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# A Proposed Statistical Monitoring of Quality Characteristics for Detergent

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***Abstract*****—** *Statistical quality control has become a vital tool employed in the field of quality assurance in both product and service providing industry in order to meet the set management standard and keep the process in control so as to remain in the global business. This study therefore: a statistical monitoring of quality characteristics of detergent by investigating some quality characteristics of the detergent using control chart, test of randomness and process capability analysis to ascertain if the process is actually in control. Four quality characteristics of the product will be considered in this study which includes active detergent, moisture content, bulk density and acid-base concentration (pH). Secondary data of the production process will be observed from the Quality Assurance Department in the production plant of Unilever Nigeria Plc. The histogram will be used to test for normality of the data set. X-bar and the Moving Range (MR) control charts will be employed in assessing the aforementioned quality characteristics. The test for randomness process capability study of the process for the in-control charts will be further carried out to ascertain whether the quality characteristics under monitoring was actually in statistical control. The correlation coefficients will be observed to test if there exist any sort of relationship between quality characteristics.*

***Keywords*****—** *Statistical Quality Control, Randomness, Correlation, Process Capability Index, p-value.*

## I. INTRODUCTION

Quality refers to the perception of the degree to which the product or service meets the customer's expectation. It can also be defined as making product uniformly around the customer's target. According to Montgomery, (2005), quality is the extent to which the customers or user believe the product or service surpasses their needs or expectations.

Quality can also be defined as conformance to the need, requirement and expectation of the customer. Quality can be viewed from many perspectives as given by the philosophers which include satisfying the customers' requirements, fitness for use and conformance to requirement among others.

Most people have a conceptual understanding of quality as relating to one or more desirable characteristics that a product or service should possess. In order to be persistent and to have continuity in a production process the returns after the completion of the process must be encouraging that is, the two agent or factor involved; the producer (Unilever NIG PLC) and the consumer or final consumer which is the general public must be in good terms. The manufacturer's product must satisfy the consumer's expectation. In view of this, Quality can be define as system of means to economically produce goods and services which satisfies the consumer's requirement.

In our society today, Quality has become one of the most important consumer decision factors in the selection of competing products and services and as a matter of fact it is incapable of being avoided in every day's routine. The phenomenon is widespread, regardless of whether the consumer is an individual, an industrial organization, a retail store, a bank or financial institution, or a military defense program and so on. Consequently, understanding and improving quality are key factors leading to business successes, growth, and enhanced competitiveness. There is a substantial return on investment from improved quality and from successfully employing quality as an integral part of overall business strategy. The characteristics of quality are; Psychological, Technological, Time-oriented, Contractual, and Ethical.

Statistical process control is the practical changing of the process based on the results of process monitoring. Once the process monitoring tool has detected an out-of-control situation, the practitioner responsible for the process makes the necessary change required to bring the process back into control. Meanwhile, Statistical Process Control (SPC) is about continuous monitoring or surveillance of a process to ensure that neither the mean nor the variability of the process distribution has changed (Hawkins and Zamba, 2005b; McCracken and Chakraborti, 2013). Examples of process control may include: monitoring some quality characteristics of manufactured items to ensure compliance to certain standards; detection of an increased birth rate of infants with congenital malformations; surveillance of health data to detect an outbreak of a disease or increased rate of incidence of diseases; the observance of a natural phenomenon such as water salinity levels, or adverse drug reactions and so on (Zamba and Hawkins, 2006).

In-control process is a process that is operating at or around some target value and only under some random variation; and out-of-control (OOC) process is a process that has somehow changed from its in-control state. Meanwhile, ideal process control should consist of monitoring both the process mean and variability (Hawkins and Zamba, 2005a & 2005b; Hutchison, 2002). For in most cases, special causes can result in a simultaneous change in both the mean and the variance. In such cases, simultaneous monitoring of both parameters is a logical approach to process control. And, in standard practice, this is done by pairs of control charts. For example, Shewhart $\bar{X}$chart is used to control the process mean, and R or S chart is used to control the process variability (Park, 2014); Shewhart X chart (on which the individual observations are plotted) and MR (upon which the ranges of successive individual observations are plotted) chart are respectively used to control the process mean and variability, when it may not be feasible to take samples larger than one (Reynolds and Stoumbos, 2001).

A production process is said to be in statistical control if the process is operating in the absence of any assignable cause of erratic fluctuation. On the other hand, if variation due to assignable cause is present in any process then the process is said to be out of control (Prajapati, 2013; Albers and Kallenberg, 2006 and Gan, 1995).

Statistical quality control is an analytical decision making tool which allows us to see when a process is working correctly and when it is not (Allen, 2006). Statistical quality control is one of the most important applications of the statistical technique in industrial field today. As a matter of fact, it is impossible to think of an industrial field where statistical techniques are not used.

Statistical control is the branch of quality control which involves the collection, analysis and interpretation of a statistical data for use in quality control activities. Statistical quality control is aimed at achieving a successful marketing of the product by keeping the various steps involves in the production process of the product (Badiru, 2014).

Sunlight detergent is a surface–active chemical widely used in laundering. It is a surfactant (a chemical agent capable of reducing the surface tension of a liquid in which it is dissolved) with cleaning properties in dilute solutions. These substances are usually Alkylbenzensulfonates (a family of compounds that are similar to soap but are more soluble in hard water). In most household context, sunlight detergent by itself refers specifically to laundry detergent, as opposed to hand soap or other types of detergent, Sunlight Detergent are commonly available as powder. The use of detergent was first introduced during world war one, when there was a shortage of Oil. Synthetic Detergent were made and used instead. Below are the following quality characteristics to be studied;

i. *Active detergent*: it is composed of sulphuric acid that comprises of those foaming properties of the detergent.
ii. *Moisture content*: it is the water composition present in the detergent.
iii. *Bulk density*: it is a property of powder and other divided solids which depends on the degree of compaction that is the degree of an increase in the density of the detergent.
iv. *Acid-base Concentration (Ph)*: It is the measure of the level of concentration of the acid in relation to base in the detergent.

*Justification for the study*

In Statistical Process Control (SPC), detecting shift in process quality level and locating the point of change are significant research tasks. So far, immeasurable majority of control charts are designed to monitor a single process parameter (especially for a shift in the process mean), but special causes may result in a simultaneous change in both the mean and the variance (Das, 2008; Gan, 1997; McCracken and Chakraborti, 2013; Zhang et al., 2010). Besides, available research in the area of simultaneous monitoring of several product qualities (characteristics) has largely overlooked cases (McCracken and Chakraborti, 2013). In spite of the fact that one of the potentials of process shift approach to SPC is monitoring immediately, the usual practice is rather to subjectively involve gathering at least some carefully selected monitored observations before the SPC is set in place. Hence, there is possibility of a great concern between two or more quality characteristics that form a product. The foundation of statistical quality control originated from Bell Laboratories and was developed by a physicist named Shewart in 1920s and it was specifically developed to help detect statistical changes in process quality. furthermore, the application of statistical quality control methods were needed in determining process, test and sampling regulations to evaluate and describe process and finished products quality performance and as a result will protect the interest of both producers and consumers in the sense that its effective use will improve the quality of products.

This is the use of techniques and activities to achieve sustain and improve the quality of a product or service. Also, quality control is concerned with quality of conformance of a product or service (Montgomery, 2009). The prime purpose of quality control is to assure that the products or services (processes) are performing in an acceptable manner. The practical and pragmatic quality control based operations strategy for a service or manufacturing organization would focus on the principle of quality in design.

In view of this, we want to carry out a statistical process monitoring of some quality characteristics of some products to see if actually is meeting the specified standard from retrospective collected data from the quality control record office

It is of no doubt that the process change approach to SPC is very important for process quality improvement in that monitoring the actual shifts, after its detection, in process would ease the identification of special causes and lead to savings in time and cost. More so, monitoring the process immediately it is started should yield better information and improvement for the process. The process shift approach of the SPC problem thus disposes of the need for a long calibration sequence which is much more appealing in ongoing analyses (Hawkins et al., 2003). For the fact that these SPC methods can be implemented soon after a process is started, the question of when to start monitoring the process is what this research tends to answer. Meanwhile, there is a gap in knowledge regarding the monitoring of a process when we have more than two quality characteristics. The concern emanating from this could be greatly reduced if the required number of observations needed to meet the objective of starting process monitoring is objectively, rather than subjectively, determined.

The vast majority of control charts are designed to monitor a single process pa, such as the mean or the variance, but it is often desirable to monitor the mean (Zhang et al., 2010; 2012). Specifically, many change-point approaches to SPC are designed to detect a single shift in the mean of the process. In practice, we may have more than one quality characteristics responsible for the variability (Hawkins and Deng, 2009; Hawkins and Zamba, 2005b). So, it is neither enough to monitor just one quality characteristic all alone at all time. Therefore, in order to ensure the overall process quality, it is important that shift in the process variability is detected simultaneously with the change in means simultaneously.

*Objectives of the Study*

This overall aim of this research proposal is to study some quality characteristics of detergent to see if actually they are in statistical control according to the set standard. The specific objectives of the study will be to:

i. Study the variation pattern of the quality characteristics.
ii. Monitor the quality characteristics.
iii. Assess the capabilities of the quality characteristics
iv. Determine the level of association among the pairs of the quality characteristics.

## II. METHODOLOGY

*Sources of Data Collection*

The data that will be used for this research work will be collected from a secondary source

*Histogram*

Histogram is a column graph depicting the frequency of the data collected on a given product or process. As one of the seven tools uses for quality improvement it is a plotted graph of the observed frequencies against each value or range of value for a set of data. it is an informal representation of the variation of a product or the result of a process. It often forms the bell-shaped curve which is characteristic of a normal process. The histogram helps us to analyze what is happening in the process and it helps show the capability of a process.

Furthermore, a histogram displays a frequency distribution of the occurrence of the various measurements. The variable been measured is along the horizontal axis, and is grouped into a range of measurement while the frequency of occurrence of each measurement is charted along the vertical axis.

The reason why histogram will be used in this research work is that apart from histogram being one of the essential and distinguishing tools for improving quality, it depicts the central tendency or mean of the data and its variation or spread which allow us to study variation pattern of the quality characteristic. Also histogram shows the range of measurement which defines the process capability. A histogram can as well show characteristics of the process being measured such as;

i. Does the result show a normal distribution (a bell curve)? If not, why not?
ii. Does the range of the data indicate that the process is capable of producing what is required by the customer or the specifications?
iii. How much improvement is necessary to meet specifications? Is this level of improvement possible in the current process?

*Control Chart Techniques*

*Brief Historical Background of Control Charts*

Control chart was first introduced by Walter Shewhart in 1924 while conducting research on methods to improve quality in the Bell Telephone Laboratories (Allen, 2006). He developed the concept of quality control with regard to variation, and came up with statistical process control charts which provide a simple way to determine if the process is in control or not. A control chart is a time sequence plot of some measure of quality, with added control or decision lines. The purpose is to determine whether the process in question is in-control, Shewhart (1931). The control lines are determined in such a way that observations outside these limits suggest that the process is out-of-control.

SPC primarily involves the implementation of control charts, which are used to detect any change in a process that may affect the process quality. Control charts, therefore, are essential tools of continuous process quality control and are very effective when monitoring processes. The purpose of these techniques is to identify when the process is displaying unusual behaviour. However, variation is the key to statistical process control charts. The extent of variation in a process indicates whether a process is working as it should. Designed to detect changes in a process, these graphical displays allow a practitioner to determine whether a process is in-control or out-of-control by taking samples at specified sampling intervals and plotting values of some statistics on a graphical interface which includes decision/threshold lines called control limits. Basically, some of the usefulness of using a control chart are as follows. One, it differentiates true change from random cause of change. Two, it emphasizes early detection of meaningful change. Three, visualization can engage additional stakeholders, and thereby allows timing and degree of intervention impact to be detected (Benneyan et al., 2003).

For the fact that control charts are used to detect the presence of assignable causes of variation by checking the desired stable state of the process, reduction of variation is thus achieved through rapid detection and elimination of such special causes. A process, therefore, is said to be in a state of statistical control, if it operates under common causes of variation and the probability distribution representing the quality characteristic is constant over time. If there are some changes over time in this distribution, the process is said to be out-of-control (Prajapati, 2013). In other words, in-control (IC) process is a process that is operating at or around some target value and only under some random variation; and out-of-control (OOC) process is a process that has somehow changed from its in-control state. OOC thus creates opportunity to improve reliability. Control chart are used for the following purpose.

*Types of control chart*

There are two types of control chart which are;

i. Control Chart for Attributes
ii. Control Chart for Variables.

*Control chart for Attributes*

They are based on data that can be grouped and counted as conforming or non-conforming, present or not-present,



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defective or non-defective and so on. Attribute control chart provide useful records about a quality's history. These records may be useful in, monitoring workers, making managerial decisions about changes in process and meeting contractual obligation. Basically, this kind of control chart is used to analyze quality characteristics that cannot be represented numerically. Examples are p-chart, np-chart, c-hart and u-chart.

*Control chart for Variables*

They are Base on the data that can be measured on a continuous scale that is quality characteristics that can be expressed as numerical measures examples are $\bar{X}$ and R chart, $\bar{X}$and S chart, Control chart for individual unit. In this project, we will be making use of control chart for individual unit which is categorized into control for variables.

*Control chart for individuals unit*

There are diverse situation where single sample size is used for quality control. It occurs frequently in automated expression and measure next technology such that every unit manufacture is analyzed. It also occurs when the production rate is too low to conveniently allow sample size greater than one (Montgomery and George 2003), or when the repeated measurement differs only because of laboratory or analysis error as in chemical process. In such case, the appropriate chart to be used is control chart for individual unit control chart for individual unit is made up of X-Chart to monitor the central tendency and moving range chart to monitor the spread of the process. In view of the fact that the process under study is a chemical process Control Chart for Individual Unit is employed

*X-Chart*

The Centre line and Upper and Lower control limits for a control chart for individual are obtained using the following:

$$\text{CL} = \bar{\text{X}} \quad (1)$$

$$\text{UCL} = \bar{\text{X}} + 3\frac{\overline{\text{MR}}}{\text{d}_2} \quad (2)$$

$$\text{LCL} = \bar{\text{X}} - 3\frac{\overline{\text{MR}}}{\text{d}_2} \quad (3)$$

where $\overline{(MR)}$ represent the mean of the moving average of order 2.

*Moving Range Chart*

The Centre line and Upper and Lower control limits for a control chart for moving range are obtained using the following:

$$\text{CL} = \overline{\text{MR}} \quad (4)$$

$$\text{UCL} = \text{D}_4 \times \overline{\text{MR}} \quad (5)$$

$$\text{LCL} = \text{D}_3 \times \overline{\text{MR}} \quad (6)$$

Where $\text{D}_4 = 3.267$, $\text{D}_3 = 0$, and $\text{d}_2 = 1.128$

*Hypothesis Testing*

$H_o$: The process is random $V_S$ $H_1$: The process is not random

*Test Statistics:*

$$Z_r = \frac{(r-\mu_r)}{\sigma_r} \quad (7)$$

where

$$\mu_r = \frac{2n_An_B}{n_A+n_B} + 1 \quad (8)$$

$$\sigma_r = \sqrt{\frac{2n_An_B(2n_An_B-n_A-n_B}{(n_A+n_B)^2(n_A+n_B-1)}} \quad (9)$$

Where

r is the number of runs,

$\mu_r$is the test value

$n_A$= number of samples above the center line

$n_B$ = number of samples below the center line

*Decision Rule*

Reject $H_0$if p-value <α = 0.05,

Otherwise, Retain $H_0$.

*Process Capability Analysis*

The process capability is the performance of the process when it is operating in control. In other words, to carry out a process capability analysis we must first of all keep our process in statistical quality control to access our capability performance. It is usually necessary to obtain information about the process capability because it helps us to know whether the process is capable of giving us what we want or not. It can as well be used to study the extent to which the process is capable of producing products which conform to specification. The indices that will be used in measuring process capability are given as follows,

- Process Capability Index ($c_p$)
- Process Performance Index ($C_{PK}$).

*Process Capability Index*

A process capability index is a measure linking the existent or actual performance of a process to its assigned or specified performance, while the processes are considered to be a combination of the system, the equipment, the method used, the process itself and so on. It is a way of indicating the variability of a process relative to the product specification tolerance. The process capability index is denoted with cp.

$$c_p = \frac{USL-LSL}{6\hat{\sigma}} \quad (10)$$

The denominator is referred to as the width of the process and the numerator is referred to as the width of the specification. Also, USL is the Upper specification Limit and LSL the Lower specification Limit.

If $C_p$< 1, it shows that the process spread cannot produce materials within the specified tolerance.

*Process Performance Index ($C_{PK}$)*

It is a one-sided process capability ratio that is calculated relative to the specification limit nearest to the process mean.it is denoted with $C_{PK}$

$$C_{PK} = \min\left[\frac{\text{USL}-\bar{\text{X}}}{3\hat{\sigma}}, \frac{\bar{\text{X}}-\text{LSL}}{3\hat{\sigma}}\right] \quad (11)$$

where

USL is the Upper specification Limit.

LSL is the Lower specification Limit.

If $C_{pk}$< 1, it shows that the process spread cannot produce materials within the specified tolerance

*Determination of Correlation Coefficient between Two Quality Characteristics*

Correlation is the examination of the level of relationship between variables of interest, when interest centers on the level of relationship between bi-variate normally distributed random variable say X and Y. Correlation coefficient



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measures the degree of association among quality characteristics studied. It is sufficient to find correlation rxy given as

$$r_{xy} = \frac{n\sum xy - \sum x \sum y}{\sqrt{[(n\sum x^2 - \sum x)^2) \ \ (n\sum y^2 - (\sum y)^2)]}} \quad 12$$

*Testing for the Significance of the Correlation Coefficient*

$H_0$: $\rho = 0$ (There is no correlation between pair {I,J})
VS
$H_1$: $\rho \neq 0$ (There is correlation between pair {I,J})
Taking $\alpha$ = 0.05 {level of significant
where the pair {I,J} are:
Active Detergent, Moisture Content, Bulk Density and Acid-Base Concentration

*Test statistic*

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \sim t_{n-2,\frac{\alpha}{2}} \quad 13$$

*Decision Rule*

Reject $H_0$ if t >$t_{n-2,\frac{\alpha}{2}}$, otherwise do not reject $H_0$

*Expected Findings*

- It will be practical that the Statistical Process Control is an effective tool for monitoring the quality characteristics products of Unilever Nigeria Plc with respect to the set standard.
- The charts in the analysis will determine the level of variability and deviation from set target.
- Help to provide information regarding what the process could do under best conditions and give performance target.

*Expected Contribution to Knowledge*

This study is expected to contribute to knowledge in the following ways.

- It will reveal to us that statistical quality and process analysis could be a reliable monitoring technique that could be employed in order to meet specified standard set by any organization (either product or service provider)
- Adopted techniques in this study could be used to keep a production process in control and also to improve on the set the standard.
- Provide baseline information for Unilever Nigeria Plc so as to understand how the process product quality monitoring is operating in relative to the specification.

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