World Journal of Innovative Research (WJIR)
ISSN: 2454-8236, Volume-5, Issue-5, November 2018 Pages 16-27

Reducing Production Cost through Quality Control Study in an Aluminium Manufacturing Industry

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Abstract— **The study elucidated the use of quality control study to reduce cost of production using First Aluminium Nigeria Limited as scope of research with the aim of adopting cost minimization procedure by identifying the best quality control technique in line processing. The study background elaborate quality control and its important role in the measurement and control of the components of material production cost and thrives forward to profitability. Related literatures as pertain to quality management, value engineering, quality control in production, benefits of using quality control in manufacturing, quality assurance, cost management and quality control in production, ideas for cost reduction in manufacturing and ways to reduce production cost (cost reduction strategies) were appraised. Also, the study discussed on the potential of combining Statistical Process Control (SPC) with engineering process control methods. The study adopted analytical research method which involves visiting the plant of the study sample as Data was collected directly from the company while C-chart control process technique was used in analysing the data as to ascertain the level of causes of low recovery as results of line process problems. The results obtained show the different causes of low recovery for the period under study indicating that the line process problems were out of control. Thus: in 2013 the control level point was 9.8, with upper control level showing 19.19, while lower control level shows 0.41 which buttress the fact that the quality for the year is out of control. Also, in the year 2014, the control level was 7.65, the UCL scores 15.95, while LCL was –0.65 < 0, indicating that the process is not in control. For the year 2015 the control level was 8.48, while the UCL scores 17.22, whereas LCL was -0.26 < 0, showing out of control in line process. The year 2016 showed that control level was 6.52, the UCL was 14.18, while LCL was –1.14 < 0, implying that the process is out of control. Lastly, the control level for year 2017 was 1.09, with upper control level 4.22 while the lower control level indicated –2.04 < 0, which as well implies out of control.**

Index Terms— **Production Cost, Aluminium Manufacturing Industry.**

I. INTRODUCTION

Every year, more and more companies compete for their share in highly active product market by modifying their design, manufacturing and process methodology. It is for this need that efficient time to make and product cost reduction has become so valuable for manufacturers. So to succeed in today's manufacturing market place, companies need more parts and material simplification; they need a holistic, best-in-class approach with guarantee able result and a benchmark driven structure.[1]

Quality as one of the techniques in cost reduction and meeting key result area has an important role to play, hence there is need for quality control study. Quality of a product can be defined as degree of extent to which it meets the requirement or exceeding the customer's expectation[2].

A strong control over the management cum utilization of resources of all categories in a production process becomes the demand of the day due to high competition among the players of the present markets. The factors (5*M*s & *E*) affecting quality which include: man, material, machine, manufacturing, money and equipment and time to be utilized is a most cost effective manner to ensure the profitability of a company and at the same time no compromise in the quality.[3]

Hence, quality control has an important role in the measurement and control of the components of material production cost and thrives forward to profitability. The question is, how to achieve quality at the same time reduce production cost. Cost of quality has the answer. Statistical process control is considered as one of the most effective tool for gathering and analysing the expense in maintaining quality in a production process and brings out the non-value added expenses[4]

Most manufacturing process are imperfect and have an associated non-conformance ratio. Manufacturers seeking to achieve high quality and reducing production cost have a wide range of option which are:

(a) Improving conformance of product quality via defect prevention so as to avoid reworking or rejection thereby reducing product cost and,

(b) Improving conformance of quality delivered to the customers via inspection [5].

In many manufacturing processes, some of the fabricated products can be defective due to unstable production environment which First Aluminium due to unstable power generation sometimes experience defective and impact technology consequent human error[6].

First Aluminium does not undergo reworking rather sell defected items as scraps so quality control major highly of importance to reduce cost of production. John (2016) described the leading cause of a decline in profit as waste in the manufacturing process and making product that are of poor quality, why? Every naira spent on cost of production must come out of profits. Costs of product are only those cost that are related to making an acceptable product. These costs would decrease if the products were made right the first time[7].

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II. RELATED WORKS

Giving the highly competitive nature of markets today, companies must provide high quality products or services and minimize production cost to survive. In today's markets, quality has become a crucial competitive factor. It is not surprising that the provision of high quality products or services is often mentioned as a goal in most companies' mission statement.[1]

First Aluminium Plc. Mission Statement is to engage in continuous improvement by suggesting and implementing improvements, cost saving in our functions, work flow, customers' service, communication, and other services. Cost is an important component in the smooth working of business units; it has not enticed much attention of scholars on developing new cost control and reduction techniques [2].

"How to Control Production Cost" emphasized that the need for more detailed cost counting depicting actual conditions so good judgement can be applied to control and reduce cost. One is made aware of the need to allocate properly the cost of rework, expensive machines, work and storage areas, and similar items to specific products requiring them. The use of average figures for overhead is glared upon. Also the use of small burden centers and appropriate bases for overhead rate is stressed as being imperative if companies are to have good control of costs [3].

Impact of cost control and Cost reduction Techniques on manufacturing sector" stated that the customers are continuously demanding high quality and better performance product/services and at the same time, they want the price to fall therefore, it is necessary for companies know how to manage its product/services cost, quality and performance. Today the market leaders are even pursuing cost-reduction as a strategic imperative.

Manufacturing companies are preferring techniques like value engineering, quality control, budgetary control, for the purpose of cost reduction.[4]

This technique fulfill the objectives of company i.e. "low cost manufacturer" their study specifies that the cost reduction technique is reducing material cost, labour cost, and overhead cost. Sometimes the cost reducing investment functions directly on cost. In so many cases it takes the form of developing new product (value Engineering) that bring in the market and whatever customers' need more economic. Therefore, product development can have ultimate effect on direct costs reduction. Most industry performance is affected by majorly two (2) issues or problems, viz: Those that occur simultaneously and make the entire process of assessment of performance very difficult.

Cost reducing expenditures are firstly fixed costs. [5]

"Purchasing Research" laid emphasis on special research on purchase. He stressed that purchasing department that are not comfortable of placing orders, place orders as and when they arise; these leads to problem at times [6].

Have rightly emphasized these objectives by pointing out "that the product shall be produced in the best and the cheapest method, that it shall be of the required quality and that it shall be produced at the right time, nine steps that are important for cost benefit analysis and the ambiguity involving estimates of cost and benefits meant that costs benefit analysis was likely to inform decision instead of offering a simple decision making rule. The best strategy, under this analysis is identified by the ability to achieve an expected goal at the minimum expenditures.[7].

The problems faced by facility managers in any company. One of such problems is the estimation of operating and maintenance costs in the present and future. Development of preventive and general maintenance plans for facilities similar to those investigated. [8]

The good technical practices by individuals are not sufficient to produce and delivery good products/services quickly and at a low cost. They must be integrated through good project management to achieve better production, both market orientation and customers' satisfaction provide support for revenue expenses whereas both quality and operations provide impressive support for the cost reduction perspective. [9]

Material, labour and expenses are the three constituent elements of production cost. Simultaneously earnings of high quality may be the outcome of conservative accounting standards and strong cash flows, decrease in production costs and increase in sales[10].

Embossing supply means the roughening of a coil surface finish to increase the surface coefficient of friction. It is also a design feature on production. At this embosser a lot of rework is carried out on coils found to be defective. The paint line section ensures that paint coatings are applied to the coil according to specification.[11]

Quality as one of the techniques in cost control and meeting key result area. Quality had an important role to play thereby bringing in quality control study to reduce cost, the degree to which a product conforms to specifications and workmanship standards. Before understanding quality control study, we must first know the meaning of each word in the terms quality. 'Quality' is defined as fitness for the purpose, while 'Control' is a system for measuring and checking. It gives a feedback mechanism to explore the causes of poor quality and takes corrective steps.[12]

Quality Control which was '*Fitness for use*' has subsequently been developed to be "*Fitness for Purpose*" implies that in order for a product to fit for its purpose, every goods and services must have the right features to satisfy customer's need and further must be delivered within few time without failure[13].

The field of quality control has come a long way since the days of the industrial revolution. Back in the early 18 century, skilled craft men carried out production with one worker starting and finishing a whole product. The craftsmen produce in small quantities and took pride in the reputation of their work conveyed. When the industrial revolution was the proliferation of the factory system, semi-skilled workers, who each made a small portion of the final product, became common, with the responsibility for quality (and quantity) of final product shifted to the formation of each product inspection ranged in various organizations from nil to 100%[14].

III. MATERIALS AND METHODS

3.1 Materials (Data Collection and Source)

The data used for the dissertation were based on the readings for 2013 to 2017 obtained from the Quality Control Department (QCD) of an Aluminium Nigeria Company.

3.2 Methodology (Analytical Method):

The research methodology adopted in this work includes, visit to the plant, data collection and data analysis. The data collected resulted from the following consideration:

i) Types and nature of defects
ii) Tools for Data Analysis

3.2.1Types and Nature of Defects

The types and nature of defect undertaking in this study include:

i) Frequent occurrence of process problems: These are the defects that occur dues to – Line tension failure, Line tripping, Power failure, Coater applicator-roll, Delay in stitching, Mandrel, Metal shifting, Sensor failure, Oven failure, Air failure, Input material (Rough edges), Accumulator failure, Hydraulic failure, Accumet applicator roll, Coil car, and strip breakages.

ii) Causes of low recovery according to line problem using peatro chart: The defects attributed to line problems include: metal shifting, coater applicator roll, squeeze roll, line tripping, power failure, edge cracking, sheet surface defect, delay in stitching, accumet applicator roll, hydraulic failure, air failure, and oven failure.

Types of Defects on Coils

There are different types of defects on coils which include:

- Holes
- Edge cuts
- Buckle
- Gauge variants, etc. (Nweke, 2008).

3.2.2Tools for Data Analysis

The following tools were employed in the course of this work:

i) Cost management
ii) Statistical Tool: Statistical Process Control (SPC) i.e. Control Chart (C-chart).

3.2.3Cost Management and Quality Control in Production

Cost of production can be reduce through –

i. Reduction (product time, waiting, inventory)
ii. Elimination (waste, bottleneck, barriers)
iii. Modification (system, design)
iv. Innovation (re-engineering, methods of producing equipment, tooling).

These will now result in the following (Advantages of Cost reduction) resultant:

i. Increase profits
ii. Reduce waste
iii. Increase productivity
iv. Competition
v. Resource conservation
vi. Image enhancement.

Cost reduction is a planned positive approach to reduce expenditure and increase profit.

Production cost which is referred to the cost incurred by a business when manufacturing a good or providing a service. It includes a variety of expenses, but not limited to labour, raw materials, consumables, manufacturing supplies and general overhead. Additionally any taxes levied by the government or loyalties owed by natural resources extracting companies are also considered production cost.

Types of Production Costs are:

i. Manufacturing costs
ii. Direct cost (labour cost)
iii. Material costs
iv. Indirect cost (overhead cost) refers to maintenance or rebuilding
v. Non-manufacturing costs (general operation costs) refers to equipment maintenance, transport, salary for marketers, accountants, managers, funding spent on marketing. Facilities expenses such as rent, light, heat, property tax.
vi. Incidental expense refers to expenses for supplies such as tools, tape, lubricants, and safety gears.

3.2.4Four Categories of Cost

The four categories of costs are depicted in the figure below:

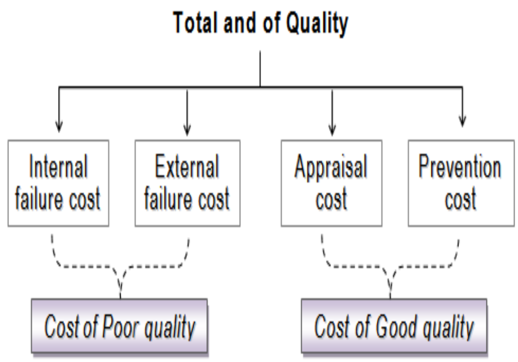

Figure 3.1 Types of Statistical Quality Control
Source Grace L D. (2013)

i) **Internal Failure Cost**

Cost associated with defects found before the customer receives the product or services. They include: waste, scrap, rework, failure analysis, etc.

This cost is dependent on the nature of the defects on the sheets. If a part fails the factory inspection processes and the defects cannot be easily corrected. It is classified as use-as-is (uai) or reworked (rwk) for alternative application as shown in Figure 3.2.

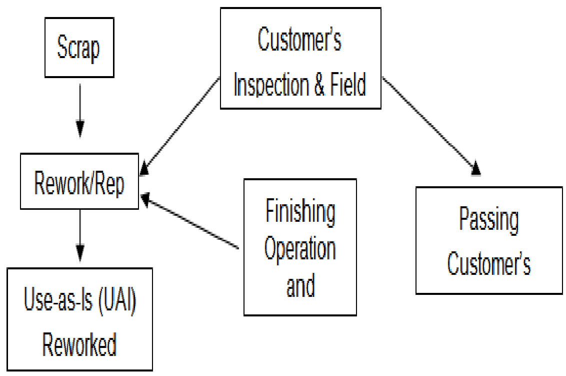

Figure 3.2 Factory–customer part inspection and testing
Source: Feiring *et al*. (1998)

The cost involved when a defective production is completely scrapped is called cost of scrap while the cost involved when a defected product is reworked for the same or alternative application is called cost of rework.

ii) **External Failure Costs**

External failure costs are incurred to remedy defects discovered by customers. These costs occur when products or services that fail to reach design quality standards are not detected until after transfer to the customer. They could include:

- Repairs and servicing—of both returned products and those in the field
- Warranty claims—failed products that are replaced or services that are re-performed under a guarantee
- Complaints—all work and costs associated with handling and servicing customers' complaints
- Returns—handling and investigation of rejected or recalled products, including transport costs

iii) Appraisal Costs

Appraisal costs are associated with measuring and monitoring activities related to quality. These costs are associated with the suppliers' and customers' evaluation of purchased materials, processes, products, and services to ensure that they conform to specifications. They could include:

- Verification—checking of incoming material, process setup, and products against agreed specifications
- Quality audits—confirmation that the quality system is functioning correctly
- Supplier rating—assessment and approval of suppliers of products and services

iv) **Prevention Costs**

Prevention costs are incurred to prevent or avoid quality problems. These costs are associated with the design, implementation, and maintenance of the quality management system. They are planned and incurred before actual operation, and they could include:

- Product or service requirements—establishment of specifications for incoming materials, processes, finished products, and services
- Quality planning—creation of plans for quality, reliability, operations, production, and inspection
- Quality assurance—creation and maintenance of the quality system
- Training—development, preparation, and maintenance of programs

3.2.5Pareto Chart Analysis

The onus lies on Process Managers to ensure that quality of scraps and off-cuts generated are minimized so as to increase % weight of finished products obtained from the raw materials. Hence the general term for measuring the efficiency of the process in minimizing scraps and off-cuts is called Recovery. Recovery is the total weight of finished products (output) divided by total weight of raw materials used for their production (input) expressed in percentage.

$$\text{Recovery:} = \frac{\text{Output}}{\text{Input}} \times 100 \qquad 3.1$$

$$\text{\% Frequency} = \frac{\text{n (freq)}}{\sum \text{n (Total freq)}} \times \frac{100}{1} \qquad 3.2$$

Wt Loss = Input wt – Output wt.

$$\text{\% Wt loss} = \frac{\text{wt loss}}{\text{Total wt.loss}} \times \frac{100}{1} \qquad 3.3$$

Input = Output + Loss in Weight:

In order to improve the recovery of the operation, it is imperative that Process Managers increase output in equation by reducing loss in weight in equation if output remains constant. If the Process Managers make the production system to be efficient in giving high recovery, this implies that cost of production shall be reduced as the following effects of law recovery shall be controlled.

1. Production volume
2. Energy consumption
3. Product delivery
4. Overhead costs

However, using Statistical Process control (SPC) to reduce cost of scrap in an aluminium manufacturing company, as measured before, Loss in recovery caused by defective off-cuts and scrap increase cost of production (Quality costs) through the following ways:

1. Decrease in production volume: As the off-cuts/scraps are generated due to poor quality, total production volume in period decreases giving rise to lower ratio of volume: overhead costs.

2. Increase in energy consumption. For re-melting of aluminium off-cuts/scraps energy is required to do so, hence this result to increase in overall energy consumption of the production unit.

3. Untimely delivery of products to customers: This gives rise to loss in revenue and customers' dissatisfaction and drop in market share of the organization.

4. Increase in other elements of production costs especially overhead costs, pilfering and other hidden costs.

SPC is valuable tool that the Process Manager shall use to define measures, analyse, improve and control operation in order to reduce cost of production, which may results in increase or drop in % recovery of finished products.

3.3 Formulae for Various Control Charts

To compute the means of the samples means, first find the value for the respective samples of the sample means first find the value for the respective samples means as follows:

$$\bar{X}_1 = \frac{X_{11} + X_{12} + X_{13}}{n} \ldots\ldots\ldots\ldots + X_{1N} \qquad 3.4$$

$$\bar{X}_2 = \frac{X_{21} + X_{22} + X_{23}}{n} \ldots\ldots\ldots\ldots + X_{2N} \qquad 3.5$$

$$\bar{X}_N = \frac{X_{N1} + X_{N2} + X_{N3}}{n} \ldots\ldots\ldots\ldots + X_{nN} \qquad 3.6$$

where,

N = Number of samples means

n = number of observations in the samples.

$\bar{X}$ = process average or the mean of the population.

On the other aspect, computing both the UCL and the LCI, we need to find the standard deviation of the population, from the normal sampling theory, the variability of our sampling plan can be expressed in terms of the standard deviation which is expressed as:

$$\bar{X} = \frac{\sum(X-X)^2}{n-1} \quad 3.7$$

$\bar{X}$ Standard Deviation

Given the value of the standard deviation, one can easily compute the standard error of the estimate.

Upper Control Limit (UCL) = $\bar{X} + (3\delta/\sqrt{\pi})$ 3.8

Control Line = $\bar{X}$ 3.9

Lower Control Limit (LCL) = $\bar{X} - (3\delta/\sqrt{\pi})$ 3.10

- The C-chart formula is:

$$UCL = \bar{C} + 3\sqrt{C} \quad 3.11$$

$$CL = \bar{C} = \frac{\sum C_1}{n} \quad 3.12$$

$$LCL = \bar{C} - 3\sqrt{C} \quad 3.13$$

- **Np chart:** In this chart, we plot the number of defectives (per batch, per day, per machine) as in the C chart. The formula for *Np* chart is:

$$UCL = n\bar{p} + 3\sqrt{n\bar{p}\,(1-n\bar{p})/n_1} \quad 3.14$$

$$CL = \bar{P} = \frac{\sum np_1}{\sum n_1} \quad 3.15$$

$$LCL = n\bar{p} - 3\sqrt{n\bar{p}\,(1-n\bar{p})/n_1} \quad 3.16$$

- The C-chart formula is:

$$UCL = \bar{C} + 3\sqrt{C} \quad 3.17$$

$$CL = \bar{C} = \frac{\sum C_1}{n} \quad 3.18$$

$$LCL = \bar{C} - 3\sqrt{C} \quad 3.19$$

- **Np chart:** In this chart, we plot the number of defectives (per batch, per day, per machine) as in the C chart. The formula for *Np* chart is:

$$UCL = n\bar{p} + 3\sqrt{n\bar{p}\,(1-n\bar{p})/n_1} \quad 3.20$$

$$CL = \bar{P} = \frac{\sum np_1}{\sum n_1} \quad 3.21$$

$$LCL = n\bar{p} - 3\sqrt{n\bar{p}\,(1-n\bar{p})/n_1} \quad 3.22$$

- The P-chart formula is:

$$UCL = \bar{P} + 3\sqrt{P\,(1-D)/N} \text{ or } \bar{P} + 3\sqrt{\bar{P}} \quad 3.23$$

$$CL = \bar{P} = \frac{\sum P_1}{\sum P_1} \text{ or } + 3\sqrt{\bar{P}\bar{q}} = 3\sqrt{\sigma} \quad 3.24$$

$$LCL = \bar{P} = 3\sqrt{P\,(1-D)/N} \text{ or } \bar{P} - 3\sqrt{\bar{P}} \quad 3.25$$

- **U chart:** . The formula for U-chart includes:

$$UCL = \bar{C} + 3\sqrt{\frac{\bar{U}}{n_1}} \quad 3.26$$

$$CL = \bar{U} = \frac{\sum U_1}{n_1} \quad 3.27$$

$$U_1 = \frac{C_1}{n_1} \quad 3.29$$

$$LCL = \bar{C} - 3\sqrt{\frac{\bar{U}}{n_1}} \quad 3.30$$

- **G chart**: formula is:

$$UCL = \bar{g} + 3\sqrt{\bar{g} \times (g+1)} \quad 3.31$$

$$LCL = \bar{g} - 3\sqrt{\bar{g} \times (g+1)} \quad 3.32$$

- **T chart**: formula includes:23

$$y = t\,\frac{1}{3\pi} = t^{0.27} \quad 3.33$$

$$UCL = \left(\bar{y} + 2.66 \times \bar{R}\right)^{3.6} \quad 3.34$$

$$LCL = \left(\bar{y} - 2.66 \times \bar{R}\right)^{3.6} \quad 3.35$$

- **Cp index** is computed as:

Cp =(*USL-LSL*)/(6*sigma) $^2{}_y$ 3.36

where *sigma* is the estimated process standard deviation, and *USL* and *LSL* are the upper and lower specification (engineering) limits, respectively.

Amongst all these, C-chart is used in this research to analyse and compared.

.3.4 Reasons for Using C-chart for Analysis

The sampled company uses Pareto chart to analyse, but the researcher deemed it appropriate to use the C-chart subject to its benefits and application for easy comparison. The C-chart is not as inclusive as the $\bar{X}$ and *R* or *P* charts; It still has a number of application. The C-chart can be established for a single quality or a group of quality characteristic, a single machine or a group of machines, or for the entire project.

The C-chart has been used to advantage in different situation such as:

1. It has been used for 100% inspection where the primary aim is to reduce the cost of rework or scrap.
2. It has been used for periodic sampling of production, where a certain number of non-conformities per unit are tolerable.
3. It has been used for scientific sampling procedures based on defects per unit.
4. It has been used in short studies to ascertain the variation in quality of characteristics or piece.
5. The C-chart is used to plot the number of defects when the sample size are equal.
6. It is also used where the possibilities for defects are infinite.

In all these situations, the chart provides information on the current quality level and whether or not a state of control exists.

3.5 Formulation of Quality Control Chart

In addition to our discussion on statistical process control as shown in Figure2.7, there is need to talk about statistical quality control in order to formulate s quality control chart. This is because control charts formulated in this project is the statistical process control chart which is a type of statistical quality control. So it is important to look at the concept of statistical quality control in general.

One of the corner stone of quality control is the use of statistical methods to determine how much inspection to use. In any case, a great deal can be by taking a sample rather than a 100 percent inspection. In other cases, there is no alternative but take a sample.

In using statistical methods, it is inferred from the sample whether or not the product conforms to specifications. This inference is made by inspecting the sample and deciding on that basis whether the entire output meets the quality standards. This process always involves the possibility of errors, since sample information is being used to reach a decision.

Two types of errors can be made in statistical sample, one being to accept the lot when it does not in fact meet the quality standards. This error occurs when the random sample happens to contain a large number of defects even though the lot itself has only a few. Although these errors cannot be eliminated completely, but they can be controlled or reduce at a desired level of accuracy by proper selection of a sampling plan.

3.6 The Pay Off from Quality Control and Management

As a result of intense global competition, some industries were downsized in 1980s, Erickson *at el*., (1990). Some companies lost a reasonable number of customers and reduced into smaller organisations. However, there has been a rebirth of competitiveness in some industries and companies under the banner of Quality Management. Associated with this industrial renaissance are high quality, low cost, short cycle times, regained market share, and increased long- term profitability.

i) **Low Cost**:

As Deming predicated, when quality goes up due to systemic and process changes, then costs go down. Many firms have reported lower cost associated with such quality efforts. Affordable quality has thus become the reality in many markets.

ii) **Short Cycle Times**

It is believed that simplifying processes and working in cross-functional teams reduces cycle time in an industry, cycle time is the time duration required to complete an operation in the manufacturing industry. For a new established organisation cycle time may refer to the time it takes to fill a customer's order. A typical example of reduced cycle time in manufacturing can be found at Motorola's Boyton Beach, Florida, plant that produces customized papers. The plant uses a simultaneous engineering effort in which the paper was redesigned for robotic assembly. It shrank its supplier base to 22 best- in- class", sole-source suppliers, chosen for their extremely high quality levels. It also uses computer-controlled, "real – time", statistical process control that attempts pre-emptively to avoid quality problems rather than just count mistakes. The plant can begin producing customised papers in lot sizes of one within 20 minutes after a sales person enters an order via computer at Motorola's headquarters in Schaumburg, Illinois. The actual production of each paper, customized to the proper radio frequency, takes less than two hours. This includes manufacture of printed circuit boards, final assembly, testing and packaging for shipment (Stahl, 1995).

3.7 Factors Affecting Quality

Quality depends on a number of factors, these factors include; policy, information, engineering and design, materials, equipment, people and field support. An integrated quality control system must focus on these factors mentioned above, thus:

i) **Policy**

Management of an organization makes polices to guide their product quality. These policies specify the standard of quality to be achieved in a product or service; they are seen as important pre-control and concurrent measures in ensuring quality (WaIter, 1993). In determining a policy in an organization, management considers three major factors, the product or services market, its competition, and image of the firm. An evaluation of the market provides an insight of customers expectations of quality and the price consumers are willing to pay for the product or services offered to them. Quality expectations and price, for example widely differ in the luxury car (Mercedes) and economy car (Geo) markets within the auto industry. Quality level provided by the competition also affects policy because the firm's product or services must be competitive to succeed in the open market place.

Besides the market and competition, management must also consider the firms image. Long-term interest may be damaged, by making a product of quality inconsistent with the firm's image. Customer image of the products (and their loyalty) may be tarnished if they associate a lower-priced product or service with lower quality.

ii) **Information**

Information plays a vital role in setting policy and ensuring that quality standard must be obtained about customer preferences and expectations and about competitor quality standards and costs. Competitive benchmarking is one effective approach to obtaining valuable information about the quality of products while they are being produced.

iii) **Engineering and Design**

The management of an organization formulates policy concerning quality, the engineer or designer who must translate the policy into actual product or services creates a product that will appeal to the customers and can be produced at a reasonable cost and competitive in terms of quality.

iv) **Materials**

In the present business world, a manufacturing firm has come to realize that the quality of product is predetermines by the good materials used in producing the product. In this regard, many manufacturing firms are implementing a new pre-control strategy with material suppliers. They screen and face out poor quality vendors and build a long-term relationship with the high quality ones.

v) **Equipment**

The ability of equipment, tools and machinery to accurately and reliably produce desired outputs is important, especially in manufacturing industries. When equipment meets acceptable tolerances, at competitive costs and quality, an organization will have the opportunity to compete in the open market place (Erickson *at el.*, 1990).

vi) **People**

Materials, design and equipment are important input in making available quality products. But people are the most important contributors to quality product or service (Adams, 1990).

Working as a team or individually, employees takes the inputs and process them into the final product or service that is offered to the market. Therefore, managers should not only provide proper training to enhance the quality of the firms output but also enable people to develop attitudes that value quality in place of manufacturing (Dupuy, 1990).

vii) **Field Support**

Often, the field support provided by the supplier determines a products quality image (perceived quality). Philip Iron, Sony, and Sears have reputation for providing strong field support for their products. Many customers select Sony, Philip Iron, and sears dishwashers for that season. This is not to say that they are the least in their industry, but an excellent field support reputation, however, can have a positive impact on a product's quality image (Donnelly *et al*., 1995).

3.8 Purpose of Quality Control in FAN

1) Prevent bad aluminium product from leaving the company
2) Discover defects at their origin in order to save time and cost of further production of scraps
3) Good quality is the basis for improve quality through the production process.

3.9 Quality Control Method in FAN

The raw material "Aluminium coil" is supplied direct from warehouse to the factory floor where production works based on customers' specification are carried out. No control or checks are conducted except the measurement of thickness with vender caliper and micrometer screw gauge. The essence is not to reject or accept the raw materials, not to ascertain the dimensions for the customer's specification. Measuring tapes are also used to measure the length of product as required by the customer.

3.10 Methods and Stages of Quality Control in the Company /

Areas of Monitoring Quality in the Plant and Out of Plant

Quality is of more important in a manufacturing set up like First Aluminum. The quality control system of FAN points at which quality is controlled and the quality parameters check for and monitor are in the following stages:

i. Raw materials (Quality control of incoming raw materials)
ii. Production process (Quality control of work in progress)
iii. Finished products (Quality control of finished goods)
iv. Storage transport and handling of products
v. Customer (after sale).
vi.

i. **Raw Materials**:

At this level it involves mainly the checking of the incoming raw materials to ensure that it conforms the ordered specification. Quality Control at this level is very important because raw material received by the company that is out of specified order, the lost will be on the company being that no customer will receive goods that does not meet the ordered standard.

The Primary raw materials used in the manufacturing are aluminum of 99.7% purity (virgin metals), from Russian Aluminum Company, Russia. Other raw materials which contribute to about 30% include: Aluminum scrap of (%AL/2fe) of (98%/1%), Hardness (*Mn*, *Si*, *Je*) are also imported from Russia. On arrival of the above raw materials at the plant, they are inspected to in order to ensure that they conformed to the set quality standard, or specifications. By this sample we collected and sort to spectrometer laboratory for compositional test. The quality control supervisors and inspectors carried out the test and the result released will determined the qualification of the raw materials before usage.

ii. **Production Process:**

Quality control at this level involves control carried out at different stages of production whereby products are examined, measured and tested, and any defects noticed on the product is correct immediately by taking necessary action

During production process, the general rule is that product should be inspected before operation takes place or before a great deal of value is added to the product. Quality must be established in the process itself.

Inspections are done in the company, human and indicators, which are:

- Water inlet temperature/flow water: It indicate the water inlet temperature/flow before and during operation
- Screw balancing meters: This measures the balancing and reduction range of rolls during rolling.
- Automatic x-ray Gauge System: This system indicates the gauge of the coils during rolling.
- Caustic/Water rinse tank temperature meters: The caustic and water temperature before and during coating of an allowance strip with polyester paint.
- Oven Temperature meter: This meter display the temperature of oven before and during coating.

The aforementioned are the quality parameters checks that determine the quality of the process during manufacturing. The quality parameter must be standardized to prove the accurate quantities or figures.

iii. **Finished Product**

Here all goods waiting for delivery to customer are properly checked and ensure that they meet the required quality standard before being delivered. Another critical point is the finished products. In production final products are inspected before storage or supply. The final/finished products of First Aluminium (FAN) Nigeria is 0.40mm thickness. The minimum norm in Nigeria set by the Standard Organisation of Nigeria (SON) for roofing sheets is 0.40mm which FAN will not also supply below this norm (0.40mm).

iv. **Storage Transport and Handling of Products**

Since quality is about meeting customer's specification, the quality of the finished products must be maintained till it is delivered to the customer. FAN maintains high standards in storage handling and transportation of their products to ensure that the quality of their products is not affected on their way to their final destination. A fork lift carried the protected coil with the planks to avoid scratch and transport it with a lorry which takes it to the final destination.

v. **Customers**

Quality check in this area is done after the finished products are dispatched to the customer. The quality control/technical engineer is responsible for doing random sampling of finished products from the market and running a general quality test. The test is measuring the finished product with a vernier caliper of aluminium to get the right gauge for the customer.

These are done to affirm the company products and ensure that product that goes to the market are of good quality standards. Also the test are carried out to enable the company advice its customers on how to store their products before usage. It is noted that because of quality checks that take place in these three (3) major areas depicted above, products of high quality would always be manufactured. If the process is not incessantly observed and evaluated sporadically, variations might occur from different sources.

- Man (operators)
- Materials
- Method
- Machine (equipment)
- Environment – deterioration

The only available way out from these sources of variations in a manufacturing set-up is to run Statistical Process Control (SPC) Study on periodic basis. This would enable the incipient source of variation to be found out and correct immediately.

3.11 Roles of Standard Organization of Nigeria (SON)

Quality control activities are undertaken by Government institutions and bodies to ensure that only products of guaranteed quality reach customers.

The Standard Organisation of Nigeria (SON) is the Federal Government Agency charged with responsibility for the promotion, enforcement and co-ordination of standard activities in Nigeria. It has different primary objectives:-

i. To upgrade the quality of Nigerian products to enable them to compete on both domestic and foreign market.
ii. To promote and improve manufacturing efficiency with a view to raising product quality and raising productivity.
iii. To instill a consciousness of standards and quality consciousness among Nigerians
iv. To safeguard the interest of consumers and the public especially in matter of health and safety.
v. To attain its objectives, SON engages in the following activities: standards development, product testing and certification, technical assistance, and promoting standards.

SON develops standard for specific product and revises existing standards if it deems this necessary.

The standard organization of Nigeria (SON) monitors and certifies the products of FAN. This monitoring process is carried out quarterly by the agency. The quality is carried out only on the final products.

The NIS value/requirements or standard (i.e. NIS 230:200) given by the Son is minimum of 0.40mm thickness for aluminiums (FAN).

IV. RESULTS AND DISCUSSION

4.1 Data Collection and Presentation

Having concluded investigation to collect the necessary data, the focus of this chapter therefore is to present and analyse them in a form that will make the important features of the subject to be easily understood and interpreted. This will enable the researcher evaluate the effect of quality control on productivity in the aluminium company. It is expected that results presented would used as a guide in forming and option and recommendation on strategies and techniques for improving productivity.

This section involves presentation of data and calculation of the following: samples mean, lower control limit (LCL) and upper control limit (UCL) Tables 4.1 – 4.5 contain the raw data from the aluminium company used for the research work. The results of practical analyses were based on the data collected from 2013 to 2017 from the aluminium company.

Table 4.1 **Causes of Low Recovery as per Line Process Problems in 2013**

S/No	Categories of Problems	Frequency
1.	Recoated coils	72
2.	Strip breakage	39
3.	Metal shifting	25
4.	Stretcher problem	21
5.	Fresh coils used as feed coils	16
6.	Line sensor	11
7.	Squeeze roll problem	8
8.	Coater application roll	8
9.	Line sensor problem	6
10.	Input material	5
11.	High DFT	3
12.	Accumet roll adjustment	5
13.	Change of colour	5
14.	Entry Mandrel	4
15.	Bad spool	2
16.	Oven Failure	2
17.	Paint particles/stains	2
18.	Paint finished from tray	3
19.	Power failure/Line tripped	2
20.	Improper coil positioning	1
21.	Backing claque application roll	1
22.	Entry accumulation	1
23.	Paint stains	1
24.	Improper chemical washing	1
25.	Delay in wrapping of coil	1
	Sum up	**245**

Calculation of C-chart variable to determine different levels of control for defects includes:

ISSN: 2454-8236, Volume-5, Issue-5, November 2018 Pages 16-27

Substituting into equation 3.19

$= \sum C_1 = 72 + 39 + 25 + \ldots \ldots + 1 = 245$

Total control limits computed from the average are as follows:

$$\bar{C} = \frac{245}{25} = 9.8$$

Substituting into equation 3.8 and 3.10 =

$$UCL = 9.8 + 3\sqrt{9.8} = 9.8 + 9.39 = 19.19$$

$$LCL = 9.8 - 9.39 = 0.41$$

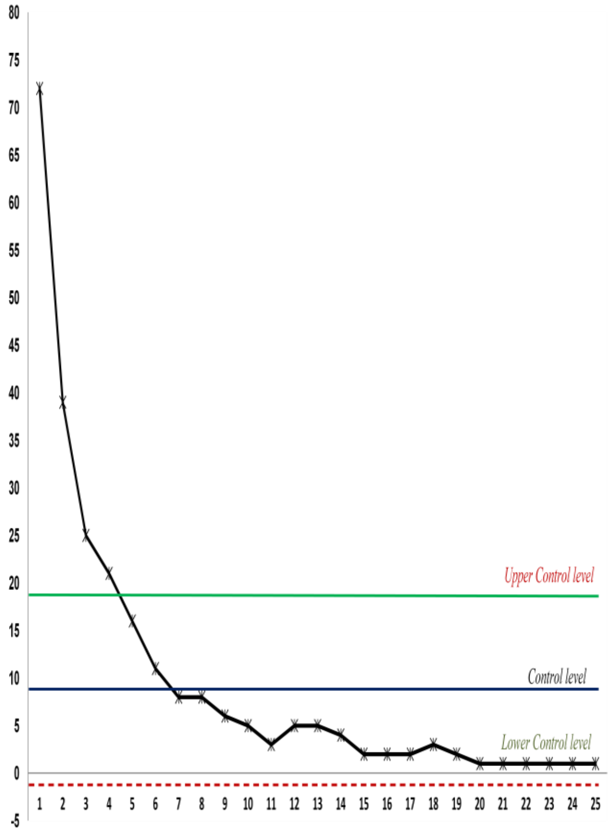

Figure 4.1 Graph showing Causes of Low Recovery as relates to Line Process Problems in 2013

Table 4.1 Causes of Low Recovery as per Line Process Problems in 2013

S/ No	Categories of Problems	Frequency
1.	Recoated coils	72
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17.	Paint particles/stains	2
18.	Paint finished from tray	3
19.	Power failure/Line tripped	2
20.	Improper coil positioning	1
21.	Backing claque application roll	1
22.	Entry accumulation	1
23.	Paint stains	1
24.	Improper chemical washing	1
25.	Delay in wrapping of coil	1
	Sum up	**245**

Calculation of C-chart variable to determine different levels of control for defects includes:

Substituting into equation 3.19

$= \sum C_1 = 72 + 39 + 25 + \ldots \ldots + 1 = 245$

Total control limits computed from the average are as follows:

$$\bar{C} = \frac{245}{25} = 9.8$$

Substituting into equation 3.8 and 3.10 =

$$UCL = 9.8 + 3\sqrt{9.8} = 9.8 + 9.39 = 19.19$$

$$LCL = 9.8 - 9.39 = 0.41$$

Table 4.2 **Causes of Low Recovery as relates to Line Process Problems in 2014**

S/ No	Categories of Problems	Frequency
1.	Recoated coils	9
2.	Metal shifting	7
3.	Use of Fresh coils as feed coils	32
4.	Strip breakage	1
5.	Oil/Thinner stains	82
6.	Oven Failure	3
7.	Power failure	1
8.	Air failure	3
9.	Delay in Stitching	6
10.	Tension failure	3
11.	Entry Mandrel failure	1
12.	Filter cloth failure	2
13.	Coater application roll	1
14.	Accumet stains	2
15.	Paint problems	2
16.	Line tripping	2
17.	Bad spool	1
18.	Sensor failure	1
19.	Paint starvation	4
20.	Input material quality	2
21.	Accumet roll failure	1
22.	Exit shear failure	4
23.	High DFT	1
	Sum up	**176**

Substituting into equation 3.19

$= \sum C_1 = 9 + 7 + 32 + \ldots \ldots + 1 = 176$

$\overline{C} = \frac{176}{23} = 7.65$

Substituting into equation 3.18 and 3.20 =

$UCL = 7.65 + 3\sqrt{7.65} = 7.65 + 8.30 = 15.95$

$LCL = 7.65 - 8.30 = -0.65 < 0$

$\therefore -0.65$ is less than 0 so it is taken as zero.

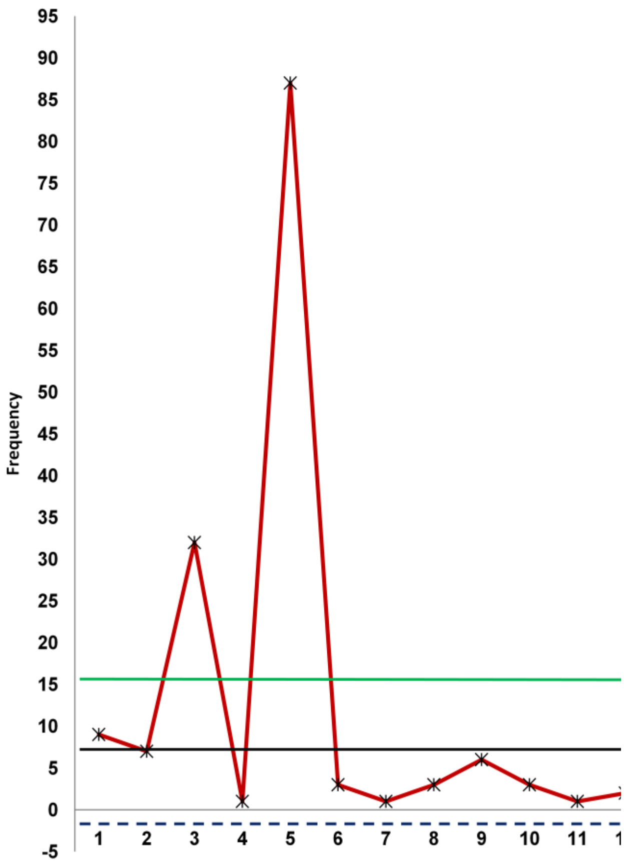

Figure 4.2 Graph showing Causes of Low Recovery as relates to Line Process Problems in 2014

From the data obtained in Table 4.2 and Figure 4.2 show that control chart for the period (2014) are above the control units , hence the process is not in control (out of control). Therefore, 7.65 value of control unit (Co.) will be recommended value for the next period.

Table 4.3 Causes of Low Recovery as relates to Line Process Problems in 2015

S/ No	Categories of Problems	Frequency
1.	Malfunction of Line tension/entry/ exit/centre operator desk (240)	27
2.	Undercure	14
3.	Draglines	1
4.	Strip breakers	17
5.	Exit coil car failure	2
6.	Change of paint	3
7.	Metal shifting	25
8.	Line tripping	2
9.	Oven failure	2
10.	Air failure	1
11.	Used as feed coil	5
12.	Chemical strains on strip	1
13.	Power failure	17
14.	Delay in stitching	12
15.	Coater applicator roll	70
16.	Squeeze roll	1
17.	High DFT	3
18.	Coater punp failure	1
19.	Metal run out	4
20.	Input material	3
21.	Accumet applicator roll	2
22.	Exit mandrel	1
23.	Recoated coils	10
24.	Line sensor failure	1
25.	Entry mandrel	2
26	Paint strains	1
27.	Exist Accumulator	1
	Sum up	**229**

Substituting into equation 3.19

$= \sum C_1 = 27 + 14 + 1 + \ldots \ldots + 1 = 229$

$\overline{C} = \frac{229}{27} = 8.48$

Substituting into equation 3.18 and 3.20, we have

$UCL = \overline{C} + 3\sqrt{C} = 8.48 + 3\sqrt{8.48}$

$= 8.48 + 8.74 = 17.22$

$LCL = 8.48 - 8.74 = -0.26 < 0$

$\therefore -0.26$ is less than 0 so it is taken as zero.

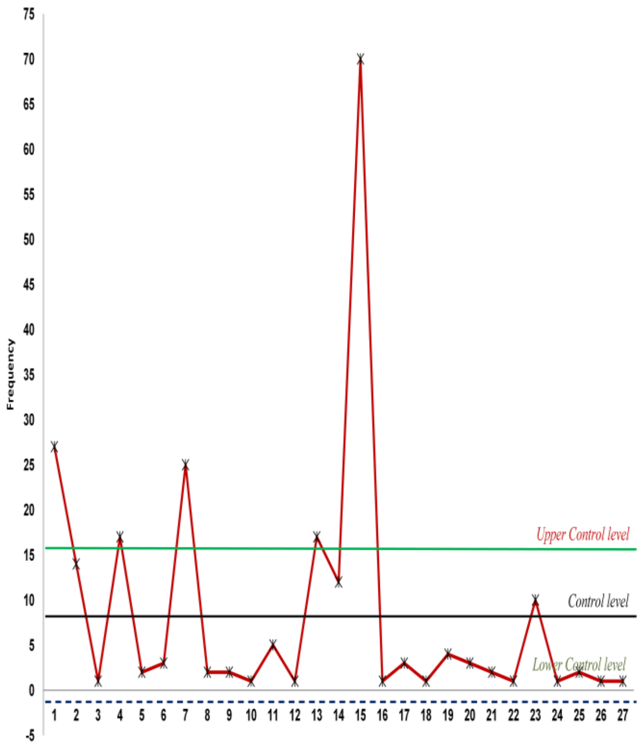

Figure 4.3 Graph showing Causes of Low Recovery as relates to Line Process Problems in 2015

From Figure 4.3 (Table 4.3) almost more than 3 points exceed the control level (which statistically indicates 17.22

upper level as against 8.48 control level), while the lower control level points was less than zero, hence the quality is out of control.

Table 4.4 Causes of Low Recovery as relates to Line Process Problems in 2016

S/ No	Types of Problem	Frequency
1.	Malfunction of Line tension	6
2.	Bad spool	2
3.	Shifting of Coater tray	1
4.	Coater application roll	32
5.	Particles in paints	3
6.	Exit mandrel	5
7.	Metal shifting	35
8.	Line tripping	22
9.	Power failure	22
10.	Oven failure	5
11.	Coil car failure	2
12.	Particles on briddle coil	2
13.	Poor stitching/Delay in stitching	11
14.	Universal joint pull out	1
15.	Paint starvation	1
16.	Filter cloth pull out	2
17.	Exit shear failure	1
18.	Sensor failure	3
19.	Air failure	3
20.	Input material	5
21.	Accumulator failure	3
22.	Hydraulic failure	1
23.	Accumet applicator roll	7
24.	Strip breakage	2
25.	Change of paint	4
26.	Backing lacquer coil bearing	2
27.	Metal squeezing	3
28.	Operator's fault	2
29.	Oil leakage	1
	Sum up	**189**

Substituting into equation 3.19

$= \sum C_1 = 6 + 2 + 1 + 32 + \ldots\ldots + 1 = 189$

$\bar{C} = \frac{189}{29} = 6.52$

Substituting into equation 3.18 and 3.20, we have

$UCL = \bar{C} + 3\sqrt{C} = 6.52 + 3\sqrt{6.52}$

$= 6.52 + 7.66 = 14.18$

$LCL = 6.52 - 7.66 = -1.14 < 0 = 0$

$\therefore$ – 1.14 is less than 0, so it is taken as zero (0).

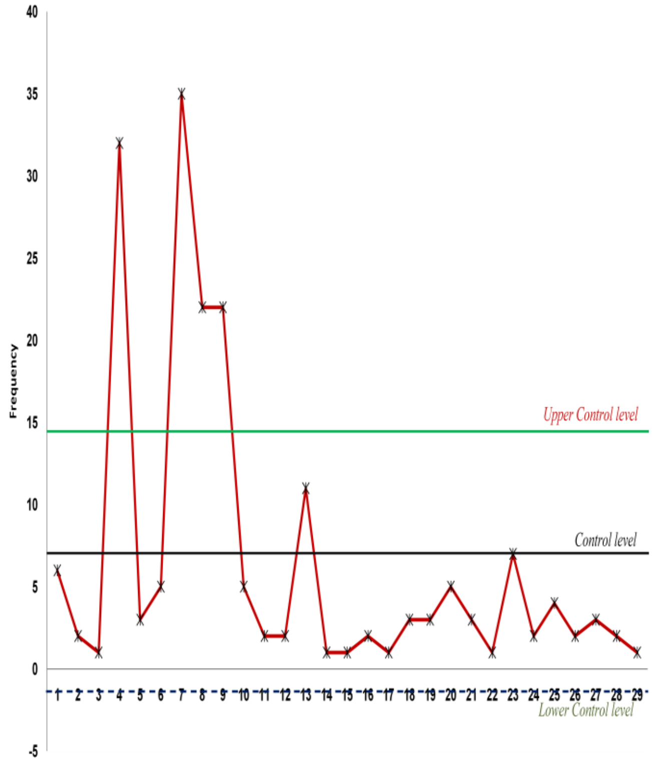

Figure 4.4 Graph showing Causes of Low Recovery as relates to Line Process Problems in 2016

Figure 4.4 illustrates the control value, $\bar{C}$, the control limits and the number of non-conformities, C, for each of the preliminary data. Since a lower control limit of – 1.14 is impossible, it is changed to zero, meanwhile as few points are falling outside the control limits, this value of $\bar{C}$ cannot be considered as the standard number. Non conformities of Co and discarding only those out of control point for which assignable causes are known (i.e. items 4, 7, 8, and 9), there is serious need to take necessary actions to eliminate the causes.

Table 4.5 **Causes of Low Recovery as relates to Line Process Problems in 2017**

S/ No	Types of Problem	Frequency
1.	Metal shifting	2
2.	High tension	1
3.	Edge guide	1
4.	Particles in paints	1
5.	Delay in stitching	1
6.	Strip breakage	1
7.	Operator's fault	1
8.	Squeeze rolls	1
9.	Power failure	1
10.	Coater applicator roll	1
11.	Delay in putting spool	1
	Sum up	**12**

Substituting into equation 3.19

$= \sum C_1 = 2 + 1 + 1 + 1 + \ldots + 1 = 12$

$$\bar{C} = \frac{12}{11} = 1.09$$

Substituting into equation 3.18 and 3.20, we have

$$UCL = \bar{C} + 3\sqrt{C} = 1.09 + 3\sqrt{1.09}$$

$= 1.09 + 3.13 = 4.22$

$LCL = 1.09 - 3.13 = -2.04 < 0$

$\therefore -2.04$ is less than 0, so it is taken as zero (0).

Since a lower control limit of – 2.04 is impossible, it is changed to zero. From the control chart, number of point crosses the control limit, yet the process is not in control because the distribution of points is not random as only one crosses the control line.

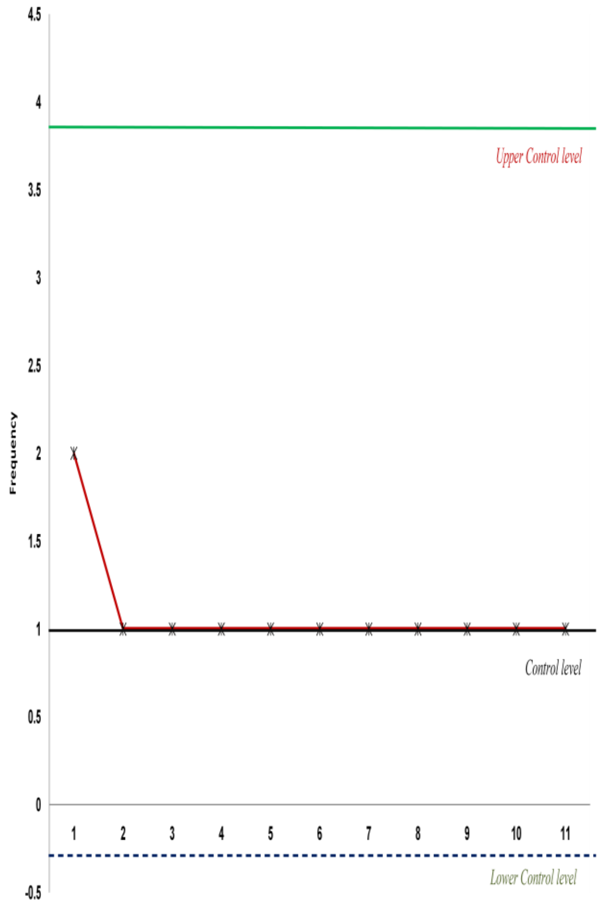

Figure 4.5 Graph showing Causes of Low Recovery as relates to Line Process Problems in 2017

From Figure 4.5 is can be observed that causes of low recovery points are nearly under control, however as one point exceed the control level, it implies that quality is out of control.

V. CONCLUTION

5.1 Conclusion

In evaluating, analyzing of data gathered in the course of this research work, regarding quality control on productivity in the aluminium manufacturing company the following conclusion are reached.

There is no sign that quality control concept improves the performance of an organisation in terms of cost reduction, increase in productivity, competiveness and customers satisfaction. The concept of quality control has been highly welcome in this company as a way of life for customers' satisfaction making the customers delighted as well as staff in achieving corporate goals and objectives.

Implementation of statistical process control (SPC) in an automated environment requires a number of issues to be addressed. Changes in sample data distribution and statistical properties such as independence will affect the use and interpretation of traditional SPC procedures; changed monitoring and adjustment techniques will influence the subsequent decision-making; at the same time, automation could facilitate implementation of SPC with other control techniques. In this study, the potential of combining SPC with engineering process control methods is discussed. Comparative analysis between traditional SPC methods and SPC combined with feedback control is presented. Actual and simulated data are used to illustrate the procedure which, because of its self-tuning ability, could greatly reduce system readjustment while most of the advantages of traditional SPC are preserved at the same time.

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