

Integration of Lean Manufacturing And Six Sigma Using Statistical Methods

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Abstract: *This research integration of lean manufacturing and six-sigma was carried out in the Nigerian Breweries Enugu Plant where management strategies were not so developed. The main objective of this work was focused on the minimization of the line wastes such as time, over-processing, over-production or defects. The DMAIC (Define-Measure-Analyse-Improve-Control) was the methodology used for the identification of compatible lean techniques and strategies for the reduction of defects and rejects bottles in the company. Data were collected and analyzed using statistical methods. The result showed the production line A rejects 0.37% of the produced bottles against 0.23% of the production line B. This showed that production line A rejects one bottle in every 271 bottles against one bottle from 435 bottles in the production line B. The result also showed that minimum and maximum value for extraction force were 20 and 40kg. Though the great time was in the inventory before the washing machines, 37.7% reduction in value added time was achieved through elimination of buffers. The problem of line A was placed on the Filling-Capsule machine which put a crown type cap and works without cork. However, the 2 defects on the Labelling (Line A) were found at the beginning of the batch production and it was the moment that appears more problems to set the new label bovines of the new product. The actual situation of the bottling line was represented where the main flow material were the bottles of beverage, though other raw materials were also necessary for the line to produce the final bottle, the bottles flow involves the quantity of other raw materials necessary because each bottle needs one cap, two labels, a box for either 12 or 24 bottles. Thus, the line production suffers some stops and for this reason the uptime available was less than 100%. Only the washing machine was working all time because the configuration and it was the bottleneck with the minimum speed (6450bot/h) and the highest Takt production time (0.558s/bottle). The Lean Six Sigma integration proposed in this work was supported by an extensive literature of most of the techniques involved in both management philosophies. Proper strategies were developed and proposed in this work. Thus, this work had provided solutions for capability and control of processes and other little changes for the company and recommended application of the outcome of this work to other similar sectors.*

Key word: *Lean manufacturing, Six-Sigma, waste, inventory, value added*

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I. Introduction

Nowadays, 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 offering to them what they are expecting. Moreover, the companies must upload their management techniques to be able to compete with their rivals, get better performance to do their best for their customers and improve every day.

Lean manufacturing and Six Sigma, which currently are together a unique management strategy called Lean Six Sigma, 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.

As the literature of the thesis explains accurately, 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 become together the business excellence for its complementation.

The challenge of this project is the connection of Lean Six Sigma in the Nigerian Breweries because 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 creation 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. To achieve the best high quality and value for the product, the final bottling phase has a lot to say because it is in the bottle where the beverage reaches the clients. This last phase has to be treated with the same attention as the creation of beverage.

1.1 Lean Manufacturing

The term “lean” defined by Oxford English Dictionary in a general definition means; “thin, especially healthy so, having 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 production and is directly descended from the Toyota Production System (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 autonomation (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 p. 13).

Lean production is generally defined with two different points of view. The first one is the philosophical perspective which seeks the leading principles and the achievement of the goals (Womack, et al., 1996), and the second one refers to the practical side related with the management practices, techniques, tools that the company can monitor directly (Shah, et al., 2003).

More recently, it can be found newer definitions. One of these it relates to the two different points of view in the last paragraph; “Lean production is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability” (Shah, et al., 2007). Sociotechnical system refers to any practical implementation of the interrelatedness of ‘social’ and ‘technical’ issues to take care about people, society, machines and technology. All of this is integrated in the organization with the employee’s participation (Walker, et al., 2007).

Nowadays critics have not found better management alternatives to the lean production and it is accepted that “lean production will be the standard manufacturing mode of the 21st century” (Rinehart, et al., 1997).

1.2 TPS in Lean Manufacturing

The beginning of this production system started in the early of the 20th century. There were two different kind of manufacturing, the American and the Japanese system. In the American system, F.W. Taylor and Henry Ford formalized and structured the concepts of mass production which had started in the last years of the 19th century with the production of armament in EEUU and steam vapor in Europe. F.W. Taylor began to take care of workers and their work methods (Villa, et al., 2009). Henry Ford was focused on the improvement of the efficiency and productivity and Ford Motor Company created a line worker factory. With this thoughtful H. Ford was thinking in the reduction of wasteful aspects. Ford’s mass production put into action the basics in the organization based on the scientific method to process, standardization, inventory, cycle times, teams, people, movements (Zarbo, et al., 2006). Afterwards, Henry Ford executed the first mass productions, with products normalization, the use of elementary machines for one task and sequences. On the other hand, there was the Japanese system. After the Second World War, the Japanese manufacturers encountered with problems about lack of suppliers, materials, financial and human resources. It was when the lean manufacturing concept appeared (Womack, et al., 1990). Early on, Kiichiro Toyota, the President of Toyota Motor Company admitted that American auto production were producing ten times more than them. American production was focused in a mass production; on the other hand, the Japanese produced many types of cars in small quantities (Zarbo, et al., 2006). Toyota knew that they did not enjoy the economies of scale of Ford or General Motors, so, Shingo Shingo and Taiichi Ohno. Ohno developed a new management system which was supposed by the Japanese that H. Ford might have implemented to achieve this production. This management system was the Toyota Production System (TPS) (Ohno, 1988). According to Ohno, the main goal of TPS is the cost reduction and the waste elimination, and it needs the quality control, quality assurance, and respect for humanity. He recommends the manufacture of the units needed, at the time needed of the kind needed. In this new system, Ohno values two basic pillars as it JIT and autonomation. Firstly, the Just in Time in Toyota changes its way of producing and decided to produce small batches manufacturing every one unit at the right time instead of forcing mass

production of the same product in large quantities. Besides, others ideas were to reduce the changeover times or setups to improve the continuous production flow, because it supposed a better reaction time to the market demand (Zarbo, et al., 2006). The JIT production included in the TPS was defined with the last two ideas based on the notion of eliminating waste through simplification of manufacturing processes such as elimination of excess inventories and overly large lot sizes, which cause unnecessarily long customer cycle times (Flynn, et al., 1995). As a second pillar, Ohno includes Jidoka, which can be translated as an “automation with a human touch” and it is the notion of stopping immediately the equipment when a problem occur to do not continue producing a defective product and it includes a role for the workers (see 1.5.8.). Ohno found out that stopping the production line to solve the problem improved the performance in long run. Thus, Jidoka gives to the operators the power to stop when it is necessary “human intelligence” or thanks to sensors in the machinery. (Ohno, 1988)

In conclusion, the JIT technique and Jidoka are the base for this new discipline called today “Lean Manufacturing”.

1.3 Types of waste and value added

Most of the principles explained before are good intentions and also are included in the business industries, but, it is necessary to know how to develop them. For this reason, with Lean Manufacturing they ought to analyze and measure the efficiency and productivity in the company with ‘waste’ and “value added” terms.

The ‘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 contrast, value adding activities cannot be defined as a waste. These activities make the product being what the customer is expecting. In other words, value adding activities transform inputs like materials or information to another superior state which is a customer requirement (Alarcon, 1997).

Regarded Ohno thinking, the present capacity is the work plus the waste. So, it is necessary to reduce waste to achieve the 100 percent of the 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 usefulness movements due to a bad workshop situation.
7. *Making defective product*: appears when the final or intermediate product does not achieve the requirements. More recently, it has appeared a new one ‘waste’ after the 7 main wastes of Ohno;
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).

In the manufacturing process the main aim is to transform the inputs into outputs adding some extra value which the customer is willing to pay for it.

II. Research method

The author had the chance to meet with the Director of Production and Quality and to visit more accurately the bottling lines of the company. So, the first step was the creation of a questionnaire focused 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 all areas from the grape growing to the customer delivery of the final product.

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 is the philosophy, procedures and objectives of Nigerian Breweries Enugu Plant.

Afterwards, the procedure was to make a visit of the bottling plant, which included the beverage storage tanks, next to them, 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 answered, 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 could be answered and more information was written down. The processes and all the machine roles were totally understood. They showed to the author how they collect data for some processes and the procedure of the samples. Moreover, it was possible to take some pictures for a posterior checking.

In the second visit, the author spent time on the bottling plant, following more accurately the processes in the line. The first step was to find out the best ways to collect data, looking at the machines layout, the point of defects occurrence, the speed of the processes, 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, during a couple of hours, the author was collecting data of 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 from all displays of the machines about the bottles per hour produced, registered the number of intermediate stock, talked with operators about any doubt and ask them about the number of defective bottles produced in some control.

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

Besides, the personnel of the laboratory department prepared to the author the data of the 'extraction force of the cork' and 'volume of beverage' which are measured accurately in the laboratory beside other attributes of the bottle. This data was the only one they control from the bottling processes. There were other control but without recordkeeping data, only to know if the step was correct or not.

2.1. Six Sigma structured improvement procedure

The Six Sigma improvement procedure is a method structured based on the continual improvement of the PDCA cycle. As it was explained before, the Six Sigma method is more detailed, it has specific quality tools to implement in each step, which are exclusive for the Six Sigma. The methodology follows the DMAIC (Define, Measure, Analyze, Improve, and Control) procedure. (Linderman, et al., 2003). This method is always seeking the excellence and trying to reduce the defects and all of the Six Sigma aims. It is found that with this procedure there is always a desire to find the cause root of the problem based on the DMAIC. The method uses some standards quality tool such as cause-and-effect diagram, statistical process control (SPC), Pareto or Control charts, benchmarking (Breyfogle III, 1999).

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).

Thank to these roles, the methodology creates a common language in the company. It is a problem-solving mentality.

III. 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, the author could understand how the company works.

The demand per year is around 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. Moreover, the company has an in-house laboratory to analyze faster, than other breweries that needed to hire the services of external laboratories which may take 2 to 3 weeks for the results to be ready. That benefits on the ability to react to the problems in the biological and chemical parts of the beverage.

3.1. Defects and rejected bottles data.

The second interest was to collect information about the rejected bottles. Based on the improvement of the quality in the company, the reduction of rejected bottles involves an improvement on this issue. The idea was to know what control rejects more bottles to pay attention on that defect. The defects that occur more often, obviously, are more interesting for the quality improvement and to create a more robust product, which means the product tries to be always with the same quality. The strategy was to focus on the main mistakes before others that are working well currently.

During the visit, the first defects collected were in the production line A for schedule production reasons. After this time the line stopped its production, so, the author collected data during 3500 bottles. The line A usually works at 10.000 bottles per hour.

This line was different from the line B, because line A was producing thread bottle type those days, for this reason the study will be different for each line.

Table 3.1 Defects of the rejected bottles/cans on data registered. Source [Author].

Day	Line	Defect	Place	Defect_LineA	Defect_LineB	Defect_B_day1	Defect_B_day1
1	B	Capping	Control 1B		Fallen bottle	Fallen bottle	Fallen Cans
1	B	Filling	Control 1B		Broken bottle	Broken bottle	Cans Leakage
1	B	Capping	Control 1B		Filling	Filling	Filling
1	B	Filling	Control 1B		Filling	Filling	Filling

In line B, the author collected data during two days. The first day, the defects and rejected bottles were studied during the production of 6200 bottles, and the second day, during 9000 bottles. The line runs at around 7000 bottles per hour theoretical speed, but the final performance was less due to the buffers between machines, stoppages, breakdowns and other unexpected problems. It was programmed close to 7000 bottles/h although it has power to run at 8.000 bottles/h, it depends on the planning of the day and they can select the best for their production.

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. On the same way, it was important to control where the defect was found because it could put out of order ting or in the electronic sensors problem. These control are 4 in the line 4; *Control1B* (Volume and Caps), *Control2B* (Cans), *Control3B* (Label), *Control4B* (Weight) (see Fig. 3.3.) and also some defects occur on the *Belt* between processes.

Table 3.2 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	0.37
Defects (%)	46.15	23.08	15.38	15.38	100

Table 3.3 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	0.23
Defects (%)	20	22.86	37.14	20	100

Table 3.4. Percentage of bottles rejected in Line B (day 1)

LINE A (6200 bottles) day1 6940b/h	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 3.5. Percentage of bottles rejected in Line B (day 2)

LINE A (9000 bottles) day2 7155b/h	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

3.2. Laboratory registered data

Regarding the information stored from the laboratory and its collaboration, it was possible to have access to data related with the bottling line process. As it has been mentioned, the plant has data about only some attributes that they analyze in the laboratory; extraction force of the cap (Kg), oxygen (mg/l), vacuum (pressure), liquid volume (ml) of product in the bottle. Of course, all these values were linked with their type of product and so on.

Table 3.6 Data provided by the brewery. (Source: Nigerian Breweries Enugu).

Line	Product	Description	Bottle volume (ml)	Cap (Cork) Type	Extraction Force (Kg)	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
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Table 3.2 showed how the database was provided by the company. The database of the study was all the data they manage from the beginning of the year 2014 to the end of July of the same year. It can be helpful for the company if they were interested in the improvement of the quality of these variables due to the data base was nearby 400 samples and the study can follow along many samples depending on their behaviour. 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. 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 if the process under control, able, 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.

IV. Result and Discussion

4.1. Result

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) Source: [Author]

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) Source: [Author]

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 A (6200 bottles) day1 6940b/h	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 A at day 1

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

LINE A (9000 bottles) day2 7155b/h	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

Table 4.5 showed Extraction Force basic statistics by Type of Cork

Table 4.5. Extraction Force basic statistics by Type of Cork Source: [Author]

Descriptive Statistics: Extraction Force

Variable	Cork Type	N	N *	Me an	SE Mean	StD ev	Minim um	Q1
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Extraction Force	Crown	41	0	28.512	0.88	5.671	15.000	25.000
	Crimped	288	0	28.417	0.295	5.009	15.000	25.000
	Screw	45	0	25.500	0.641	5.425	15.000	25.000
Variable	Cork Type	Median	Q3	Maximum				
Extraction Force	Crown	29.00	30.500	41.00				
	Crimped	28.00	32.000	44.00				
	Screw	28.00	31.000	40.00				

Table 4.7. Volume of beverage basic statistics by Line Source: [Author]

Descriptive Statistics: Volume

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

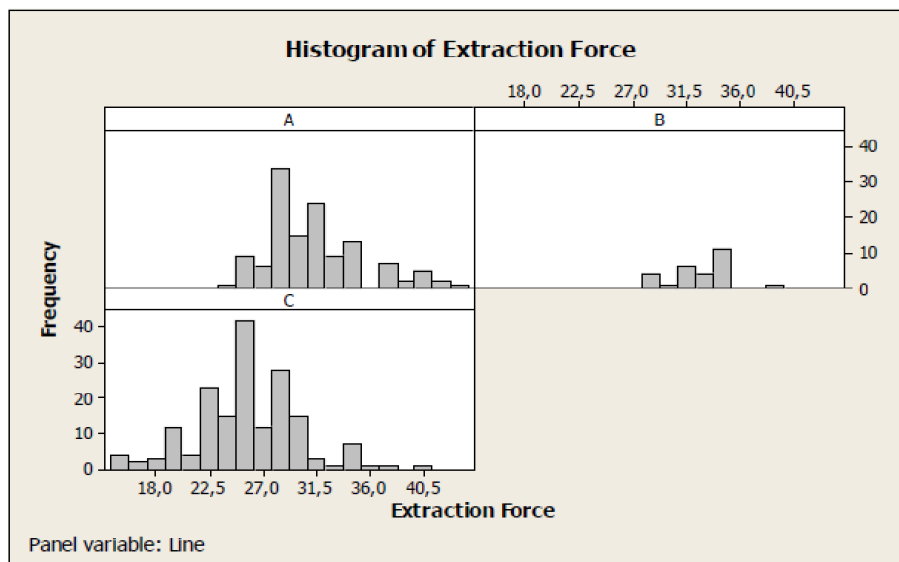


Fig. 4.1. Histogram of Extraction Force categorized by lines. Source: [Author]

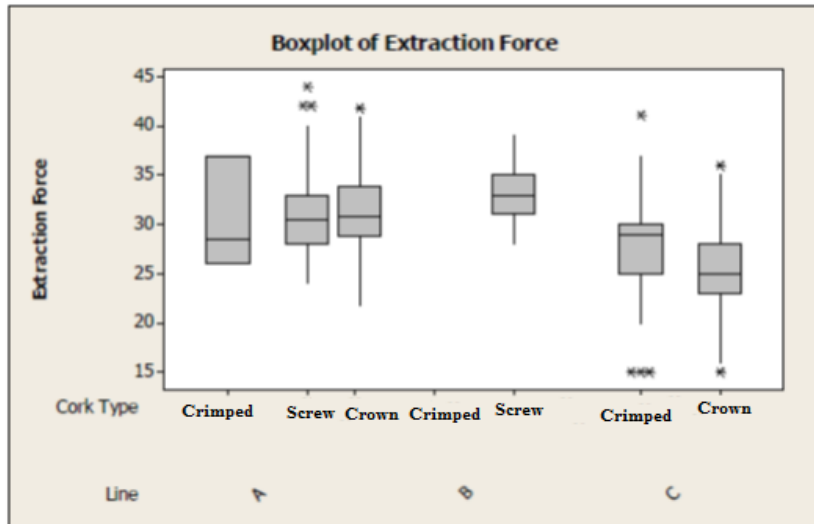


Fig. 4.2. Boxplot of Extraction Force categorized by lines and cork type. Source: [Author]

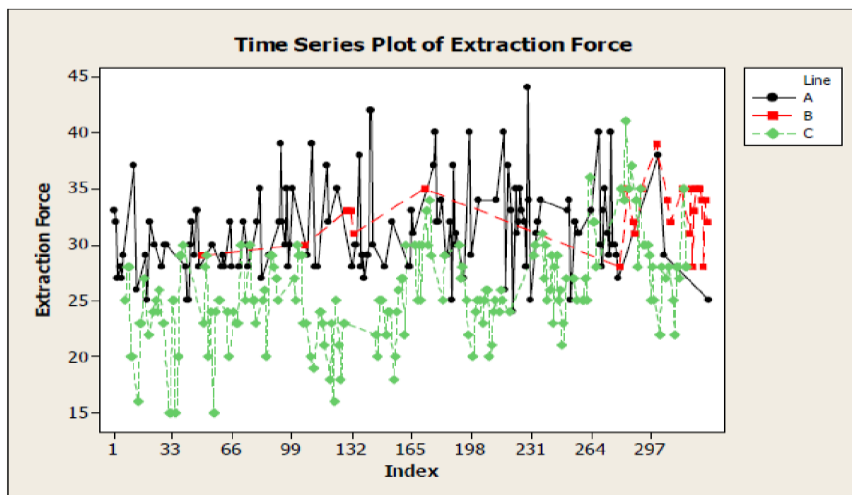


Fig. 4.3: Time Series Plot of Extraction Force categorized by lines. Source: [Author]

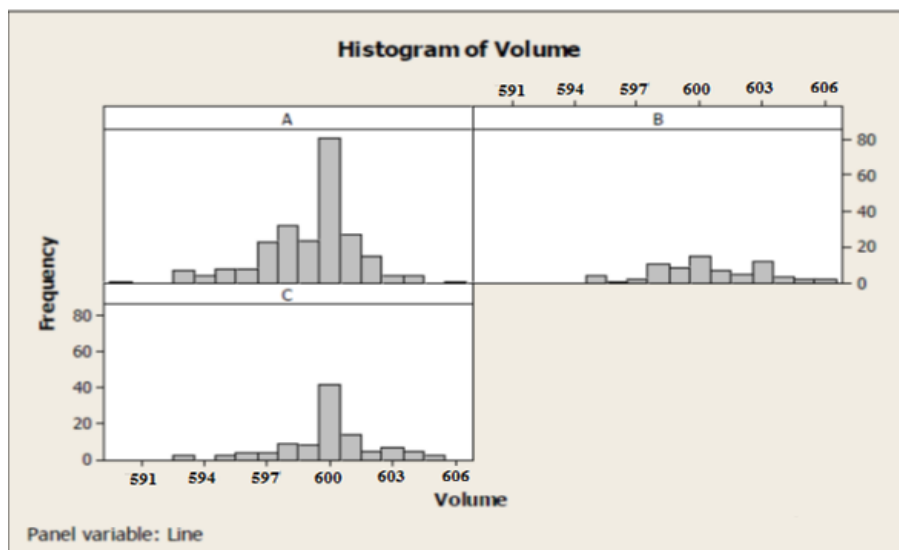


Fig. 4.4: Histogram of Volume of filling categorized by lines. Source: [Author]

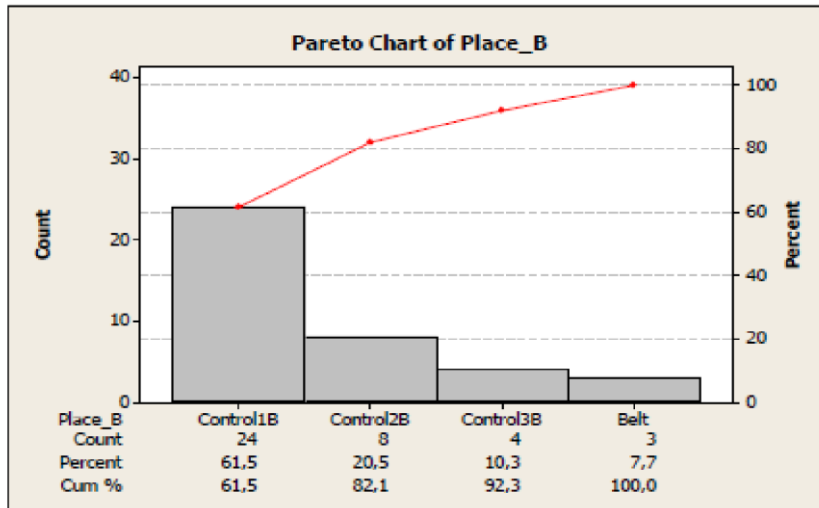


Fig. 4.5. Pareto Chart of rejected bottles depending on the control place of the line B. Source [Author]

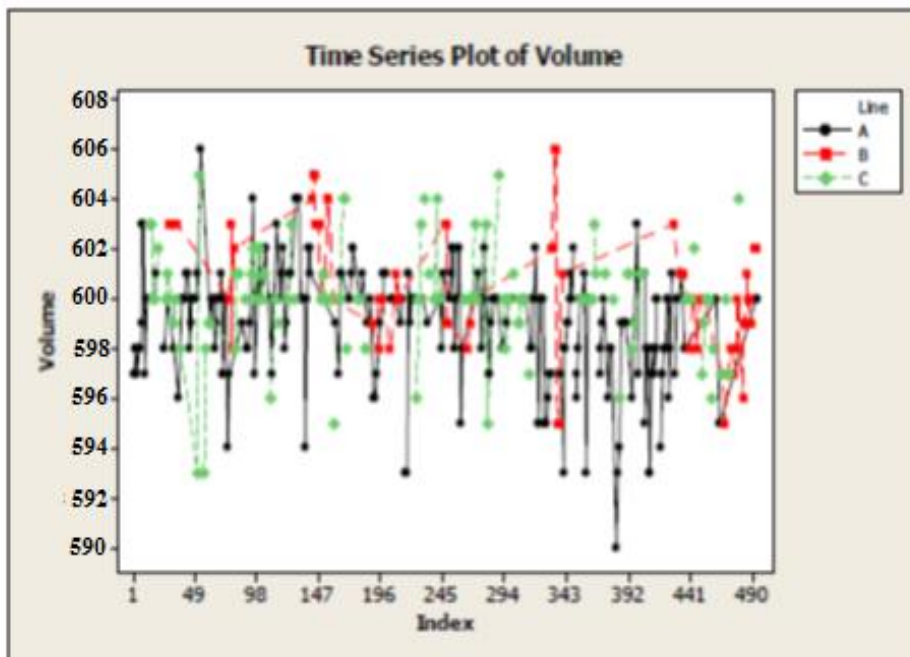


Fig. 4.6. Time Series Plot of Volume of beverage by Line Source [Author]

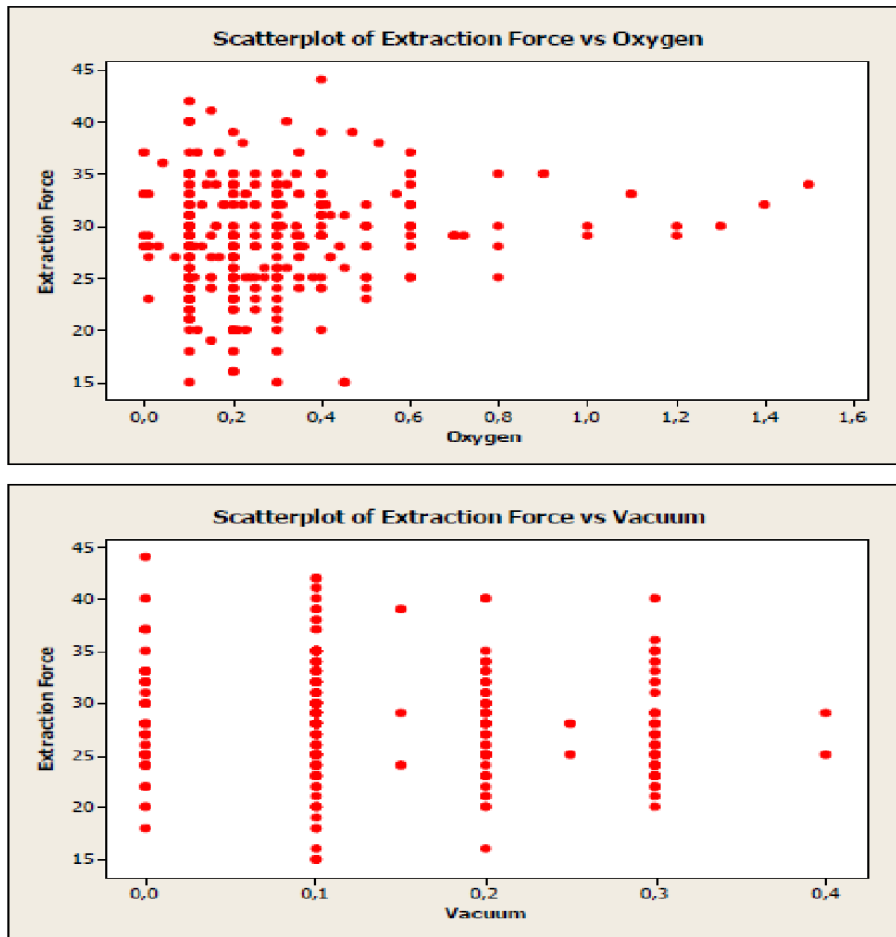


Fig. 4.7. Scatterplot Extraction Force vs Oxygen and Vacuum Source [Author]

4.2. Discussion

4.2.1. Defects and rejected bottles measurement

If we compare the rejected bottles of the two table 4.1 and 4.2, the line A rejects 0.37% of the produced bottles against 0.23% of the line B. This difference means that line A rejects one bottle every 271 bottles against 1 from 435 in the line B. This fact can be explained because the line A has more power and usually runs at more than 1000 bottles/h. The other reason was that the bottles were filled a model of 1200ml instead of 600ml in the line B, due to the planning production of the day.

Regarding the line A the problem was placed on the *Filling-Capsule* machine which put a crown type cap and works without cork. This line (line A) was installed more recently, though with make more mistakes than the line B. However, the 2 defects on the *Labelling (Line A)* where found at the beginning of the batch production and it was the moment that appears more problems to set the new label bovines of the new product (see figure 4.5). 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 bovine to produce another new bottle until the bottles were correctly performed (see figure 4.6).

Figure 4.7 showed that in line B, the problem was focused on the *Corking, Capsule and Filling*. The bottles detected were mostly in the first control (Control1B), Filling-Corking machine. Likewise, the Capsule machine (Control2B) produces sometimes some bottles without capsule but these three machines do not waste the material due to the operators move the bottles to the proper place to reprocess the bottle. The waste of the line was focused on the generation of over-processing of some bottles for the mistake of the processes. 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. What one can understand was that in this line the three defects that the company has to pay attention to reduce the over-processing were the three steps that generate more rejected bottles; Corking, Capsule and Filling, in that order.

The defects that show more difference were the Filling and Corking. It appears a reduction the second day more than 36% the number of rejected bottles (%bottles). 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. 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. Table 4.5 showed that the crimped was not so used by the company like the crown option due to the number of samples. The crimped cork has more standard deviation than the other two, but there were no significant differences in the mean. Figure 4.2 showed the Boxplot chart tries to represent the difference between the corks on the Extraction Force. Table 4.7 showed ANOVA result of the three cork types, p-value was $0.911 > 0.05$. The evolution along the time was showed in the Figure 4.3. There was stratification by lines and a general idea about the changes along the time. The line C was centring better in the last samples because it was producing defective bottles at the beginning of the year.

4.2.3. Volume of product data

Table 4.7 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 figure 4.4 with the basic statistics of table 4.7., 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.

Figure 4.20 showed that the time series plot has a good process of filling but sometimes some samples were far from the target, which generates the wide spread on the lower side.

4.2.4. Current Value Stream Mapping (VSM)

The best way to recognize the waste was through the VSM which it can be seen in the Appendix 1. Appendix 1 showed that the actual situation of the bottling line was represented where the main flow material were the bottles of beverage, though other raw materials were also necessary for the line to produce the final bottle, the bottles flow involves the quantity of other raw materials necessary because each bottle needs one cap, two labels, a box for either 12 or 24 bottles. So the whole stock management was organized. The first interesting value was the difference between the lead time of a bottle and the real added time value. This value added was referred to the processes where the bottle received an activity with added value on the final product. Result that 32mins from the lead time were not value added activities. However, the result showed that only 28.2% was value added time, while other time was not generating value. This showed that the non-value added time could be eliminated with lean techniques. For instance, the palletiser was not included in this value added time because the activity does not give anything for the product but it was a process that cannot be excluded. The bottles arrive from the warehouse in pallets of 1624 bottles and in each cycle time 232 bottles were introduced into the line. All the other processes were considered part of the product because without them the product is not the same, so, they contribute to increase the value of the product.

Thus, the line production suffers some stops and for this reason the uptime available was less than 100%. Only the washing machine was working all time because the configuration and it was the bottleneck with the minimum speed (6450bot/h) and the highest Takt production time (0.558s/bottle)

V. Conclusion

The Nigerian Breweries does not specifically apply any of the two management techniques, Lean manufacturing or Six Sigma. Therefore, the bottling line and all the involved activities might be optimized by the Lean Six Sigma thinking. There was lack of information of processes times, efficiencies, number of rejected bottles and defects occurred. The bottling production apparently runs good, but from the Lean Six Sigma view wastes were hidden and that should be reduced. In the real processes there were wastes related cases with extra waiting times in the buffers, big raw materials inventories, overproduction, reprocessing and defects in bottles as a main problems. These information that could be collected by the author, the laboratory information and the three objectives were defined. In July, it was 4 products per day and reduction of the batch size. These changes improved the lead time by 56.6%, reduce the final stock and raw material inventories and optimize the resources. The variation of the process was fundamental. By controlling these variables helped to avoid excessive products out of specifications. Consequently, the Nigerian Breweries do not analyse data by statistical

tools, so, they do not know the behaviours of the processes, variables, and it was quite impossible to find accurately why the processes were having accidental variability, and not only the natural variation.

However, a new methodology to collect data based on the control of the number of rejected bottles and defects was proposed. A Lean Six Sigma project could be developed working with enough information to do more statistical studies along the time to find out some possible patrons in the behaviour. Data collected by the author from Nigerian breweries showed that about defects, the line A was having more rejected bottles, in particular the *Filling* process. Apparently, it could be the bottle or the speed of the line, for this reason a detailed collection of rejected bottles might help the company to find out the reasons. In the line B, *Corking* and *Capsule* processes generate more rejected bottles.

In the case of the variables of *Extraction Force* of the Cork and *Volume of beverage*, the Brewery collects data of many attributes, but only one sample each time. This fact makes more difficult the study of the variability because there are not consecutive samples in which the variation in the values must be just the natural variation of the process. Regarding the data provided by the laboratory of the Nigerian Breweries, the conclusions that can be deducted from the Extraction Force is that the three bottling lines are having more variation than the desired if they want to get a low number of defects for this reason. In a first solution, they have to pay attention because the processes are not within a good capability; even the line C is not capable. Because not all the bottles can be checked, the analysis of capability expects in the line A was 3.4% and line C 3.7% of bottles out of specifications because, the line A is shifted to the upper side expecting most of the defects over 40 kg and the line C the opposite, is shifted to the lower side, with most of the defects under 20 kg. Besides all the deductions and proposed solutions, this works could help other researches and future studies in the manufacturing sector. Lean Six Sigma is related with other phases of the beverage such as the growing and laboratory work before bottling and also transporting of the beverage. It is based on some other case studies and companies which are already applying Lean Six Sigma projects in their operations.

Thus, this work had provided solutions for capability and control of processes and other little changes for the company and recommended application of the outcome of this work to other similar sectors.

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