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INSTITUTE OF QUALITY AND PRODUCTIVITY MANAGEMENT

QUALITY IMPROVEMENT USING SPC TOOLS IN MOBILE PHONE ASSEMBLY INDUSTRY IN CASE OF TRANSSION MANUFACTURING PLC

BY:

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

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DECLARATION

I, the undersigned, declare that this thesis is my original work, prepared under the guidance of Dr.Ing Amare Matebu. All sources of material used for the thesis have been duly acknowledged. I further confirm that the thesis has not been submitted either in part or in full to any other higher learning institutions for the purpose of earning any degree.

Signature________________

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Endorsement

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

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Advisor

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LIST OF ACRONYMS AND ABREVIATIONS

SPC- Statistical process control

QC- Quality control

TQM- Total Quality management

PCA- Printed circuit assembly

CEA- cause and effect analysis

US- United states

UCL- Upper control limit

LCL- Lower control limit

CL- Control Limit

RCA- Root cause analysis

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Abstract

In order to survive in a competitive market, improving quality and productivity of product or process is necessary for any company. The principal aim of this study is about identifying the practices and challenges of a company in applying statistical process control (SPC) tools in the production processing line and on final product in order to improve the quality of the product and suggesting appropriate solution for the challenges. The approach used in this study is direct observation, thorough examination of production process lines, and information has been collected from managements, quality department and from company's workers working in the area of production process through interview and questionnaire. Pareto chart/analysis and control chart was constructed in order to prioritize the major defects occurred and to suggest a suitable control limits for some variables. 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.

CHAPTER ONE

1. INTRODUCTION

This chapter consists of background of the study, statement of the problem, general and specific objective of the study, significance of the study, limitation of the study, scope of the study, definition of basic terms and background of the organization.

1.1 Back ground of the Study

The control and quality improvement has become one of the core strategies of business for countless organizations, fabricants, distributors, transporters, financial, health and manufacturing company. Quality is a competitive advantage and any given organization that satisfies its clients through quality improvement and control can prevail over the competition. For the Manufacturing and assembly plant industry, the quality is expressed through the customers' satisfaction in relation to the products and offered services. An answer to this increasing demand is the Statistical Process Control (SPC) – a set of tools for process management and for determination and monitoring of the quality of an organization outputs. It is also a strategy for improving capability through the reduction of variability of products, deliveries, processes, materials, attitudes and equipment.

The correct implementation and use of the SPC can lead to decisions based on facts, to a growing perception about quality at all levels, to a systematic methodology concerning problem resolution, to a gathering of experience and to all kind of improvement, even in communication. Predominantly in manufacturing and concerning quality, SPC is the most widely used technique and once appropriately applied, can improve operational and financial benefits.

Statistical process control (SPC) has been used to great effect in the manufacturing industry to increase productivity in processes by specifically identifying and reducing variation, Deming; (2000). Generally, the Seven QC tools are check sheet, Pareto chart, flowchart, cause and effect diagram, histogram, scatter diagram and control chart . These tools are also known as Total Quality Management (TQM) tools .Paul and Rabindra (2006) used subjective assessment through questionnaire, direct observation method, and archival data to improve productivity, quality, increasing revenue and reducing rejection cost of the manual component. Brown and Mitchell (1998) investigated operators, engineers and managers of PCA (Printed circuit assembly) factories to determine the work environment parameter that inhibited there performance and they recommended opportunities to improve Quality.

1.1.1 Benefits of Statistical process control (SPC) implementation

SPC implementation is important as it could develop process performance by reducing product variability and improves production competence by decreasing scarp and rework. According to Attaran (2000), in their attempts to stay competitive, business had embarked on Total Quality management (TQM) techniques such as SPC that leads to higher quality product by reducing-variability and defects.

Most of the production and quality cost that SPC aims to reduce such as rework loss of sales and proceedings are measurable. The success and failure in SPC operation does not depend on company size or resources, but it relies on suitable planning and immediate actions taken by workers with regards to problem solving. According to Benton and Talbot, the advantages of implementing SPC could be categories into the following categories, viz., maintain a needed degree of conformance to design, raise product quality, eradicate any unnecessary quality checks, trim down the percentage of defective parts purchased from vendors, diminish returns from customers, lessen scrap and rework rates, afford evidence of quality, facilitate trends to be spotted, ability to reduce costs and lead times.

The primary tool of SPC is the Shewhart control chart. The Shewhart control chart quantifies variation as either special cause or common-cause (natural) variation. The control limits on control charts put a figure on variation as that intrinsic to the process (natural variation data inside the control limits), or variation caused by an event or assignable-cause (special cause variation data located outside the control limits). Data outside the control limits are also referred to as “out of control” points. SPC utilizes statistical methods to monitor manufacturing processes with an aim to maintain and improve the product quality while decreasing the variance. Much research has been conducted on the issues of SPC and the consequential developments are readily available in the literature.

However, SPC is a combination of statistical and problem-solving technique where control chart is one of the tools listed in SPC (Montgomery, 2009). Variation reduction enables the SPC users to achieve other SPC benefits as depicted by the Deming‘s chain reaction model.

1.2 Statement of the problem

Quality improvement is the key factor for the success and growth of any business Organization. Thus, it is important to focus on the process; how it proceeds, how to control and how to improve the process. Even if, the company uses SPC as a good practice for quality improvement, in doing this the company faces challenges like lack of management commitment, 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 . 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 analyzing the process quality. Due to these and other reasons, the company has still many defective products. So as to monitor the variability's such as; common defects happen during daily production, weight of products for cross checking materials inside whether there is loss or more and related defects of the product occurs in TRANSSION manufacturing PLC and the sampling technique specifically for one of the product of a company having high market share with a brand name called TECNO mobile. Implementing a proper SPC technique can resolve all the practical challenges that the company faces and reduces all the variations that affect the product quality.

1.3 Objective of the study

1.3.1 General objective

To investigate the practices and challenges of implementing statistical process control and Recommend quality improvement approach.

1.3.2 Specific objective

The specific objectives are:

- To identify the most common techniques used, the scope of usage, and source of information used in setting up the systems.
- To assess the existing quality related problems of the company.
- To have through understanding of the basics of statistical process control and its effective application in the company.
- To identify constrains for applying quality tools such as SPC.
- To recommend a possible solution for the identified causes of variation for achieving quality improvement.

1.4 Significance of the study

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. This tactic could not only keep products on schedule, but maybe even possibly show that the estimated activity durations were inflated due to consistently inefficient operations in the past. A SPC is essentially a visual aid that objectively reveals where improvement efforts should be directed. The output will provide the alternative waste or defects reduction mechanisms and productivity improvement tools for assembly industry. This study can be used as an input for further study for similar future researchers and to forward suggestions, conclusions, and recommendations based on the finding. Based on the objective of the research, the ultimate result can facilitate the company to solve the low-quality level problem and production manager, Engineering manager, Quality manager can receive the improved solution and implement it into the plant.

1.5 Scope of the Study

The scope of this thesis work will focus on proposing improvement solution for minimizing defective product and low grade in Transsion manufacturing PLC by application of SPC tools. In addition, due to occurrence of defect in daily basis the six month recorded data in the company are collected. The latest six-month defect, rework and reject data are collected from the case company Transsion manufacturing PLC for further analysis. Moreover, the research work focus on process variation caused by quality problem or defective product. In addition, the company produces Television and accessories. However, the research will focus mobile assembly processing.

1.6 Limitation of the Study

The major constraint in the course of the study was time and company's rules and regulation, which prevented the researcher from undertaking in depth study and analysis. There are also resource constraints, in terms of utilization of SPC tools, lack of cooperation of employs to respond on questionnaires and interviews.

1.8. Definition of Basic Terms

Statistical Process Control:- is a scientific, data- driven methodology for quality analysis and improvement.

Quality: - The totality of characteristics of an entity that bear on its ability to satisfy stated or implied needs (ISO 9000)

Quality Improvement: - is a continuous improvement process and a proactive approach to improve processes and systems. Alternatively, it can be defined as the reduction of variability in processes and products.

A control chart: - is a "Trend Chart" with the addition of statistically calculated upper and lower control limits drawn above and below the process average line.

1.7 Background of the organization

Transsion manufacturing was established in 2006, and it is a global company dedicated to providing most favored mobile communication products and mobile internet services for local consumers in emerging markets. The company is best known in emerging markets for its leading mobile brands, including TECNO, itel, Infinix. After 10 years of expansion, the company is now leading player in the mobile industry, with a market share of over 40% in Sub-Saharan African countries. Its cumulative sales volume has reached a landmark of more than 246 million Dual-sim handsets.

CHAPTER TWO

2 Review of Related Literature

This chapter aimed at giving insight to the researcher regarding the study. It included literature works from the books, articles, journals and previous studies which are relevant to quality improvement practices.

2.1 Quality concept

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

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

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

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

2.1.2 Quality Control, Quality Assurance and Quality Improvement

The terms Quality Control (QC) and Quality Assurance (QA) are often used interchangeably. But, according to International Standard of Organization (ISO) for Quality Management often referred to as IS0 9000:2005 distinguished the subjects as follows: "QC is a part of quality management focused on fulfilling quality requirements" while "QA is a part of quality management focused on providing confidence that quality requirements will be fulfilled". The standard further reiterated that QA involved all the planned and systematic activities implemented within the quality system that can be demonstrated to provide confidence that a product or service will fulfill requirement for quality. Conversely, QC was seen as operational techniques and activities used to fulfill requirements for quality. In other hands, QA is concerned with defects prevention while QC is concerned with defects identification and quality improvement is a continuous improvement process and a proactive approach to improve processes and systems.

2.1.3 Inspection-Based Quality Control vs. Prevention-Based Quality Control

The traditional approach to manufacturing is to rely on production to make the product and on quality control to inspect the final product and screen out items not meeting specifications. This involves a strategy of "detection" or "inspection". Inspection is an activity which is often expensive, unreliable and provides very little information as to why the defects or errors occurred and how they can be corrected. The following figure shows the generalized process diagram for a process operating on an inspection-based quality control.

2.2 SPC tools

Based on the SPC definitions discussed in the previous section, it is assumed that the tools related to SPC are broad enough to include all statistically based techniques range from taking a random sample to the very sophisticated design of experiments (Montgomery, 2012). 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).

In 1974 Dr. Kaoru Ishikawa brought together a collection of process improvement tools in his text guide to quality control. Known around the seven quality control tools, they are:

Check sheet:

A check sheet is a form specially prepared to enable data to be collected simply by making check marks. It is used for tallying the occurrences of the defects or causes being addressed by graphing or charting them directly. Check sheet is a powerful data recording tool.

Pareto Charts:

First developed in 1906, by Italian economist, Vilfredo Pareto, then Joseph M. Juran applied it in classifying problems of quality. The Pareto Principle also known as the 80/20 rule states that only a “vital few” 20% causes are responsible for producing most of the 80% problems (trivial many). It is used to detected problems by classifying them, showing their frequency in the process and set their priority. Pareto Charts allows the user to focus attention on a few important problems in a process and makes it easy to see which of many problems have the most serious effect on quality, productivity, cost, safety, morale, delivery time, surrounding etc. together with their relative proportions process and set their priority.

Cause and effect diagram:-

It is sometimes called Ishikawa Diagram because it was invented by Dr. Karou Ishikawa in the 1943. It is also called fish-bone diagram because it looks like fish bone. Cause and effect diagram is a tool that identifies, sort and display possible cause of a specific problem or effect.

Its main use is to pick up and arrange all possible causes without any omissions. And it allows many factors to be seen at the same time, and can be used by everyone from beginners to experienced workers. Picture composed of lines and symbols designed to represent a meaningful relationship between an effect and its causes and Effect (characteristics that need improvement) on the right and causes on the left.

Histograms:-

Histograms or frequency distribution Diagrams are the most commonly used graphs to show frequency distributions in convenient class intervals and arranged in order of magnitude. They are useful in studying patterns of distribution or shape of a distribution and comparing it with specifications or standard values. It organizes bulk data in an easy manner to understand the population or data. Histograms Can Be Used to determine distribution of sales and Say for instance a company wanted to measure the revenues of other companies and wanted to compare numbers.

Flow Charts:-

It is a diagram showing the development of something through different stages or processes.

Flow chart is a pictorial representation showing all of the steps of a process.

Control charts:-

The control chart is a graph used to study how a process changes over time. It is used to analyze a process and to determine whether a process will process a product or service with consistent measurable properties. A control chart always has a central line for the average, an upper line for the upper control limit and a lower line for the lower control limit. These lines are determined from historical data. By comparing current data to these lines, you can draw conclusions about whether a process is in control or is unpredictable (out of control, affected by special causes of variation).

If your process is in control, then

- 99.73% of all the data points will be inside those lines or no sample points outside limits
- most points near process average
- about equal number of points above and below center line points appear randomly distributed

Scatter Diagrams:-

A scatter diagram shows the correlation between two variables in a process. Also called scatter plot, X–Y graph. Its purpose is to find if there is correlation between paired sets of data to identify the correlations that might exist between a quality characteristic and a factor that might be affecting it. If the variables are correlated, the points will fall along a line or curve. The better the correlation, the tighter the points will hug the line.

2.2.1 Statistical Process Control (SPC) versus Statistical Quality Control (SQC)

Statistical quality control is defined as the application of the 14 statistical and analytical tools (7- QC and 7-SUPP) to monitor process outputs (dependent variables). Statistical process control is the application of the same 14 tools to control the process inputs (independent variables). Although both terms are often used interchangeably, statistical quality control includes acceptance sampling where statistical process control does not.

Table 2.1SPC tools and its application

Tools	Description	Tools application	References
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: Emphasis 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?	* Customer/consumer complaint analysis Sensory evaluation * Vendor selection * Ingredient/raw material risk assessment *Marketing and sales * Manufacturing deficits * Process and quality control *Equipment maintenance priorities	(Cravener et al., 1993, Varzakas and Arvanitoyannis, 2007, Dalgiç et al., 2011, Fotopoulos et al., 2011)
Scatter diagram	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?	* Product and process improvement * Process control * Process and product design * Downtime trend * Trend of craft productivity	(Knowles et al., 2004, Grigg, 1998, Pluta, 2014)
CEA/ Ishikawa diagram	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?	* Product and process design * Product and process improvement * Process optimization * Hazards and risk assessment Process control * Audit (laboratory control and process, product and field performance.	(Varzakas and Arvanitoyannis, 2007, Saini et al., 2011, Hubbard, 2013, Desai et al., 2015)
Histogram	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?	* Stock and storage distribution analysis * Estimation of the maintenance workload Process characterisation * Customer/consumer complaint analysis * Process performance distribution * Analysis of shift in downtime distribution * Raw material supplier reliability	(Ooi and McFarlane, 1998, Srikaeo et al., 2005, Mertens et al., 2009, Mataragas et al., 2012, Dalgiç et al., 2011, Rábago-Remy et al., 2014)

Tools	Description	Tools application	References
Flow chart	Main purpose: to endeavor 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?	*Process control and monitoring *Process improvement * Process characterization	(Dalgiç 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?	*Data collection for process/quality performances * Stock and storage check *Work sampling * Reviewing raw materials *Incoming quality *Raw materials * Supplies	(Bidder, 1990, Hubbard, 2013)
Control chart	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 analyze 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?	* Vendor control and selection *Process and product specification conformance * Package integrity, code, feel, appearance Defects and wastage calculation *Productivity *Process performance *Product specification conformance * Process, product, process performance * Process, product, control planning	(Grigg, 1999, Grigg and Walls, 2007a, Ittzes, 2001, Hayes et al., 1997)

2.2.2 SPC and inspection

An inspection is an organized examination assessment of formal evaluation exercise. The results are usually compared to the specified requirements and standards for determining whether the target is achievable and this practice are usually destructive. In the error of inspection quality control of the product was limited only to the corrective inspection (e.g. it was away to check the uniformity of the final product by determining the defective products). In 1922, the inspection were linked formally with the quality management with the publication of the book "The Control of Quality in Manufacturing" (Paiva, 2013). The objective of inspection is to send only non-defective product to the customers which similarly the reasons why SPC is applied.

Deming (1986) criticized the US manufacturing that applied mass inspection as quality control practice has significant drawbacks and bringing the industry down. Similarly, some of the critics of the inspection practice were listed below (Prosser, 2009, White, 2013, Fotopoulos and Psomas, 2009, Hurst and Harris, 2013):

- Inherently, it is timely, not economic call and ineffective to inspect each item very closely.
- Quality control inspectors have to be paid although they may not add value to the product.
- Inspection to improve quality is too late, ineffective, and costly.
- The inspection has a demoralizing effect on employees, which reduce the likelihood of zero-defect production, which an architect of the Toyota production system Taichi Ohno, concluded after his study tour of Ford in Detroit (early 1950s)− that ― there was too much ways and rework in the so-called most efficient car plant in goal‖. He argued, "The mass production properties errors to keep the line running caused errors to multiply endlessly. Any worker could reasonably think that errors will be caught at the end of the line and he was likely to be disciplined for any action that caused the line to stop"(White, 2013).
- There is no infallible inspection system. Inspectors also inevitably influenced inspection system by the human factor such as fatigues and inconsistency.

In fact, Deming (1986) accentuated that even if there is inspection of every products, it does not necessary assure quality. Both Deming (1986) and Crosby (1984) agreed on the basic policy of eliminating product defects by prevention instead of reaction. It is also mean that quality control should start at the production process instead of production end line, which, leads to the implementation of SPC.

Table 2.2 Differences between SPC and inspection

SPC	Inspection
Prevention	Detection
Proactive	Reactive
Control start at the production process	Control start at the production end light
Exist a feedback to production process for improvement	No feedback to production process
Output information gained: process behavior, process trend, process performance	Output information gained: yes /no, go/no-go, defect/non-defect, conformance/non-conformance, accept/reject

2.2.3 Statistical Process Control Charts

Statistical process control (SPC) is a statistical procedure using control charts to check a production process to see if any part of it is in some way not functioning properly, which could lead to poor quality. A control chart is a graphical method for displaying control results and evaluating whether a measurement procedure is in control or out of control. Control results are plotted versus time or sequential run number; lines are generally drawn from point to point to accent any trends, systematic shifts, and random excursions. The chart contains a centerline that represents the average value of the quality characteristic corresponding to the in control state. Two other horizontal lines, called the upper control limit (UCL) and the lower control limit (LCL) are also drawn.

2.2.3.1 Types of Control Charts

Control charts are important statistical tool for quality control. They display the results of inspecting a continuous process and separate random variations due to real assignable causes from normal variations due to chance causes. Such a running commentary as to what is happening in the process provides a convenient and rapid feedback suggesting when adjustments, corrections or overhauls may be needed. Control charts are basically of two types.

These are-

A) Control charts by variables

Those capable of being measured and the product can be classified well or bad, acceptable or non-acceptable based on quantitative measurements of their properties. Typical examples of variables are diameter, volume, length, thickness, weight, temperature, humidity, voltage, hardness, viscosity etc.…Control charts for variables are the following:-

i. The average chart (X-chart), which measures the central tendency of the process.

To calculate control limit of X chart

Center line: CL $=\bar{X}=\frac{\sum X}{N}$

Upper control limit UCL$=\bar{X}+A_2\bar{R}$

Lower control limit LCL$=\bar{X}-A_2\bar{R}$

ii. The range chart (R-chart), which measures the spread of the process.

To calculate control limit of R chart

Center line CL= R

Upper control limit UCL=D_4 R

Lower control limit LCL=D_3 R (Unnecessary） because D_3=0

Since average chart and range charts are usually used together, they are commonly known as X_{bar} - R charts

B) Control charts by attributes

- Properties, which are difficult to measure quantitatively.
- These properties are usually measured by comparison and any sample taken is classified good or bad, ok or defective by quality characteristics.
- Typical examples of attributes are surface appearance, color, texture, cracks, imperfections, burns etc.
- Control charts for attributes are basically the following:-

i. The fraction defective chart (P-chart) which records the proportion of defective items in a sample.

$\bar{P}$ = total no. of reject items divided by total no. of inspected items

To calculate the control limit;

Control limit = $\bar{P}$

Upper control limit UCL = $\bar{P} + 3 \times \sqrt{\frac{P(1-P)}{n}}$

Lower control limit LCL = $P - 3 \times \sqrt{\frac{P(1-P)}{n}}$

ii. The number defective chart (nP - chart) which records the number of defective items in a sample.

The control limit CL = Average of rejected No. = No. of reject divided by Size of group

Upper control limit UCL = nP + 3x $\sqrt{np(1-p)}$

Lower control limit LCL = nP – 3x $\sqrt{np(1-p)}$

iii. The defects chart(C-chart) which records the number of defects in a component/product

The control limit CL = Average of defects No. = C

Upper control limit UCL = C + 3 x $\sqrt{C}$

Lower control limit LCL = C – 3x $\sqrt{C}$

iv. Control chart for defects per unit (U - chart)

Control limit = the average number of defects per unit = U

Upper control limit UCL = U + 3x $\sqrt{\frac{U}{n}}$

Lower control limit UCL = U - 3x $\sqrt{\frac{U}{n}}$

2.2.4 Implementing SPC in a Quality Improvement Program

The methods of statistical process control can provide significant payback to those companies that can successfully implement them. Although SPC seems to be a collection of statistically based problem-solving tools, there is more to the successful use of SPC than learning and using these tools. SPC is most effective when it is integrated into an overall, companywide quality improvement program. It can be implemented using the DMAIC approach. Indeed, the basic SPC tools are an integral part of DMAIC. Management involvement and commitment to the quality improvement process are the most vital components of SPC's potential success. Management is a role model, and others in the organization look to management for guidance and as an example. A team approach is also important, as it is usually difficult for one person alone to introduce process improvements. Many of the magnificent seven are helpful in building an improvement team, including cause and-effect diagrams, Pareto charts, and defect concentration diagrams. This team approach also fits well with DMAIC. The basic SPC problem-solving tools must become widely known and widely used throughout the organization. Ongoing education of personnel about SPC and other methods for reducing variability are necessary to achieve this widespread knowledge of the tools. The objective of an SPC-based variability reduction program is continuous improvement on a weekly, quarterly, and annual basis. SPC is not a one-time program to be applied when the business is in trouble and later abandoned. Quality improvement that is focused on reduction of variability must become part of the culture of the organization.

The control chart is an important tool for process improvement. Processes do not naturally operate in an in-control state, and the use of control charts is an important step that must be taken early in an SPC program to eliminate assignable causes, reduce process variability, and stabilize process performance. To improve quality and productivity, we must begin to manage with facts and data, and not simply rely on judgment. Control charts are an important part of this change in management approach.(Douglas C. Montgomery, 1997)

According to different researches and books, in implementing a companywide effort to reduce variability and improve quality, several elements are usually present in all successful efforts.
These elements are as follows:

Elements of a successful implementation program

1. Management leadership program
2. A team approach, focusing on project-oriented applications
3. Education of employees at all levels
4. Emphasis on reducing variability
5. Measuring success in quantitative (economic) terms
6. A mechanism for communicating successful results throughout the organization

2.2.4.1 Problems and Difficulties in the Implementation of SPC in Organization

The following points seem to inhibit the successful application of SPC in organizations: .

- Lack of commitment and involvement of top management. One of the most common reasons for the failure of SPC implementation in many organizations is due to lack of commitment and involvement of top management (Mason and Antony, 2000). It is always important to remember
- That change within the organization cannot occur until there is a “change agent” present. In this case, the change agent would usually be top or senior management

representatives. Management must understand that variability-reduction techniques such as SPC are their responsibility and therefore they should be the first recipients of SPC training. They should believe in SPC as a powerful problem-solving tool and understand the requirements or key ingredients for a successful SPC system within the organization. .

- Lack of training and education in SPC. Lack of training and education in SPC creates problems company-wide, from the operators to the senior management, because there is a general lack of understanding and awareness of why SPC is being implemented. The purpose of this training and education is to establish a culture in which SPC is welcomed as a powerful quality management technique to understand, manage and reduce variation due to special causes and to support the goal of continuous improvement (Gaafar and Keats, 1992). .
- Failure to interpret control charts and take any necessary actions. The purpose of a control chart is not only just to hunt for special causes of variation but also to bring a process into a state of statistical control by taking appropriate remedial actions on the process. The emphasis must be placed on the selection of and interpretation of control charts and not on the construction of control charts. Many existing training programmers' have given an awful lot of importance on the construction of control charts and not on when, where and why a particular control chart must be chosen for a certain process. .
- Lack of knowledge of which product characteristics or process parameters to measure and monitor within a process. Many SPC initiatives in organizations get kicked-off without having a good understanding of the process and the product characteristics or parameters related to core processes. It is best to identify the key process parameters and its relationship to process output using experimental design methods. Experimental design is a powerful technique to discover a set of process variables which are most important to the process and determine at what levels these variables should be kept to optimize the process output (Montgomery, 1991). The critical product characteristics may be identified from a quality function deployment exercise by working closely with customers (Chen, 1995).

- Invalid and incapable measurement system at workplace. Measurement is a process, and varies, just like all processes vary. Many organizations often ignore the variation associated with the measurement system that is certainly an important feature for the successful implementation of SPC in organizations. There is uncertainty in every measurement that is taken and this can be attributed to a number of key inputs such as gauges, operators, parts, methods or the interaction between these inputs. If the measurement system is not capable, the SPC study must be deferred (Bird and Dale, 1994). . SPC should be implemented not as a customer requirement rather it must be used to make customers happy with your stability and capability of processes. SPC should not be used as a requirement from your customers. It should be used to improve the stability and capability of processes that are most critical to your customers and thereby a distinct competitive edge and increased market share can be generated.

2.3. Process Capabilities

So far, we have discussed ways of monitoring the production process to ensure that it is in a state of control and that there are no assignable causes of variation. A critical aspect of statistical quality control is evaluating the ability of a production process to meet or exceed preset specifications. This is called process capability. To understand exactly what this means, let us look more closely at the term specification. Product specifications, often called tolerances, are preset ranges of acceptable quality characteristics, such as product dimensions. To be capable of producing an acceptable product, the process variation cannot exceed the preset specifications. Process capability thus involves evaluating process variability relative to preset product specifications in order to determine whether the process is capable of producing an acceptable product. In this section, we will learn how to measure process capability.

2.3.1 Measuring Process Capability

Simply setting up control charts to monitor whether a process is in control does not guarantee process capability. To produce an acceptable product, the process must be capable and in control before production begins. Process capability is measured by the process capability index, Cp, which is computed as the ratio of the specification width to the width of the process variability

$$CP = \frac{Specification\ width}{process\ width} = \frac{USL - LSL}{6\delta}$$

The process width is computed as 6 standard deviations (6δ) of the process being monitored. The reason we use 6δ is that most of the process measurement (99.74 percent) falls within ±3 standard deviations, which is a total of 6 standard deviations. There are three possible ranges of values for Cp that also helps us interpret its value.

Cp =1: A value of Cp equal to 1 means that the process variability just meets specifications. We would then say that the process is minimally capable.

Cp ≤ 1: A value of Cp below 1 means that the process variability is outside the range of specification. This means that the process is not capable of producing within specification and the process must be improved.

Cp ≥1: A value of Cp above 1 means that the process variability is tighter than specifications and the process exceeds minimal capability.

A Cp value of 1 means that 99.74 percent of the products produced will fall within the specification limits. This also means that .26 percent (100% - 99.74%) of the products will not be acceptable. Although this percentage sounds very small, when we think of it in terms of parts per million (ppm) we can see that it can still result in a lot of defects. The number .26 percent corresponds to 2600 parts per million (ppm) defective (0.0026 X 1,000,000). This number can seem very high if we think of it in terms of 2600 defective products out of a million. You can see that this number of defects is still high. The way to reduce the ppm defective is to increase process capability. Cp is valuable in measuring process capability. However, it has one shortcoming: it assumes that process variability is centered on the specification range. Unfortunately, this is not always the case Because of this, another measure for process capability is used more frequently.

$$C_{PK} = \min\left(\frac{USL - \mu}{3\delta}, \frac{\mu - LSL}{3\delta}\right)$$

Where μ = the mean of the process

δ = the standard deviation of the process

This measure of process capability helps us to address a possible lack of centering of the process over the specification range. To use this measure, the process capability of each half of the normal distribution is computed and the minimum of the two is used.

CHAPTER THREE

3 Research Methodology

This chapter explained the research methodology that was used in carrying out the study. Research methodology present brief explanation on how the study conducted basically it includes; the study design and approach, sample size, sampling techniques, data collection methods, data analysis.

3.1 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 researcher used a mixed methods approach both quantitative and qualitative in order to achieve the main objective of this research. 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.

3.1.1. Inductive

The Inductive reasoning, is the process of reasoning in which the premises of an argument were believed to support the conclusion but do not entail it; i.e. they did not ensure its truth. Induction was a form of reasoning that makes generalizations based on individual instances. (Wikipedia-Inductive Reasoning) A process of thought could be happened using known facts in order to achieve the rules or ideas in general.

3.1.2. Deductive

Inference in which the conclusion about particulars follows necessarily from general or universal premises is called deductive. (Merriam Webster) Using the knowledge or information you had an opinion could be formed or an event could be understood.

3.2 Data source

To acquire data on the nature and extent of quality control tools usage such as SPC in Transsion manufacturing PLC the researcher used both primary and secondary data sources. Self-administered close-ended questionnaire, semi structured interview, focus group discussion was held to technical managers, quality department, production managers, 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 Sample Size and Sampling Technique

Employing convenient sampling technique, all managers and Engineers were chosen as respondents. So as per the information obtained from company 45 employees are working mainly in the area of the management and Engineering. Therefore, the researcher employed purposive convenient sampling method and all the staffs were taken for the research.

3.4 Data Collection Methods and Procedures

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.

Direct Observation

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.

Oral (open) Interviews

As of the interview, even though could take much time, was costly and was hard to analyze and compare, the researcher choose it to obtain full range and depth of information. Besides, the researcher could get the opportunity to develop relationship with clients and could be flexible with them as well. More over the researcher fully understood employee impressions or experiences, or learned more about their answers to questionnaires.

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.

Questionnaire

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 analyze 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 45 sample respondents and 45 of them were returned.

3.5 Data Analysis Methods

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

3.6 Ethical Consideration

In order to keep the confidentiality of the data given by the respondents they will not require writing their name and they are assured that responses will be treated in strict confidentiality. The purpose of the study will be disclosed in the introductory part of the questionnaire. Furthermore, the researcher tried to avoid misleading or deceptive statements in the questionnaire.

CHAPTER FOUR

4. DATA ANALYSIS AND INTERPRETATION

In order to achieve the main objective of the research the researcher prepared and distributed 45 questionnaires to the employees of the Transsion manufacturing plc working in the area of the manufacturing process. Out of the 45 questionnaires, 45 responses were valid with complete answers. Therefore, the researcher used 45 questionnaires for further analysis. On the other hand, in order to have some idea on how the production staffs view on quality related issues and SPC the researcher prepared an interview for the production management staffs and used all the responses for analysis.

4.2 Results

Under this section the existing SPC are presented using descriptive statistics. The descriptive statistics tool implemented to explain the findings including frequencies, measure of relative position (percentages), and measure of central tendency (mean) of the SPC related issues.

The questioner contains five parts. Accordingly, the demographic characteristics of the respondents are addressed in the first part. The other SPC related questions are addressed in the second part with mixed part questions were used to measure the respondents' perception on SPC implementation practices.

4.2.1 Demographic characteristics of the employees

This section provides respondents background in terms of gender, work position and Educational background .The following tables present the personal data of the respondents in detail.

Table 4.1 Demographic characteristics of the respondent

Variables	Groups	Frequency	Percentage
Gender of the respondent	Male	32	71.11%
	Female	13	28.89%
Work position	Managers	6	13.33%
	Supervisors	6	13.33%

	Engineers	20	44.44%
	Leaders	13	28.89%
Educational background	Degree	34	75.56%
	Diploma	11	24.44%

From the above table 32(71.11%) are male and 13(28.89%) are females. Also 6(13.33%) managers, 6(13.33%) supervisors, 20(44.44%) Engineers and 13(28.89%) leaders respond for the questionnaire respectively. In other hand 34(75.56%) Degree holders and 11(24.44%) Diploma holders participated in the questionnaire. This indicates all the respondents can understand all the questionnaire questions and respond properly. The major components of SPC are assessed under this part of the question. The major questions are managerial action for major Quality related Problems, Identification of critical measurements characteristics, Causes for quality problems, Familiarity of using SPC tools, factor that affect quality of mobile phone assembly process and trainings in Statistical and cognitive methods for process control and improvement.

4.2.2 Major quality related problems / obstacles of the company

Table 4.2 Mean and Percentage frequency of the respondent on major quality related problems.

Statement	No.	No. of response					Mean	Percent of the maximum frequency scale
		1	2	3	4	5		
Management commitment for quality improvement	45	1	4	9	28	3	3.62	62.22% Moderate
Skill of operators of machine production process	45	3	3	13	18	8	3.56	40% moderate
Customer requirements identification	45	0	0	8	12	25	4.38	55.55% High
Company plan for quality and process improvement	45	1	1	17	6	20	3.93	44.44% Moderate

Technology of machines, methods, etc…	45	0	2	8	33	2	3.78	73.33% Moderate
Quality of raw materials	45	6	14	17	4	4	2.69	37.77% low
Awareness of workers/ operators on quality of process and product improvement	45	2	13	28	2	0	2.67	62.22% Low
Training of the production process for operators	45	2	2	22	10	9	3.49	48.88% Moderate
Maintenance and handling of machines	45	5	7	12	19	2	3.13	42.22% Moderate
Awareness of SPC tools by the operators and supervisors	45	12	22	6	3	2	2.13	48.89% Low
Company implements all SPC tools to control and improve production process/products	45	9	25	7	3	1	2.16	55.55% Low
Identified quality related defects in the production process	45	2	7	7	20	9	3.6	44.44% Moderate
Diagnose the causes of quality defects in the production process	45	2	1	17	19	6	3.58	42.22% Moderate
Ability to take correction action for defects in the production process	45	0	2	4	21	18	4.22	46.66% High
Consistency to take corrective action for defects	45	0	1	8	16	20	4.22	44.44% High
Regularly check the status of production process capability	45	4	8	17	14	2	3.04	37.77% Moderate

Based on the above table 66.22% of respondents said that management commitment for quality improvement was high. Almost there was a visible support from top-level management teams, On the other 40% of the respondents, agree that skill of the operators of machine production process was moderate. From the above table the customer requirement identification, Technology of machines and methods, the respondents agree there is a high and moderate status in the company.

In addition, from the above table the respondents filter out that the major quality related problems are quality of raw materials (37.77% low), awareness of operators on process and product quality improvement (62.22% low), awareness of the SPC tools by operators and supervisors(48.89% low), and company implementation of SPC(55.55%). Thus, the data revealed that the company was not experiencing the implementation of SPC tools.

Regarding to company plan for quality and process improvement, training of the production process for operators, maintenance and handling of machines and the ability to take corrective action for defects in the production process, the respondents very extremely agree it is in a good status.

4.2.3 Identification of critical measurement characteristics

Table 4.3 Mean and Percentage score of respondents on identification of critical Measurement characteristics

Statement	No	No. of response					Mean	Percent of the maximum frequency scale
		1	2	3	4	5		
The quality characteristic (s) associated with this process has been documented by an operator	45	0	0	10	12	23	4.289	51.11% Regular
The impact the manufacturing process on key quality characteristics of final product is well-known	45	0	0	0	22	23	4.511	51.11% Regular
Customers have been surveyed to identify those quality characteristics associated with this process	45	8	4	1	26	6	3.4	57.77% Often
Quality characteristics associated with manufacturing process is being monitored via control charts	45	0	4	3	26	12	4.022	57.77% Often

No one has bothered to identify and define how or why this process affects the quality of the final product delivered to our customers	45	8	4	6	15	12	3.422	33.33% Often
Our customers have been asked to identify quality problems of final product	45	5	0	10	22	8	3.622	48.88% Often
Quality problems with final product have been related back to particular parameters of this process	45	0	0	15	22	8	3.844	48.88% Often
Process parameters affecting the quality of the final product delivered to our customers have been documented for the process operator	45	0	0	8	18	19	4.244	42.22% Regular
Process parameters affecting quality of final product delivered to customers are being controlled using SPC tools	45	3	0	6	30	6	3.8	66.667% Often

As shown in the above table the identification of critical measurement characteristics has been evaluated with different variables. Based on the result with an average mean value of 3.92 most of the critical measurement characteristics are identified often. According to the above data compared to other variables customers have been surveyed to identify those quality characteristics associated with this process have the least mean value that is 3.45.

Regarding documentation by the operators, 51.11 % of respondents witnessed that the quality characteristic associated with the process were always documented.

In addition to this, the manufacturing process knew the impact of the key quality characteristics up on final products. This was revealed by 51.11% of respondents as cited above.

Associated with customers surveying, 17.77% of the respondents showed that customers have never been surveyed to identify those quality characteristics associated with the process while 8.8% and 2.22% the respondents respectively said that the company have been rarely surveyed and sometimes surveyed. To the contrary, the remaining 57.77% and 13.33% of the respondents said that customers have been surveyed to identify those quality characteristics associated with process often and always respectively as shown in the graph below.

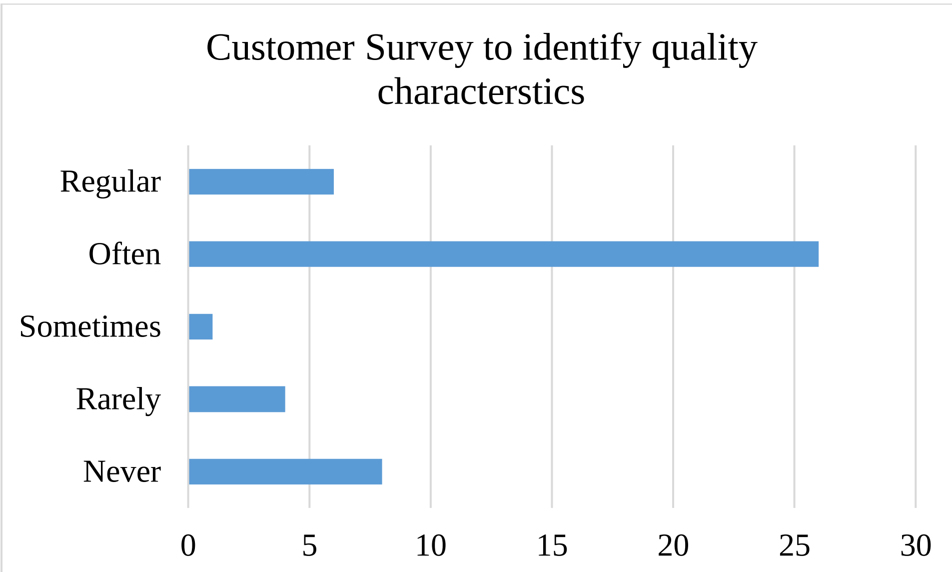

Figure 1 Graph for Analysis for customers has been surveyed to identify quality characteristics.

4.2.4 Causes of quality problems

Table 4.4 mean and percentage score of respondents on cause of quality problems

Statement	No	No. of response				Mean	Percent of the maximum frequency scale
		1	2	3	4		
Instructions	45	1	2	33	9	3.11	73.33% High
Environment	45	3	10	24	8	2.82	53.33% Moderate
Materials	45	2	5	31	7	2.96	68.89% Moderate
Measurements'	45	7	30	6	2	2.07	66.67% Moderate
Machines	45	28	17	6	4	2.13	62.22% Moderate

From the above table Instruction has a highest percentage coverage for the causes of quality problems (73.33%). Material and measurements cover the second stage for the causes of quality problems by 68.69% and 66.67% respectively.

4.2.5 Familiar SPC quality improvement tools

Table 4.5 mean and percentage score of respondents on familiarity of SPC tools

Statement	No.	No of response			
		1	2	3	4
Basic Statistics calculations(mean, median, mode, standard deviations, range and defect counts)	45	34	6	4	1
Check Sheets	45	10	26	6	3
Histograms	45	36	6	2	1
Pareto Analysis	45	39	5	1	0
Cause and effect/Ishikawa/Fishbone /diagrams	45	35	8	1	1
Scatter diagrams	45	28	26	1	0
Flow Charts	45	29	12	3	1
Control charts	45	34	11	0	0

According to the above table, the respondents do not have enough knowledge about the SPC tools.

4.2.6 Factors that affect quality of mobile phone assembly process

Table 4.6 factor that affect mobile phone assembly process

General approaches Strongly Disagree(SD) (2)Disagree(D) (3)Neutral(N) (4)Agree (A) (5) Strongly Agree(SA)					
MACHINE RELATED FACTORS	1	2	3	4	5
Was the correct tool used?	5	10	24	6	O
Is the equipment affected by the environment?	4	10	3	20	8
Is the equipment being properly maintained (i.e., daily/weekly/monthly preventative maintenance schedule	5	15	3	19	3
Is the machine the right application for the given job	2	20	4	18	1
Are all controls including emergency stop button clearly labeled and/or color-coded or size differentiated?	21	16	2	3	3
MATERIALS RELATED FACTORS					
Was the material properly tested?	2	30	5	2	6
Were quality requirements adequate for part function?	25	10	5	3	2
Was the material handled properly (stored, dispensed, used & disposed)?	26	4	5	5	5
ENVIROMENT RELATED FACTORS					
Is the process affected by temperature changes over the course of a day?	4	18	9	10	4
Is the process affected by humidity, vibration, noise, lighting, etc.	3	20	8	9	5
Does the process run i a controlled environment?	10	15	10	5	5
METHODS RELATED FACTORS					
Were the workers trained properly in the procedure?	2	2	4	35	2
Is the process under Statistical Process Control (SPC)?	2	5	3	33	2
Are the work instructions clearly written?	2	2	3	36	2
Are mistake-proofing devices/techniques employed?	3	7	10	23	2

Based on the above table, related to machine factors the respondents agree that tools that used for production process available by 53.3%, the machines where affected by external environment factor by 44.4% and the machines where maintained or used the corrective and preventive action by 42.2%.

Regarding to raw materials the respondents disagree that the materials not tested the quality properly by 66.6% and raw material storage, disposal by 57.7%. According to the above table Workers were get proper training by 77.7% and work instruction or standard operation procedure written and placed at correctly place and agreed by 80%.

4.2.7 Training in statistical and cognitive methods for process control and improvement

Table 4.7 Mean and Standard derivation for training in statistical and cognitive methods for process control and improvement.

Statement	No.	No. of response					Mean	Percentage Frequency
		1	2	3	4	5		
Almost everyone in this organization has received training in the construction of SPC tools	45	0	10	19	16	0	3.13	42.22% Some times
Almost everyone in this organization can describe what a SPC tools are saying about the performance of a critical process/product characteristics	45	4	12	10	19	0	2.98	42.22% Almost never
Almost everyone in this organization has received training in applying various off-line tools to quality improvement	45	1	17	6	21	0	3.04	46.66% Sometimes
There are on-going refresher classes in the application of SPC tools and/or various off-line tools	45	3	9	10	23	0	3.18	51.11% Sometimes
Periodic refresher training is mandated for everyone in the organization	45	18	4	1	16	6	2.73	40% Almost never

From the table above under training in statistical and cognitive methods for process control and improvement, 46.66% (the maximum frequency scale) of the respondents labeled sometimes to “almost everyone in the organization has received training in the construction of control charts”. While 34.29% of the respondents said almost every time the training has been given to everyone. On the contrary, 22.85% of the respondents revealed almost everyone in the organization almost never received training in the construction of control chart. Thus, the presented data from the questionnaire coincided with the observation revealed that the control chart was applied align with the production process. However, it was not simple to ensure whether the training was frequently given to them.

As cited above in the table, 42.85% of the respondents approved that almost everyone in the organization can describe what a control chart is by labeling almost every time. While the remaining 57.15% of the respondents labeled almost never, never and sometimes so as to say most of them were not capable to describe the control chart properly.

51.43% of the respondents agreed that there were ongoing training classes given almost every time on the application of control charts but, the researcher investigated through the interview that there was remarkable problem in respect to training either in control chart usage or in any other various off-line tools.

Although periodic refreshing training classes is mandated for everyone in the organization had a lowest mean value from the other variables, it does not mean that training was never given for everyone. In this regard, 40% of the respondents agreed that there was not any periodic refreshing training given for anyone in the organization. 8.57% of the respondents responded saying that the training was almost never given, while 34.26% and 14.29% of the respondents agreed that the periodic refreshing training was given for everyone in the organization saying almost every time and every time respectively as shown below.

4.3. Data gathered through document review

This part is dedicated to present and discuss the data that was gathered from the case factory, which is Transsion manufacturing PLC with respect to the objectives of the thesis.

After using the methodologies like questioner, interviewing, visiting and personal contact, the following 2 month report real data has been identified from the quality and assurance department of the company starting from March 1 until April 30 has been recorded.

4.3.1 Application of control chart for the defective products

Table 4.8 Sample size with varied number of defective product for the month of March and April

Sample no.	Sample size	Number of Defects		Sample no	Sample size	Number of defects	
1	20000	48	0.0024	14	20000	66	0.0033
2	20000	102	0.0051	15	20000	110	0.0055
3	20000	128	0.0064	16	20000	56	0.0028
4	20000	92	0.0046	17	20000	48	0.0024
5	20000	76	0.0038	18	20000	30	0.0015
6	20000	104	0.0052	19	20000	130	0.0065
7	20000	80	0.004	20	20000	52	0.0026
8	20000	70	0.0035	21	20000	42	0.0021
9	20000	62	0.0031	22	20000	44	0.0022
10	20000	78	0.0039	23	20000	64	0.0032
11	20000	68	0.0034	Total	460000	1592	
12	20000	68	0.0034				
13	20000	38	0.0019				

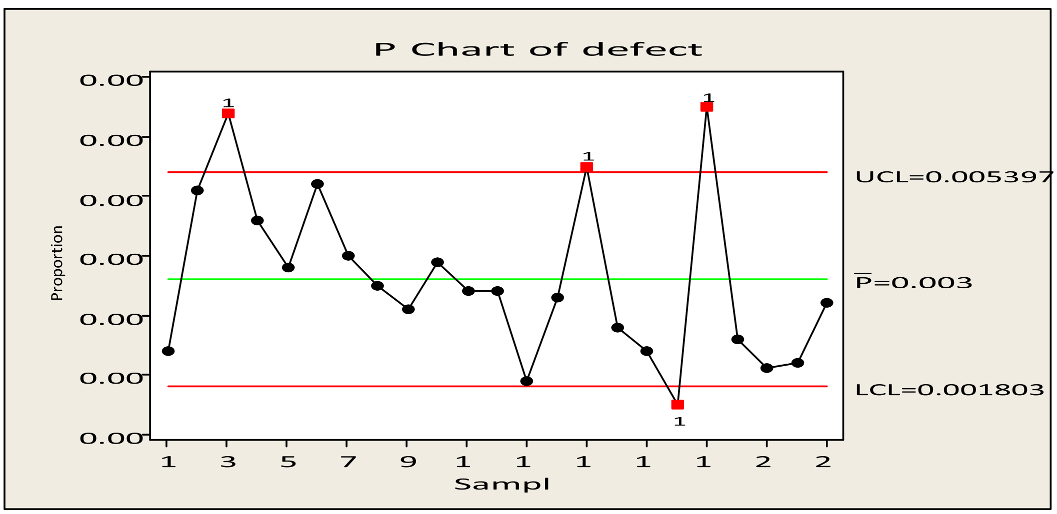

Figure 2. P- Chart of defect count

The control chart with centerline at p = 0.0036 and the above upper and lower control limits are shown in .The sample fraction nonconforming from each preliminary sample is plotted on this chart. Note that four points, those from samples 3, 15, and 19 plots above the upper control limit and sample 18 plots below the lower control limit so the process is not in control. These points must be investigated to see whether an assignable cause can be determined.

Analysis of the data at sample 3, 15 and 19 indicates that there was a Soldering box temperature-reading problem and some of the soldering box were not working properly. Consequently, the causes of the problem for sample 3, 15 and 19 are eliminated by using maintenances system. Therefore, the new centerline and control limits are calculated as follows.

UCL = 0.005034

LCL= 0.001587

CL_P = 0.003311

4.3.2 Prioritization of defects

To prioritize the defects/non-conformities and determine the vital problems in each cause from. Based on Table 4.9, the Pareto diagram in Fig 2 elaborates the problems that affect quality significantly.

Table 4.9 Defect rate analysis based on cause of defects

No	Defect type	Number of defects	Cumulative total	Percentage	Cumulative percentage
1	No echo sound	321	321	38.72%	38.72%
2	No receiver sound	299	620	36.07%	74.79%
3	white screen	144	764	17.37%	92.16%
4	No network	51	815	6.15%	98.31%
5	Gap	8	823	0.97%	99.28%
6	vibrator noise	3	826	0.36%	99.64%
7	camera error	3	829	0.36%	100.00%
Total		829		100	

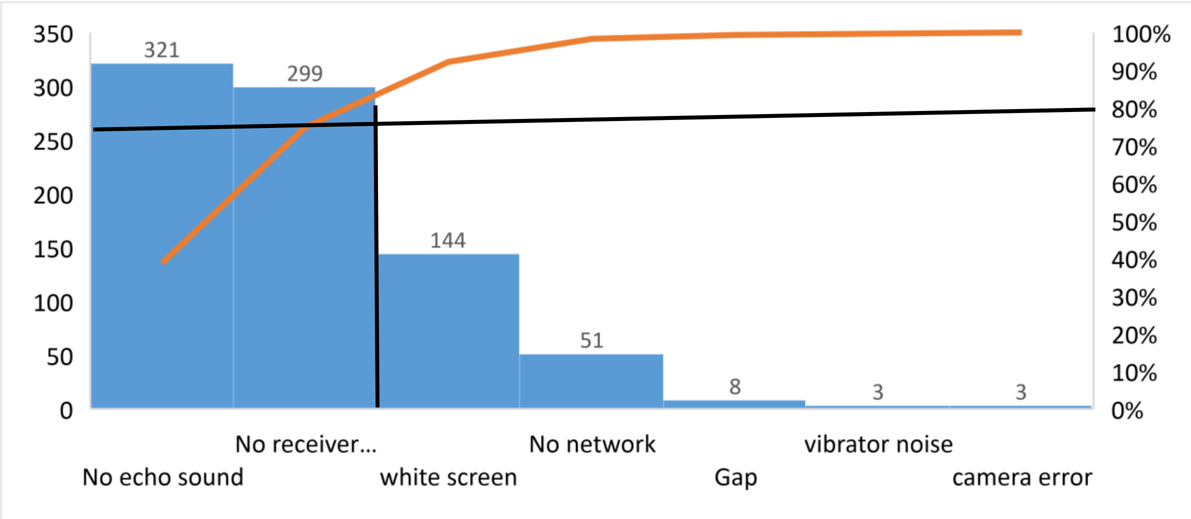

Fig 3 Pareto Diagram for prioritization of defects

As the above Pareto chart indicates, improvement efforts should be focused on the categories to the left line, which are called the “vital few”. In this case, the vital few are no echo sound and No receiver sound.

4.3.3 Application of control chart for the weight of feature phones

Table 4.10 below, shows data collected for 18 sample days with 4 shifts taken by the quality control department of the company with four observations, each of the weight of the feature mobile phones are in grams.

Due to a large number of data, the excel software was used to compute the mean and range for time consumption. Table below shows the computed mean and range using data from table.

Table. 4.10 Mean and Range for the sample of gross weight

Sample number	Shift 1	Shift 2	Shift 3	Shift 4	X- bar	R-bar
1	299.08	302.06	301.7	306.835	302.4188	7.755
2	300.58	302.92	298.99	298.8	300.3225	4.12
3	299.655	296.625	302.22	297.57	299.0175	5.595
4	297.85	299.345	296.395	296.25	297.46	3.095

5	295.57	301.64	296.53	297.065	297.7013	6.07
6	300.58	302.915	298.985	298.8	300.32	4.115
7	295.385	298.16	299.1	295.935	297.145	3.715
8	295.085	300.39	296.63	297.95	297.5138	5.305
9	299.435	297.06	300.93	300.105	299.3825	3.87
10	307.255	299.905	306.875	301.135	303.7925	7.35
11	299.895	298.865	298.975	296.915	298.6625	2.98
12	298.8	297.965	297.345	295.92	297.5075	2.88
13	310.2	313.9	311	311.3	311.6	3.7
14	299.415	299.68	297.655	299.25	299	2.025
15	306.395	304.64	301.265	296.825	302.2813	9.57
16	305.27	297.65	300.62	298.8	300.585	7.62
17	303.545	294.885	299.095	305.27	300.6988	10.385
18	301.44	298.27	301.47	306.06	301.81	7.79
19	306.685	306.17	308.74	306.18	306.9438	2.57
					ΣX-bar=5714.163	ΣR-bar= 100.51
					S X-double bar=300.75	R-double bar=5.29

Establishing control limits

From table 4.10 the average of the mean, X=300.75

The average of the range, R=5.29

We can compute UCL, CL and LCL for each X-bar and

R-chart

a) For X-bar chart, the UCL & LCL can be determined as;

$$UCL= X_{GA} + A_4R_A$$

$$=300.75 + (0.729* 5.29) = 304.61$$

Center line (CL) = X-double bar = 300.75

$$LCL= X_{GA-} -A_4R_A$$

$$= 300.75-(0.729*5.29) = 296.89$$

b) For R-chart, the UCL & LCL can be computed as;

$$UCL= D_4R_A$$

= 2.574*5.29=13.62

Center line = R-bar = 5.29

LCL= D_3R_A, since D_3 is 0, LCL=0

Construction of control charts

X-bar charts are plotted as means against the sample no while, the R-bar chart is plotted as a range against sample days.

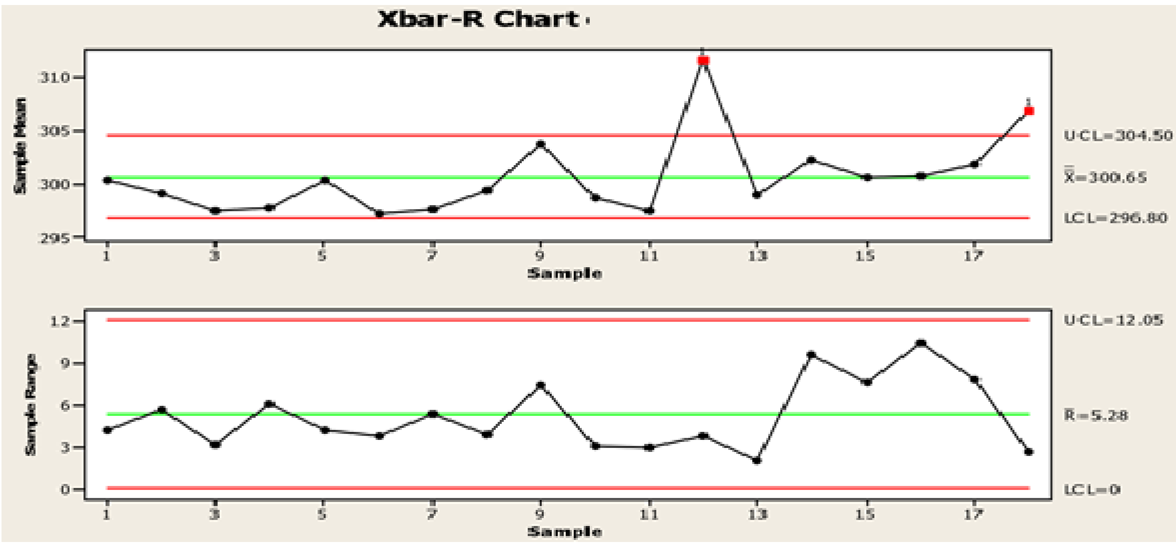

Figure 4 Graph for X bar-R chart of gross weight

From the above graph, 4 points are almost on the central line, 9 points are just below the central line, 2 points are above the central line on the other hand, two points are out of the upper limit. Excluding the points that are out of the control limit, recalculating the new control limits, resulted process is under control. As shown in the graph below. This pattern might be indicative of a sudden increase in the process variation due to packing carton weight difference or more materials are included.

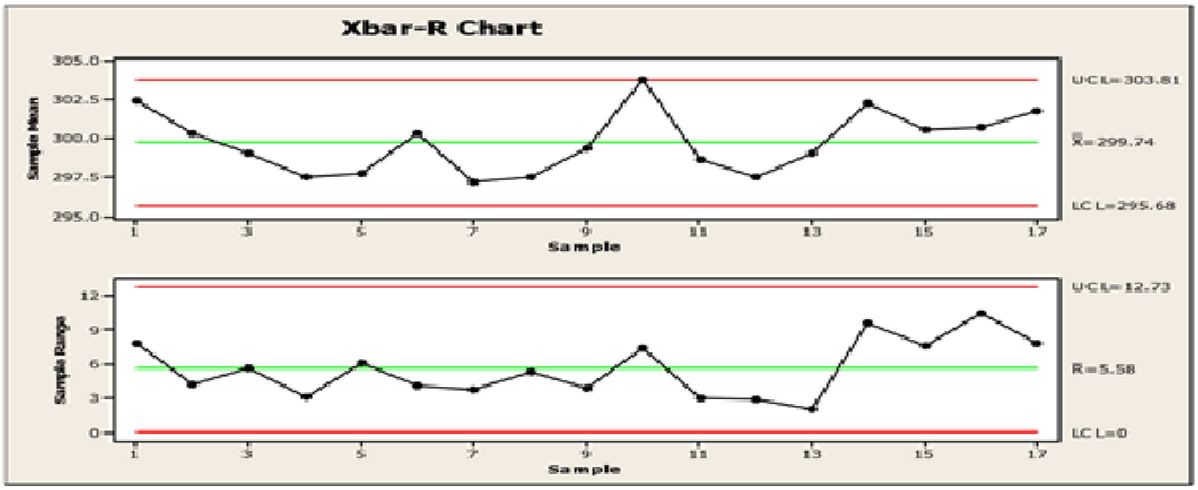

Fig 5 Graph for the revised gross weight

As shown in the above graph, the revised control values are CL= 299.74, UCL= 303.81 & LCL= 295.68. Therefore; to monitor the process properly and to increase the process capability, these control limits are advisable to take as a specification limits.

4.3.4 Application of cause and effect analysis

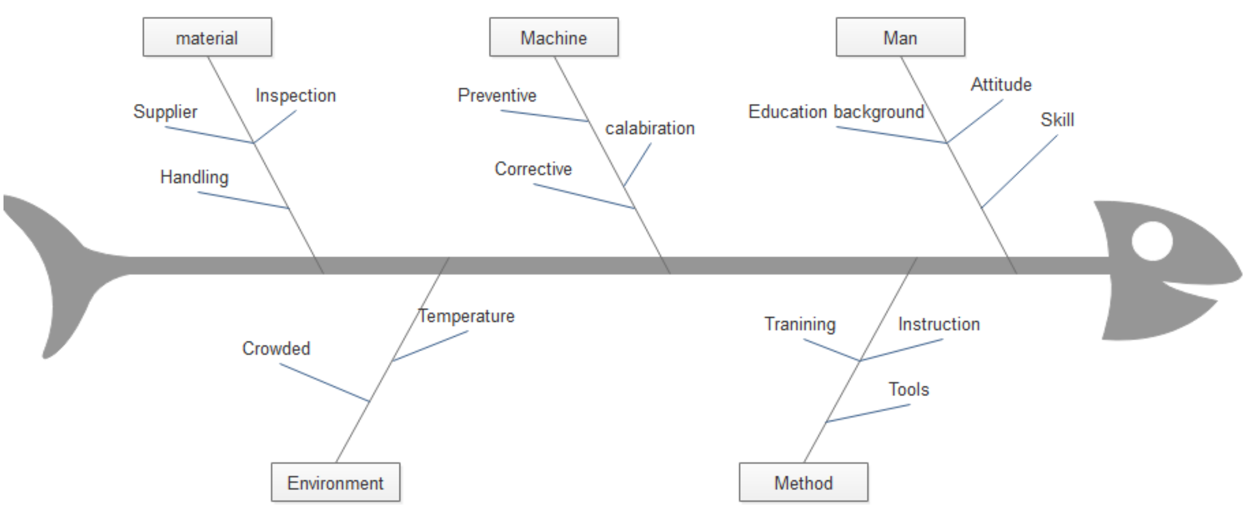

Fig 6 Cause and effect (fish bone) analysis

Brainstorming is a technique used to elicit a large number of ideas from a team using its collective power. It normally takes place in a structured session involving between three to twelve people, with five to six people being the optimal group size. The team leader keeps the team member focused, prevents distractions, keeps ideas flowing, and records the outputs (or make sure that team members record their own outputs). The brainstorming session should be a closed-door meeting to prevent distractions. In analyzing the dairy product defect or quality problem, we elected to lay out the major categories of Mobile phone defects as man, machine, material, methods and environment. The team identify the root causes of quality defects by asking or raising the following brainstorming questions

Questions to Ask When Performing RCA:

 PEOPLE (MAN)

- Was the document properly interpreted?
- Was the information properly disseminated?
- Was the proper training to perform the task administered to the person?
- Were guidelines for judgment available?
- Did the environment influence the actions of the individual?
- Is fatigue a mitigating factor?

❖ MACHINES

- Was the correct tool used?
- Does the environment affect the equipment?
- Is the equipment being properly maintained (i.e., daily/weekly/monthly preventative maintenance schedule)
- Was the machine properly programmed?
- Was the tooling used within its capabilities and limitations?
- Are all controls including emergency stop button clearly labeled and/or color-coded or size differentiated?
- Is the machine the right application for the given job?

❖ MEASUREMENT

- ➢ Does the gage have a valid calibration date?
- ➢ Was the proper gage used to measure the part, process, chemical, compound, etc.?
- ➢ Was a gage capability study ever performed?
- ➢ Do measurements vary significantly from operator to operator?
- ➢ Does the gage have proper measurement resolution?
- ➢ Did the environment influence the measurements taken?

 MATERIAL

- ➢ Was the material properly tested?
- ➢ Was the material substituted?
- ➢ Is the supplier‘s process defined and controlled?
- ➢ Were quality requirements adequate for part function?
- ➢ Was the material contaminated?
- ➢ Was the material handled properly (stored, dispensed, used & disposed)?

❖ ENVIRONMENT

- ➢ Is the process affected by temperature changes over the course of a day?
- ➢ Is the process affected by humidity, vibration, noise, lighting, etc.?
- ➢ Does the process run in a controlled environment?

❖ METHODS

- ➢ Was the canister, barrel, etc. labeled properly?
- ➢ Were the workers trained properly in the procedure?
- ➢ Was the testing performed statistically significant?

- Have I tested for true root cause data?
- Has a capability study ever been performed for this process?
- Is the process under Statistical Process Control (SPC)?
- Are the work instructions clearly written?
- Are mistake-proofing devices/techniques employed?
- Are the work instructions complete?
- Is the tooling adequately designed and controlled?
- Is handling/packaging adequately specified?

CHAPTER FIVE

5. SUMMARY OF FINDINGS, CONCLUSION AND RECOMENDATION

5.1 Summary findings

This part of the section tries to summarize the key findings of the study. The objectives of the study were to identify the practices and challenges of implementing statistical process control for improving quality in the case of Transsion manufacturing PLC . In order to meet the objectives of the study the researcher collected primary data by the use of Questionnaire and Semi structured interview and observation. Thus, 45 questionnaires were retrieved from the respondents and analyzed. Accordingly, the findings of the study are summarized as follows.

From the different dimensions shown, findings revealed that the practices and challenges of the company on SPC for improving quality were identified. There were still certain limitations investigated. These are: - lack of management commitment in the implementation of SPC, low awareness of workers /operators, poor maintenance and handling of machines, low awareness of SPC tools usage by process operators and supervisors, low level of implementation of all SPC tools, lack of consistency to take corrective actions, lack of regular checking on the status of the production process, lack of periodic refreshing trainings, lack of team working and poor sampling.

Also from the application of cause and effect analysis, there were classified problems by man, material, machine, method and environment. From man side there were attitude, skill and educational background limitation problems pointed out. From method, side observed that lack of operators training, problem of clear standard operation procedure and not enough guiding operation tools. In addition, there was no preventive and corrective maintenance plan for machine services pointed out from machine side. There were also a lack of inspection materials, different suppliers supply the materials and it costs to have a different inventory place. Also the working place is a little bit crowded and makes some suffocations for the operators during process.

On the other hand, even if the company has many limitations but due to the good practices implemented and identified from the data gathered through documentation review, from semi- structured interview as well as from the questionnaire revealed that the company was benefited after the implementation of the SPC as the findings exhibited. These benefits are mention as; reduced non-conforming product, minimize the risk of product recalls, improved process visibility, understandability, and reduced rework and defects.

5.2 conclusion

Based on the findings of the study, the following conclusions are drawn by the researcher. Practices like documentation of the quality characteristics by operators, identification of the impact of the manufacturing process on key quality characteristics, usage of control charts, usage of computerized technology for data recording and usage of calibrated measuring devices are some of the good practices of the company so as in the implementation process of SPC all these are very basic to improve the process and the quality of the product. The other good practice of the company was planning for quality improvement so planning is very important to use all the appropriate tools for quality improvement. Therefore, they should keep on doing this practices and also improving them more so that all the quality characteristics associated with the process can be improved.

The survey has indicated that quality improvement related problems are a serious deal to the survival of industries. The main goal of this study is apply SPC tools, identify different quality causes, and suggest where to focus. Quality tools i.e. Pareto chart and Cause and effect diagram are used to identify and evaluate different defects and causes for these. Quality tools can be much wider applied with certain success. Quality tools are not so wider spread as expected although they are quite simple for application an easy for interpretations. Quality Control Tools could improve process performance by reducing product variability and improves production efficiency by decreasing souring and returns. From the study it reveals that SPC techniques can give the significance improvement of quality. In this paper it has found that the SPC tools can be applied to different products for reducing the defects. Thus, the SPC techniques are used globally to improve quality. Although SPC seems to be collection of statistically based problem solving tools, there is more to the successful use of SPC than learning and using these tools, SPC is the most effective when it is integrated into an overall, companywide ,quality improvement program

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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 Besides, the organization improved process visibility and understandability, brought guarantee food safety. So as to increase the benefits or maintain the company should work more on the implementation of SPC.

Moreover, the organization could bring improvement on product quality characteristics, rework and could reduce customer compliance. It also exhibited waste product minimization.

Finally, it can be concluded that 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.

5.3 Recommendation

Based on the above findings and conclusions for sustainable quality improvement the following recommendations are suggested.

The most challenging in SPC implementation is in answering how and where to get started the implementation. If the implementation is planned at the organizational level, the support of organizational scale must be prepared as well.

1. Educating employees to aware on the values for SPC implementation in the company and guarantee top level management commitment.
2. Top level management be supposed to be convinced that SPC has the ability to improve the company‘s bottom-line. To enable the top level management to be familiar with the fundamentals of SPC, points should be briefed as;
    - SPC requires changes of management style with respect to the delegation of tasks and employee empowerment.
    - SPC is a technique used to establish process capabilities.
    - SPC is a technique to recognize, quantify, reduce and control variation.
    - Top-level management should be the first recipients of the session.

If the top-level managers are willing to accept all the points mentioned above the challenges of the company associated with implementation of SPC could be solved.

3. SPC Training: As cited above the company is highly in need of consistent training provision. Thus, some of the recommended suggestions are indicated as follows :-
    - Training of SPC in the company should be more than just once, as SPC involved both technical aspect and managerial aspect where the training is highly suggested to be delivered in level-by level within the organization's hierarchy.
    - The training should consist of underlying philosophy of SPC, theoretical and management aspect of SPC and other quality tools and technique.
    - The training materials should focus on statistical tools, leadership, and change of culture, which wider attendance of participants should be encouraged at this point of training sessions.
    - Continuous training session and workshops focusing on awareness creating could help the company to achieve such objectives.
    - Providing trainings for technical personnel who are required to collect and analyze data is highly suggested to be appropriate with the level of employees understanding.
4. Poor maintenance and handling of machine. This was identified as an obstacle for the implementation of SPC and quality improvement. Thus, the researcher recommended recalibrating the equipment/machine, preventive maintenance, updating the latest model of manufactured machines to be improved.
5. As constant learning leads to continual change and learning facilitates response to change, the company should be a learning organization.
6. Benchmarking and learning from best practice of internal and external competitors will continuously keep the company in the momentum for change. Therefore, the company should give a value to.

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APPENDEX-A

QUESTIONAIRE

Survey questionnaire for a study on Productivity Improvement Techniques Using Statistical Process Control (SPC) in Dairy industry. Dear Sir/Madam, I am student of Master of Quality Control and Productivity Management (QMP) in St. Mary's University. The following research is part of my QMP study and conducted for purely academic purposes. The purpose of the research is to find out the Quality improvement techniques using SPC tools in manufacturing industry. All the Information collected through the questionnaire will be used only for contribution to knowledge and kept secret/confidential. Please ensure that you mark all the given statements otherwise incomplete responses will not fulfill researcher requirements.

To this end, kindly request you to answer the following short questions regarding with the stated objective. It will take no longer than 15 minutes of your time. Your response is utmost important to me. Therefore, you're genuine, honest and prompt response is available input for the quality and successful completion of the project research paper.

General Instruction

- There is no need of writing your name.
- In all case where answers options are available, please make mark(X) in the appropriate place.

Part1: General Information

This section of questionnaire refers to general information about the respondent. The information will allow me to compare groups of respondent.

1, Gender:-Male___________ Female________________

2. Qualification:- Diploma_____ Degree_____ Masters______ others_______

Part 2: Rate the following questions and put "X" in the respected area.

1-Very low 2-low 3-Moderate 4-High 5-Very high

1. **Major quality related problems/obstacles in the company**

	1	2	3	4	5
Management commitment for quality improvement					
Skill of operators of machine production process					
Customer requirements identification					
Company plan for quality and process improvement					
Technology of machines, methods, etc…					
Quality of raw materials					
Awareness of workers/ operators on quality of process and product improvement					
Training of the production process for operators					
Maintenance and handling of machines					
Awareness of SPC tools by the operators and supervisors					
Company implements all SPC tools to control and improve production process/products					
Identified quality related defects in the production process					
Diagnose the causes of quality defects in the production process					
Ability to take correction action for defects in the production process					
Consistency to take corrective action for defects					
Regularly check the status of production process capability					

2. **Identification of critical measurement characteristics**

1-Never 2- Rarely 3-sometimes 4-often 5- **regular**

	1	2	3	4	5
The quality characteristic (s) associated with this process has been documented by an operator					

The impact the manufacturing process on key quality characteristics of final product is well-known					
Customers have been surveyed to identify those quality characteristics associated with this process					
Quality characteristics associated with manufacturing process is being monitored via control charts					
No one has bothered to identify and define how or why this process affects the quality of the final product delivered to our customers					
Our customers have been asked to identify quality problems of final product					
Quality problems with final product have been related back to particular parameters of this process					
Process parameters affecting the quality of the final product delivered to our customers have been documented for the process operator					
Process parameters affecting quality of final product delivered to customers are being controlled using SPC tools					

3. **What is the cause of quality problems in Transsion manufacturing? In Your opinion, what is the level contribution of the following causes for mobile phone assembly quality problems in Transssion manufacturing?**
   1; Low, 2; Moderate, 3; High, 4; Very high

	1	2	3	4
Instructions				
Environment				
Materials				
Measurements‘				
Machines				

4. **Please rank your familiarity with the following quality improvement basic tools in your company**,
   1: Not familiar, 2: Basic understanding, 3: Well Familiar, 4: Expert

	1	2	3	4
Basic statistics calculation (mean, median, mode, standard deviation, range, defect counts)				
Cause and effect/Ishikawa/ fishbone diagram				

Check sheets				
Histograms				
Pareto analysis				
Scatter diagrams				
Flow charts/diagrams				
Control Charts				

This section of the questionnaires prepared to collect data about the main factors that affect quality of mobile phone assembly process in Transsion manufacturing PLC. Please indicate the extent to which you agree or disagree with each statement by Ticking(X) on correspondent number. Higher number indicates higher level of agreements.

Choose only one answer for each statement.

General approaches

1. Strongly Disagree (2)Disagree (3)Neutral (4)Agree (5) Strongly Agree

MACHINE RELATED FACTORS	1	2	3	4	5
Was the correct tool used?					
Does the environment affect the equipment?					
Is the equipment being properly maintained (i.e., daily/weekly/monthly preventative maintenance schedule					
Is the machine the right application for the given job					
Are all controls including emergency stop button clearly labeled and/or color-coded or size differentiated?					

MATERIALS RELATED FACTORS					
Was the material properly tested?					
Were quality requirements adequate for part function?					
Was the material handled properly (stored, dispensed, used & disposed)?					
ENVIROMENT RELATED FACTORS					

Is the process affected by temperature changes over the course of a day?					
Is the process affected by humidity, vibration, noise, lighting, etc.					
Does the process run in a controlled environment?					
METHODS RELATED FACTORS					
Were the workers trained properly in the procedure?					
Is the process under Statistical Process Control (SPC)?					
Are the work instructions clearly written?					
Are mistake-proofing devices/techniques employed?					

5. **Training in statistical and cognitive methods for process control and improvement**

1-Never 2- Almost never 3-Sometimes 4-Almost every time 5-Everytime

	1	2	3	4	5
1. Almost everyone in this organization has received training in the construction of SPC tools					
2. Almost everyone in this organization can describe what a SPC tools are saying about the performance of a critical process/product characteristics					
3. Almost everyone in this organization has received training in applying various off-line tools to quality improvement					
4. There are on-going refresher classes in the application of SPC tools and/or various off-line tools					
5. Periodic refresher training is mandated for everyone in the organization					

Thank you very much to respond questions in the Questionnaire.

APPENDEX-B

INTERVIEW QUESTIONS

1. How your company defines quality?
2. Does the company identify the customer requirements for its products? How often the company communicate with its customers? Are objectives of the company linked to customer needs and expectations?
3. Does the company focused on the production process improvement to satisfy its customers? Does the company recognize and solve the quality related problems?
4. Does the company implement the SPC tools? When is the company implementing SPC? Is that implemented throughout the company
5. Which statistical process control (SPC) are applied and used in the company to monitor, inspect, and control the process:

A. Histogram
B. Pareto analysis
C. Control charts
D. Scatter diagram
E. Check sheet
F. Cause and effect diagram
G. Flow chart

6. Does the company have procedures for continuous improvement and preventive action?
7. What are the major benefits gained after the implementation of SPC?
8. What major challenges faced in the implementation of SPC to improve quality?
9. How the company does evaluate the effectiveness of SPC implementation?