

**THE APPLICATION OF LEAN-SIX-SIGMA METHODOLOGY IN THE
MANUFACTURING SECTOR**

BY

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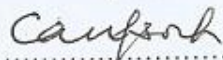
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Certification

This is to certify that this work "Application of Lean-Six Sigma Methodology in a Manufacturing Sector" was carried out by **OLANREWAJU FOLORUNSO SULAIMON** in partial fulfillment for the award of Master of Engineering degree in Industrial Engineering in the Department of Mechanical Engineering of Federal University of Technology Owerri.



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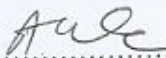
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Dedication

This work is dedicated to God Almighty for his wisdom and protection

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Abstract

This research on application of lean six sigma methodology in the manufacturing company was carried out in the Nigerian Breweries at Enugu. Nigerian Breweries was selected for the study because it has many production lines, operating systems and management strategies which were not properly developed. The main objective of this study was to determine how application of lean six sigma can be used to minimize product and time wastes. Three production lines (line A, B and C) were considered and data were collected from each production line. The data obtained were analyzed using statistical tools. The result obtained from the analysis showed that the two (2) defects on the labelling in line A occurred at the beginning of the batch production. In line B the corking machine produced some bottles without cork. The extraction forces in Line A and B were well centered between the limits 20 and 40N while line C shifted to the left with more samples under lower specification limit of 20N. The result obtained showed the relationship between the oxygen and vacuum with respect to the pressure exerted on the cork. Capability analysis result showed that the corking machine in line B was working in a capable process with number of defects less than 0.13% which was much better than the one in line A. Line A had 0.17% of bottles rejected in the filling machine which showed that 0.028% were mistakes of the normal variability of the process. VSM analysis result showed that 32mins from the lead time were not value added activities, thus only 28.2% was value added time. Though the greater time was in the inventory before the washing machines. A reduction of 37.7% in value added time was achieved. The cause-effect diagram provided the main priorities to control and solve the problem of number of defects in each production line. The study recommended the adoption of the output of this work to other similar company.

Key word: Lean manufacturing, Six sigma, cause-effect, capability, value added

CHAPTER ONE

INTRODUCTION

1.1. Background

Companies are more competitive and every detail is important if the business wants to improve its competitiveness. For this, it is relevant to keep the customers satisfied by offering to them what they are expecting. Moreover, the companies must continue to improve on their management techniques to be able to compete with their rivals, achieve better performance and do their best for their customers (Welch, 2005).

Lean manufacturing and Six Sigma, which currently are together a unique management strategy called Lean Six Sigma, is one of the best managerial methodologies applied in companies as of today. Lean Six Sigma is improving on results continuously (Walker, et al., 2007). Lean manufacturing focuses its efforts on the 'waste' reduction and reducing cycle time process. Six Sigma reduces variation improve process. Lean manufacturing and Six Sigma have different origins, the first one, in Toyota, a car company, and the second one, in Motorola, a producer of electronics and telecommunications gadgets. Both are manufacturers that have different aims, but at the end, both strategies merged to become the business excellence for its complementation (Walker, et al., 2007).

The challenge of this project is the introduction of Lean Six Sigma in the Nigerian Breweries because it is not as developed as in other areas even though it can be implemented in all kind of business. Nigerian Brewery is based on long century tradition and this is one of the most important reasons why the process is not as updated as in other manufacturing companies.

This century long tradition has made the breweries being focused on the production of the beverage, which is the essence of the business. Nevertheless, to keep the customer satisfied, the company has to go further and optimize all the processes of the beverage including the bottling phase.

The principal phase of the investigation has been the bottling process of the company because it is where the company can get more benefit from the Lean Six Sigma techniques. This last phase of the beverage-making involves many machines, automatic equipment, materials flow, replacement of material, line operators, managerial decisions and so on.

The reason is that this phase involves routine problems, unexpected problems, non-optimized processes and occurrence of mistakes in which most are the principal objective of improving in Lean Six Sigma.

Consequently, the situation in the Nigerian Breweries showed that, this philosophy can be applied in the bottling process of the beverage-making business as it is being implemented in other industrial and services companies. Nigerian Breweries has not implemented Lean or Six Sigma although some concepts are known by them. So, in the bottling lines of the company, the

processes can be improved by introducing changes and new ways for data collection to benefit from Lean Six Sigma.

In this work, the important steps to follow based on this proposed methodology are to know the company, its philosophy, their processes efficiencies, activities, material flows, employee's routines, customer and company requirements to develop the most effective strategy of improvement using the DMAIC methodology in Lean Six Sigma.

When enough information is collected, it becomes necessary to identify wastes, because many production concepts can be improved such as waiting times, bad material flows, over-processing, and defects. It will reduce the delay time of the batch production. Also large inventories of all kind of materials, overproduction or unnecessary movements or inefficient transports are using resources that are not valuable to customers. Lean techniques like Value Stream Mapping help to focus where there are wastes and try not to use any resource that is not needed at that moment. Also, the understanding of the production process makes it easier to combine with other main techniques associated with Lean to obtain new changes in the future.

Six Sigma also influences waste reduction with its statistical analysis aimed to forecast possible changes in the performance of the processes based on available data. In addition, it is used for controlling and improving the real process when the variability or specifications are not needed by the customer or the company.

1.1.1. The bottling process of the company

Packaging of bottled product typically involves drawing the product from a holding tank and filling it into bottles in a filling machine (*filler*), which are then capped, labeled and packed into cases or cartons

1.1.1.1. Depalletizing

This involves the removal of bottles from the original pallet packaging from the manufacturer. After the removal, the bottles are rinsed using filtered water, air or **oxygen to aid** in reducing the amount of oxygen in them, thus making them ready for process.

1.1.1.2. Filling

The bottle at this stage enters a "filler" which fills the bottle with the product and may also inject a small amount of inert gas (usually carbon dioxide or nitrogen) on top of the beer to disperse the oxygen, as oxygen can ruin the quality of the product via oxidation.

Refilling of the bottle with brewery product depends on the type of the machine: the capacity of the bottles that the machine can accommodate and the speed at which the filler can fill the bottles.

1.1.1.3. Capping

This is the process whereby the already filled bottles are run through a capping machine that seals them with the cap. This capping process is also dependent on the type of the filling machine. If the filling machine has a high speed with a

large capacity of bottles, then the capping machine will also have the same feature. However, in beer bottling processes, the bottles are sealed with a cork and bottle cage.

1.1.1.4. Labelling

In this process, the already packed and sealed beer bottles are run through a labelling machine, called the labeler. This process is vital since it ensures that all the bottles have the date of manufacture and expiry, which is a requirement for all manufacturers by the standardization organ of any state, to ensure that the health of the citizens is safeguarded.

The process of beer bottling is then concluded by the packaging of the certified beer bottles into the crates or cartons for transportation to the store or market, ready for consumption or exportation to foreign countries.

Some available variables such as the extraction force of the cork and the volume of product filled are information provided by the company and gives the opportunity to analyze this data to find out the best Lean Six Sigma solutions.

As a result, the company does not control many processes related with the number of defects, a simple methodology will be proposed to the Lean Six Sigma solution for measuring and controlling this number of rejected and defective bottles.

Moreover, some changes are proposed in the current collection of data to take advantage of all the information. The number of defects in each machine can

inform the company what is happening, and why these problems are occurring, for instance, if there is a maintenance problem, configuration or equipment out of order. Therefore, if the data is collected, there is the possibility to analyze, find the cause of the problems reoccur and solution. This solution for measuring defects complements the lean waste reduction, because the improvement of rejected bottles and defects reduce the waste of time of reprocessing, waste of materials, waste of resources employees' time and it improves the final performance of the product.

In conclusion, the company can improve its processes, reaching a more optimized bottling process, increasing, its competitiveness against the rivals saving resources and of course, money.

1.1.2. Lean Manufacturing

The term “lean” means; “thin, especially healthy so, with no superfluous fat” and regarding a company; “efficient with no wastage”. Lean term inside the industry was created by a research group which wanted to reflect both the idea of the Toyota production System and to compare with the mass production of the American system. (Womack, et al., 1990). Likewise, it refers to lean manufacturing or lean (TPS) (Shah, et al., 2007).

Two illustrative definitions from Ohno, who is considered the father of Lean manufacturing and Toyota Production System (TPS) and Womack, who is the founder and chairman of the Lean Enterprise Institute, about lean production

and Toyota Production System are; the basis of TPS is the absolute elimination of waste. The two pillars needed to support the TPS are the just-in-time (JIT) and automation (Ohno, 1988) and also the definition of Womack is “lean production uses half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. It requires keeping half the needed inventory, results in many fewer defects, and produces a greater and ever growing variety of products” (Womack, et al., 1990).

1.1.3. Types of waste and value added

Waste can be defined as any loss produced by activities which cost directly or indirectly to the company but do not add value to the final output from the point of view of the customer (Alarcon, 1997). Waste is measured in terms of costs, there are other kinds of waste that are not related to the product and they are also waste because they reduce the efficiency of the processes, equipment or employees, but these are more difficult to measure. Therefore, those activities which are consuming resources, time or space and are non-value adding activities can be defined as a ‘waste’. In other words, value adding activities transform inputs like materials or information to a superior state which is a customer requirement (Alarcon, 1997).

The present capacity is the work plus the waste. It is necessary to reduce waste to achieve 100 percent capacity. The responsibility of the managers is to

identify this excess and use the resources effectively. The original 7 non-adding value 'waste' (Japanese: 'muda') were defined by Ohno philosophy which are (Ohno, 1988; Formoso, et al., 1999);

1. **Overproduction:** is when the production is higher than the required or it is produced before the right moment.
2. **Waiting time:** is a lack of synchronization, delayed operations or changeovers times.
3. **Transportation:** is referred to internal movements of the materials, so it should try to create the best for routes of the materials and the layout for the products.
4. **Processing:** appears when there are mistakes in the process and could be avoided.
5. **Inventory:** is excessive or unnecessary inventory and this create deteriorations and stock.
6. **Movement or unnecessary motion;** is when the workers made unnecessary movements due to a poor workshop layout.
7. **Making defective product:** appears when the final or intermediate product does not achieve the requirements.
8. **Underutilized People:** is very linked to personal motivation of the employees, because it can be wasting their creativity, skills and so on

(Goodson, 2002).

1.1.4. Lean Thinking

Up-to-date it is known that Lean was originating from Toyota Motor Company and based on its philosophy Toyota Production System. Lean it can be defined with the reduction of the seven wastes explained before. However, Lean is much more because it is also built under a theory that the organizations are formed by processes. There are the five Lean principles (Womack, et al., 1996) which are a sequential way for organizations to add value, eliminate waste and improve to a repeating continuous improvement 'kaizen' process.

The five Lean Principles (Womack, et al., 1996):

1. Define accurately the value from the customer view and specify the value desired of the customer associated to the product, capabilities, price and time. It is important because it might be adding value to the company but not to the end customer, so, it could be resulting the wrong product or service and generating waste.

2. Identify the value stream for each product or service and eliminate the waste. There are three critical activities, product definition (from design to launching), information management (from order taking to delivery), and physical transformation (from raw materials to finished goods). Identifying the value stream it is an indeed way to realize about unnecessary steps in each product and department.

3. **Make the remaining value creating steps flow.** Standardizing processes based on kaizen and also in the thinking that there is no waiting, downtime or scrap within or between the steps of production.

4. **Design and provide what the customer wants at the time the customer wants.** It means a 'pull' system reducing inventory 'muda', so, a JIT application, because the company does not produce any product which is not desired. The idea is to create, on the same way, a flexible production process.

5. **Pursue Perfection.** There is no end in the search of perfection in the processes but constant re-evaluation and upgrading and optimization is the way.

1.1.5. Factors and techniques involved in Lean Manufacturing

In this literature it has already been defined the main objective of Lean but the techniques used in the Lean Manufacturing are many. The most important are Just in time, which involved others like Kanban and Heijunka, Setup time reduction and SMED, standardization, 5S, Total Productive Maintenance (TPM), Jidoka and Total quality management (TQM)

1.1.5.1. JIT

The Just in Time technique has already been mentioned and it is one of the main pillars of the Lean Manufacturing. This philosophy is popular since the effectiveness appeared in the manufacturing world, and many companies in the world have been implemented successfully (Ohno, 1988; Mondem, 1993). JIT

production systems need both input stock, which can be the parts, pieces or raw material, and output stock already manufactured as a final or intermediate product at each stage but, these outputs have to be reduced under the “zero inventories” approach (Mondem, 1993).

JIT involves some main tools to implement Lean which are more specific about planning, organization, controlling the production and logistic chain. The first tool is the *Kanban* system and the *pull system*, which is totally related with it. The second is *Heijunka* and it is created by several tools that are used to manage the customer demand helping the aim of the JIT too. Both are explaining in the following points.

1.1.5.2. Kanban

Kanban system (kahn-bahn) is a Japanese word which translated it literally means “visible record” or “visible part” (Surendra, et al., 1999). This system is a pull system approach that allows the plan production to manufacture a specific rate and time in order to reload the necessary materials or products which the customer has already acquired and it is used for coordinating the stages of production (Singh, et al., 1990). This definition is the idea of Kanban, because it is defined as a Material Flow Control mechanism (MFC) and it controls the correct quantity and right time of the products needed in the production. It has been recognized in the world by its cards because it based on a card system to manage the delivery and production of parts, items, or raw material (Graves, et

al., 1995).

1.1.5.3. Heijunka

Lean production seeks the high capacity utilization combined with low inventories. Many of the lean techniques reduce the inventories like kanban, but Heijunka minimize inventories on a different way, with high variability of production.

Heijunka technique refers to the smoothing production or leveling production (see below) and it is fundamental in the Just in Time production and an essential element of the Toyota Production System (Liker, 2004). This practice controls the variability of the product sequence during production cycle (Mondem, 1983). Therefore, the production schedule of the products is planned in a period of time with the proper sequence and the idea is to sort the orders to produce with a sequence which is relatively smooth. Their goals are to balance or level the production volume but also the mix production using the same sequence of items for every production cycle (Coleman, et al., 1994). The aim is also enhancing production efficiency by the reduction of waste, unevenness and overloading of people or equipment (Liker, 2004).

1.1.5.4. Takt time

Takt time is the maximum time allowed to produce a product and it is used to know the pace of production needed to synchronize it with the pace of sales. The pace is the ratio of available working time per day by the customer demand

rate per day (Rother, et al., 2003). The available working time refers to the period that the machines can work. This value is the time without planned stoppages like lunch time or regular breaks or time planned for maintenance revisions. The other term, customer demand rate, is the total demand of final product regarded to the line product.

$$Takt\ Time = \frac{\text{available working time per day}}{\text{customer demand rate per day}}$$

Obviously, it can also be calculated using the rate per period or interval of time in both terms like available working time per shift or month. For example, if the shift of the operator is 9h but 1h to have lunch and breaks, so, the available working time would be 8h per day, and the demand per day is 400 units; the takt time would be 0,05h/unit, it means 3 min/unit (Fig. 1.3.). Consequently, the takt time indicates that every 3 minutes a unit must be finished from its stage, what it means that in the last stage, it will be producing a final product (if it is the last cell of the production) every 3 minutes to reach the expected demand. Moreover, inside the line production with the piece running as a continuous flow (see below *one-piece flow*), every takt time the piece or part have to end its stage where it is being manufactured to go forward to the next to achieve the number of units demanded by the customer. If the production line is sequencing more different models, it is the same but with a change in the machines' configuration. These machines will need to be adapted to the new model. At the end of the takt time, every part from all models must have

finished its stage to produce the number of products at the end of the day.

The takt time is not easy, it requests a lot of effort to not stop the production and have a very quick response to the problems, elimination of downtimes and reduction of changeover times. Otherwise, delays can appear and do not obtain the output demanded.

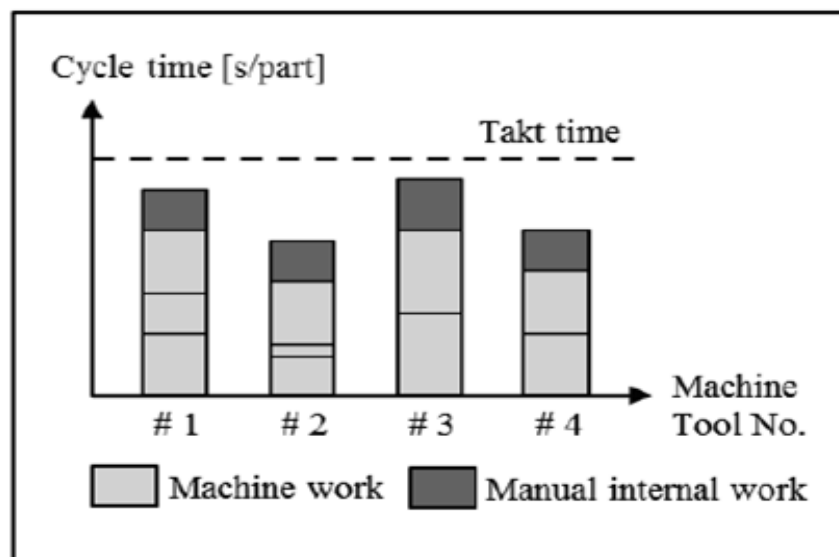


Fig. 1.1. Example of Cycle and Takt time in the Manufacturing system.

Source: (Metternich, et al., 2013)

1.1.6. Jidoka

The Lean Manufacturing involves a large quantity of concepts. The following two points of the Lean techniques (Jidoka and TQM) are more related with the organization, the managers, the intermediate positions and workers including the quality as well. Jidoka forms the other big pillar in the Toyota Production System.

Jidoka is “the practice of stopping the process when a problem occurs” (Osono, et al., 2008). It is very focus on the people of the company because they need to be able to realize about the wrong running of the process and stop it to solve the problem just in that instant and at the same process. *Jidoka* is also called automation because it comes from a Japanese item that means that word. Automation is defined as intelligent automation or automation with a human touch (Ohno, 1988). This technique wants to enhance the roll of the employees and allows them taking decisions to fix the problems. For this reason, the automation of the machines needs the supervision of some people or even devices (see below) to realize about the mistakes. *Jidoka* looks for intelligent machines working as if a human were controlling and when the defect occurs the employee must be able to solve it. The idea is not only the automation in the processes, it is also the objective to have a process that has its own quality auto-control including tools to detect automatically the errors or making it easier for the operators in the production.

1.1.7. TQM (Total Quality Management)

Total Quality Management is an approach for improving the quality of goods and services through continuous improvement of all processes, customer driven quality, and production without defects, focused on improvement of processes rather than criticism of people and data-driven decision making (Flynn, et al., 1994). The Deming Prize Committee (see below *William E. Deming*) is a set of

activities carried out by the entire organization for effective and efficient satisfaction of the customers at the appropriate time and price. Consequently, the practices of this management philosophy are related with the organization of the company to improve the processes and the continual improvement of the quality.

Quality is an attribute that the customer is willing to pay for. For example a product made from a material that deteriorates less with time is said to be of higher quality and the clients will pay more if they want it. From user point of view, the product must fit into this expectations. In the manufacturing-based approach, quality is related with standards, so, it can be measured. The last point is the quality based on value. There are several attributes which are associated with this value such as performance, features, reliability, conformance, durability, serviceability, aesthetics and perceived quality (Jones, 2014).

1.2. Statement of problem

The major problem of this study is to integrate Lean Six Sigma as a single method in the Nigerian Breweries because it is yet to be introduced as in other areas even though it can be implemented in different companies. Nigerian Brewery is based on old and traditional technology and processes are not updated.

This century long tradition has been used in the production of the beverage. To keep the customer satisfied, the company has to go further and optimize the production processes of the beverage. To achieve the best quality and value for the product, the final bottling phase should be properly analyzed because it is in the bottle that the beverage reaches the clients. This last phase has to be treated with the same attention as the processing of the beverage.

The aim of this work is to optimize the bottling processes of the company by the application of model Lean Six Sigma. With these developments the company can improve its processes, reaching a more optimized bottling process, increasing, its competitiveness with the rivals and saving.

1.3. Objectives of the study

The main objective is the application of lean-six sigma methodology in the Nigerian Breweries.

Specific objectives are;

- To study the bottling process of the company in order to identify some problems.
- To develop a new method for proper data collection based on number of rejected bottles and defects.
- To find the problems and their causes and use statistical methodology to fix them.

1.4. Significance of the study

This study would help the company to find solution on how to survive in the business environmental since it is known that the market is dynamic.

Lean Six Sigma can provide the tools and resources needed for the improvement of the company.

This study would be used by other researchers for further work.

1.5. Scope of the study

This is case study on Nigerian Breweries at Enugu state in the south-east region of Nigeria. To study the bottling processes of the company, to identify some problems and use statistical method to fix them.

CHAPTER TWO

LITERATURE REVIEW

2.0.1. Application of Six Sigma

Six Sigma was first applied by Motorola Inc. in the 1980s as systematic method for strategic process improvement, new product and service development using statistical and scientific methods to reduce defects rates (Linderman, et al., 2003).

The key elements of the Six Sigma are focused on the customers' needs, business improvement processes by a reduction of inherent variation in the processes, and a well-structured improvement process to solve the problems with proper methods and the earning of tangible results in the company (Linderman, et al., 2003; Schoroeder, et al., 2008).

Six Sigma philosophy includes the amount of tools to be used and using this idea profitably in the business. It is related to statistical process, non-deterministic control and engineering process control. Consequently, the use of these techniques requires data analysis, optimization methods, design of experiments (DOE), analysis of variance, statistical methods and consistency assurance. It is the process capability to always look for a better quality of the product and improve the productivity (Taghizadegan, 2006).

Schoroeder, et al, (2008) used Six Sigma techniques to reduce variation in organizational processes using a structured method, improvement specialists and performance metrics to achieve specific objectives.

Six Sigma uses statistical distribution curve based on a normal distribution (Fig

2.1.) which is the most common probability distribution in the real processes. Normal distribution is defined by mean (μ) and variance (σ^2) which are basic statistics concepts. Therefore, Six Sigma means six times its standard deviation (σ). The objectives are to eliminate defects from every process, product or transaction up to 6σ levels and have the process controlled. The defects are situated in the both queues of the normal distribution of the process outside the specification values LSL (Lower Specification Limit) and USL (Upper Specification Limits).

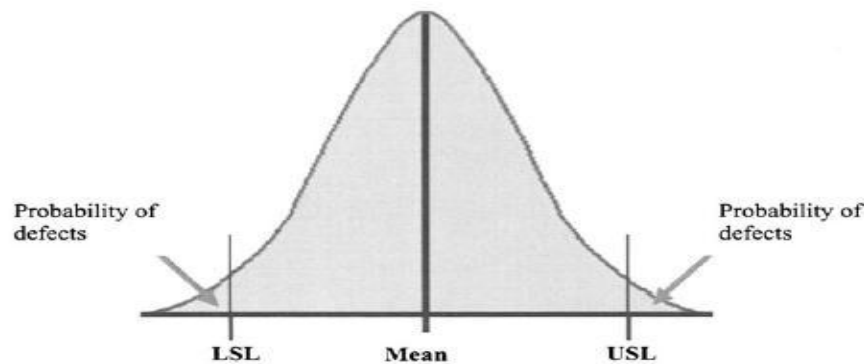


Fig. 2.1. Distribution curve of sample dimensions. Source: (Taghizadegan, 2006)

A manufacturing process that produces parts, pieces or products, must achieve certain requirements established by the customer or even by the same company. It could be any kind of requirements such as dimensional or physical like size, weight, volume or chemical properties, mechanical, etc. Otherwise, it is a defect product and the customer will not accept it. For this reason, it is important that the specification limits the production of many items as possible

inside them. So, when a process remains inside the limits it means that the process is capable.

The capability is divided into Short-term capability and Long-term capability. Six Sigma *short-term capability* occurs when the process is centered on the target and there is no shift that in this short-term the process is uniform without changes. The *long term capability* is based on an experienced assumption in which the mean of the processes changes from time to time and more often when they produce big quantities of items. These changes can be caused by machine's performance, or operator and also because a minimum of variability always exists. The defect rate (DPMO) is calculated (Fig. 2.3.), by assuming possible variation in the mean of the process to be 1.5σ (Fig. 2.2.). This shift means a distance of 7.5σ from one side and 4.5σ to the other (grey distributions) in a 6σ design process. With this the number of defects showed in Fig 2.3., is calculated by statistical probability to define the number of defects depending on the sigma σ level achieved (Taghizadegan, 2006).

Moreover, Six Sigma techniques was used to achieve the 'zero defects', using statistical 6σ number, that yield 3.4 defects per million opportunities (DPMO) for every defect occurrence. In fact, it was a 4.5σ due to the variability explained in the long-term capability with efficacy will be 99.99966% of good products (Linderman, et al., 2003). It is very difficult to change drastically from a lower sigma performance to a 6σ Six Sigma. As a result, the

process has to be implemented progressively, improving from 3σ to 4σ , and then 5σ , 5.5σ and at the end, to be able to achieve the excellence 6σ reducing the number of defects step by step.

Inside the Six Sigma processes, business should produce with the excellence of 6σ but there is another essential issue. The production can be in the right number of defects but the product has also to achieve the limits of capability. The process of capability represents the allowable tolerance interval spread when the process follows a normal distribution (Breyfogle III, 1999).

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

If the company is working with another sigma level the formula will be the same but with the width of the design process for example; 3σ , 4σ or 5σ .

The general rule of interpreting Cp is:

$Cp < 1.0$ inadequate; process variation is higher than specification and has more defects.

$1.0 \leq Cp < 1.33$ adequate; the process is acceptable and just meets specifications. The process still requires to be centered.

$Cp \geq 1.33$ good; the process variation is less than specification, but possible defects and process are required to be centered or to be maintained in control.

The USL and LSL are the upper and lower specification limit. The 6σ is the

range where the product is inside the tolerances. Another value to consider is the mean (μ) of the specific value to control. The Cpk used to control the mean and spread of the process (Breyfogle III, 1999).

$$C_{PK} = \min \left[\frac{USL - \mu}{3\sigma}, \frac{\mu - LSL}{3\sigma} \right]$$

$$\text{Where CPU} = \frac{USL - \mu}{3\sigma} \quad \text{and} \quad \text{CPL} = \frac{\mu - LSL}{3\sigma}$$

Thanks to that capacity number, it can be evaluated if the process is not centred inside the tolerances and if it is capable from each side. CPU gives information if the process is centred on the upper side and CPL on the lower side.

The right values are the same as the Cp values mentioned before.

In the Fig 2.2. the grey distribution show the long-term capability with the 1.5σ shift. The white one is representing the short-term normal distribution which is centred in the middle of both specification limits.

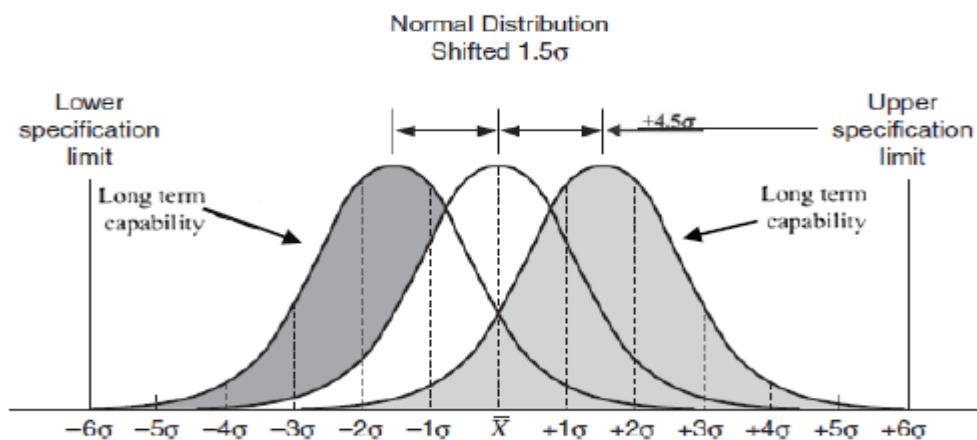


Fig. 2.2. Effects of a 1.5σ shift where only 3.4 ppm are out of the

specifications. Source: (Breyfogle III, 1999)

In the Fig 2.3. is showing the reduction of defects in defect per million opportunities regarding the long-term normal distribution.

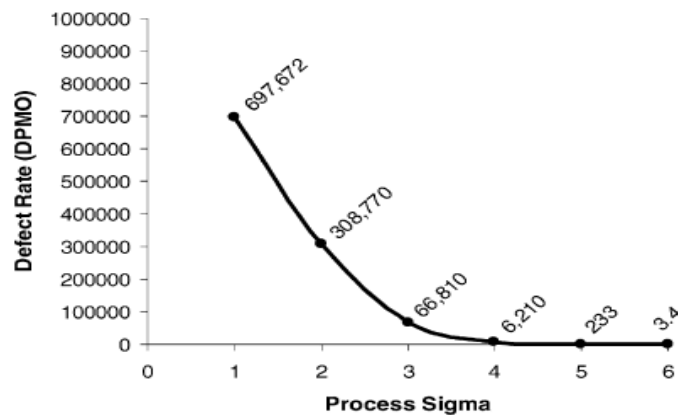


Fig. 2.3. Defect rate (DPMO) and the Process Sigma Level. Source: (Linderman, et al., 2003)

2.0.2. Six Sigma methodology

Six Sigma method is more detailed and has specific quality tools to implement improvement in each processing step. The methodology follows the DMAIC (Define, Measure, Analyze, Improve, and Control) procedure (Linderman, et al., 2003). Six-sigma employed statistical analysis and other qualitative tools in its efforts to identify and eliminate defects in an operation. It provides a means to find out the root cause of any problem inherent in a process.

The six sigma techniques consists of measured and reported financial results, uses additional, more advanced data analysis tools, focuses on customer concerns, and uses project management tools and methodology as presented in a

paper by (Riddhish et al, 2014).

Thomas (2015), provided the application of Six Sigma methodology within operation Department in National Bank. He focused on the establishment of the Lean Six Sigma and its impact on operation efficiency. The result of the data collected showed that, positive factors like management style, operation, and process and variation reduction were achieved due to Lean Six Sigma Implementation.

Nayan and Darshak (2014), worked on Six Sigma methodology which provides the techniques and tools that improved the capability and reduced the defects in a process.

Breyfogle III, (1999) proposed the integration of the method with standard tools like cause-and-effect diagram, statistical process control (SPC), Pareto or Control charts, benchmarking.

The Six Sigma DMAIC phases are defined as follows (De Koning, et al., 2006; Tenera, et al., 2014; Taghizadegan, 2006):

1. **Define:** problem selection and benefit analysis.

D1: Identify and map the main processes in the company

D2: Identify stakeholders to focus the Process Mapping on them. The SIPOC (Supplier, Input, Process, Output and Customer) diagram could be very useful for specify the related stakeholders and the main project activities.

D3: Identify the customers, their needs and requirements. Detect the Voice

of the Customer (VOC).

D4: Make the project charter elaboration. Business case.

2. **Measure:** translate the problem into a measurable form to evaluate what is the current situation. Updating the goals which were defined in the first phase.

M1: Select the CTQs of study, which are considered necessities. The CTQs are the Critical-to-Quality process factors. Measure internal parameters of quality that are considered by customer's opinion a priority in Lean Six Sigma philosophy.

M2: Determine operational definitions for CQTs and requirements.

M3: Gather data to validate measurements systems of the CTQs and make good decisions about what criteria are needed.

M4: Assess the variables based on statistical tools such as Pareto charts, histograms, with a data collection plan.

M5: Define the target.

3. **Analyze:** identification of factors and causes that determine the CTQs.

A1: Identify root-causes and potential influence factors with an exhaustive analysis. It is used to identify root-causes to determine variance components and sources by identifying the process factors (most dominant X's), process delay factors, and estimating process capability such as hypothesis testing, p-

value, and other statistical tools. Then, the Value Stream Mapping is used to obtain a detailed view of the improvement process opportunities.

A2: Prioritize the vital few influence root-causes and factors.

4. **Improve:** design of solutions and implementation of adjustments to increase the CTQs performance.

I1: Quantify relationships between Xs and CTQs, with techniques like design and analysis of experiments or statistical models.

I2: The implementation of a design to improve the process or changes in the settings in order to optimize the CTQs. So, the idea of robust designs is the aim to produce inside the tolerances.

5. **Control:** Empirical verification of the results and adjustments to ensure a long-term improvement, monitoring process and control to remain the changes to ensure that it is producing the product attributes inside the specific conditions all the time.

C1: Determine the new performance of the process and its new capability using statistical and process capability analysis tools.

C2: Implement a process control to keep the changes they have created with run control charts.

DMAIC also is formed by different members in the different steps of the method. In the first one, Define step, the Champion plays an important role and

a supporting role in the others steps. In contrast, Process Owners take more participation in the Control step and supporting the others. In the Measure, Analyze and Improve steps the Green Belts are more active. Finally, Black Belts work as a project leaders and control, and create reports in all of the steps of the process (Schoroeder, et al., 2008).

2.0.3. Lean Application

Lean-Six-Sigma involves the application of the two techniques, lean and six-sigma in the manufacturing processes for better productivity. Lean manufacturing was first adopted from the Toyota Production System in the 1980's when Toyota began its growth to a greater height in a car production business. Recently, lean-six-sigma has been rated as one of the best managerial techniques for productivity improvement.

Lean manufacturing technique is a concept adopted to eliminate those waste and processes that do not add any value to the customer satisfactions. This will equally improve the effectiveness and efficiency of the organization. On the other hand six-sigma is needed to reduce process variability. Six-sigma is a continuous improvement plan developed in the 1980's by Motorola in a quest to improve quality level by reducing variability in the manufacturing operation (Antonio et al, 2007).

Adnan and Mohammed (2014), investigates the implementation of lean tools in

construction project and its impact on safety conditions in the Gaza Strip. A questionnaire survey was undertaken with contractors and clients in order to express their attitudes on the implementation of lean tools in construction projects. The result showed a significant weakness in the application in the construction projects as well as limited information about lean construction tools. Training will be a key aspect of implementation and success of the lean construction techniques. However the paper demonstrated the theoretical and empirical study using Construction Company as the study area.

Richard et al (2016), worked on the conceptual models of construction management and the tools have been criticized. This paper noted that practical and robust models techniques will help project teams to deal with the issues of wastes in projects are needed. This technique was applied in the construction Industry as lean construction methodology and the importance has been discussed. A very high level of wastes/non-value added activities exist in the construction industry which represent production cost. Lean construction aims at reducing the wastes in workflow. And also, the application of lean tools and techniques will minimize or eliminate waste, improve performance and lead to a great cost savings. This paper contributed to the knowledge and practice from delay control or waste elimination and also serve as a benchmark for continuous improvements.

2.0.4. Lean-Six-Sigma Methodology

The integration of lean manufacturing and six sigma started in 1997 when BAE

system first applied the two techniques in aerospace industry (Smith & Adams, 2001). The company named the program lean six sigma strategy in an effort to protect market share and plan at reducing variation within the product processes. The result showed that BAE system achieved appreciable improvement in productivity, lead time, savings and reliability. Two years later, Maytag Corporation adopted the methodology to reengineered one of its production lines. This approach reduced the manufacturing cost and savings in million dollars (Dubai Quality Group, 2003).

Smith and Adams, (2001), stated the IBM Consulting Group experience in implementing lean-six-sigma methodology. The company used two approaches to identify the system problem. Lean technique was used to identify waste, while six-sigma was adopted to reduce variation and improve reliability.

Rockwell Automation Power System employed value stream mapping approach while applying lean techniques with 5s program to ease large improvement opportunities and to implement lean flow (Illing, 2001). A modified DMAIC approach was adopted in a paper documents to Electronic Copies Convention Company. At every stage of the DMAIC process, lean concepts are introduced to reduce error rate, production cost and enhance productivity (Goyal, 2002).

Northrop Grumman Company integrated workout with Kaizen and Lean Thinking events. The company also used six-sigma methodology to validate solutions and to treat with the higher quality problems (McIlroy & Silverstein, 2002). The main objective of this paper is to review lean-six-sigma

methodology tools, its applications and benefits these two concepts in the manufacturing industries.

Joshua et al (2014), studied the implementation of new Lean Six Sigma concept. He employed Lean tools added at the analysis phase of the initiatives and used six sigma principle to reduce and then eliminate the variation found. The integrated techniques were applied in the Small Medium Enterprise (SME), particularly in the label printing industry. The development of the framework depends on the environment of the particular company in which it belongs.

The framework of the system is used in problem identification, providing suitable solutions to solve problem(s) and controlling the improvement made. This technique emphasizes on problems derived and the solutions. Conclude of this paper showed that, the adoption of the lean-six-sigma framework has provided a systematic and guided approach help to identify the problem and to provide a feasible solution and sustain the improvement made.

Furthermore, it is observed that lean and six-sigma being on a separate page often fails to provide organizations desired improvement. While six-sigma identifies and eliminates waste, it does not however provide any means to improve or optimize system operations/ on the other hand lean technique provide means for optimizing the system but lacks the statistical analysis very much needed to improve system performance.

The above deficiencies inherent in each technique necessitate an integration of the two concepts for better improved and optimum organizational/operational

result, including customer satisfaction. Ultimately, total production cost reduced, product quality improved with increased productivity.

Kanakana et al (2010), noted that combination of two concepts (lean manufacturing and six sigma) aims to achieve total customer satisfaction and improved operational effectiveness and efficiency by removing waste and other non-value added activities.

Abdullah et al (2018), studied the integration of lean management and six sigma strategies to improve the performance of production in industrial pharmaceutical. The paper evaluated factors related to the application of lean six sigma in the improvement of the management activities and performance of a selected pharmaceutical industry. This paper made an attempt to emphasis on the satisfaction of lean six sigma technique in the pharmaceutical industry.

Rathilall and Singh (2018), worked on a lean six sigma framework to enhance the competitiveness in selected automotive component manufacturing organizations. The paper examines the integration of lean and six sigma tools as a unified methodology to improve and develops a functional manufacturing process in the company. The result showed that the technique offered the company great opportunity to combined operations with both tools with respect to a high quality management style and customers wants implementation.

The Lean Six Sigma is an improvement methodology of the two management philosophies, which implemented together to increase the power and the benefits in the industries.

The Lean Six Sigma concept was published by George (2002) and his definition was:

“Lean Six Sigma is a methodology that maximizes shareholders value by achieving the fastest rate of improvement in customer satisfaction, cost, quality, process speed, and invested capital” (George, 2002).

George (2002) also said that the combination is necessary because Lean cannot have a statistical control process, and on the other hand, Six Sigma cannot get totally better results in the process speed or in the reduction of the invested capital (George, 2002). Thanks to the synergy of their methods and principles, the Lean Six Sigma integrates the DMAIC cycle (Define, Measure, Analyze, Improve, Control), which is the main methodology of Six Sigma, used as a tool in the continual improvement implementation and also focusing on the reduction of defects and variability in the processes through the standardization, waste reduction and lead time reduction of the products, which are some of the aims of Lean Manufacturing by optimizing the current value stream. Both together attacks directly to quality and costs more effectively than another previous improvement strategy, it comprehends quality and speed process (George, 2003).

Regarding an only Six Sigma strategy, it lacks of three lean manufacturing benefits which according to Devane, are the following (Devane, 2004):

- Inventory reduction.

- Speed process improvement.
- Financial benefits in short-term because it requires time to learn, collect data, analysis and apply the methodology.

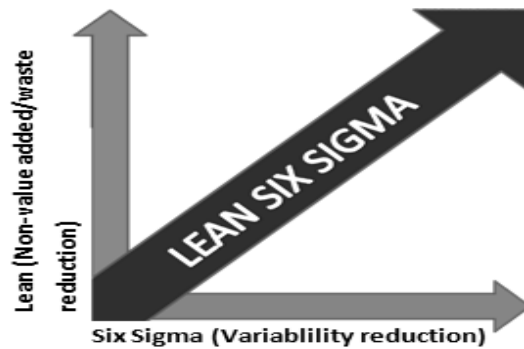


Fig. 2.4. Lean Six Sigma approach. Source: [Devane, 2004]

On the other hand, if the strategy is based only in lean manufacturing techniques, there is lack of other three main benefits from Six Sigma which are (Devane, 2004):

- Control process under statistical tools.
- Measurement of the variations in the processes.
- Practices related with quality and mathematical tools to find out the roots of the problems that are hidden and after a waste reduction remains there.

In contrast, the combination of both strategies together is an integrated approach. The key Lean Six Sigma approaches based on Devane are (Devane, 2004):

- The Voice of the Customer and the Critical-to-Quality (CTQ).
- Six Sigma metrics
- Elimination of waste and non-values added activities.
- Process study.
- Accidental variability is main problem.
- Value Streams.
- The “DMAIC” improvement process.

The benefits that DMAIC cycle will provide is that it is focused on finding solutions to problems and opportunities, and to do it, it is based on data and information to manage the decisions, rather than assumptions. Therefore, the project management standards will create the formal steps to the implementation of the solutions.

Lean Six Sigma is considered as an operational excellence strategy model. Both Six Sigma and Lean management involve cultural changes in organizations, new ways to produce and customers’ service, higher training of the employees from management to operators (Arnhneiter, et al., 2005). This methodology manages with a more intelligent management in the organization.

As it has been explained in the previous chapters, the customer requirements and his satisfaction are the key. The methodology works always using data and facts to elaborate the solutions and strategies to follow. For achieving the

maximum benefits the employees must be encouraged with the change and its implementation. It generates better confidence in the employees and promotes more creativity and innovation in the job. These improvements in the employees' skills can be useful to a better participation in the continual improvement. So, regarding Lean Six Sigma and the organization, if the company invests in the employees, then, they will have better skills influencing on their positive spirit and confident in their workplaces and organization. Always they look for the aim of achieving the maximum efficiency for the company. Furthermore, there is a good point with this implementation because it has the power to deploy a continuous organizational change by aligning the objectives of the organizational vision to the excellence model. (Pamfiliea, et al., 2012)

2.0.5. Summary of review

In this work numerous literatures have been reviewed and various contributions noted. The review showed that Lean manufacturing and Six Sigma are currently together as a unique management strategy called Lean Six Sigma, which is one of the best managerial methodologies applied in companies as of today. Currently in many companies, Lean Six Sigma is improving their results from the last years.

The literature also explained accurately, that the Lean manufacturing focuses its efforts on the 'waste' reduction and everything that do not generate value for the customer. Then, Six Sigma dedicates to what the customer wants and to

produce the best quality products with a new methodology based always on data to optimize the processes under statistical tools. Lean manufacturing and Six Sigma have different origins, the first one, in Toyota, a car company, and the second one, in Motorola, a producer of electronics and telecommunications products. Both are manufacturers that had different aims, but at the end, both strategies have come together to achieve business excellence through complementation.

The challenge of this study is the integration of Lean Six Sigma in the Nigerian Breweries because it is not as developed as in other areas. Nigerian Brewery is based on long century tradition and this is one of the major reasons why the process is not applicable as in other manufacturing companies.

In this study the principal phase of the investigation was on the bottling process of the company because it is here that the application of Lean Six Sigma techniques can benefit the company more than any other area.

The bottling process serves as the best area of implementation because it involves routine problems, unexpected problems, not optimized processes and occurrence generation of mistakes that constitutes the principal objective of improvement in Lean Six Sigma.

The aim of this study is to apply Lean-Six-Sigma methodology in the bottling processes of the company. Lean Six Sigma can provide the tools and resources needed for the development of the company. The bottling processes of the company will be optimized using statistical method.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0.0. Research Materials

In order to achieve the stated objectives of the study, a study on lean six sigma methodology and techniques was carried out using a manufacturing industry (Nigerian Breweries Enugu Plant) as a case study

3.0.1. Data Collection

Essential information for the research was collected, which include:

- (i) Structured interview with Director of Production and Quality of the company.
- (ii) Observation of the production process to observe the flow of goods in the conversion process. Materials handling and storage.
- (iii) Relevant data from the company's annual report and journals.
- (iv) Library and internet services.
- (v) Questionnaire

3.0.2. Analysis of results

This is the process of analyzing the outputs from the optimization process to draw inferences and make recommendations for the problem resolution.

3.0.3. Validation

Finally, the work ends at the stage of validating the results.

3.1. Research method

The author had the chance to meet with the Director of Production and Quality and to visit the bottling lines of the company. So, the first step was the designing of a questionnaire with focus on the bottling production line and all the possible matches with Lean Six Sigma. The main reason was to try to identify the main points of improvement, weakness, and strengths and so on. It was also necessary to know about general information of the company and their practices and a little research questions from other areas like the barley importation and delivering of the final product to the customers.

During the first appointment with the Director of Production and Quality, the schedule was a short introduction of author's interests and then having a pleasant conversation with him, the author could begin to know how the philosophy, procedures and objectives of Nigerian Breweries Enugu Plant.

Afterwards, the procedure was to make a visit to the bottling plant, which included the beverage storage tanks, next to them was the bottling, labelling and packing lines where the director explained to the author the function of every machine. Then, the storehouse was also seen with the stock of final beverage bottles and other raw materials. After that, the prepared questionnaire was distributed, and the author visited the laboratory of the company. The personnel responsible for the Quality Control department explained to the author how they control all the necessary attributes to get the best quality in the

grapes and beverage and how the grapes and beverage properties are being analyzed in the laboratory.

During the visit some questions were answered and more information were revealed. The bottling processes and all the machine roles were totally understood at the end of the visit. The author was showed the processes and procedure of data collection in the laboratory.

In the second visit, the author spent time at the bottling plant, following accurately the processes in the line. The first step was to find out the best ways to collect data, considering the machines layout, the point of defects occurrence, the speed of the processes, and the placement of the raw material, how the operators carry out their tasks and others. With some prepared table to write down the information on an easier way, within a couple of hours, the author was able to collect data for the processes, materials flow, paying attention on the times and defects produced in the plant where there were two bottling lines (A and B).

The third visit was carried out on the same way as the second and the author continued collecting data. There were unexpected difficulties in the second visit, one of them was that the lines had some changes in the production, another were the stoppages to check some machines parameters or problems with the bottles and the last one, the changes on the processes speed. The author took data about the bottles per hour produced from the machines, registered the

number of intermediate stock, recorded the number of defect bottles produced and asked operators question about any doubt.

The third day, the activity was to register all the bottles rejected from one bottling line.

Besides, the personnel at the laboratory department gave the author the data for the 'extraction force of the cork' and 'volume of beverage' which are measured accurately in the laboratory beside other attributes of the bottle. These data were controlled from the bottling processes. There were other control data without recordkeeping, only to know if the steps were correct or not.

The statistical tools were recommended and could be implemented in any phase of the strategy because of their usefulness in each stage of the processes, (Taghizadegan, 2006).

3.1.1. Research Tools

The main research tools used for the implementation of the study were histogram, cause-effect-diagram and control charts.

3.1.1.1. Histogram

Histogram illustrates frequency data in the form of a bar graph with bell-shaped referring the normal distribution. It is used to learn about the distribution of the data collected in the measure phase. It is a highly effective tool in identifying the mean and capability of the process. Each rectangle is proportional to the number of observations within the interval of the x-axis. The frequency

represents the dependent variable (y-axis) and independent variable (x-axis).

3.1.1.2. Cause and effect diagram

Cause and effect diagram is used to study a problem or improvement opportunity in identifying root causes. The cause-and-effect diagrams (also called fishbone or Ishikawa diagram) are used to explore all the potential real causes or inputs that result in a single effect or output.

It is used in the Analysis phase because it can help for finding root causes and identify areas where there may be problems.

3.1.1.3. Control Charts

It is also known as Statistical Process Control. The objective of control charts is to distinguish between random variation and variation due to an assignable cause and then, the monitoring of process performance along the time for checking its stability. It also helps to identify opportunities and to understand and control variations.

The common types of control charts depend on the circumstance and type of data available to determine and construct the following charts:

- \bar{X} and R -average and ranges
- \bar{X} and S -average and standard deviation

The subgroup size of the data is important to decide the right chart. I-MR charts are for subgroup sizes of 1 and \bar{X} -R charts are for subgroup sizes greater than 1 (and typically less than 9 or 10). \bar{X} -S are recommended for

bigger subgroups.

3.2. Description of the study area

Nigeria Breweries Plc was incorporated on 16th November 1946 as Nigeria Breweries limited. It started production on June 1949, when the first bottle of star lager beer rolled off the line in Lagos. This was followed by Aba Breweries in 1957, Kaduna Breweries in 1963. Nigerian breweries Plc is one of the largest firm in the Nigeria stock Exchange. It is also one of the nationally well-known concerns in Nigeria. The corporate mission of the organization is to remain the leading beverage company in Nigeria producing high quality brands to meet the needs of identified viable sectors in the market. In the bid to achieve its corporate mission which is to remain the largest beverage company in Nigeria and also to produce high quality brands, the management of the company has plans to continue, to dominate the premium sector of larger market where its products are currently positioned towards this ends, the company has identified that there is need to strength the existing brands by communicating to its customers in clear terms, those qualities which the company claims for its products. In 1982, Ibadan Breweries was established. In September, 1993, the company acquired its fifth Brewery in Enugu State. Ama breweries is the largest brewery as well as the sixth brewery in Nigeria and one of the most modern brewery worldwide operation in the old Enugu Breweries were discontinued in 2004, while that breweries

sited in Ama Eke Along **Ninety** Miles in Enugu state was christened Ama Breweries. The company acquired a malting plant in Aba in 2008.

In October 2011, Nigerian Breweries acquired majority equity interest in Sona system Associations Business Management Limited (Sona Systems) and Life Breweries Limited from Heineken N. V., This followed Heineken's acquisition of controlling interest in five breweries in Nigeria from Sona Group in January 2011. Sona Systems two breweries in Ota and Kaduna and Life Breweries in Onitsha have now become part of Nigerian Breweries plc together with the three brands, Goldberg larger, Malta Gold and Life Continental Larger, Thus, from the humble beginning in 1946, Nigerian Breweries from which its high quality product are distributed to all Nigeria in addition to the ultra-modern malting plant in Aba and Kaduna. The company has a portfolio of high quality brands, including:

- Star lager (launched in 1949), Pale lager
- Gulder lager (1970) pale lager
- Legend Extra Stout (1992), 7.5% ABV extra stout
- Heineken Lager (June 1998), premium Lager
- Goldberg Lager (Become part of NB family in October, 2011).
- Life continental lager (become part of the NB family in October, 2011).
- Maltina (1976), in three varieties namely, Maltina classic, Maltina

strawberry and Malta Pineapple

- Malta Sip-it (2005) in Tetrapak.
- Amstel Malta (1994).
- Fayrouz in pear and pineapple (2006).
- Malta Gold (became part of the NB on October 2011) etc.

3.3. Data Collection

3.3.1 Background of respondents

The respondents sampled are, Director of production and quality, one member of the Inventory Control team, a member of the Production planning department, and a member of the laboratory department. These were the people who had the time to take part in the study. They have been working with the firm for over 10 years.

3.3.2. Data Collection plan

To extract the needed data for easy analysis, a 14 page questionnaire was designed (appendix 1) which was addressed to the Director of production and quality control.

3.3.3 Data Collection process

The data obtained for this study were collected using self-administered questionnaire, observation, laboratory tests and interview. The study was between January 6th 2014 and December 22nd 2014.

3.4. Presentation and analysis of data

The information collected from different ways during the visits to the company was explained in this point. The first appointment with the Director of Production and Quality, the other two visits to the production plant, and the deductions based on the questionnaire.

Table 3.0 Represents the annual Production, Demand and Inventory of the Company

Product	Description	Bottle volume (ml)	Cap (Cork) Type	Production (million tons)	Demand (million tons)	Inventory (million tons)
Heineken	Alcoholic Beverage	600	Crown Cap	6.9	6.5	0.4
Gulder	Alcoholic Beverage	600	Crown Cap	6.25	6.2	0.5
Life	Alcoholic Beverage	600	Crown Cap	7.6	7.0	0.6
Ace Root	Alcoholic Beverage	600	Crown Cap	5.8	5.3	0.5
Amstel Malta	Non-Alcoholic Beverage	330	Crimped Cap/Screw Cap	1.5	1.2	0.3
Fayruz	Non-Alcoholic Beverage	330	Crimped Cap/Screw Cap	1.4	0.8	0.2

Table 3.0 shows that the demand per year is 45 million bottles of breweries and 2 million belong to nonalcoholic brands. The number of sold bottles shows the size of the company, which enjoys 3 bottling lines but 2 bottling work every day, so, each line works around 66% of the year.

In beverage production, there was a problem with the main raw material (the barley). It was a cereal grains and it cannot be ordered when they want, they should start the product-making when the barley is ready and mature enough. For this reason they do not follow a just-in-time production. They produce when they received the barley in the beginning of the harvest period. This fact creates a problem to the lead time from the barley to the packed bottle because it can be from 2 months to 6 years depending on the quality of the product. For the brewery, the activity that adds more value to the product is the production of beverage, as a result, they always start the product-making when the barley arrives.

For them, it was a priority interest to have always a stock of products because they want to deliver the orders in time and always. The products do not have the same fermenting time. It depends on the variety, quality and other properties. The bottle was a bit restricted to the type of product that was already produced. They manage around 400 products, with batches usually about 40,000 bottles of a product model and they tried to schedule and not to unbalance the stocks too much.

3.4.1. The responses of the Director of production and quality control

The Director of production and quality control was interviewed on the following areas:

1. The philosophy of the company with respect to lean-six-sigma

implementation

2. The relationship between the organization and employees
3. The production planning method
4. The level of customers satisfaction and demand

3.4.1.1. Based on the Philosophy of the company

According to Enugu Plant Director, the company does not implement Lean Manufacturing or Six Sigma philosophy. Obviously they know about it, but their philosophy was focused on delivery always, working with big inventories as it could be seen in the table 3.0. In the operations of the company, they do not work under variability reduction strategy. The company based their improvement on the suggestions from the employees, without monitoring, or paying attention on the interest of the customers.

3.4.1.2. Based on the organization and operators

In the Enugu Plant the communication between departments was open and informal, and between top managements and operators as well. The participation from top managers to plant operators was really important for the development of Lean Six Sigma strategy. The company has interest in the opinions of the employees and they collect information and suggestions every day from the production plant. So, the employees are totally involved and encouraged. They would be ready if the managers would like to develop a Lean production.

Most operators have Lean manufacturing notions because they carry out tasks about maintenance, cleaning, solving problems and they pick the bottles when the defect occurs during production. Also, the operators receive the production plan to not produce more than what was expected by the predicted demand. They are responsible for production and their own machines' maintenance and preventive maintenance, cleaning routine and they have the tools and the knowledge to fix them. As a result, the personnel are equipped with the basics for a Lean Six Sigma implementation. Looking at this topic, they have routines which help to reduce downtime and reduction of defective bottles but without standardization of the tasks. Therefore, the activities can be improved by Lean techniques.

3.4.1.3. Based on production planning

Enugu Plant has a production plan that depends on the predicted demand, so it does not follow a just-in-time philosophy, because they do not wait for the demand to produce the units that the customers desire. The brewery, based on its experience, generates their forecasts that were usually regular with a seasonal increasing in Christmas. It was the way they plan the production. Therefore, they produce and store the product waiting to be sold because it was not easy to handle the beverage-making when they want. They have a big number of tanks to store a large quantity of product for some weeks until it

ordered to bottle, so, they have to plan the bottling to this product during these weeks to not deteriorate their quality. With this overproduction, one strategy that was very common for them was to keep around 20% of the products produced for the next year.

3.4.4. Based on customers and demand

Regarding the customer approach, the brewery know what is the customer opinion from several ways, but they do not have specifically surveys for them to know more details about other aspects of the purchase. They know that customers are satisfied with a very high quality-price opinion.

Enugu plant was focused on their percentage of alcohol and taste of the products because it was what customers appreciate more. Also, the winning awards were a consolidation for their products. The interesting point was that these awards have repercussions on the sales, being important products for the company.

Based on the Director of Production and Quality opinion, the most important factors were the delivery on time and the price for both side of the business. As it was said the philosophy is delivery always to not lose or postpone any demand order, so, also time of especial deliveries and send the completed orders were their priorities. Currently, they were working on some new products. From the customer's opinion, the company does not have any special way to know the important factors. Only sales reports give them a

general idea, but in the interview he considered more important factors related with price, discounts and relationship with the customer, always after the delivery in time. The customers were wholesalers, distributors, supermarkets and shops, and when they want the product, the brewery should have the product for the date. This fact generates influences in others factors because it keeps the confidence, good relationships, creating benefits in mid and long term. According to the forecasts, there were no big differences between types of customers and their demands. They follow the general predictions mentioned earlier, and rising of bottles on Christmas season.

3.4.2. Questionnaire

To keep the survey within a reasonable time frame of 15minutes, ranking scale questions were considered. The scale of 0 to 100% was used to present the opinion of the participants.

Table 3.15 shows the summary of the data obtained through questionnaire (appendix 3).

3.4.3. Observation

Four activities were observed as presented in table 3.1 with respective outcome.

Table 3.1. The considered activities and observations

Activity	Observation
The level of stock per month	5% of total production were stocked
Supply to the customers per month	Always delivered on time because of much number of stocks
Movement of the operators per day	Operators do cover a distance of 40m per day causing waste of time
Availability of control devices	There were Control devices present but there were no registered data for future information
Application of Statistical tools	Do not test data using any statistical tool

3.4.3.1. Stock section

One of the problems for a Lean manufacturing implementation would be the big stock they have. At least, they always work with one month of stock of all the materials and they order when they achieve the security stock, which was one month of material. Taking into account that they can produce more than 3 million bottles of beverage every month, the quantity of

raw materials were very significant besides the stock of the final beverage bottles. The space that was required is very huge. They have a big plant where they store all the materials and this was a cost for the company and a 'waste' from the Lean point of view. These materials were bottles, barleys, chemicals, boxes, adhesives tapes and others. An inconvenience was that they do not have available suppliers of bottles, and others main materials, so they do not like to take any risk of delay its production for lack of raw materials, keeping in mind the idea of delivery always in time.

A good point was that the product tanks were situated next to the bottling line and the stock replaced next to the machine which uses the raw material like bottles, labels and cases. Therefore, it tries to reduce movement of the operators.

Then, the final stock of bottles have a benefit to the brewery because the product does not almost deteriorate once is bottled, even it can improve its quality. Consequently, there is 'waste' in the brewery. The principal are overproduction and inventory. Anyway, they sell under FIFO (First in first out), so the first beverage of a model should be sold first.

3.4.3.2. Suppliers

The replacement was ordered depending on the expected production for the next month. On the other hand, in a just-in-time production, they have to wait until the customer's order to start to produce the right number of bottles. This

helps to manage the stocks better and consequently, lower inventories. They also need the collaboration of the suppliers to receive the raw material as soon as possible to reduce the inventories. Once the stock is supplied, some employees carry out the task of replacing the raw material to the point of use in the production line.

3.4.3.3. Wastes

Other wastes considered in the company were the movement of the operators. Despite each worker has their area or workplace, in author's opinion, the movements could be optimized better with a more compacted layout to reduce times. The other one was underutilized workers because most of the processes were automatic and if there was no problem or changes in the settings some workers were waiting for the next activity because the machines do not have the exact speed.

The last waste considered happening in the bottling line was the over-processing. The rejected bottles were continuously fixed and put them in the process again when it was possible (more about rejected bottles).

3.4.3.4. Control devices

Enugu plant bottling lines applies many Jidoka practices from Lean manufacturing. During the bottling process there were electronic devices or sensors which control and ensured that the activity performed correctly. It was a way to reduce the defects after the stages but this controls does not

monitor values, they do not register data of the attributes. The lines run automatically because they also have sensors to detect that there were bottles in the entrance of the previous belt. Consequently, the machines stop or reduce the speed when they do not detect enough bottles to fill the machine. Thanks to that, the machines can auto-control the different speed between stages because they do not have the same cycle time and for this reason the line works with intermediate stock to avoid the downtimes and stoppages.

There were more sensors which ensured that only products with the right specifications could pass the step. So, many defects were detected during the processes. These sensors were explained before and were the tools to control at the exit of the processes. They let the control system know which bottle was rejected. In addition, the operators have the power to stop the line when the problem requires it.

All the machines have a display where you can get information about the bottles performed in the stage, speed or bottles per hour. Also in each line, there is a display on the computer to monitor the temperature of the beverage, pressure, valves of beverage pipes and many other parameters.

More accurately, the company has three bottling lines. Regarding the bottling line B, the first control was when the bottles were filled. The electronic device control the position of the bottle and also detects if there is no defect, besides checking the level of beverage in the bottle. The display

showed the number of bottles that passed through the system. The beverage volume must be inside for an interval of about 25 mm from the ideal height; otherwise, the bottle was rejected. The second control was after the insulating machine. It works in the same way, with an infrared system which checked if the bottle was placed correctly or if it was not placed. After that, the labelling process has its control too. It decides if the label was placed in the correct position, with the correct angle, without wrinkles and so on. In this control the display shows to the operator the number of defective labels and the number of produced bottles of that model, also telling what was the defects percentage in this model. Problems usually appear after the changeover of the label because they should place again the bobbin of the new beverage label. This always generates some troubles to align it. The last control was situated at the end of the bottling line, where it packs the bottles. It was scaled and detects when the weight was out of the limits. It means that some bottles are missing.

This control rarely rejects boxes due to it was difficult to lack bottles. It would be likely a problem in the previous processes.

Figure 3.2 showed the 4 control places represented in the process. These were the 4 automatic controls after the 4 processes which were more important for the final quality of the product.

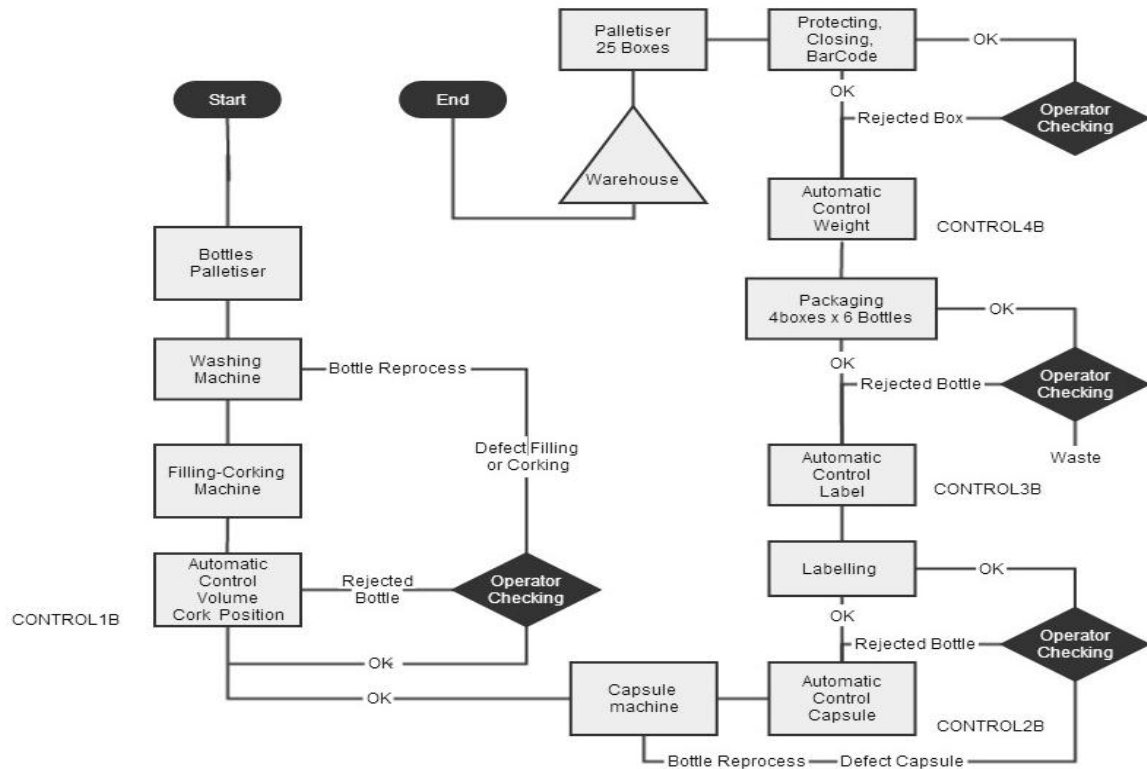


Fig. 3.1. Bottling and Packaging process and the control detectors of the line B.

Figure 3.1. Also showed how the employees operate when the bottles were rejected. When the bottle that contains beverage inside was returned to the beverage pipe and was removed then the bottle was not correct. Therefore, the empty bottle would be put on the line again, before the washing machine to start the process again.

3.4.3.5. Recordkeeping

It was observed that they were no data recorded in most of the processes, even if it performed well or not. They do not control the variability of the process, therefore, lack statistical process control implementation. However,

the company in the last years has increased its number of controls and samples to check more often the quality of the final products.

3.4.3.6 Six Sigma Statistical Process Control (SPC)

It was observed that the Enugu plant does not use statistical methods to analyze the processes. The brewery does collect information but failed to test the data using any statistical tool. They only carry out check on the values of all the necessary attributes. The information that they mainly keep to control were values of variables of the process, the speed of production and bottleneck of the process. With this information, they pay attention on the limits and the value. The product must have all the variables inside the specification limits instead of going further with statistical process control (SPC) and control how the variables behave.

Therefore, they do not develop a Six Sigma philosophy on reduction of defects or variability because they do not register this data, so, they cannot analyze them. The author saw that they only have software on the labelling machine which informs the operator about the number of bad labels in that batch and showing the last statistics of the 100 units and the percentage of the total bad bottles from the total. Although they do not control the defects in the production.

With much emphasis, the number of defects according to the company was less than 1%, but the philosophy of Six Sigma goes much more further

by reducing up to best significant levels.

It was observed that, there was no statistical process control during the production of the bottles of beverage. However, the author consider it necessary to distinguish between the beverage-making, because the company pays much more attention to this phase due to the fact that it is the main objective. Creation of beverage, and the bottling of the beverage, which were more of manufacturing processes were not as optimize as the other phase. The good point was that as the author explained before, they have their own laboratory. Therefore, the brewery controls the whole evolution of the grape, taking samples of the fruit, analyzing, modifying what they consider to achieve the best grape for their products. The Quality Control personnel, explained to the author that they always check all the growing phases to know the values such as sugars, acidity, PH, pesticides, proteins, and others biological aspects which influence in the flavour, taste, aromas, in other words, on the final quality of the beverage.

This was the essential part, for this reason they invested in that small laboratory to have the power to control all of the growing. They employ the laboratory for other checking controls like oxygen or vacuum, which form part of the after bottling process.

The key interest of the plant was to develop new software to optimize the processes in the company and have a better control of these concepts they do

not monitor yet in the bottling process. Until now, the principal way to analyze results was the benefits and sales reports, so, based on financial parameters. There was no valuation of operator and machine performance, rejected bottles data or statistical process control to give some examples. This information would improve the results of the brewery, which were fundamental for a Lean Six Sigma implementation.

3.5. Collected data

3.5.1. Bottling processes

Once all the information obtained from the company has been explained, during the visit it was possible to analyze the data based on the current situation of the processes. Bottling line was considered. The data collected were presented in appendix 2. The values for the VSM were collected during the second visit. The main symbol would be explained based on the value stream mapping (Appendix 2. and Appendix 3.).

3.5.1.1. Process

C/T (s) = Cycle Time (time since an item starts its manufacturing process until it finishes)

Speed (bottles/h) = Rhythm of production of the machine or process.

Uptime (%) = OEE (Availability)

Batch = Number of bottles inside the process at the same time.

TAKT = Each Takt is time a unit is processed and comes out of the process...

(Related with the Speed)

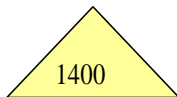
1 Operator



Push system: The material flow was pushed by the process without pull production.



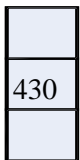
Pull system: The material was pulled by the demand of the next process or customer.



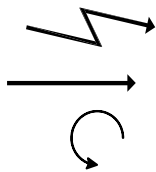
Inventory: It indicates the number of bottles usually in the inventory. At the end of the day, the line remains with this number of units in the inventory, ready for the next day.

Empty Bottles

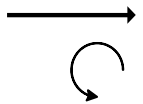
Buffer: It was situated between the processes. The number of bottles in the buffer is indicated. The line usually works with these buffers full, because during the production there is some variation because the speeds are not the same in all the processes.



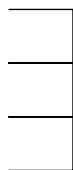
Manual information flow



Electronic information flow



Material pull: The operator remove the material from the 'supermarket' when was going to use it. Remove each day the needed material for each batch production of a model.



Supermarket symbol: The processes downstream come to the 'supermarket' to pick the material they need. The upstream process should replenish as requires. In continuous flow was common work with *batches size but every day its material required.*

All the times were showed in the value stream represented in the Appendix 2. These values for the VSM were collected during the second visit. All the speeds, times, quantities, correspond to the way that the process was working.

3.5.2. Defects and rejected bottles data.

The bottling lines were monitored for 2 days under 5 hours production operation and the following tables show the number of bottles rejected per hour.

Line A --- day 1 (3500 bottles)

Table 3.2: Number of defects and rejected bottles per hour in line A day 1

Time (hr)	Number of defects bottles				Number of bottle rejected			
	Filling	Capping	Labeling	Other	Filling	Capping	Labeling	Other
0	0	0	0	0	0	0	0	0
1	2	1	1	0	2	1	1	0
2	1	0	0	1	1	0	0	1
3	1	1	0	0	1	1	0	0
5	2	1	1	1	2	1	1	1

Line A ---day 2 (7000 bottles)**Table 3.3: Number of defects and rejected bottles per hour in line A day 2**

Time (hr)	Number of defects bottles				Number of bottle rejected			
	Filling	Capping	Labeling	Other	Filling	Capping	Labeling	Other
0	0	0	0	0	0	0	0	0
1	1	1	1	2	1	1	1	2
2	1	1	2	1	1	1	2	1
3	1	1	0	1	1	1	0	1
5	3	2	2	4	3	2	2	4

In line A, at the first day, the defects and rejected bottles were studied during the production of 3500 bottles, and the second day, during 7000 bottles.

Line B ----day1 (6200 bottles)**Table 3.4: Number of defects and rejected bottles per hour in line B day 1**

Time (hr)	Number of defects bottles				Number of bottle rejected			
	Filling	Capping	Labeling	Other	Filling	Capping	Labeling	Other
0	0	0	0	0	0	0	0	0
1	0	2	1	0	0	2	1	0
2	1	1	1	1	1	1	1	1
3	1	2	0	1	1	2	0	1
5	1	2	2	0	1	2	2	0

Line B ----day2 (9000 bottles)**Table 3.5: Number of defects and rejected bottles per hour in line B day2**

Time (hr)	Number of defects bottles				Number of bottle rejected			
	Filling	Capping	Labeling	Other	Filling	Capping	Labeling	Other
0	0	0	0	0	0	0	0	0
1	1	0	2	1	1	0	2	1
2	1	1	2	1	1	1	2	1
3	1	0	3	1	1	0	3	1
5	1	0	2	2	1	0	2	2

In line B, at the first day, the defects and rejected bottles were studied during the production of 6200 bottles, and the second day, during 9000 bottles.

Line C ----day1 (3000 bottles)**Table 3.6: Number of defects and rejected bottles per hour inline C day1**

Time (hr)	Number of defects bottles				Number of bottle rejected			
	Filling	Capping	Labeling	Other	Filling	Capping	Labeling	Other
0	0	0	0	0	0	0	0	0
1	0	2	1	0	0	2	1	0
2	1	0	1	1	1	0	1	1
3	0	0	0	0	0	0	0	0
5	1	2	1	0	1	2	1	0

Line C ----day2 (6000 bottles)

Table 3.7: Number of defects and rejected bottles per hour in line C day2

Time (hr)	Number of defects bottles				Number of bottle rejected			
	Filling	Capping	Labeling	Other	Filling	Capping	Labeling	Other
0	0	0	0	0	0	0	0	0
1	0	0	1	0	0	0	1	0
2	1	0	1	1	1	0	1	1
3	0	0	0	1	0	0	0	1
5	0	2	1	1	0	2	1	1

In line C, at the first day, the defects and rejected bottles were studied during the production of 3000 bottles, and the second day, during 6000 bottles.

It was considered necessary to be commented that sometimes a mistake occurred in the line during the data collection because some of the rejected bottles in the capsule machine were rejected but the bottles were corrected, with the cap. It only happened at the *capping* process. Another comment was that the defect of *Filling* and *Capping* were counted separately despite they were controlled together because they produce under continuous piece flow but they were different machines, so the defects do not influence each other.

3.5.3. Laboratory registered data

Tables 3.8 to 3.14 were obtained from the company. Table 3.8 shows product brand, type of beverage, type of crown, crown extraction force, carbon

dioxide content, nitrogen content, vacuum pressure, and volume of beverage recorded in January to July 2014.

Table 3.8. The product brand, type of beverage, type of crown, crown extraction force, carbon dioxide content, nitrogen content, vacuum pressure, and volume of beverage recorded in January to July 2014.

(Source: Nigerian Breweries Enugu).

Line	Product	Description	Bottle volume (ml)	Cap (Cork) Type	Extraction Force (N)	CO ₂	Nitrogen	Vacuum	Volume
A	Heineken	Alcoholic Beverage	600	Crown Cap	33	0.30	0.30	0.10	570.00
A	Gulder	Alcoholic Beverage	600	Crown Cap	32	0.30	0.30	0.10	570.00
A	Life	Alcoholic Beverage	600	Crown Cap	32	0.25	0.25	0.10	570.00
C	Ace Root	Alcoholic Beverage	600	Crown Cap	32	0.30	0.30	0.10	580.00
C	Amstel Malta	Non-Alcoholic Beverage	330	Crimped Cap/Screw Cap	27	0.17	0.17	0.00	320.00
C	Fayruz	Non-Alcoholic Beverage	330	Crimped Cap/Screw Cap	27	0.17	0.17	0.00	320.00

It is important in the improvement of the quality of these variables because the data base has nearby 400 samples. More exactly, is about 386 samples but the analysis of the study was based on 326 samples of *Extraction Force* for the ‘crown cap Brand’ and 60 of *Volume* of beverage, which were the most important variables from this data if one considered only the bottling processes. The automatic extraction force tester (Compact Force Gauge+ (CFG*)) was used for testing force (both on opening and closing) without the intervention of the operator and in standard conditions of repeatability. The

instrument saves the test reports and statistical data analysis (minimum, maximum, average value, standard deviation). It has a communications port for an external computer or printer

Furthermore, there was another attractive point of this study because they do not treat these data with statistical methods like statistical process control, which can give information about the process under control, and give charts to interpret the behaviour.

The data includes samples from the 3 bottling line; A, B and C. The data from all lines was considered to employ the whole information and analyze differences between lines too. There were more data about the Line A and C because they produce more beverage per hour, hence, more samples were taken in these lines.

Table 3.9 shows the extraction force for the crown cap brand per month for production line A.

Table 3.9. Extraction force (N) for production line A per month (Source: Nigerian Breweries Enugu).

Observation	Extraction force (N) for line A by month						
	Jan	Feb	Mar	April	May	Jun	July
1	33	31.94	36	28	38	31	34
2	32	29.5	28	28	40	27	32
3	28	31.94	30	42	31	44	30
4	29	32	36	42	31	33	28
5	28	32	28	29	33	22	29
6	29.5	28	39	27.5	28	30	40
7	37.3	30	28	32	28	31	29

8	26	29.5	28	27	31	33	28
9	29.5	28	31.44	27	22	31	26
10	25	28	37.38	32	38	33	38
11	32	32	36	30	30	22	28
12	31.94	28	28		29	31	22
13	29.5	28	29		24	29	
14	31.94	32	29		40	29	
15	31.94	30	37.9		28	32	
16	29.5	28	27		33.25	40	
17	26	31	28		33.25	32	
18		34	26		26	28	
19		27.5	32		40	27	
20		28			38	9	
21		38			30	11	
22		31			21.9	4	
23		31			36	0	
24		29			30	3	
25					31	2	
26					36	2	
27					32	2	

Table 3.10 shows the extraction force for the crown cap brand per month for production line B.

Table 3.10. Extraction force (N) for production line B per month (Source: Nigerian Breweries Enugu).

Observation	Extraction force (N) for line B by month	
	Jun	July
1	29	29
2	30	35

3	33	32
4	33	31
5	33	35
6	31	40
7	35	34
8		32
9		35
10		31
11		35
12		29
13		32
14		34
15		34
16		33
17		34
18		33
19		32

Table 3.11 shows the extraction force for the crown cap brand per month for production line C.

Table 3.11. Extraction force (N) for production line C per month (Source: Nigerian Breweries Enugu).

Observation	Extraction force (N) for line C by month						
	Jan	Feb	Mar	April	May	Jun	July
1	25	24	26	23	30	30	35
2	28	28	25	21	24	29	34
3	28	29	28	25	30	31	40
4	20	21	27	25	30	30	36
5	20	25	23	23	30	27	35
6	16	25	23	24	25	25	36
7	24	13	20	24	26	26	35

8	27	26	19	20	24	28	28
9	23	25	24	24	22	27	35
10	25	21	23	21	20	22	30
11	26	25	22	24	23	28	30
12	25	24	18	25	24	26	29
13	26	24	23	25	24	27	24
14	24	29	16	22	22	20	29
15	14	25	24	30	25	28	24
16	25	29	20	30	19	28	22
17	25	25	23	24	25	24	29
18	14	24	19	24	24	24	28
19	20	25	23	30	24	24	29
20	29	26	22	33	25	25	24
21	30	21		30	24	35	21
22	29	28		34	24	30	29
23		28				30	28
24		27				28	29
25		26					36
26		25					29
27							29

Table 3.12 shows the number and frequency of filling defects per line production. The volume of filling in each bottle was measured using a graduated Measuring Cup of 1000ml capacity. The content of the sample bottles were poured into the measuring cup one after the other, the values of the volume were read and recorded as presented in table 3.12.

Table 3.12. The number and frequency of volume of filling defects per line**(Source: Nigerian Breweries Enugu).**

Observation (day)	Volume of filling per line (ml)							
	Line A	frequency	Day	Line B	frequency	day	Line C	Frequency
1	591	2	1	591	2	1	591	0
2	596	5	2	591	2	2	591	0
3	596	3	3	596	4	3	596	5
4	596	5	4	596	1	4	596	1
5	597	21	5	597	3	5	596	4
6	597	30	6	597	10	6	597	6
7	597	21	7	597	8	7	597	6
8	600	80	8	600	10	8	597	7
9	600	22	9	600	18	9	600	10
10	600	10	10	600	8	10	600	9
11	603	3	11	603	6	11	600	50
12	603	3	12	603	12	12	600	18
13	606	2	13	603	4	13	603	5
14	606	4	14	606	3	14	603	10
15	606	1	15	606	20	15	606	20
16	609	0	16	606	20	16	606	20
17	609	0	17	606	0	17	606	10
18	609	0	18	609	0	18	609	3
19	609	0	19	609	3	19	609	1

Table 3.13 shows the number cartoons of the product produced per month in 2014.

Table 3.13. The number of products produced per month in cartoons

(Source: Nigerian Breweries Enugu).

month	Number of products (cartoon)
Jan	5200000
Feb	4900000
Mar	4900000
April	4900000
May	4900000
Jun	4900000
Jul	4900000
Aug	4900000
Sept	4900000
Oct	4900000
Nov	4900000
Dec	5200000

Table 3.14 shows the number cartoons of the product supplied to the customers per month in 2014.

Table 3.14. Quantity of the products supplied per month (Source: Nigerian Breweries Enugu).

month	Number of products (cartoon)
Jan	4000000
Feb	3700000
Mar	3700000
April	3700000
May	3700000
Jun	3650000
Jul	3650000
Aug	3650000

Sept	3650000
Oct	3650000
Nov	3750000
Dec	4350000

3.6. Data Analysis

The data collected was presented and now the data was shown on an easy way to understand the information simply and quickly using a statistical software MINITAB. Tables 3.2 to 3.7 were analyzed using percentage value of the bottles produced per day. Tables 3.8 to 3.14 were analyzed by application of statistical tools using Minitab software

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Results

4.1.1. Bottling processes

1. Defects and Rejected bottles per production line

Table 4.1 showed the percentage of bottles rejected in line A at day 1

Table 4.1 Percentage of bottles rejected in Line A (day 1).

LINE A (3500 bottles)	Filling	Capsule	Labelling	Others	Total
Defect	6	3	2	2	13
Bottles (%)	0.17	0.09	0.06	0.06	0.38
Defects (%)	46.15	23.08	15.38	15.38	100

Table 4.2 showed the percentage of bottles rejected in line B at day 1 + day 2

Table 4.2. Percentage of bottles rejected in line B (day 1 + day 2).

LINE B (15200 bottles)	Filling	Capsule	Labelling	Others	Total
Defect	7	8	13	7	35

Bottles (%)	0.05	0.05	0.09	0.05	0.24
Defects (%)	20	22.86	37.14	20	100

Table 4.3 showed the percentage of bottles rejected in line B at day 1

Table 4.3. Percentage of bottles rejected in Line B (day 1). Source: [Author]

LINE B (6200 bottles)	Filling	Corking	Capsule	Others	Total
Defect	3	7	4	2	16
Bottles (%)	0.05	0.11	0.06	0.03	0.26
Defects (%)	18.75	43.75	25	12.5	100

Table 4.4 showed the percentage of bottles rejected in line C at day 1 + day 2

Table 4.4. Percentage of bottles rejected in Line C (day1 + day 2). Source: [Author]

LINE C (9000 bottles)	Filling	Corking	Capsule	Others	Total
Defect	3	6	6	4	19
Bottles (%)	0.03	0.07	0.07	0.04	0.21
Defects (%)	15.79	31.58	31.58	21.05	100

4.1.2. Laboratory results

Table 4.5. Volume of beverage basic statistics by Lines.

Volume of Filling Defects

Variable	Line	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median
Volume	A	239	8	599.00	0.151	2.33	590.00	598.00	600.00
	B	72	2	600.00	0.306	2.59	595.00	599.00	600.00
	C	104	70	599.00	0.220	2.24	593.00	599.00	600.00

Variable	Line	Q3	Median
	A	600.00	606.00
	B	603.00	606.00
	C	601.00	605.00

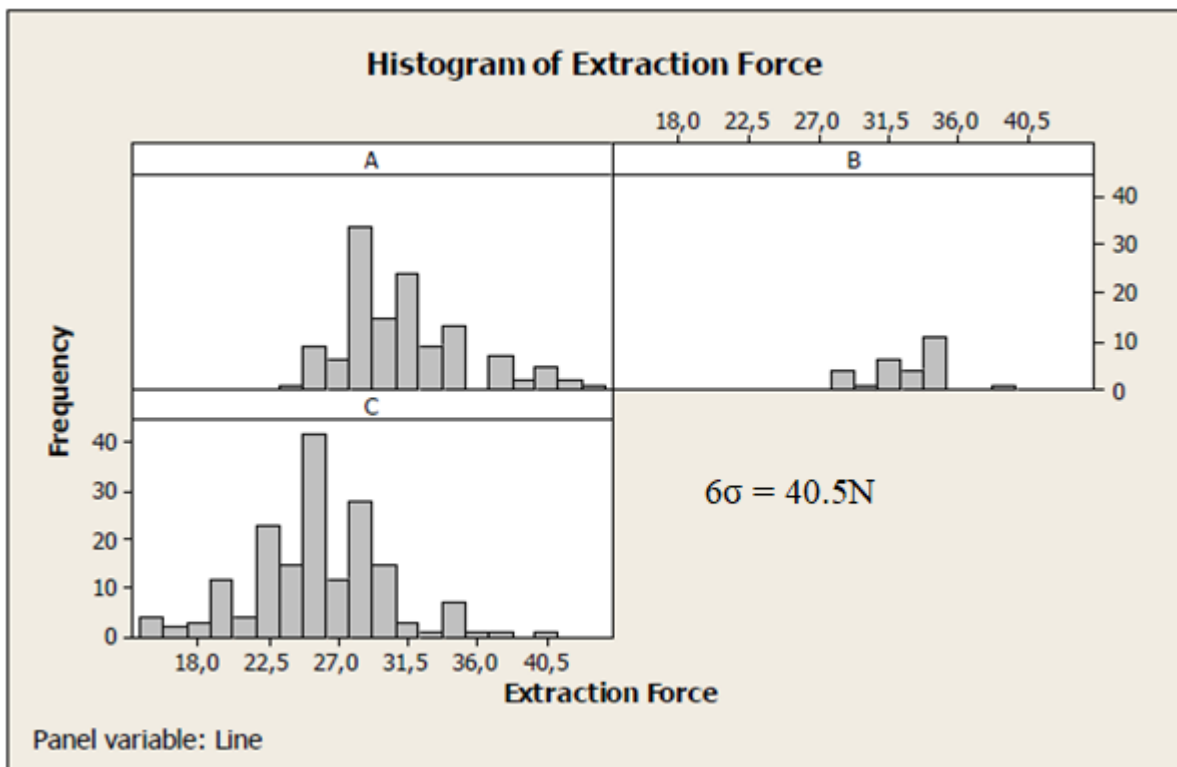


Fig. 4.1. Histogram of Extraction Force categorized by production lines.

[Author]

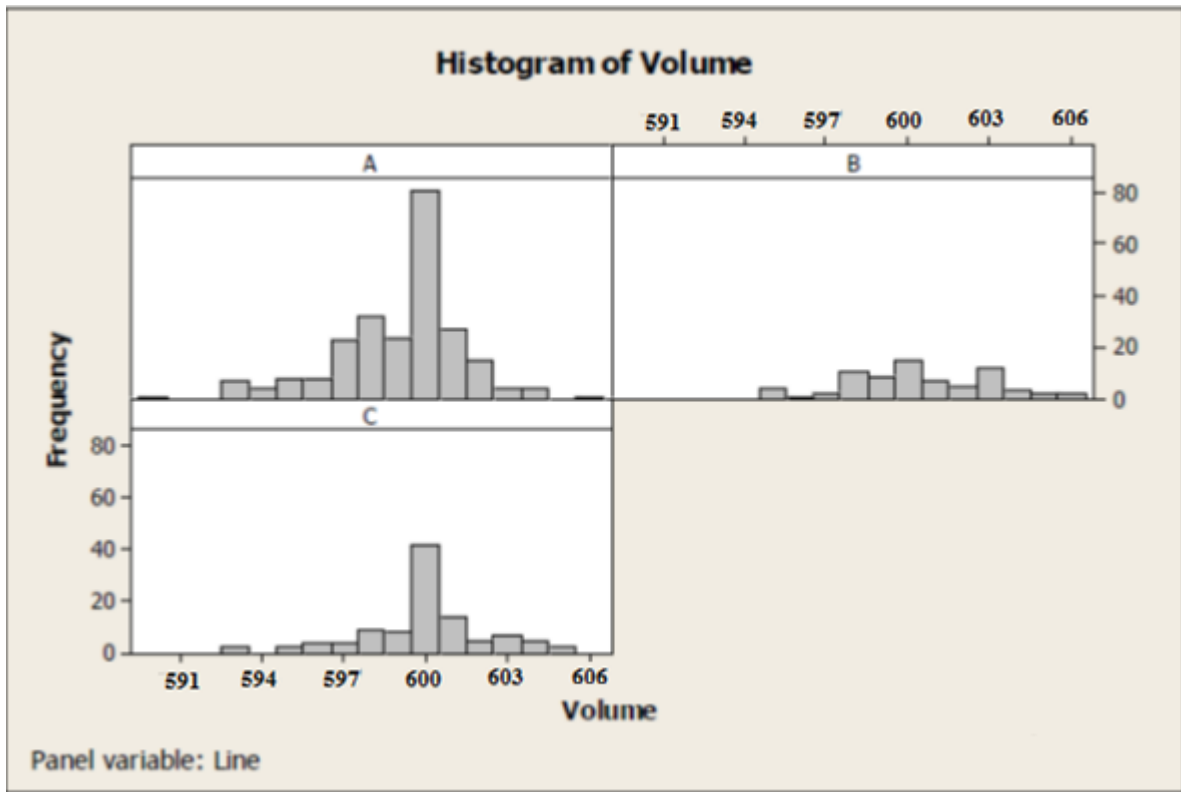


Fig. 4.2: Histogram of Volume of filling categorized by lines

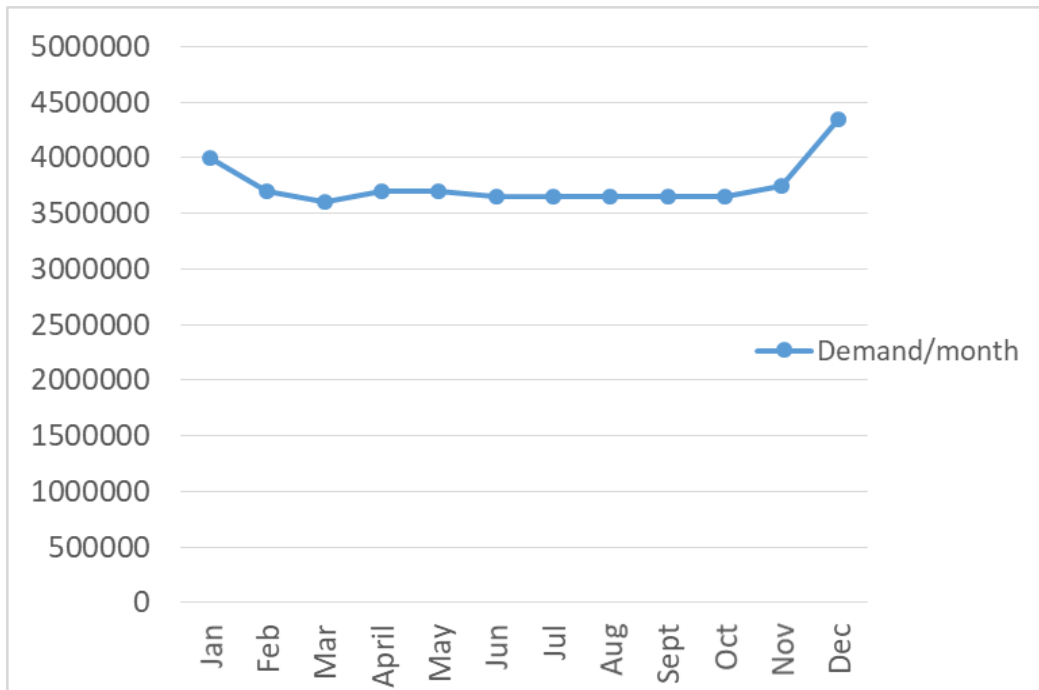


Fig. 4.3. Expected demand of beverage

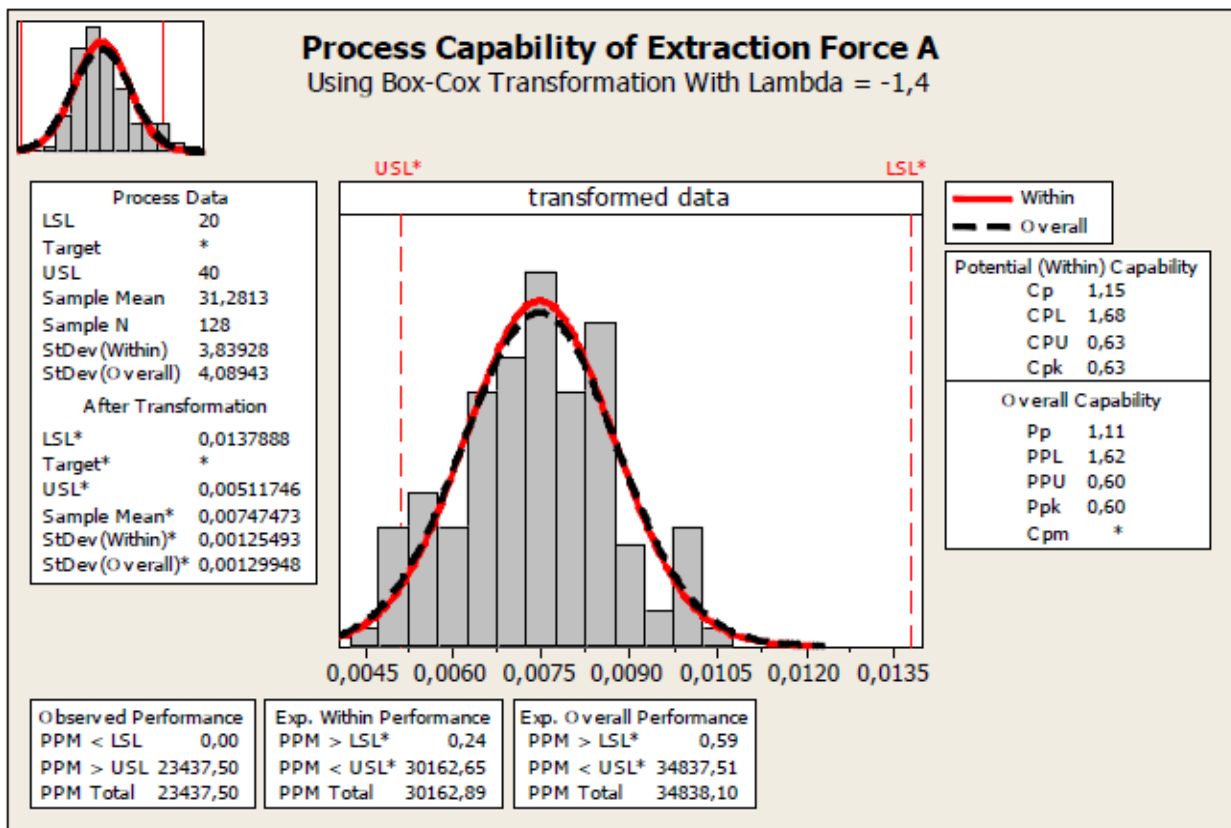


Fig. 4.4. Capability analysis of line A

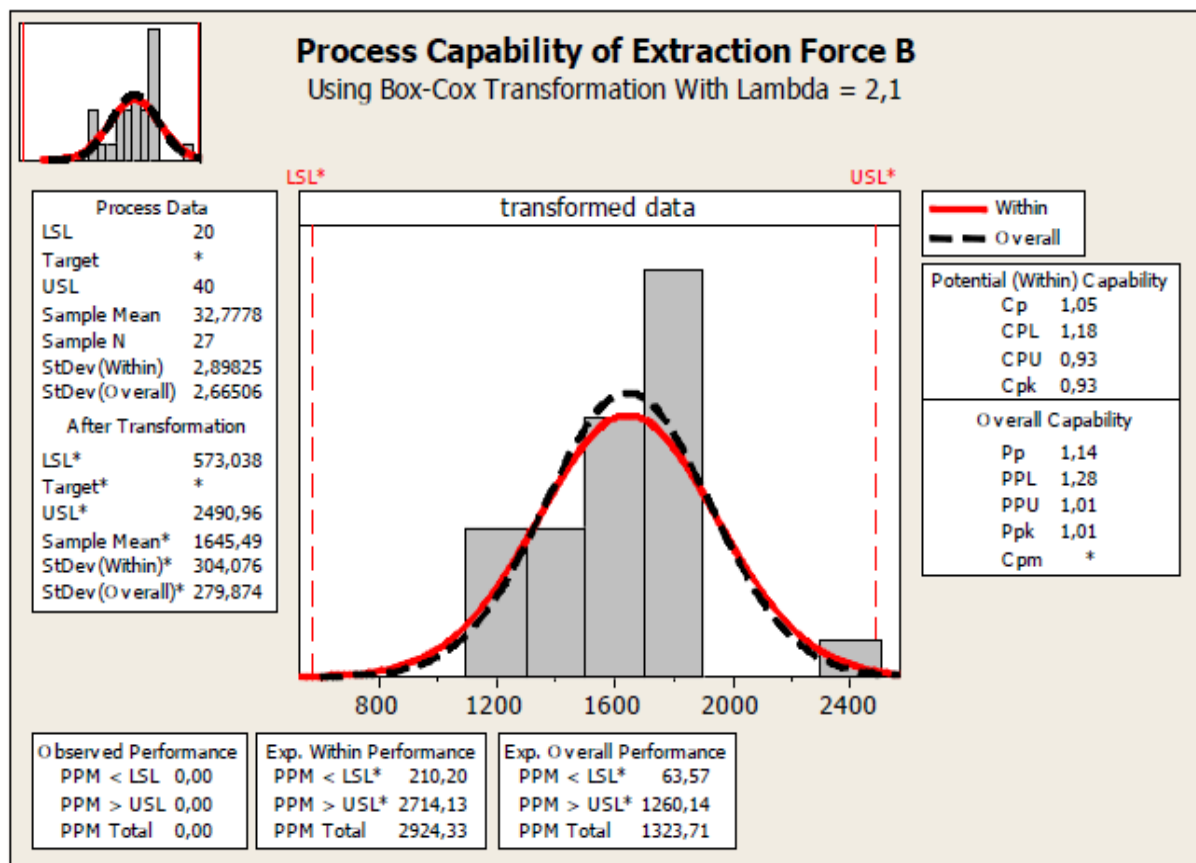


Fig. 4.5. Capability analysis of line B.

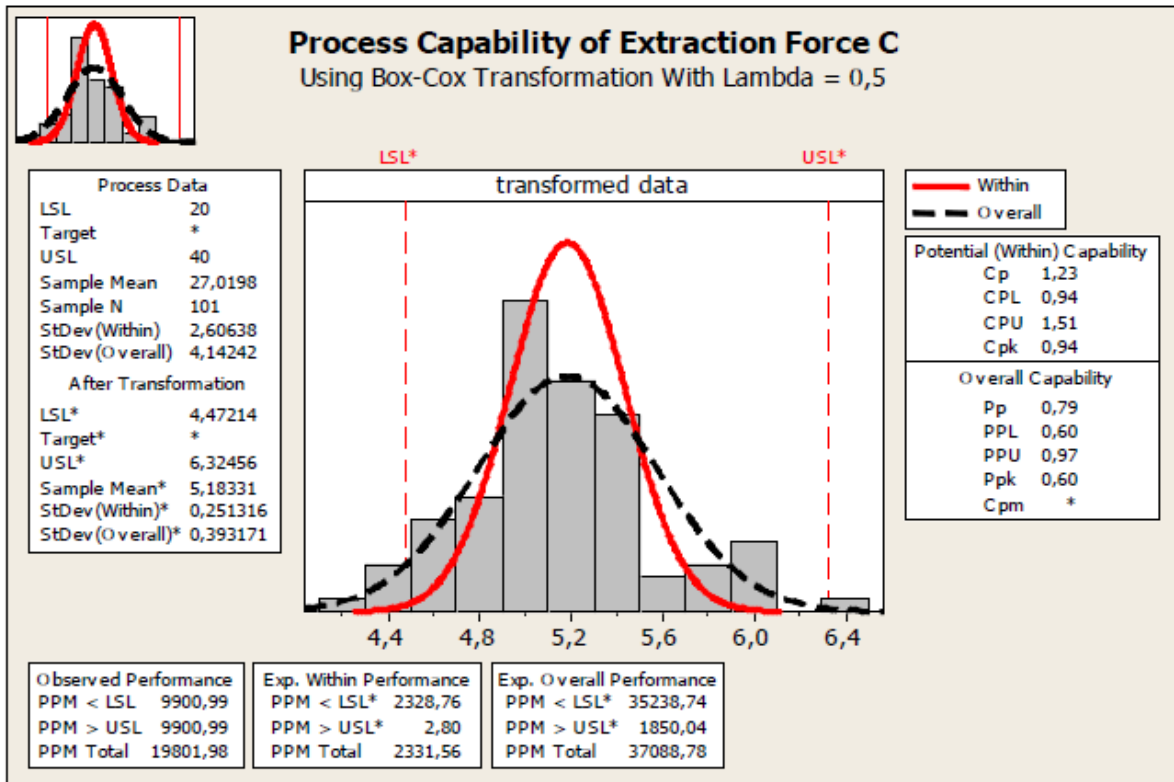


Fig. 4.6. Capability analysis of line C.

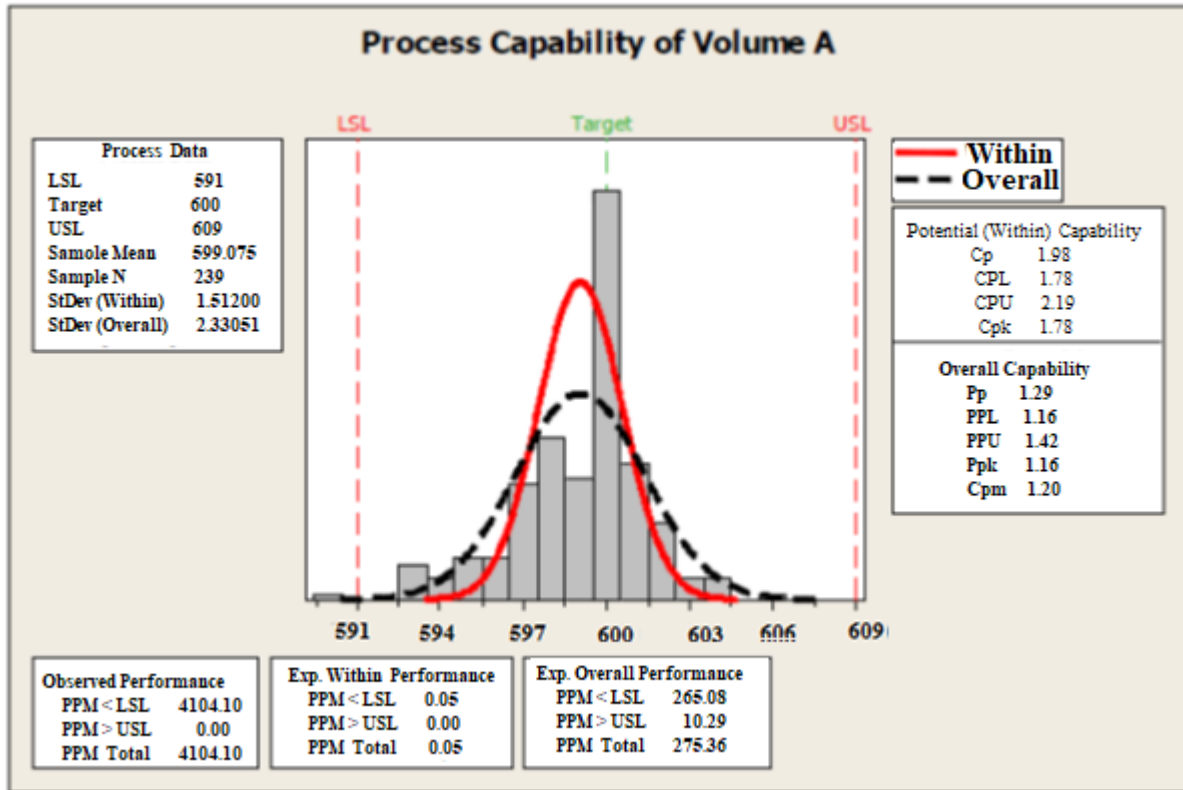


Fig. 4.7: Capability analysis of volume for line A. Source: [Author].

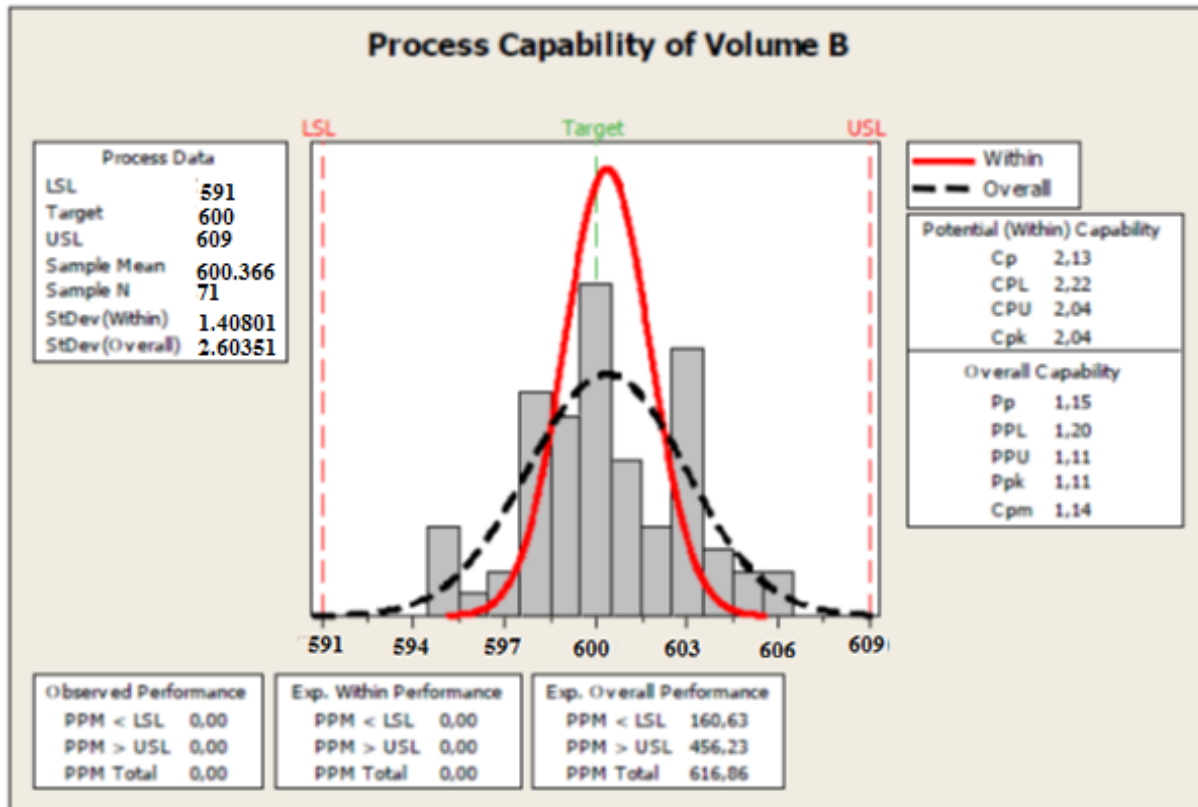


Fig. 4.8. Capability analysis of volume for line B.

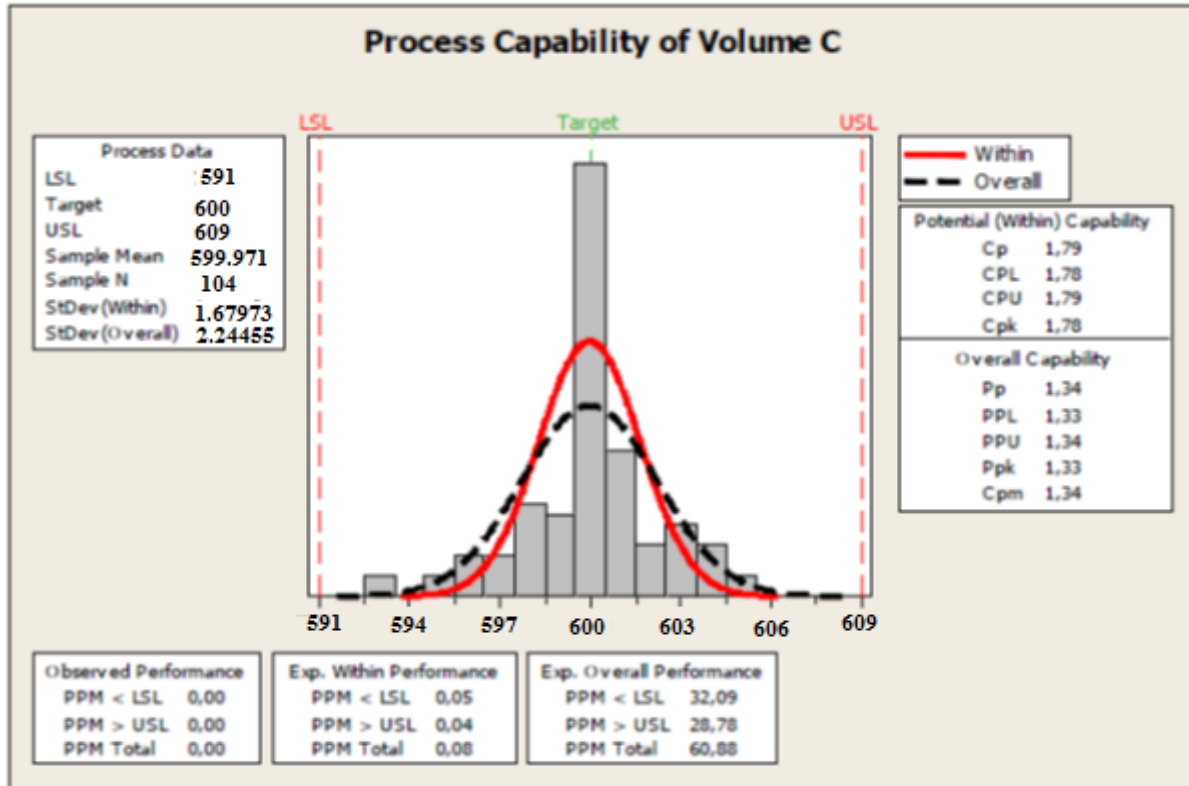


Fig. 4.9. Capability analysis of volume for line C.

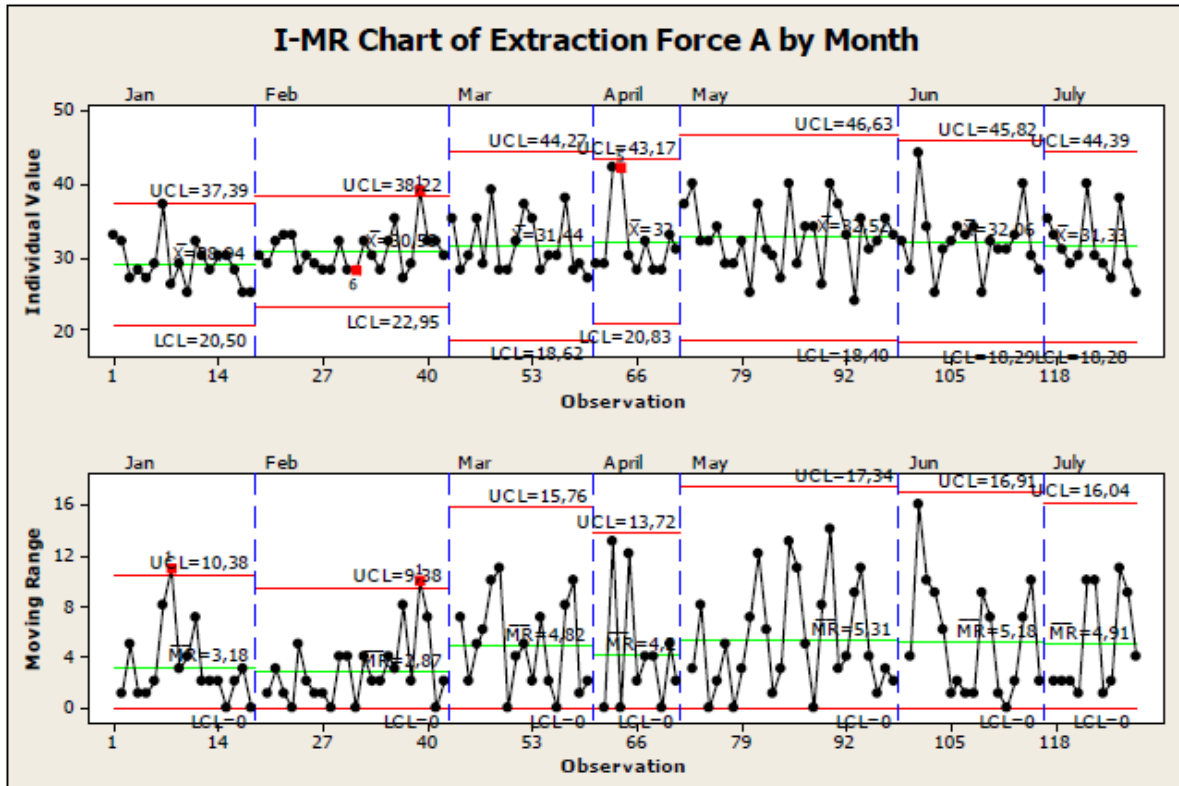


Fig. 4.10. I-MR chart of Extraction Force for line A.

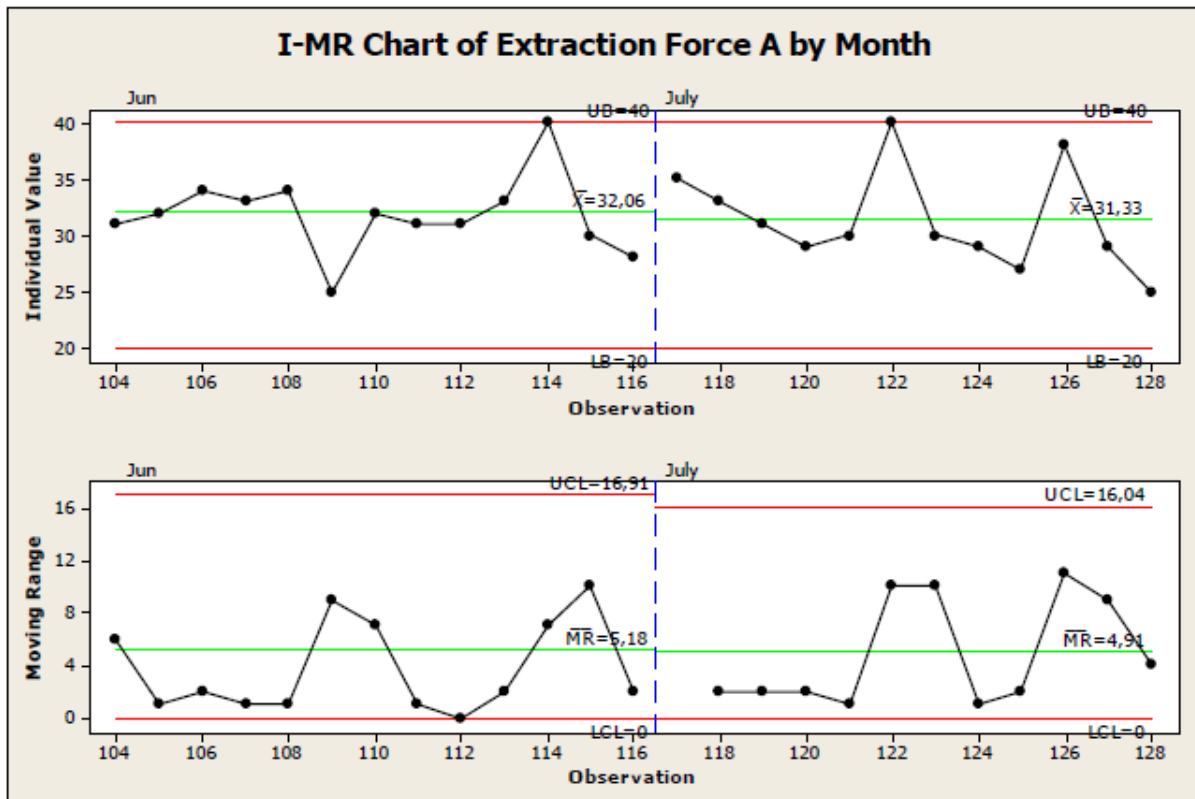


Fig. 4.11. I-MR chart of Extraction Force A last 25 samples.

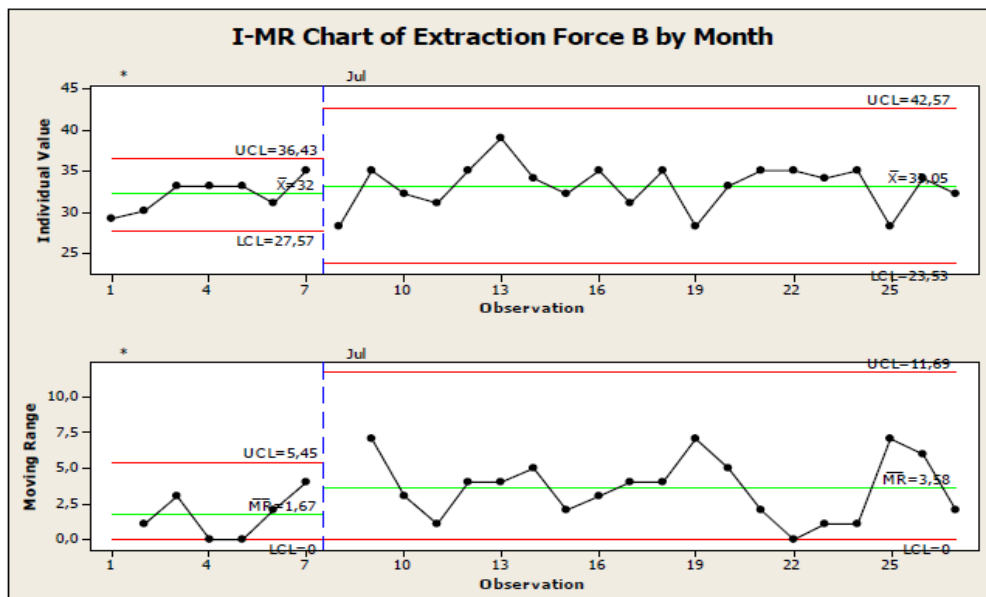


Fig. 4.12. I-MR chart of Extraction Force B. Source [Author].

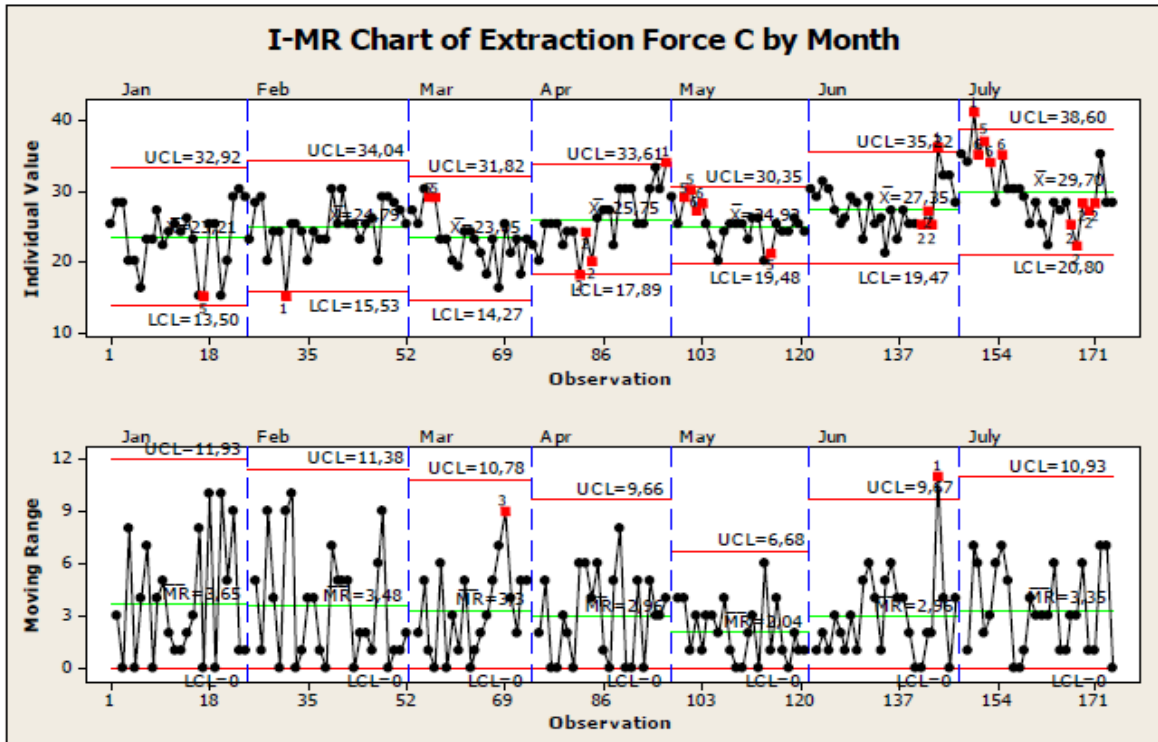


Fig. 4.13. I-MR chart of Extraction Force C. Source [Author]

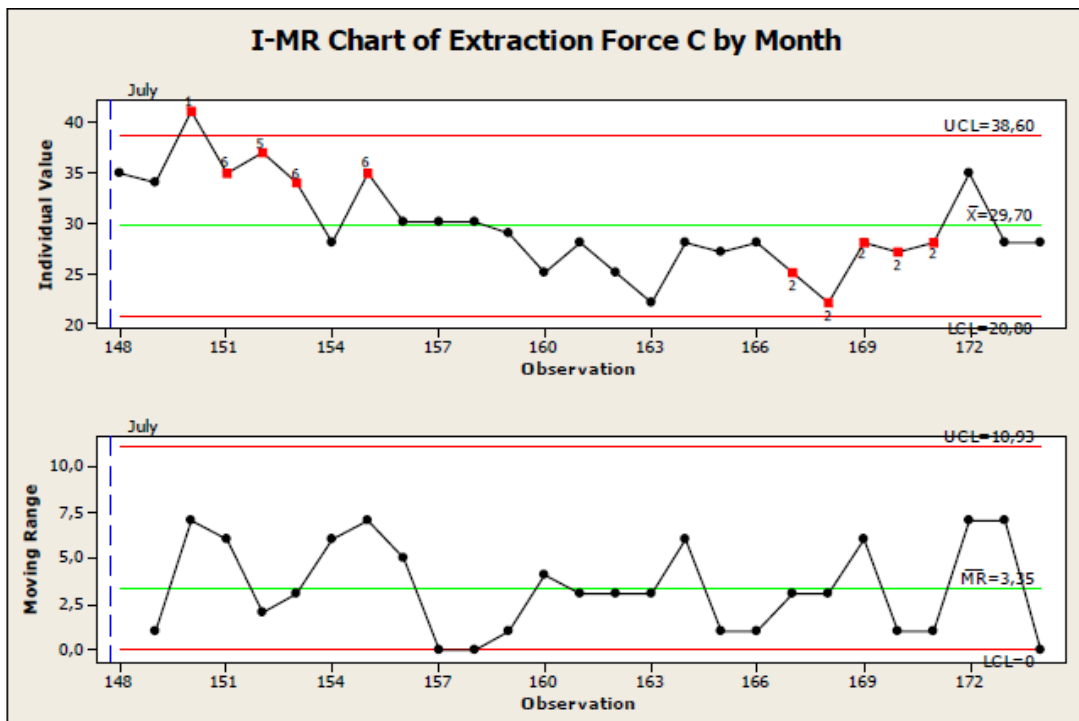


Fig. 4.14. I-MR chart of Extraction Force C last month.

4.2. Discussion

4.2.1. Defects and rejected bottles measurement

Table 4.1 shows that the line A rejects 0.37% of the produced bottles while table 4.2 shows that 0.23% of the bottles produced in line B were rejected. When compared, the difference in the two tables means that line A rejects one bottle every 271 bottles against 1 from 435 in the line B. This is because line A was designed to run at more than 1000 bottles/h. The other reason was that the bottles were filled to a volume of 1200ml instead of 600ml in the line B, due to existing production planning of the day.

Regarding line A, the problem was on the *Filling-Capsule* machine which puts a crown and works without cork. This line (line A) was installed recently, though with mistakes more than the line B. However, the 2 defects on the *Labelling (Line A)* were found at the beginning of the batch production and it was at that moment more problems of setting the new label of the new product appears. At the beginning, the operator produces one bottle labelled, if it is rejected, the operator stops the machine, check distances of the label to fix again the label and to produce another new bottle until the bottles were correctly produced.

In the last two tables 4.3 and 4.4 the comparison of rejected bottles was focused on the line B which was producing the same product of a 600ml beverage bottle.

Consequently, line requires constant attention in order to reduce overprocessing because it is on this line that more rejects are recorded originating from corking, capsule and filling (in that order).

The defects that show more difference were the Filling and Corking. The number of defect bottles reduced with more than 36% rejected bottles in line B on the second day. So, an interesting point to study was this defect reduction and thinking on the input parameters of the process, the speed changed from 6940b/h to 7155b/h. It was not possible to analyze the evolution of the defects along the time because the company does not have such information.

4.2.2. Defects and variability of bottling process variables

4.2.2.1 Extraction Force

This variable has a minimum and a maximum value because the company does not want a cork that requires much strength or the opposite. It was specified between 20 and 40 kg of force. Figure 4.1 showed that line A was quite well centred between the limits 20 and 40 kg. The same happens in the line B although the number of samples was lower. On the other hand, the line C seems to be shifted to the left, having much more samples under the lower specification limit of 20 than the company would desire.

Inside non-alcoholic brand, the company works with three types of cork, crown,

crimped and screw.

4.2.2.2 Volume of product data

Table 4.5 showed that the processes were not capable because the spread of the samples was quite big having samples up to 590ml. It was true that most of the samples were on the correct volume (600ml). Complementing the histogram in fig. 4.4 with the basic statistics of table 4.5., the line A has a mean of 599.08 ml, as a result, it should be interesting to realize why filling was less and not symmetric, for this reason the mean was lower.

4.2.3. Analysis of defects and rejected bottles

4.2.3.1. Cause-effect diagram

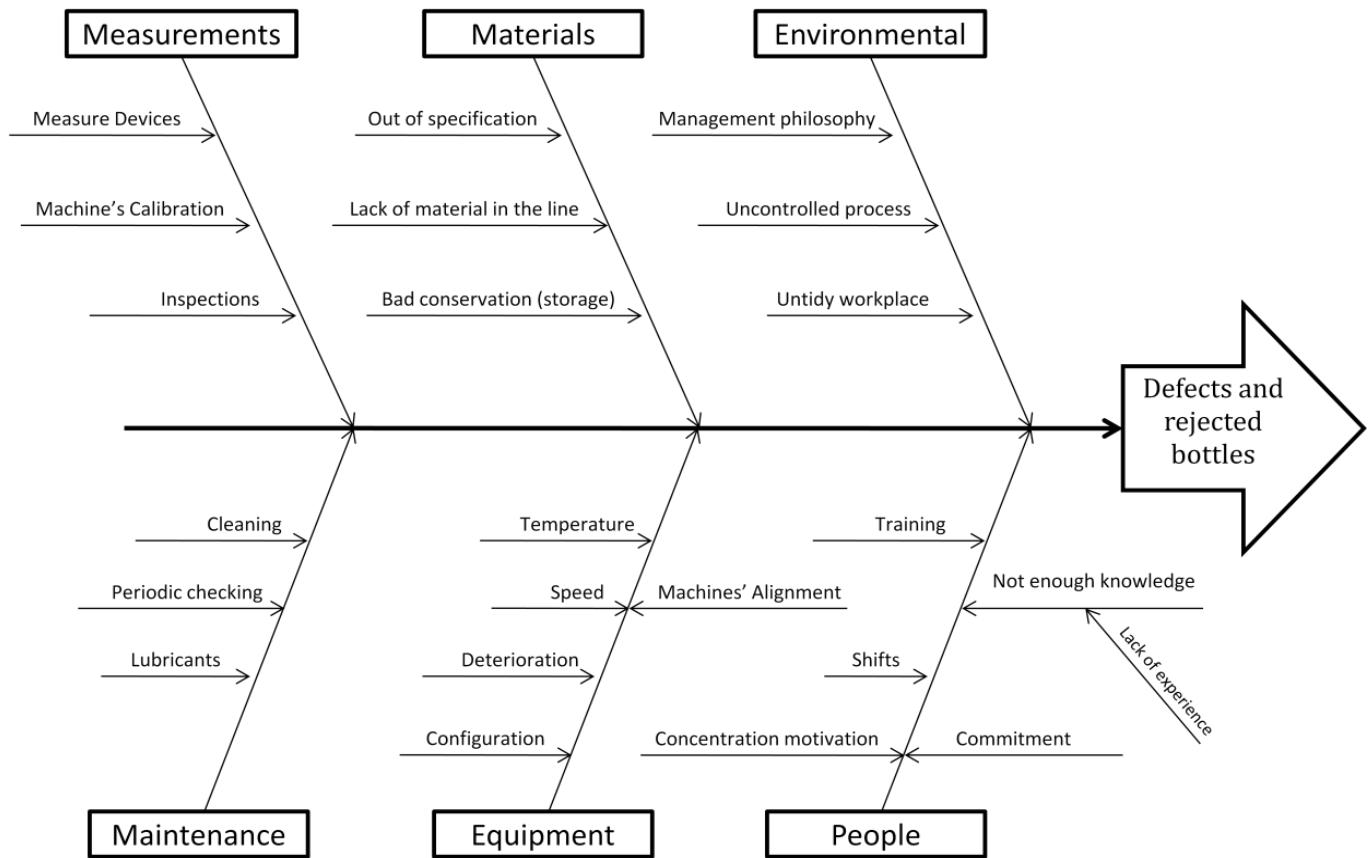


Fig. 4.15: Cause-effect diagram of defects and rejected bottles.

The defects and rejected bottles, which were caused by many possible changes in all of the attributes were represented in the cause-effect diagram. It is divided into six categories; measurements, materials, environmental, maintenance, equipment and people. Inside the main branches, there were other influencing causes that generate the defects on the bottles. All types of defects that appear on the previous *MEASURE* phase can be caused by bad equipment fitting of the right values, performance and behaviour of the employees (people),

The result obtained from scatter plot chart showed the possible relationships

between the variables of 'oxygen' and 'vacuum' that could be generating some pressure to the cork and generating bad bottles.

The important issues are all the causes included in the cause-effect diagram. Most of them cannot be evaluated with a number, but reasonably, aspects like cleaning, motivation, bad raw material properties to give some examples will affect the product.

With the cause-effect diagram, the company now know the main areas to solve and control in order to keep the number of defects low. For the moment, if the company would implement the study, these would be the best points to focus first.

4.2.3.2 Capability analysis

4.2.3.2.1 Extraction Force of the cork

Fig. 4.4 showed that the 'Extraction Force' of the line A samples were centered quite well but has some prolongation to the upper limit.

Capability analysis result showed that the line A process data without transformation of the values, but the interesting information for the company was the overall capability. The observed results (calculated with the transformed data to get the normality in the distribution); *Overall Capability* which represents the coefficients of capability of the bottling process and the *Overall Performance* which was the expected number of unit per million out of the LSL and USL or the

total number of defective bottles with the extraction force out of the interval.

The important values for the business of the company were the expected products out of the limits. Fig. 4.5 showed that the Six Sigma capability was placed between 3σ and 4σ because the number of expected overall performance is 34,838.10 units per million. If one pay attention to the short-term normal distribution, the defects in the extraction force is 3.4% of the bottles and all of them appeared on the upper limit, so, the company should pay attention to control all the causes that could affect the performance of the such as calibration, lubrication, configuration, maintenance of this machine and so on.

It has a problem with the higher specification. Actually, based on the current data there is a 2.34% of bottles with the extraction force higher than 40 kg but this data is not the entire quantity of bottles produced, for this reason the short-term will give to the company the expected number if they have analyzed all the bottles.

The line B was running better than the line A. It was also transformed to improve the normality of the distribution to get better expected results of number of defective bottles.

Fig. 4.6 showed that the corking machine was working in a capable process only a bit shifted to the upper limit. The number of defects expected in overall performance was less than 1,324 bottles per million (0.13%) much better than the

line A. The main issue was to control the well-balance process to keep in center (30 kg) of force the corking machine. As one can see the sample mean was more than 32, so, this little shift of the total samples generated some extra units outside the USL. The PP was not good enough with 1.14, so, as always they have to be carefully with the causes that generates variability to make the samples distribution narrower.

The recent mean was 27.02 kg (Fig. 4.7.), so, it was a little bit shifted to the left, the low limit and the capability was not correct. The $Pp < 1$, so this line was not capable. Therefore, the expected results were 37,089 bottles out of specification. The company has to react to this fact because the 3.7% of the bottles were expected to be defective on the extraction force attribute.

The importance of this was to keep control all the causes that could change the results. They have to bear in mind always to try minimizing the variability to achieve a better capability on the process.

Figure 4.7 also showed that the number of defective bottles during these months were almost 20,000 bottles per million. However, changing the parameters to produce bottle centered in 30kg the process will be able to improve a lot if all the causes were controlled. The expected potential capability was $Cp = 1.23$, quite better comparing with the actual value.

In this case it is important to comment the fact that the overall capability was quite different from the potential capability and this means that there were other causes different from the intrinsic variability that makes the process to have a wider distribution. This makes the range of samples being bigger. Therefore, if this machine is controlled more often it could avoid any shift on the corking machine and reduce external causes that change the variability. It means that if the samples were taken consecutively, the potential (within) capability could be achieved.

4.2.3.2.2 Volume of beverage

Fig. 4.8 showed expected bottles out of the limits because just one sample appears in the data with less than 691ml. Therefore, the proportion in a million of bottles was a significant \ number. It generates this equivalence to bottles per million and probably it was a mistake in the control machine or the bottle had more width and it let this bottle passed the control. Anyway, the most relevant information was that the capability of the process should be better trying to achieve the $P_p > 1.33$ or even $P_p > 1.50$ if possible. If the company reaches this performance the overall performance will be improved and it will reduce the number of rejected bottles in the line, which expected the defect of bad filling to be 0.028%. Table 4.1 showed that line A has 0.17% of bottles rejected for filling reasons. So, assuming the supposition that this 0.17% was the percentage mean of the process, a

difference of 0.142% were mistakes of failing fillings such as middle filled or not filled because of another type of defects in the filling machine. So, the 0.028% were mistakes of the normal variability of the process. The process also needs to be centred the mean 1ml to the right, because it is now in 579,1ml, avoiding fillings with less than 599ml and balancing both capabilities side, PPU and PPL.

For the company would be great if they can avoid all the rejected bottles caused by filling and at least trying to fill all the bottles inside the limits. In this case, in a batch production of 40.000 bottles the rejected bottles by this variability would be around 25 bottles, so this number will accumulate more number of bottles along the weeks.

Fig. 4.9 showed that the samples of filling for the line B were quite well-balanced with capability of $P_p = 1.15$. The process need to improve its capability to reduce the number of fillings out of the control limits. This line rejected more bottles for intrinsic variability on the filling than the other two.

The rejected bottles by filling in the line B collected during the visits was a 0.23%. For improving, the company needs to control the parameters such as speed, fitting of the neck of the bottle and the beverage system feeding to reduce the spread of the real distribution and reduced the rejected bottles.

The last analysis was the third line (Fig 4.10.). The line C has the best results, with

only 60 bottles out per million, and perfectly centred in the target 600ml. All the capability parameters were greater than or equal 1.33. This line was working near the 6σ excellence, and reaching the 5σ level. From the chart the filling machines of each line, showed that the line C was filling with a good capability and well-balanced. Line A and B need to control the parameters such as speed, fitting of the neck of the bottle in order not to lose beverage, the product system feeding and other causes could get to the process at better performance by avoiding most of the bottles out of specification.

The next step can be the reduction of the limits of specification once the processes were completely capable to perform better process quality for the product with always the same quantity of volume.

4.2.4 Controlling Extraction Force

The tools used for this control was the I-MR chart. For this control there was a difference between the control limits (UCL and LCL, Upper and Lower control limit) that were used here and the specification limits (USL and LSL) which were the limits for the company or customer quality. The control limits were dependent on the experimental data results, and the specification limits were based on the customer desire or product functionality limits decided by the company.

The first line, *Extraction Force Line A* was controlled from the beginning of

the year (Fig. 4.11). The range of the limits was indicating the *individual value* with 3 times the standard deviations in on each side, every month. This is because the objective was to have the process under control without any samples outside and any alert. The limit of the *moving range* indicates the difference between the last and the current sample, alerting if there was too much variation in two consecutive samples.

Fig. 4.12 showed that the first impression was that the process was gaining variation, if one looks at the first two months in comparison with the last months. The month of March some cause was affecting this variability on the line A. This fact was appreciated in the moving range as well, increasing the moving range of standard deviation from 9.38 to 15.76kg.

The problem of this new variability was that the limits were bigger than the desired from the company. The limits were between 20 and 40. Both limits, upper and lower were out of specification generating more defective bottles than the desired.

Regarding the alerts, the most important was the alert of April, because the two consecutive samples was with the same product on the same day, so, it was important to analyze why it was corking bad and producing defective bottles.

As a result, there was the possibility of analyze better the last 25 samples. Now, the

limits were selected by the author according to the desired values and more recently, there was no any alert in the process.

Regarding *the Extraction Force of the Line B*, the process was under control. Any alert and any strange behaviour appears during the year (Fig. 4.13.).

There were not as samples as the other lines, but the in the month of July the chart does not show unstable points. Only it was considered to check the well-balance of the line because the process was corking bad because the extraction force was more than 30 kg. The adjustment will keep the limits between the specific limits for the company between 20 and 40 (figure 4.14).

In the line C, the *Extraction Force* (Fig. 4.14) can be appreciated, the last months increases the mean because it was not centred. Along the first months of the year, the process was totally out of specification. It was true that the process was performing quite good but shifted from the required target near 30, only 2 samples were alerted by being far from the mean.

In March there was an alert of 6 points increasing the moving range consecutive. It was an alert because it was not common in a process under control. It may inform the company that some maintenance could be necessary because of the increase in moving range.

It was interesting to study what happened during May because the process achieves

excellent variation levels reducing about 33% of its standard deviation. After that, the process started to get the right way to shift the mean of the extraction force closer to 30.

At the end of the month of June the process was out of order because it changes and increase around 10 kg more and remains there for 12 samples but then, the results were placed under the mean, so the company should control in order to avoid the extraction force been shifted below the correct well-balance.

4.3. Proposed lean-six-sigma improvement

Based on the information of the company, if one wants to produce more 'lean' it is necessary to incorporate the improvements step by step. It cannot be implemented this technique directly because of the nature of the business, the idea was to try the improvement as much as possible.

The first step will be balance the production with the sales. The company has sales of 45 million bottles per year. The tendency was a rise on the Christmas time, so, the forecast for the lines were; 10million for line B, 15million and 20 million for the other two lines. The number of bottles was proportional to their working speed. Thus, 3.650.000 bottles were expected to sell in a month during the middle of the year by the three lines, which was an approximate number of 810.000 bottles for the line B (proportional to 10 from 45).

Therefore, applying the calculation for the takt time in a normal month during middle of the year, for example July, the information from the questionnaire informs about the use of 66% of the time each line. So, if a month has 22 available days of work, the 66% of the days there is production for the line B (see Appendix 1). 15days, 12 hours of available time, eliminating cleaning time and other planning downtimes were considered. Therefore, demand per day was 54,000 bottles/day, using 810,000 bottles/month.

$$\begin{aligned}
 \textit{Takt Time} &= \frac{\textit{available working time per day}}{\textit{customer demand rate per day}} = \frac{15\textit{days} \times 12\textit{hours}}{810,000} \\
 &= 0.8\textit{s/bottle}
 \end{aligned}$$

This takt time was a number easy to produce for the company due to the real data was producing less than 0.6s/bottle. The bottleneck process was the washing machine with a unit every 0.558s, so, this ‘extra time’ between the takt time and bottleneck process allows the company to sequence the production to reduce the quantity of stock to the levelling production with its benefits, enjoying that extra time for the changeover of the models of product.

As a result, the production plan could organize its production realizing more changes on the model sequence. Based on the production of 6450 bottles/h, the bottling of 54,000 bottles and including the new lead time of the first bottle until the line working stable takes 8h 36min. The available time was 12h, then, it

leaves more than 3h for the 3 model changes on the production sequence. The changeover was approximately 1hour each and time of the run- up including when the first bottles come into the processes and fill the reduced buffers were inside the time of the changeover; so, the number of possible changeover was 3 every day for this takt time, having around 30 min for solving unexpected problems.

The main step for reducing this extra lead time was through the creation of intermediate buffers. In the case that all the buffers were eliminated the reduction will be 37.7% of value added time, but the great time was in the inventory before the washing machine. Due to the palletiser speed was higher than the washing machine, the stock could be enough with 232 bottles (1 batch of the palletiser) because a bottle enters every 0.558s, but the palletiser comes out 232 bottles at the same time. It means that in 120 seconds, the washing machine will have 232 bottles more, and it still will be using the last units of the inventory. In addition, the buffers were not eliminated totally because when the control rejects a bottle that one disappears from the line, so, having a little buffer only for this expected bottles. A 10% of the space in the buffer was decided because of the possibility of the fact that some rejected bottles occur but not to slow down the speed of the line. The Packaging 4x6bottles process worked without a bottle in the buffer because this process does not need any run-up time or run-down. Therefore, reducing the

space of the buffer, the layout could be more compact thereby decreasing the movements of the operators, with fewer meters of belts between processes.

Under this scenario, the lead time can be decreased from 13min 57sec up to 837sec. It reaches the 65% of value added inside the process.

4.4. Improvement strategy for defects and rejected bottles reduction

The specific improvement strategy on the reduction of the defects was focused on the introduction of new ways for collecting data. The benefit of recording data will give them the opportunity to understand the behaviour of the rejected bottles. The bottling line has detectors to decide which bottles passed the control and which do not. It was considered the first step due to the process improvement by Six Sigma need data.

For this collection data, a template place has been designed to place next to every automatic control (table 4.6). The proposal for this improvement is formed by a simply way to collect the information and measure the number of rejected bottles in each control.

Table 4.6: The proposed table for defects collection

Control	Day	Product

	Defect 1	Defect 2	Other
Start time			
Total Bottle			
1			
2			
3			

The benefits of this new way of collecting data is that the company will be able to analyze the data as it has been done with the two attributes that the company collect data; Extraction force and Volume .

This table is an easy way for the personnel to register all the defective bottles which are rejected on all the automatic controls (Fig. 4.2.); *filling-corking, capsule, label, package weight* and even other problems that could appear on the *belt* such as broken bottles due to bad alignment because they fall or other reasons. It will not disturb the habitual tasks of the operator, so, it will not make them more extra movements for this data collection. The tasks of the line operators is also to check the rejected bottles because sometimes the sensors could fail as it happened during the visit in the capsule machine rejecting some bottles that were correct. Consequently, the operator's methodology will be to write down the number of rejected bottles on the paper each time the operator goes the check and pick the bottles to reprocess again depending on their defects.

It was considered necessary to follow a study for every product to know more details about the run-up, run-down of the process. It was just enough to fill out the information of what control, day, product, and the main defects in this control. Then, every hour control and write the time and during the hour write down the defects each time the operator goes to the control to do their task of checking. Also it was necessary to know the number of bottles produced in that hour, it would be easy to write the total number of bottles produced at that moment because all the controls show the bottles produced on the display.

The company has the opportunity of enjoying the benefits of this new information through the following ways:

- Know exactly what processes have more rejected bottles to reduce the over-processing and waste material to invest first on the most effective process.
- Find possible patrons along the time because each product is collected separately.
- Know how number of defects varies depending on the starting of the production or after periodic maintenance.
- Implementation of SPC. Run charts about the number of defects, time series plots to realize about variation along the time on the number of rejected bottles.

- Find out the optimal time for a general maintenance and overhaul of the equipment (Realizing if the defects have tendency of increasing from a specific time).
- Focus to optimize the worst machines to be more effective.
- Improve the calibrations, configurations, based on the knowledge about when the equipment is put out of order and realize it faster.
- Study what is the most efficient production speed where the rejected bottles are minor. Scatter plot (Number rejected bottles-speed) or DOE (Design of Experiments).
- More effective strategy of production comparing the three lines.
- Grouping data by shifts, model of cork, bottle, label, and others.

4.4.1. Extraction Force

In the first *Extraction Force Line A*, the variability has to be studied to reduce it and to get better capability levels because it is not enough capable to keep high Six Sigma levels so, many bottles are produced out the limits.

The company needs to fix the calibration because the historical data is 31.3 kg for this reason the naturalness of the samples are producing all of the defective bottles upper 40 kg.

When the process become better centred then, the second step will be reduction of the variability to make it capable good more than $C_p > 1.33$.

In the *Extraction Force Line B*, the methodology applied will be the same as line A. The process has to shift to the left side to reduce the force up to 30 kg because most of the bottles are out of the USL (Upper Specification Limit) of 40 kg. Then, it is necessary to have the control of all the causes that generate this variability. The movement of the samples distribution can generate a better placement of the spread of the attribute product distribution to reach higher capability results.

Finally, the *Extraction Force Line C* was not capable. Moreover, it was not centred properly, so, it needs to improve both mistakes because it was not centred and it was shifted 3kg from the expected mean around 30kg.

As a result, this line needs to solve these two problems at the same time because the shift was very considerable and the incapable cannot be allowed if the objective is the reduction of defective bottles.

4.4.2. Volume of Beverage

For the volume of filling, it was considered the same first solution as the extraction force. The increase of samples followed. The intern variability of the filling machine will not be affected by others because the 2, 3 or 4 samples followed

can be considered that work under the same conditions because there was no time for shifts.

For the volume of filling, it was considered the same first solution as the extraction force. The increase of samples followed. The intern variability of the filling machine will not be affected by others because the 2, 3 or 4 samples followed can be considered that work under the same conditions because there was no time for shifts, or changes on the machine's calibration, etc. Therefore, the expected bottles out of the specification will be very accurately.

This methodology could be implemented taking 4 following bottles every day, every hour, during a week and afterwards return the product to the filling pipe to not waste material. With this information the process can be studied perfectly and find all the causes to understand every external cause that makes the process vary more than its natural variability.

For the moment, based on the analysis of the filling of product process, the *Volume Line A* has a shift of 1ml to the low side. On the other hand, the *Volume Line B* should improve their capability and shift a bit the process to the left side (Low level) the configuration of the volume B because was filling more than the target.

The *Volume Line C* process was capable and centered. It does not need any specific change.

What was interesting for the process was the improvement of the capability. If the company finds out the relationship between the causes to know if it was more related with material, operators, configuration and setting, speed of the line or others, they could increase the capability and achieve a minimum number of bottles rejected. After achieving that, the next step will be the reduction of the control limits, step by step, to achieve a product with less variation and more units closer to the target.

This methodology can be achieved through the following:

- Control better the parameters to reduce the variability and standardizing the activities, for increasing the capability.
- If the process is shifted, readjust the configuration of the related attributes to center processes.
- When the capability is improved up to levels of $Pp > 1,5$, reduce the limits (LSL and USL) and then continue controlling the price.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The integration of Lean and Six sigma has been successfully introduced in this work as the best methodology that can be implemented in all manufacturing companies. The application of this methodology was carried out in the bottling line of the Nigerian Breweries. It was observed that the Nigerian Breweries does not specifically apply any of the two management techniques, (Lean manufacturing and Six-Sigma). Therefore, it was possible to optimize the bottling line and all the involved activities by the Lean-six-sigma techniques.

Based on this fact, the principle issue that appeared at the beginning of this study was the lack of data from the bottling processes. There was no proper information on the processing times, efficiencies, number of rejected and defects bottles occurred per period. As a result of this the bottling lines were not optimized as they could.

The bottling production apparently runs good, but from the lean-six-sigma view there were wastes hidden that should be reduced. In the real processes there were wastes related with extra waiting times in the buffers, big raw materials inventories, overproduction, reprocessing and defects in bottles as a main

problems. These information were collected by the author from the laboratory of the company. It was also observed that the company do not analyze data using statistical tools, therefore it was impossible to know the behaviours of the processes and why the processes were having accidental variability.

The result of the analysis showed that the variation of the processes was fundamental. These variables were controlled in order to avoid excessive products out of specifications using statistical tools.

A new methodology was developed to collect data based on the control of the number of rejected bottles and defects. The data collected about defects in each bottling line, the result showed that line A has more rejected bottles in the filling processes, while line B had more rejected bottles in corking and capsule processes. Considering the data provided by the laboratory of the company, the result from the extraction force analysis showed that the three bottling lines were haven more variation than desired if they want to get a low number of defects. The first result suggested that the company has to pay attention because the processes were not within capability; even line C was not capable. Because not all the bottles can be checked, the capability of line A was 3.4% and line C 3.7% of bottles were out of specification. Line A shifted to the upper side with expected defect of over 40kg and line C shifted to lower side with most of the defects under 20kg.

The second variable considered in this work was the volume of product (beverage) filled in the bottles and the three bottling lines capability. The result showed that bottling line A experienced deviation of 1ml in the filling which should be controlled to avoid rejected bottles. In line B, the main problem was the spread of the distribution although there were more expected bottles out of the upper limit. The defectives bottles in the filling processes do not continue in the line. They were reprocessed again, carrying out their tasks and putting the bottles again at the beginning of the stage. The result of the capability process has showed that the methodology of collection of samples should change for a better statistical analysis.

5.2 Recommendations

The DMAIC cycle is a continuous improvement philosophy, so once the improvement would be developed, implemented and controlled, if the processes reached the right values, it will mean that the causes were detected and were well implemented. To detect these causes and control them, the process must be capable. To achieve reduction on the variation to be under control, therefore, the following recommendations were made:

1. The specification limits should be reduced in order to increase the quality in the product variables and to continue with the cycle again. It could be that

the processes change to worse or different scenarios. In all cases, the cycle will start again, defining the new situation.

2. The application of adequate techniques and statistical tools for data analysis. These will help for the business excellence, with the best savings, less waste and high quality output.
3. The management should encourage all the employees when new changes are to be implemented. All of them need to put their efforts on the aims of the company in order to reduce defects, time or mistakes and so on.
4. The spirit of continual improvement has to be promoted by the company and top managers to persuade the whole organization. It will get the greatest saving costs when the improving changes would be assimilated and applied properly and continue the cycle again not to lose the improvement spirit.
5. The application of 5S methodology to reduce waste in operators' time in the activities avoiding some of the future mistakes or confusions in their tasks in all processes. The technique would focalize on the facilitation of the operators recognition and sorting of the tools used for their activities.

5.3 Contribution to knowledge

From company's annual production report it was observed that the company does not specifically apply lean six-sigma in any of the activities in the bottling line. This made it difficult for the company to actually ascertain the number of

defectives and rejected bottles, information about processes times and efficiencies. This work has be enable to optimize all the activities involved in the bottling lines using lean six-sigma techniques. However, a new methodology has been also developed to collect data based on the control of the number of rejected bottles and defects. This methodology will equally help to reduce waste in operators' time in the activities avoiding some of the future mistakes or confusions in their tasks in all processes.

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Appendix 1.

QUESTIONNAIRE

Table 1: General information about the lean-six-sigma methodology

Question	Rank (0 to 100%)
At what percentage does the company implement Lean manufacturing or Six Sigma procedures	
At what percentage does the company use some continual improvement techniques?	
At what percentage does the company have some waste reduction plan in the processes?	
At what percentage does the company implement variability reduction strategy?	
At what percentage does the company implemented some quality projects in the past	
At what percentage does the company use some continual improvement techniques?	
At what percentage does the operators have notions about Lean or Six Sigma?	

Table 2: Communication, Involvement and employee's skills

Question	Rank (0 to 100%)
At what percentage does the employee suggest improvements for its workplace and job?	
At what percentage does the employees know about the managerial objectives of the company?	
At what percentage does employees of the operation line know	

about the number of bottles needed to produce?	
At what percentage does they know about improvement strategies of the process?	
Does the operation line employees have the skills to fix a problem in the operation line at the same moment? At what percentage	
Does the equipment have some devices to detect when the bottle is in the process or when is not? Example: To not fill a place without bottle. At what percentage?	

Table 3: Voice of the Customer VOC

Question	Rank (0 to 100%)
At what percentage does the company received feedback from the customers?	
At what percentage is the customer opinion about the reliability of the products?	
At what percentage is the customer satisfaction?	

Table 4: Bottling Process

Question	Rank (0 to 100%)
Is there a continuous flow inside the bottling? At what percentage?	
Is there continuous flow with the input and output (after the previous stage, with the distributor or client)? At what percentage?	
What is the percentage of bottleneck in the process?	
At what percentage does the bottling line have “buffers” inside the production line?	

What percentage of the good deliveries is on time?	
Is the production of a finished bottle stored in the company waiting for the customer's order? At what percentage?	

Table 5: SPC (Statistical Process Control) from Raw material supply to the bottle (Quality Control)

Question	Rank (0 to 100%)
At what percentage does the company implement SPC for controlling the processes?	
What percentage of the processes is with SPC	
At what percentage does the company have recordkeeping data of the processes?	
At what percentage does the company register time about the bottling process?	
At what percentage does they take samples to control the final quality of the products?	
At what percentage does the company works with descriptive statistics (mean, standard deviation, data distribution)?	

Appendix 2. Control chart information

I-MR Chart of Extraction Force A by Month

Test Results for I Chart of Extraction Force A by Month

TEST 1. One point more than 3,00 standard deviations from center line.
Test Failed at points: 39

TEST 5. 2 out of 3 points more than 2 standard deviations from center line (on one side of CL).
Test Failed at points: 64

TEST 6. 4 out of 5 points more than 1 standard deviation from center line (on one side of CL).
Test Failed at points: 31

Test Results for MR Chart of Extraction Force A by Month

TEST 1. One point more than 3,00 standard deviations from center line.
Test Failed at points: 8; 39

* WARNING * If graph is updated with new data, the results above may no longer be correct.

I-MR Chart of Extraction Force C by Month

Test Results for I Chart of Extraction Force C by Month

TEST 1. One point more than 3,00 standard deviations from center line.

Test Failed at points: 31; 97; 144; 150

TEST 2. 9 points in a row on same side of center line.

Test Failed at points: 82; 83; 84; 141; 142; 143; 167; 168; 169; 170; 171

TEST 5. 2 out of 3 points more than 2 standard deviations from center line (on one side of CL).

Test Failed at points: 17; 56; 57; 84; 97; 100; 101; 115; 152

TEST 6. 4 out of 5 points more than 1 standard deviation from center line (on one side of CL).

Test Failed at points: 57; 97; 102; 103; 151; 152; 153; 155

Test Results for MR Chart of Extraction Force C by Month

TEST 1. One point more than 3,00 standard deviations from center line.

Test Failed at points: 144

Appendix 3

Table 3. Summary of the data obtained through questionnaire

Description	Percentage value (%)
Implementation of Lean manufacturing or Six Sigma	0
Consideration of waste	
1. Overproduction	90
2. Operators movement	88
3. Overprocessing	85
4. Inventory	5
Communication network	
Employee's involvement in decision-	45

making	
Employee's skill	30
Jidoka, application	60
Modern devices	80
customer satisfaction	93
bottleneck in the process	
1. Washing	95
2. Filling	5
3. Corking	5
4. Labelling	5
5. Encapsulating	5
	89
Implementation of SPC	0
Available time data for the bottling process	0
Defects/mistakes in the bottling production line	
1. broken bottles	15
2. placement of the labels	89
3. quantity of liquid filled	90
4. bad cleaning of the bottles	5
5. bad fitting of the caps	88
6. operator's mistakes	20
Defect rate in the bottling process line	0.621 (4sigma)