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The Application of Lean-Six-Sigma Methodology in the Manufacturing Sector: A Case Study of Nigerian Breweries

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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, operation systems and management strategies which were not so 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 statistically. Three production lines (line A, B and C) were considered and data were collected in each production line. DMAIC methodology was used for identification of compatible lean techniques and strategies for the minimization of defects and rejects bottles in each production line. The statistical tools used for the analysis of data obtained were histogram, box plot, pareto-charts, one-way ANOVA, cause-effect diagram and control charts. The result obtained 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 capsule machine produced some bottles without capsule. Line A and B were well centred between the limits 20 and 40kg while line C shifted to the left with more samples under lower specification limit of 20kg. The result obtained from scatter plot chart showed the possible relationship between the variables of oxygen and vacuum based on 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 expected defects in overall performance 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 actives, 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 through elimination of buffers. The cause-effect diagram provided the main priorities to control and solve the problem of number of defects in each production line. However, this work had provided the necessary tools and techniques needed to eliminate product and time wastes in any manufacturing company. The study recommended the adoption of the output of this work to other similar company.*

Keyword: *Six sigma, lean, DMAIC, cause-effect, capability*

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I. Introduction

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. 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.

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 (Welch, 2005).

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 (Walker, etal.,2007).

Leanterminsidetheindustrywascreatedbyaresearchgroupwhichwantedto reflect both the idea of the Toyota production System and to compare with the mass production of theAmericansystem.(Womack,etal.,1990).Likewise,itrefers tolean manufacturing or lean production and is directly descended from the Toyota Production System(TPS)(Shah, etal.,2007).

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, etal.,1996),and the second one refers to the practical side related with the management practices, techniques, tools that the company can monitor directly(Shah, etal., 2003).

More recently, it can be found newer definitions. One of the se 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 con currently reducing or minimizing supplier, customer, and internal variability"(Shah,etal.,2007). Socio technical system refers to any practical implementation of the inter relatedness of'social' and 'technical' issues to take care about people, society,machinesandtechnology.Allofthisisintegratedintheorganization with the employee's participation(Walker, etal.,2007).

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 (Uzorh, et al, 2018).

1.1 Description of the company

Nigeria Breweries Plc was incorporated on 16th November 1946 as Nigeria Breweries limited. Its tarted production on June 1949, when the first bottle of star lager beer rolled off the line in Lagos. This was followed by Aba Breweriesin1957, 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 brandstomeettheneedsofidentifiedviablesectorsinthemarket.Inthebidtoachieveitscorporate 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 productsarecurrentlypositionedtowardsthisends,thecompanyhasidentifiedthatthereisneedtostrengththe existing brands by communicating to its customers in clear terms, those qualities which the company claims for itsproducts.In1982,IbadanBrewerieswasestablished.InSeptember,1993,thecompanyacquireditsfifth Brewery in Enugu State. Amabreweries is the largest brewery as well as the sixth brewery in Nigeriaan done of the most modern brewery worldwide operation in the old Enugu Brewerieswered is continued in 2004, while that breweriessited in Ama Eke Along Ninety Miles in Enugu state was christened Ama Breweries.The company acquired a malting plant in Aba in2008.

In October 2011, Nigerian Breweriesacquired majority equity interest in Son a system Associations Business Management Limited (SonaSystems) and Life Breweries Limited from Heineken N.V., This followed Heineken's acquisition of controlling interest in five breweries in Nigeria from Son a Group in January 2011. SonaSystemstwobreweriesinOtaandKadunaandLifeBreweriesinOnitshahavenowbecomepartof 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 port folio of high quality brands, including:

- Star lager (launchedin1949), Pale lager
- Gulder lager (1970) pale lager
- Legend ExtraSt out (1992), 7.5% ABV extrast out
- Heineken Lager (June1998), premium Lager
- Goldberg Lager (Become part of NBfamilyinOctober,2011).
- Life continental lager (become part oftheNBfamilyinOctober,2011).
- Malt in a(1976), in three varieties namely, Malt in a classic, Malt in a straw berry and Malt in a Pineapple
- Malt in a Sip-it (2005) in Tetrapak.
- Amstel Malta (1994).
- Fayrouzinpeerandpineapple(2006).
- MaltaGold(becamepart oftheNBonOctober2011)etc.

1.2. Statement of problem

Six Sigma influences waste reduction with its statistical analysis aimed to forecast possible changes in the performance of the processes base in data. Even more, it is used for controlling and improving the real process when the variability or specifications are not the desirable by the customer or the company. Some available variables such as the extraction force of the cork and the volume of wine filled are information provided by the company and gives the opportunity to analyze this data to find out the best Lean Six Sigma solutions.

The challenge of this project is the application of Lean Six Sigma in the Nigerian Breweries because it is not as developed as compared to other methods currently applied in other 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.

As a result, as Nigerian Breweries 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 will be 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 and fix the problem root. Obviously, 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 like employees' time and it improves the final quality performance of the product. The aim of this work is to optimize all the bottling processes of the company and as a result, the application of the excellence model Lean Six Sigma can be as olution to survive in the business environment tbeca use it is known that the market is dynamic and always changing. The quick answer to the se changes will take advantage of the situation.

Lean Six Sigma can provide the tools and resources needed to the development of the company. With these developments the company can improve its processes, reaching a more optimized bottling process, increasing, its competiveness against the rivals saving resources and of course, money.

1.3. Objectives of the study

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

Other specific objectives are;

- To investigate the bottling process of the company in order to find the cause of the problems and fix the problem root.
- To develop a new methodology for proper data collection based on the control of the number of rejected bottles and defects.
- To optimize all the bottling processes of the company using statistical methods in order to ensure improvement of rejected bottles and defects reduction, the waste of time of reprocessing, waste of materials, waste of resources like employees' time and to improve the final quality performance of the product

II. Research Materials

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

2.1. Data Collection

Essential information for the research will be collected through primary and secondary sources, which include:

(i) 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.

2.1.1. 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.

2.1.2. Validation

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

2.2 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.

2.3 Data Collection plan
To extract the needed data for easy analysis, a 40 page questionnaire was designed which was addressed to the Director of production and quality of the Nigerian Breweries Enugu plant.

2.4 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.

2.5. 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 v is its 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 bottle so fbreweries and 2 million belong to non alcoholic brands. The number of sold bottles shows the size of the company, which enjoys 3 bottling lines but 2 bottling work everyday, 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.

III. Collected data

3.1. Bottling processes
Once all the information obtained from the company has been explained, during the visit it was possible to take data to analyze the current situation of the processes. Bottling line was considered. The data collected were presented in appendix 1.

3.2. 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 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 collecteddataduring3500bottles. The line Ausually work sat 10.000bottlesper 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.

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 run sat around 7000 bottles per hour the oretical speed, but the final performance was less due to the buffers between machines, stoppages, break down sand other unexpected problems. It was program medcloseto 7000 bottles/hal though 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 become nted 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 orderting or in the electronic sensors problem. These control are 4 in the line 4; *Control1 B*(Volume and Caps),*Control2B*(Cans),*Control3B*(Label),*Control4B* (Weight)and also some defect soccur on the *Belt* between processes.

3.3. Laboratory registereddata

Regardingtheinformationstoredfromthelaboratoryandits collaboration,itwaspossibletohaveaccesstodatarelated with thebottlinglineprocess.As it hasbeen mentioned,theplanthasdataaboutonlysomeattributesthattheyanalyzein the laboratory; extraction force of the cap(Kg),oxygen (mg/l),vacuum(pressure), liquid volume (ml)of product in the bottle.Of course, all the sevalues were linked with their type of product and soon.

Table 3.1 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	580.00
A	Gulder	Alcoholic Beverage	600	Crown Cap	32	0.30	0.30	0.10	580.00
A	Life	Alcoholic Beverage	600	Crown Cap	32	0.25	0.25	0.10	580.00
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

Table 3.1 showed how the data base 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 beverageper hour, hence, more samples were taken in the selines.

Table 3.2: Extraction force for production line A per month (Source: Nigerian Breweries Enugu).

Observation	Extraction force 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 3.3: Extraction force for production line B per month (Source: Nigerian Breweries Enugu).

Observation	Extraction force 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 3.4 Extraction force for production line C per month (Source: Nigerian Breweries Enugu).

Observation	Extraction force 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 3.5: The number and frequency of volume of filling defects per line (Source: Nigerian Breweries Enugu).

Observation (day)	Volume of filling per line							
	A	frequency	day	B	frequency	day	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	593	3	11	593	6	11	600	50

12	593	3	12	593	12	12	600	18
13	596	2	13	593	4	13	593	5
14	596	4	14	596	3	14	593	10
15	596	1	15	596	20	15	596	20
16	599	0	16	696	20	16	596	20
17	599	0	17	596	0	17	596	10
18	599	0	18	599	0	18	599	3
19	599	0	19	699	3	19	599	1

Table 3.6: Quantity of the product produced per month (Source: Nigerian Breweries Enugu).

month	Quantity (bottle)
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 3.7: Quantity of the product supplied per month (Source: Nigerian Breweries Enugu).

month	Quantity (bottle)
Jan	4000000
Feb	3700000
Mar	3700000
April	3700000
May	3700000
Jun	3650000
Jul	3650000
Aug	3650000
Sept	3650000
Oct	3650000
Nov	3750000
Dec	4350000

3.4. Data Analysis

The methodology for the collection of the data was explained and now the data was showed on an easy way to understand the information simply and quickly using a statistical software MINITAB. The Pareto diagram was one of the best tools to display this kind of information. The tool used construct and prioritize the defects and rejected bottles that occur more frequently.

3.4.1. Cause-effect diagram

The analysis of all the X's(inputs) that can come into the processes also based on the SIPOC diagram was complemented now by the diagram cause-effect which is representing the causes that modify the answer Y, in this case the defects and rejected bottles. All the inputs like materials, manpower, machine's setting and speed influences the final result of the line.

3.5. Research Tools

The methodology of Six Sigma uses a variety of quantitative metrics in continuous improvement. The measurements are critical-to-quality metrics, defects measurements, the process capability, and also financial and strategic measures. These performance metrics can be used for organization, manufacturing processes and also in services, administrative processes (Schoroeder, et al., 2008; Linder man, et al., 2003).

Consequently, Six Sigma metrics seeks two aims based on its philosophy and wants the customer's satisfaction and this satisfaction must prove that it generates a better financial results. For that reason, the VOC (Voice of the Customer) is included in the DMAIC method because customers are one of the aims of the Six Sigma.

The statistical tools are recommended but they can be implemented in any phase of the strategy because it can be helpful in each stage. The main tools which are used for the implementation of this work are:

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 internal of the x-axis. The frequency represents the dependent variable (y-axis) and independent variable (x-axis).

2. Box Plot

A box plot is used to show the distribution of a single variable. It is a graphical representation of data using 5 values; Median, First quartile (25% of the values), Third quartile (75% of the values), and largest and smallest values. This helps to visualize the center and the spread of a data and to compare data by categories.

3. Pareto charts

The Pareto chart creates and prioritizes the defect factors to determine which issue has the most effect in the process. A Pareto chart is a column chart and is used to prioritize the problem solving order. The Pareto chart applies to all the frequencies (outputs or effects or defects) of any process in any organization. It is another form of histogram, with the frequencies starting form the highest to lowest. The rule is to pay attention on the 80% of the causes that generate the problems.

4. One-Way ANOVA

The one-way (also called the one-factor) ANOVA (Analysis of variance) is used for determining if the mean of one or more population is different or not from the independent factor. Normally is used a 95% of confidence interval, so, the hypothesis is that if the p-value 0,05 the hypothesis that the independent factor is irrelevant for the mean's population is true. In the other case, the factor would influence the population results.

5. 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.

6. Scatterplot diagram

The diagram shows the visual view of the qualitative relationship with linear or nonlinear relation that exists between two variables input and output using an X and Y diagram. It is used to provide the data to confirm that two variables are related. The data must be a paired data collection, it mean, to know the two values of the variables in the same sample to find the relationship when these values change.

7. 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:

- X and R -average and ranges
- X and S -average and standard deviation

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

Table4.5. Analysis-of-variance ANOVA of Extraction Force by Type of Cork Source: [Author]

One-way ANOVA: Extraction Force versus Cork Type

```
Source     DF      SS     MS     F      P
Cork Type   1     0,3    0,3  0,01  0,911
Error     327  8486,2   26,0
Total     328  8486,6

S = 5,094   R-Sq = 0,00%   R-Sq(adj) = 0,00%

                              Individual 95% CIs For Mean Based on
                              Pooled StDev
Level      N    Mean  StDev   ---+---------+---------+---------+------
Crown     41  28,512  5,671   (-----------------*------------------)
Crimped  288  28,417  5,009             (------*-------)
Screw     45  28.500  5.425   ---+---------+---------+---------+------
                              27,20     28,00     28,80     29,60

Pooled StDev = 5,094
```

Table 4.6. 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**

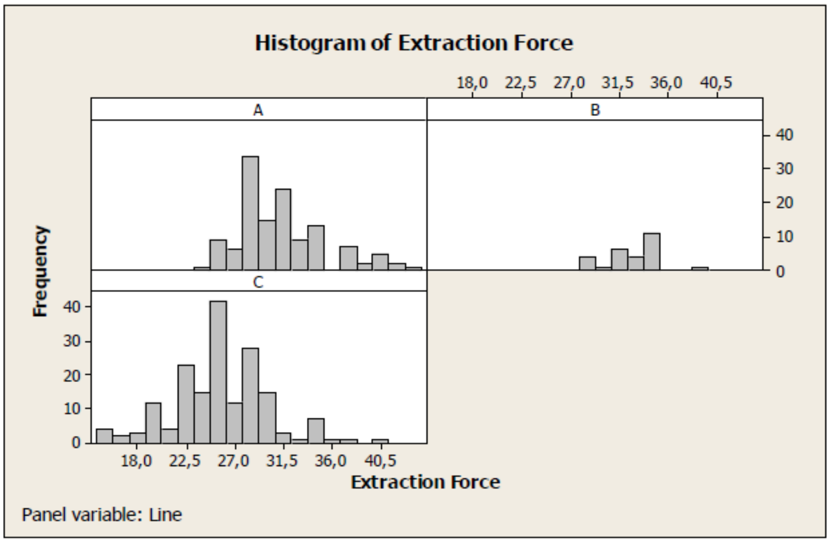

Fig. 4.1. HistogramofExtraction Force categorized by lines.Source: [Author]

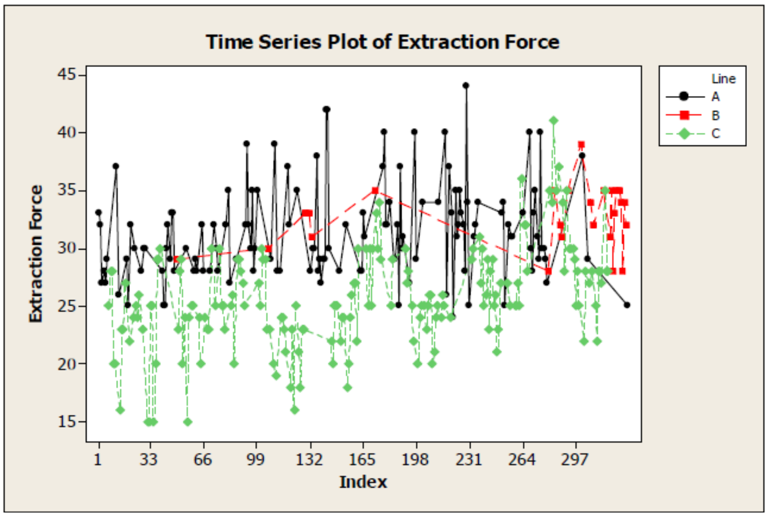

Fig. 4.2: TimeSeriesPlotofExtraction Force categorized by lines.Source: [Author]

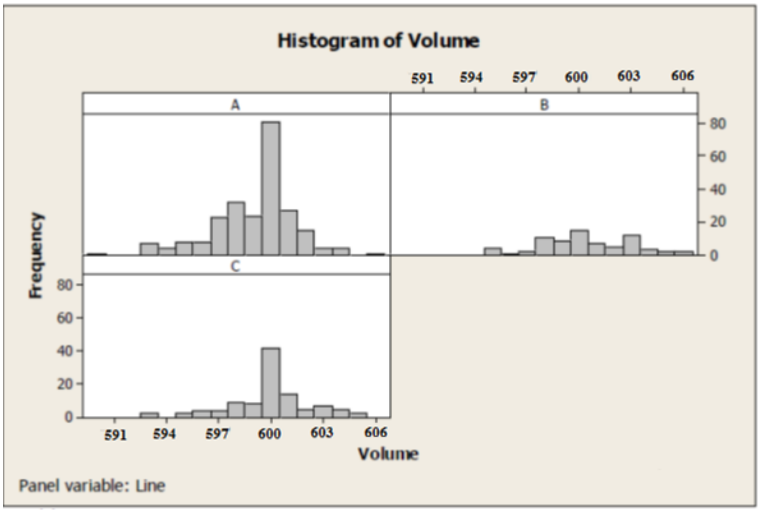

Fig. 4.3: Histogram ofVolumeoffilling categorized by lines.Source: [Author]

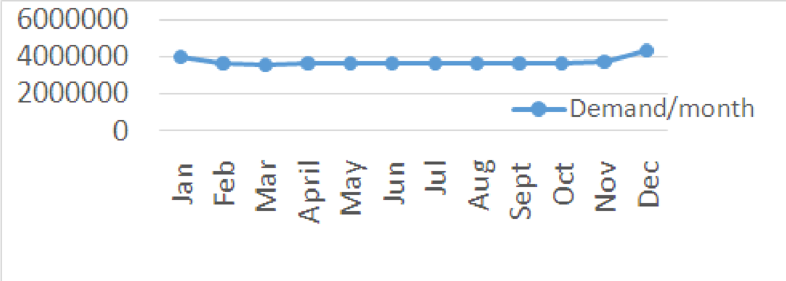

Fig. 4.4. Expected demand of beverage.Source: [Author]

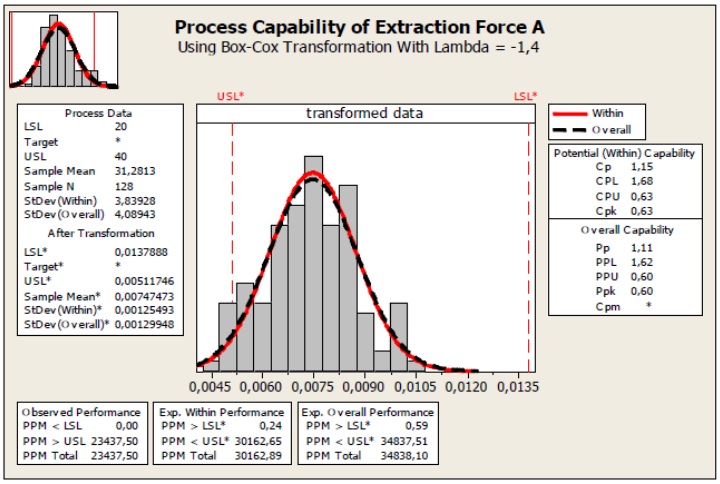

Fig. 4.5. Capability analysislineA.Source: [Author]

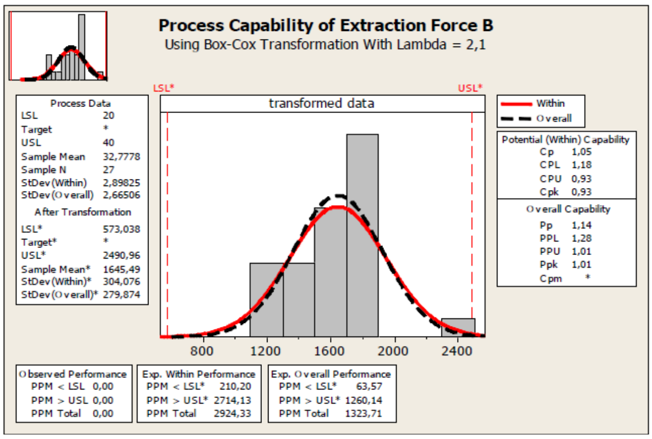

Fig.4.6. Capability analysisline B.Source: [Author].

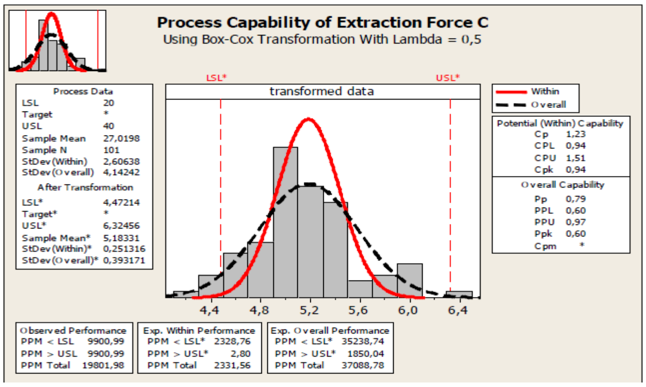

Fig.4.7. Capability analysisline C.Source: [Author].

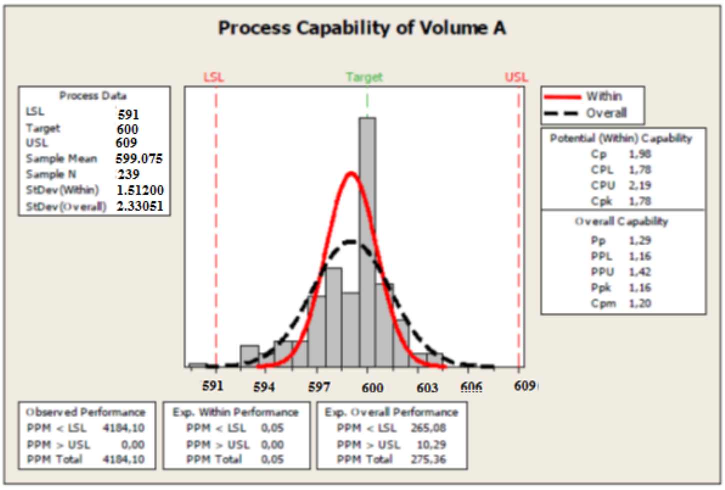

Fig. 4.8: Capability analysisvolume line A.Source: [Author].

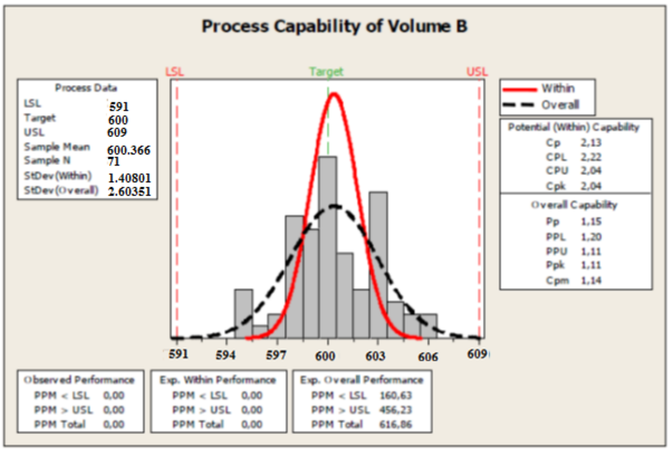

Fig. 4.9. Capability analysisvolume line B.Source: [Author]

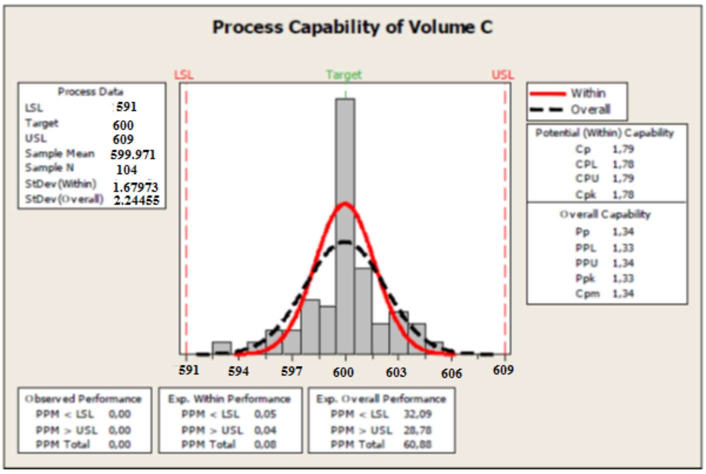

Fig. 4.10. Capability analysisvolume line C.Source: [Author]

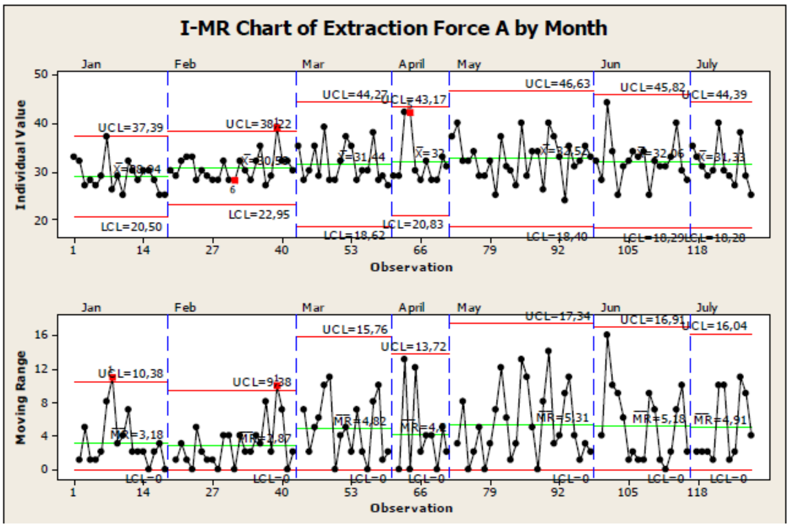

Fig. 4.11.I-MR chartofExtraction Force A.Source [Author]

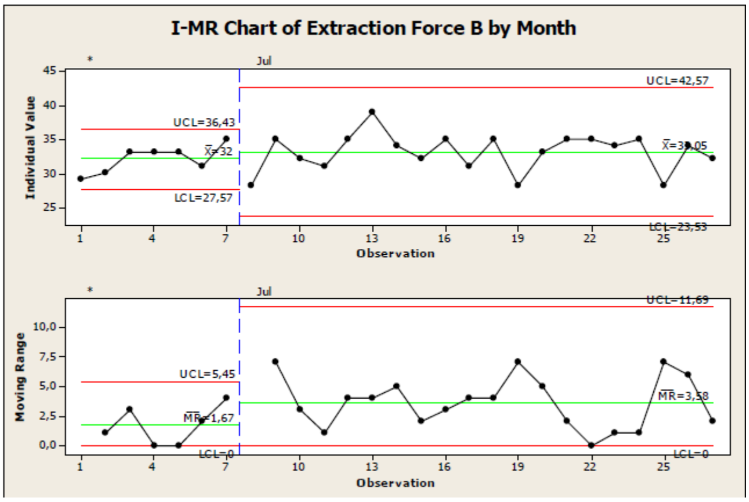

Fig. 4.12.I-MR chartofExtractionForce B.Source [Author].

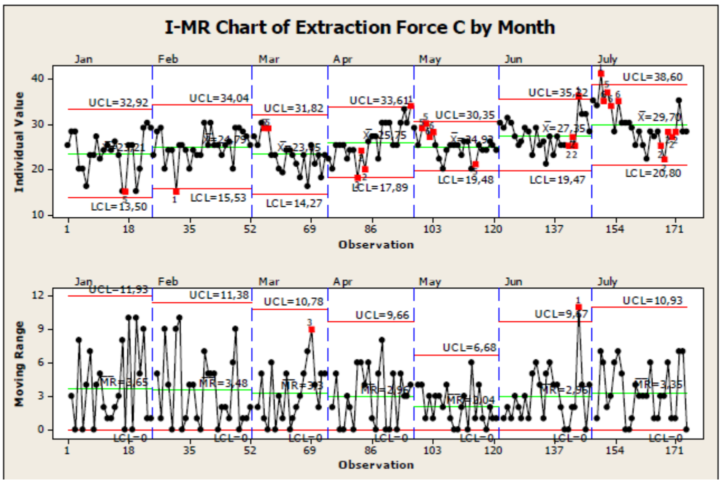

Fig. 4.13.I-MR chartofExtraction Force C.Source[Author]

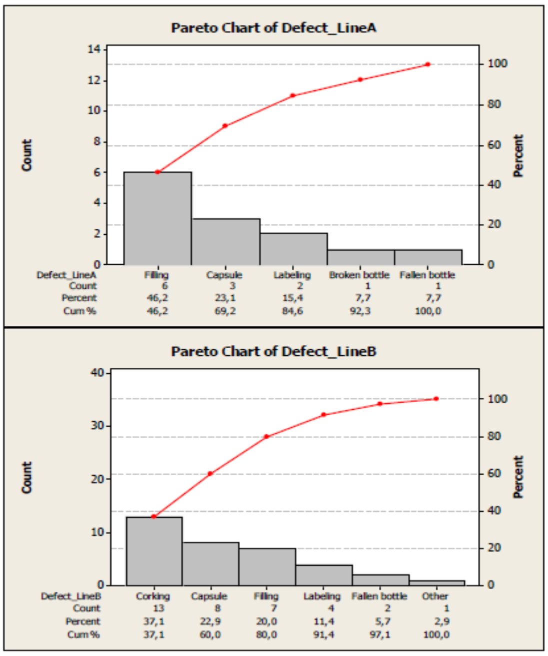

Fig. 4.14. Pareto chart of Line A (1 day) and Line B (2days) Source [Author]

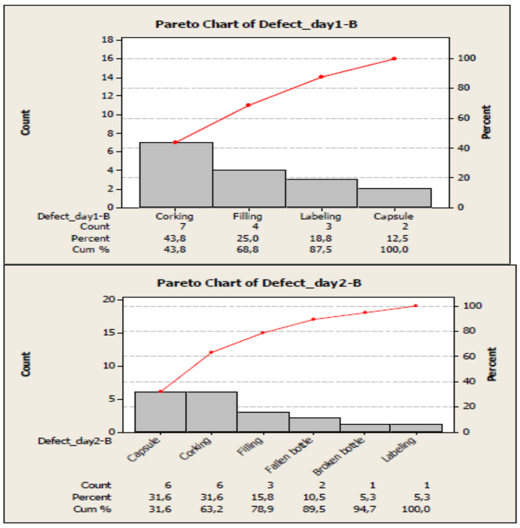

Fig. 4.15. Pareto chart within 2 days of samples in the Line B Source [Author]

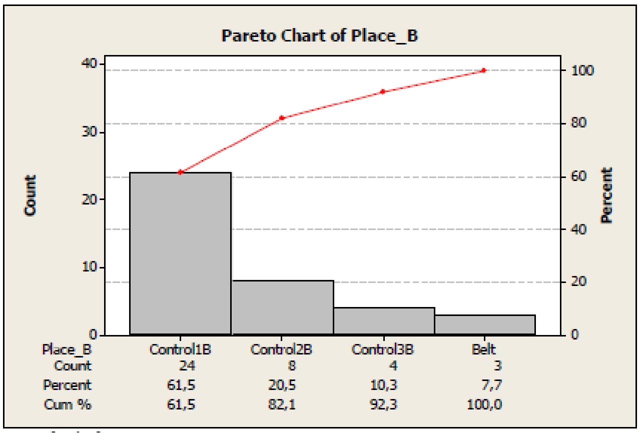

Fig. 4.16. Pareto Chart of rejected bottles depending on the control place of the line B. Source [Author]

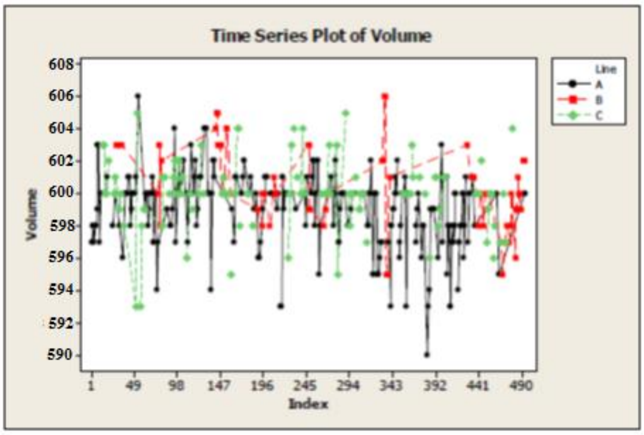

Fig. 4.17. Time Series Plot of Volume of beverage byLineSource [Author]

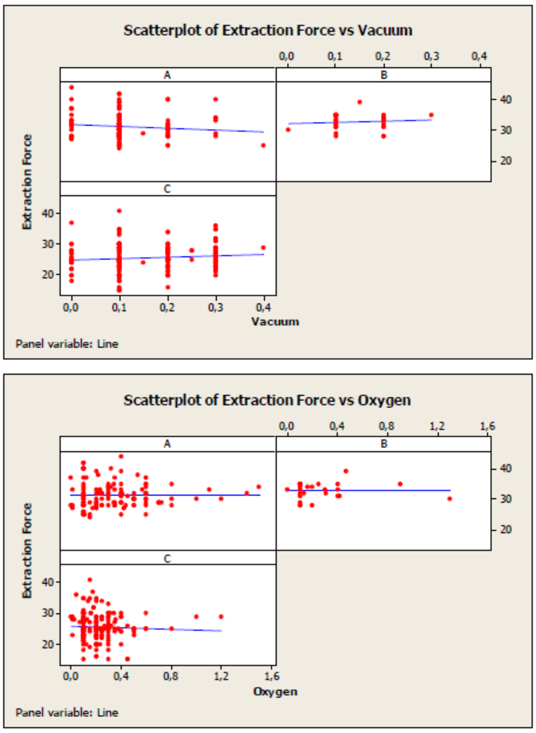

Fig. 4.18. Scatterplot Extraction Force vs Oxygen or Vacuum by lines

4.2. Discussion

Table4.1 and 4.2, showed that 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 filleda model of 1200 ml instead of 600 ml in the line B, due to the planning production of the day.

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 600 ml 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 are duction 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/hto7155b/h. It was not possible to analyze the evolution of the defects along the time because the company does not have such information (Uzorh, et al, 2018).

Figure 4.5 showed that line A was quite well centred between the limits 20 and 40kg. The same happens in the line Bal though the number of samples was lower (see figure 4.6).On the other hand, the line C seemstobeshiftedtotheleft,havingmuchmoresamplesunderthelowerspecificationlimit of 20thanthecompany would desire(see figure 4.7).

Table 4.5 showed ANOV A result o f the three cork types, p-value was 0.911 >0.05.Table 4. 6 showed that the processes were not capable be cause the spread of thesampleswasquitebighavingsamplesupto590ml. It was true that most of the samples were on the correct volume(600ml). Line A has am ean of 599.08ml, asa result, its hould 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

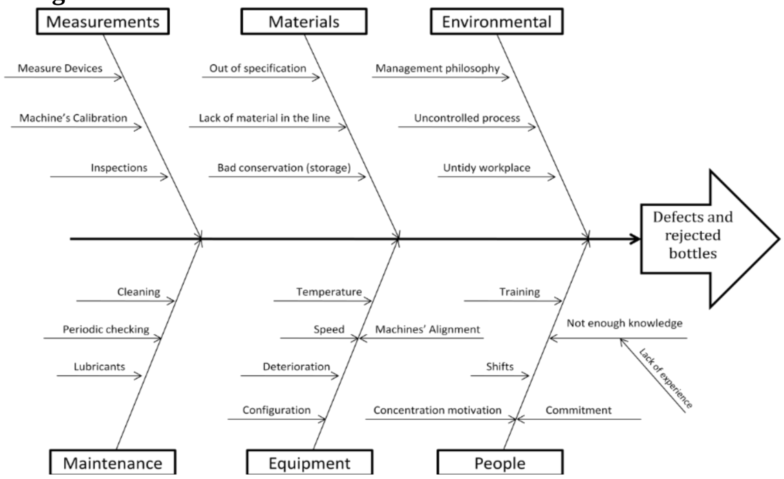

Fig. 4.19: Cause-effect diagram of defects and rejected bottles. Source: [Author].

The defects and rejected bottles, which were cause by many possible changes in all of the attributes were represented in the cause- effect diagram. It was divided into six categories; measurements, materials, environmental, maintenance, equipment and people. Inside the main branches, there were other influencing little causes that generate the defect son the bottles. All type sof defects that appear on the previous *MEASURE* phase can be caused by the bad equipment fitting of the right values, performance and behavior 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. These two attributes (oxygen and vacuum) were not included in the cause- effect diagram because there is no significant evidence of relation to the Extraction Force. The important issues are going to be all the causes included in the cause-effect diagram. Most of them cannot be evaluated with a number, but reasonably, as pects 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 priorities to solve and control i n o r d e r to keep the number of defects low. For the moment, if the company would implement the project, these would be the points to focus first

4.2.3.2 Capability analysis

4.2.3.2.1 Extraction Force of the cork

Figure4.5 showed that the 'Extraction Force' of the line A samples were centered quite well but has some prolongation to the upper limit. The software Minitab was used to obtain the best value for the transformation. 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 to tal 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.

Figure 4.5 also 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 the 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 soon. It has a problem with the higher specification. Actually, based on the current data there is a 2.34% of bottles with the extraction forcehigherthan40kg 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.

Figure4.6 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 meanwasmorethan32, so, t his little shift of the to tal samples generated some extra units outside the USL. The P P was not good enough with1.14, so, as always they have to be carefully with the causes that generates variability to make the samples distribution narrower.

The last line C was considered necessary as from the April to the end of July. The whole data was not possible to transformin to a normal distribution. So, analyzing the time series plot of the line C (seeFig.4.2) showed that the company carried out a bad configuration of the corking machine, because the range was from15 to 30 kg producing defective bottles. From the index 132 of the chart, it can be appreciateda new amount of samples better centered. This difference in the range of the samples generates together a distribution which could not be a normal distribution because it has two internal diverse distribution processes. With the lasts months of data the requirements were kept.

The recent mean was 27.02kg (see Figure. 4.7.), so, it was a little b it shifted to the left, the low limit and the capability was not correct. The Pp<1, so this line was not capable. Therefore, the expectedresultswere37,089 bottles out of specification. The company has to react to this fact becausethe3.7%of the bottles wereexpectedtobedefectiveontheextractionforceattribute.Theimportanceofthiswastokeepcontrolallthecausesthatc ouldchangetheresults.They have to be in mind always to try minimizing the variability to achieve a better capability on the process.

Figure4.7 also showed that the number of defective bottles during these months of the data 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 it could be achieved.

4.2.3.2.2 Volume of beverage

The interesting concept to study was to know how the capability of the process works because the bottles rejected in the process should be related with the bottle out of specifications in the expected overall performance.

Figure4.8 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 asignificant \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 Pp>1.33 oreven Pp>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 was expected for this defect of bad filling to be 0.028%.Table4.1 showed that line A has0.17% of bottles rejected for filling reasons. So, assuming the sup position 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 notfilled 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 mean1mltothe right, because it is now in 579, 1ml, avoiding fillings with less than 599 ml and balancing both capabilities side, PPU and PPL.

For the company would begreatif 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.

Figure 4.9 showed that the samples of filling for the line B were quite well-balanced with capability of Pp= 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.

TherejectedbottlesbyfillinginthelineBcollectedduringthevisitswasa0.23%.The time series ploto f volume (seefigure4.17) showed that the line worked under less variation. The line can be working better reducing the number of bad filling because the expected overall performance based on the data from 7 months is 616 bottles permillion. A saresult, the line was filling with less than a 5σ level.

Forimproving, the company needs to controltheparameterssuchasspeed,fitting ofthe neckofthebottleandthe beverage system feedingtoreducethespreadof therealdistributionandreduced therejectedbottles.

Thelastanalysiswas the thirdline(seeFig 4.10). ThelineChasthebestresults,with only60 bottlesoutpermillion,and perfectlycentredinthetarget600ml.Allthe capabilityparameters weregreater than orequal 1.33.Thisline wasworkingnearthe6σexcellence,and reachingthe5σ level. From the chart thefillingmachines of eachline,showedthatthelineC wasfillingwith a goodcapabilityandwell-balanced. LineAandBneedtocontroltheparameterssuchas speed,fittingof theneckofthebottle in order not to losebeverage,theproductsystemfeeding and othercausescould gettotheprocessatbetter performance by avoiding most ofthebottlesoutof specification.

The nextstepcan bethereductionof thelimits of specificationonce the processes were completelycapabletoperformbetterprocessqualityfor theproductwithalways thesame quantity of volume.

4.2.4 ControllingExtraction Force

Thetoolsusedforthiscontrolwasthe I-MRchart.Forthiscontroltherewas a differencebetweenthecontrollimits(UCLand LCL, UpperandLowercontrollimit)that were usedhereandthespecificationlimits(USLand LSL)which werethelimitsforthecompanyor customerquality. Thecontrollimits weredependenton theexperimentaldataresults,and the specificationlimitswerebasedon thecustomerdesire orproductfunctionalitylimitsdecided by the company.

Thefirstline,*ExtractionForceLineA*wascontrolledfromthebeginningoftheyear(seeFig. 4.11).Therangeof thelimitswasindicatingthe*individualvalue*with3timesthestandard deviationsinoneachside,everymonth.Thisisbecausetheobjectivewastohavetheprocess undercontrolwithoutanysamplesoutsideandanyalert.Thelimitofthe *movingrange* indicatesthedifferencebetweenthelastandthecurrentsample,alertingiftherewastoomuch variationin two consecutivesamples.

Figure4.11 showed thatthefirstimpression wasthattheprocesswasgainingvariation,ifone looksatthefirsttwomonthsincomparisonwiththelastmonths.ThemonthofMarchsome causewasaffectingthis variabilityon thelineA.Thisfactwasappreciatedinthemovingrangeas well, increasingthemovingrange ofstandarddeviationfrom9.38to15.76kg.

Theproblemofthisnewvariabilitywasthatthelimitswerebiggerthanthedesiredfromthe company.Thelimitswerebetween20and40.Bothlimits, upperandlowerwere outofspecificationgeneratingmoredefectivebottlesthanthedesired.

Regarding the alerts, the most important was the alert of April, because the two consecutivesampleswaswiththesameproduct on thesameday,so,itwasimportantto analyze whyitwascorkingbadandproducingdefectivebottles.

Asaresult,therewas thepossibilityofanalyzebetterthelast 25samples.Now,thelimitswere selectedbytheauthoraccordingtothedesiredvaluesand morerecently,there wasnoanyalert intheprocess.

Alsoone ofthebenefits ofenjoyingaprocessundercontrolwasthatthe variabilitywasunder control,so,whenin theANALIZEphasethecapabilityanalysiswasrealized,theauthornoticed thattheprocessshouldimproveitscapabilityandthiscontrolcomplementthemethodology for achievingthereductionofthe defects.

Regarding*theExtractionForceofthe* *LineB*,theprocesswasundercontrol.Anyalertandany strangebehaviourappears duringthe year(seeFig. 4.12).

Therewerenotassamplesastheotherlines,butthe inthemonthofJulythechartdoesnot showunstablepoints.Onlyitwasconsideredtocheck thewell-balance ofthelinebecausethe processwascorkingbadbecausetheextractionforcewasmorethan30kg.Theadjustmentwill keepthe limits betweenthe specificlimitsfor thecompanybetween20and 40 (see figure 4.12).

InthelineC, the*ExtractionForce*(seeFig. 4.13)canbeappreciated, thelastmonths increasesthe meanbecauseitwasnotcentred.Along thefirstmonths oftheyear,theprocess wastotallyoutofspecification.Itwastruethattheprocesswasperformingquitegoodbut shiftedfromtherequiredtargetnear30,only2sampleswerealertedbybeingfarfromthe mean.

InMarchtherewasanalert of6pointsincreasingthe movingrangeconsecutive.Itwasanalert becauseitwasnotcommon inaprocessundercontrol.Itmayinformthe companythatsome maintenancecouldbenecessarybecause of the increasein movingrange.

It was interesting tostudywhathappened during Maybecausetheprocessachieves excellent variationlevelsreducingabout 33% of itsstandard deviation.Afterthat,theprocessstartedto get therightwaytoshiftthemeanof theextractionforcecloser to30.

Attheendofthe month ofJunetheprocesswasoutoforderbecauseitchangesandincrease around10kgmoreandremainstherefor12samplesbutthen,theresultswereplacedunder themean,sothecompanyshouldcontrol in ordertoavoidtheextractionforcebeen shiftedbelowthecorrectwell-balance.ItcanbeappreciatedbetterintheFigure4.18both amount ofsamplesoutof control.

V. 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 Recommendation

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.

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Appendix 1. SIPOC diagram

S (Supplier)	I (Input)	P (Process)	O (Output)	C (Customer)
NB · (Tanks of stored Beverage)	Filtered Beverage	- Product settings	Beverage bottles in package of 6 bottles. NB	Shops
	Raw materials: Bottles, Corks, Capsules, Label Bovines, Boxes.	- Bottles Palletiser		Supermarkets
Raw materials, Complement and Chemical suppliers.	*Complement material*; Laser Ink, Adhesive tape.	- Washing		Wholesalers
	Chemicals; Soda, Sulfur, Nitrogen	- Filling-Corking		Distributors
		- Encapsulating	-	
		- Labelling		
Machinery equipment	Manpower	- Packing		
	Machine settings: Speed (bottles/h), Internal configurations (ml of filling, cork, label and capsule position).	- Protecting, Closing, BarCode		
	Belt speed	- Packaging, Storing.		

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