tools, to improve the process of footwear and other leather products. As seen in this study, the tool is used to identify and determine problems, to find root causes of the problem and defects, to check the process is within standard limit or not and to check if the process is capable or not.

Beyond applying those ISO quality principles, using and practicing quality tools like statistical process control and process capability indices can boost managers to pass numeric based rational decisions and increase process performance of the organization.

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