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APPLICATION AND ENHANCEMENT OF QUALITY ENGINEERING IN SOME SELECTED MANUFACTURING INDUSTRIES OF ETHIOPIA

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ABSTRACT

This research is intended to enhance the quality engineering pillars in some selected manufacturing industries of Ethiopia. The products should attain high quality and serve to the provided function and life span. However due to different reasons including poor quality of raw material the products get low quality and are usually affected by different causes including improper use of quality pillars, quality parameters, machine failure and operators. The objective of this research was thus applying and enhancing quality engineering pillars in manufacturing industries of Ethiopia. To carry out the research six industries were selected and samples were taken from each industry and then theoretical including physical observation, questionnaire and experimentation methods were used. Purposive sampling method was considered and relative samples were taken from each industry for analysis. The non-conforming products produced from each process were identified and their quality distribution from the process central tendency were quantitatively analyzed using statistical quality control methods. The analytical results show that such a SPC methods predict quality characteristics of products during the process and their causes in the existing process. Process capability of the industries were successfully identified using the quality pillars and found that some were capable while others were far to meet the specification limits

KEYWORDS: Defectives, Grand average, central limits, Process capability, Standard deviation, Enhancement.

I. INTRODUCTION

Quality is the totality of features and characteristics of a product or service [1] that bear on its ability to satisfy stated or implied needs. As experience and literature [2] show quality has other several meanings such as a degree of excellence, a conformance with requirements, a fitness for purpose, a freedom from defects imperfections and a delighting customers. As underlined in the work of [1,3], quality is the loss a product causes to society after being shipped, other than any losses caused by its intrinsic functions. Quality improvement [4] is the reduction of variability in processes and products and it is that part of quality management focused on increasing the ability to fulfill quality requirements. Quality Engineering [5] is the set of operational, managerial, and engineering activities that a company uses to ensure that the quality characteristics or parameters of a product are at the required levels. In literature [6] and industrial practice it is known that off-line quality control aspects like system design, parameter design and tolerance design leads to good part integrity, high product quality and low part rejection. Tolerances that are too narrow increase manufacturing costs and tolerances that are too wide increase performance variation and the lifetime cost of the product. A process may vary due to common and special sources [7] of variations. The common causes of variation are the probability that the observed phenomenon may fail because of any unknown random cause of variation whereas the special or assignable causes of variations are the variation is caused by a source of variation that is not part of the constant system and leading to a process that is less variable. A statistical process control (SPC) [8] provides a statistical signal when assignable or special causes are present and detect and eliminate assignable causes of variation and uses a valid analytical statistical methods to identify the existence of special causes of variation the in a process. Performance statistics [9] were used to estimate the effect of noise factors that affect the performance characteristics of a product and in the study almost all problems mentioned in the above paragraph contribute for production of some parts with low quality characteristics. Statistical Process Control (SPC) [10] was performed to enables visualization of variability that may be inherent in every process of production. The result presented shows that reduction of proportion defectives and external failure costs using a statistical control charts. It is also used to minimizing the variance of the distribution of the performance characteristic that achieved by selecting a suitable process and by eliminating sources of variation and close mean of the quality characteristic distribution to the target value that achieved by process setting, including proper selection of levels of the process parameters. A central concept in statistical process control [10] significantly indicated that every measurable phenomenon in statistical distribution or an observed set of data constitutes a sample of the effects of unknown common causes are present, the distribution is constant and predictable and when assignable causes are present, the distribution varies and is not predictable and has the basic properties of a distribution namely location, spread, and shape. The attribute control chart tools [11] were used to evaluate the proportion defectives or non-conforming proportion of products produced during the process. The results presented that special cause of variation caused the central tendency of the process to produce an abnormally large or small number of defective units over the time period observed. The process capability [12] is the long-term performance level of the process after it has been brought under statistical control or process capability is the range over which the natural variation of the process occurs as determined by the system of common causes. It is also the ability of the combination of people, machine, methods, material, and measurements to produce a product that consistently meet the design requirements or customer expectation. It is also a scientific and a systematic procedure that uses control charts to detect and eliminate the unnatural causes of variation until a state of statistical control is reached. As underlined in the work of [12], knowing the capability of the manufacturing processes helps to summarize process capability in terms of meaningful percentages and metrics, to predict the extent to which the process can be able to hold tolerance or customer requirements, bringing the process under statistical control requires fundamental changes, to choose from among competing processes, the most appropriate one for meeting customers' expectation and can specify better the quality performance requirements for new machines, parts and processes. Also knowing the capability of the supplier's processes provides to set realistic cost effective part specifications based upon the customer's needs and the costs associated by the supplier at meeting those needs, to understand hidden supplier costs and to be pro-active. The uses of process capability indices and defect rates [13] in the practices of quality enhancement of the products have been presented that process capability indices measure the degree to which a process produces output that meets the customer's specification and can be used effectively to summarize process capability information in a convenient unitless system. The results presented that the higher the process capability index value (>1.33) the highly capable process whereas the small the process capability index value (<1) the process was not capable.

From the above point of view, it is clear that various factors including misunderstand of quality engineering pillars be the causes of poor quality characteristics of products and lead to risks for the clients, industries and as a whole for the nation. Some analytical methods of statistical process control namely central tendency, lower and upper control limits standard deviation and process capability indices has been used to enhance the quality of products in this regard.

II. MATERIALS AND METHODS

The materials for sickle, bottle, garment, chipboard, moha soft drink and sugar products were taken respectively galvanized steel, mixed silica sand and refractory of bottles, cotton, eukleptes, ground water and some additives (chemicals) and sugar cane and other additives elements. The sickle is mainly used for farm sectors for harvest of grass, different crops and many other inland activities. Similarly, the other products mentioned above are also used for the specified purpose of the client's order within or abroad of the country, Ethiopia. Composition analysis of raw-materials and their additives used for processing of each product were made using automatic composition checking machines in each industry.

METHODS

The method used was experimental and theoretical (data analysis based on questionnaire, brain storming and physical observation). The research was conducted in six (**6**) selected industries of Ethiopia that have been assembled in productions of instruments and tools, soft drinks, textile (garments), sugar, bottle and glass and chipboard. The outputs of each industry that previously produced using the existing production system and design were physically observed. Brain washing and interviews of 5 workers from each industry including, designers, expertise and managerial groups were also conducted to gather the required data about the overall problems in relation to quality engineering pillars, product quality characteristics, raw material handling (storage), product quality enhancement and process design improvement aspects. Relative samples of products from each industry that ordered by customers were taken using purposive sampling method. Quality characteristics of the samples were checked after their respective production processes and the number of non-conforming proportion defectives and good products were identified. The averages, standard deviations, average proportion defectives of the non-conforming items were analyzed using statistical process control (SPC) tools. The central limits (CL), upper control limits (UCL) and Lower control limits (LCL) of the production processes were designed as per the available data collected from each process. The products quality characteristic defect levels distributions and also the tendency of the process failure were identified and plotted using X-charts and P-charts and the process capability indices were also used to identify the process capabilities of the industries participated in the research work. Detailed discussion of the products produced from each selected industries is as follows.

III. RESULTS AND DISCUSSION

Physical observation of the products was made and found that poor quality, rework, reject, under sized and shape changes were the main problems due to improper uses of quality engineering pillars that affect the quality characteristic levels of the products**.** The data collected were also analyzed and was found that the defects were occurred due to lack of applying proper quality characteristics (parameters) that was connected with lack of skilled man power and improper use of quality engineering pillars. The six industries selected for the research work were Kotobe metal and instruments product factory, Addis Ababa bottle and glass factory, Hawassa textile factory, Hawassa chip wood factory, Hawassa millennium pepsie cola industry and Wonji sugar factory.

1. Kotobe Metal and Instruments Product Factory

Kotobe metal and instruments product factory has been produced the common and useful hand tools and instruments such as shovel, sickle, hammer, chisel, axe and crowbar used for farming applications. A sickle (tool) with its whole production process was selected to identify number of good and reworked items and number of non-conforming parts and hence to analyze the quality characteristics. The strips were passed through various operational steps such first straightening, size cutting, helve trimming, notching, second straightening, bow bending, tip trimming, marking, rough grinding, hardening, tempering, finish grinding, polishing, wire brushing, painting and assembling and the actual sickles with their final limits were found. The number of strips entered in to the first straightening operation were 1857 each with a length of 85cm (one strip has cut in to two-sickles).The number of good, rework and rejected sickles throughout the process were recorded as shown in Table 1.

Before analyzed, length of each sickle was taken as a quality characteristic of the process. The average of proportion defectives or non-conforming of sickle products produced throughout a single stage process were determined taking the above number in to account with a control chart (**P**-Chart) method using Equation (1) as follows.

$$\bar{P}=\frac{\text{Sum of subgroup defective counts}}{\text{Sum of subgroup sizes}} \quad [14] \qquad (1)$$

Where, $\bar{p}$ - average of proportion defects and considered as the center line of control limits as shown in Table 1.

Table 1: Defective units (or non-conforming proportions)

Process	No. Input	No. Output	Reject	Rework	P. defects
Size cutting	3414	3414	66	33	0.0188
Helve trim	3358	3325	33		0.0098
Notching	3325	3319	6		0.0018
2nd straighten	3319	3319			0
Bow bending	3319	3216	103		0.0310
Tip trimming	3216	3196	20		0.0062
Marking	3196	3196			0
Rough grind	3196	3196			0
Harden	3196	3196			0
Tempering	3196	3196			0
Finish grind	3196	3162	34	81	0.0106
Coating	3162	3162			0
				Average	**0.0065**

Hence, the average proportion defective, $\bar{P}$, of the sickle products was calculated and average results was 0.0065**.** As per the experiment result, the average proportion defective of the samples was compared to the minimum standard limit of quality engineering of any process and it is within the standard [14].

To determine the specific but most important quality characteristics indicated distribution of the non-conforming proportion sickles, analysis was carried out on control system design and related elements. The control system proposed in production of the sickle products was designed based on the statistical quality control pillars. The

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critical process control parameters of the process namely lower and upper control limits were designed or set at plus and minus three standard deviations of the defective subgroups using equation (2) as follows.

$$LCL=\bar{P}-3\sqrt{\frac{\bar{P}(1-\bar{P})}{n}} \quad \text{and} \quad UCL=\bar{P}+3\sqrt{\frac{\bar{P}(1-\bar{P})}{n}} \quad [11] \qquad (2)$$

Where, $\bar{p}$ -is the center line of control limits, n-subgroup sizes, LCL and UCL - Lower Control Limit and Upper Control Limit of the process respectively. Therefore, the overall non-conforming products distribution of the process was plotted using P-charts as shown in figure 1.

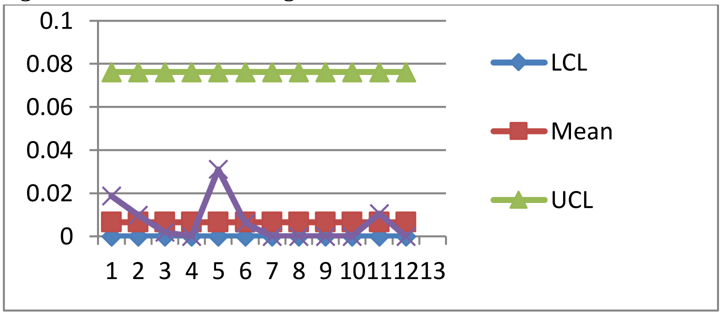

Figure 1: Distribution of Proportion defects using P-charts

Thus, based on the equation used the results of proportional defects of the sickles distribution was found near to the lower control limit and away from the upper control limit. As per the collected data distribution of the defective sickles were between the UCL and LCL and so that the process was found in control process and mostly shift to lower control limit (using P- chart).

2. Addis Ababa Bottle and Glass factory

Addis Ababa bottle and glass industry has been producing bottles and glasses of different sizes as per the customers' specifications. The production process was started from preparation of raw materials such as silica sand, marble, cullet and soda ash. The required bottle product with the specific sizes, weight and shell portion at its top side was formed. The bottle products was hardened through the annealing process and quality of each bottle was inspected through visualization, physical analysis and chemical analysis methods. The standard quality characteristics of these products were taken from the factory and given as weight of 290 to 310 gm, pressure of 250 psi, brim full capacity of 335-355 ml and pill point capacity of 320-340ml. Among these parameters, weight of the products affect their quality and chosen as a quality characteristic for this research work. Table 2 shows the weight (gm) of the each bottle collected form seven consecutive working days and six samples of bottles were taken from each day.

Table 2: Weight (gm) of six pieces produced in 7 days

Day	Pull	Sample size					
		1	2	3	4	5	6
1	25.19	312.8	311.4	313.2	312.5	311.9	312.7
2	25.32	313.9	312.6	315.4	314.6	314.7	311.9
3	24.89	313.2	312.5	313	311.4	314.3	312.2
4	25.36	314.5	315.6	313.9	314.5	315.6	313.6
5	25.33	313.2	315.4	314.9	312.5	315.4	313.8
6	25.24	311.8	312.6	314.2	313.1	313.7	312.9
7	24.60	313.2	311.3	312.2	312.5	312.9	311.7

Thus, the control charts for variables were used to monitor the weight as a variable and then the mean (central tendency), the range and the standard deviation (dispersion or spread) of process were evaluated using equations (3), (4) and (5) respectively using the control charts for variables as follows [4].

$$\bar{X} = \frac{\textit{Sum of subgroup weights}}{\textit{Subgroup size}} \qquad (3)$$

R = Largest in subgroup - Smallest in subgroup (4)

$$\sigma_x = \sqrt{\frac{\sum_{i=1}^{n}(X_i-\bar{X})^2}{n-1}} \qquad (5)$$

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As per the equations used the average weight, the range and standard deviation results were found and summarized as shown in Table 3.

Table 3: Average weight (gm), rang and deviation of pieces

Day	Pull	Average	Range	Standard deva.
1	25.19	312.4	1.8	0.89
2	25.32	313.9	3.5	1.56
3	24.89	312.8	2.9	0.84
4	25.36	314.6	2	0.73
5	25.33	314.2	2.9	0.656
6	25.24	313.1	2.4	1.347
7	24.60	312.3	1.9	1.022

Considering the subgroup deviations and subgroup averages the control limits for both the variables were placed at plus and minus three standard deviations of sigma from the average sigma as it was calculated using equation (5) and of the mean of means or grand average using equation (8). The center line or control limit for sigma charts based on sigma-bar for all the processes was calculated using equation (6) as follows.

$$\sigma_{\bar{X}} = \frac{\text{Sum of subgroup Sigmas}}{\text{number of subgroup}} \qquad [15] \qquad (6)$$

The center line (central tendency) of the control limit for average charts based on sigma bar was designed using equation (7) and then the lower and upper control limits respectively using equation (8)

$$\bar{\bar{X}} = \frac{\text{Sum of subgroup averages}}{\text{number of subgroups}} \qquad [16] \qquad (7)$$

$$LCL = \bar{\bar{X}} - A_3 * \sigma_{\bar{X}} \quad \text{and} \quad UCL = \bar{\bar{X}} + A_3 * \sigma_{\bar{X}} \qquad [17] \qquad (8)$$

Where, A_3- constant taken from Appendix and used to facilitate calculations in control limit equation. Based on equations (6), (7), (8) the average deviation of the pieces, grand average and the two control limits of the distribution were $\sigma_{\bar{X}}$=1.006428571 kg and $\bar{\bar{X}}$=313.32857 kg respectively as shown in Figure 2.

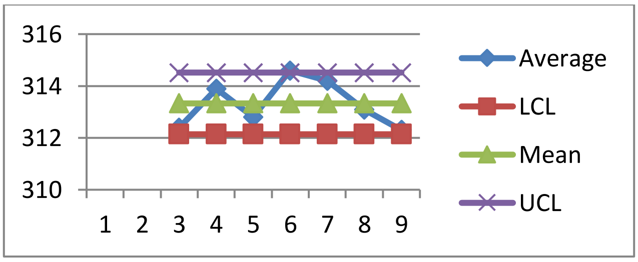

Figure 2: Distribution of average weight from process mean.

So, based on the equations used and as per the data collected the average weight of the bottle indicated that the distribution is beyond the upper control limit and hence the production process of the bottles based on this quality characteristic was out of control process due to the special causes present during the process.

In addition, process capability of the factory was also considered as one of the quality characteristics. This parameter is used to indicate range of the quality characteristics distribution over which the natural variation of the process occurred and affecting by the system of common causes. It is also used to display the relations between processes and products' specifications, i.e., whether the design specifications (requirements) have been going to consistently meet the customers' specifications or not. As per the collected data, the process capability measuring indices (tools) of the factory were evaluated using equations (9), (10) respectively as follows.

$$\mathbf{Cp} = \frac{USL-LSL}{6\sigma} \qquad \mathbf{[12]} \qquad (9)$$

$$Cpk = \min\left(\frac{USL-\bar{\bar{X}}}{3\sigma}, \frac{\bar{\bar{X}}-LSL}{3\sigma}\right) \qquad \mathbf{[13]} \qquad (10)$$

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Where, **Cp,** and **Cp$_k$** - process capability and process capability index of the industry respectively, **σ**- standard deviation computed based on average range from equation (5), USL and LSL-upper specification limit and lower specification limit of the bottle weight and $\bar{\bar{X}}$- grand average of the bottles weight.

Based on equations (9), (10) the process capability and minimum process capability index of the industry were found as Cp=3.312 and Cpk = -1.10024. As per the test results, the process capability indexes of the industry were compared to the standard process capability indexes and the process was not capable. As per literature [17], the process capability with possible ranges of Cp = 1 indicated process variability just meets specifications whereas Cp ≤ 1 indicated process not capable of producing within specifications and Cp ≥ 1 indicated process exceeds minimal specifications. In addition, the value of **C_{PK}** is simply taken as minimum value of **C_{PU}** and **C_{PL}** and since the smallest value represents the nearest specification, the value of C_{PK} gives if the process is truly capable of meeting requirements and hence a **C_{PK}** of at least +1 is required and +1.33 is preferred.

3. Hawassa Textile Factory

Hawassa Textile industry has been producing garment products with different styles and colors. In many aspects the garment products of the industry are more competitive in the global market. Any garment product has been passed through the complex mechanism of machines and process lines to obtain the final item as per the customers' or design specification limits. The process lines are spinning, pre-treatment, weaving, finishing and quality control (or inspection). Initially, the raw material which is cotton with different gradients and color has been collected from farmland and stored as a bell shape in the factory's store. The gradients were mixed together using a **blacker machine** to have uniform layer and then sucked to suction pipes by centrifugal force in to the spinning section and then spinning process was performed.

For the production of Abujedi**,** total of **2352** ends each with a length of 2452 m bed sheet and beam width of **165 cm** was used. Quality of each fabric was inspected and good sized fabrics was sent to the finishing section. The most commonly fabric products of the factory were Plc foam, cot foam, B/sheet, twill and abujedi**.** Quality characteristics of the product such fabric grayness, color quality, color uniformity were inspected through physical observation and using laboratory. The overall inspections indicated that main causes of the products to reject were breakage, cross winding, weak splice, low and high twist, tangled yarn, double end and long tail (Table 4).

Table 4: Average proportion defectives of the articles

Causes	Reject (m)	Reject (%)	Prop. defective (P)
Crease	2438	80.46	0.8046
Machine stop	168	5.58	0.0558
Screen breakage	160	5.3	0.053
Stain	8	0.3	0.003
Color contaminate	60	2	0.02
Sample hole	196	6.5	0.065
Rags Pauli	12	3	0.03

The average of proportion defectives or non-conforming products produced throughout the process were calculated by the control charts (**p**-charts) method using Equation (1) and also as per the available data the important quality characteristics of the process namely the center line, the lower control limit, and the upper control limit were designed. Again the center line was considered as the average proportion defective, while the other two control limits were set at plus and minus three standard deviations of the defective subgroup articles and calculated using equation (1) and equation (2) respectively.

Based on equations (1), (2) average proportion defective was 0.144 and the control limits were plotted as shown in Figure 3.

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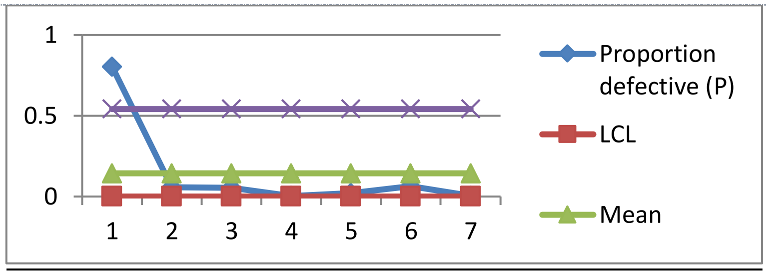

Figure 3: distribution of proportion defects using p-chart

As per the proportion defectives distribution shown in figure 3, the central limit of the defective foam products is mostly concentrated near to the lower control limit and some points are beyond the upper control limit. Thus, process of the foam articles as per the collected data was out of control process and mostly shift to LCL of the control charts and this could be due to special factors such as operators skill, machine conditions and physical characteristics of the materials used for production.

4. Hawassa Chip wood Factory

The factory was planted to produce chipboard products needed for various activities done in the country. Eukleptes (a raw material) has been used to prepare the floor chips of the product due to its availability and good mixing property with chemicals (water and wax). Eukleptes with a diameter of 10 to 30 cm was cut in to pieces and get dried to a moisture of 20-25% using solar energy. The pieces were crushed using hammering machine with a power of 300 kW and floor chips were produced and passed through screw conveyor and bucket elevator to get fine sized particles. The chemical was prepared from urea with powder of 60%, 40% of water and ammonium chloride with PH of eight (8). Inspection was conducted during the glue process to inspect the qualities related to solid content (60%), PH (>8.5-8.7), hardener (5.5-5.7), density (1.25g/mL), jell time or curing time at 100^{o}c (55-60 sec.), viscosity (80-120/sec.) and curing time at 25^{o}c.

For the study, a chipboard with a thickness of 9mm was selected. Compactness was considered as good quality characteristics during this process. Surface finish was done using sanding operation. Quality of the products related to thickness, surface finish, density, thickness swelling, water observation and material distribution were inspected through physical observation and experimentation methods before given to the customer(s). For production of a chipboard with the final dimension of 11.2m*1.83m*9mm, thirty six samples (36) from six shift working hours were taken each with the quality parameters of thickness, mass and density as shown in Table 5.

Table 5: Checking the thickness, mass and density of the board per shift

Sample	Shift 1			Shift 2		
	Thickness (cm)	Mass (gm)	Density (Kg/m^3)	Thickness (cm)	Mass (gm)	Density (Kg/m^3)
1	0.93	215.4	762	0.92	213.7	772
2	0.95	221.3	787	0.94	220.8	780
3	0.94	211.7	743	0.93	211.8	817
4	0.93	213.4	699	0.95	215	766.8
5	0.94	209	765	0.93	212	776.3
6	0.94	213.8	768	0.95	212.8	776
7	0.95	210.6	749	0.92	209.7	774
8	0.94	219.5	811	0.91	221.6	768
9	0.94	213.7	768	0.93	214.8	780
10	0.93	220.1	800	0.95	220.4	790
11	0.92	219	815	0.94	216	812
12	0.93	216.8	817	0.91	221	811

Sample	Shift 3			Shift 4		
	Thickness (cm)	Mass (gm)	Density (Kg/m^3)	Thickness (cm)	Mass (gm)	Density (Kg/m^3)
1	0.93	210.5	765	0.94	209.8	764
2	0.92	212.2	778	0.96	218.3	783

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3	0.94	209.9	750	0.93	213.9	746
4	0.96	208.5	750	0.95	212	822
5	0.91	210	755	0.92	214.1	759
6	0.95	214	769	0.94	213.7	784
7	0.94	211	753	0.95	219.6	790
8	0.97	213.3	769	0.93	222.7	767
9	0.93	213.7	768	0.92	216.2	760.4
10	0.94	220.1	781	0.93	218.2	812
11	0.91	215.9	767	0.92	214.6	785
12	0.92	219.5	769	0.94	215.9	808

Sample	Shift 5			Shift 6		
	Thickness (cm)	Mass (gm)	Density (Kg/m^3)	Thicknes s (cm)	Mass (gm)	Density (Kg/m^3)
1	0.91	215.6	758	0.93	212.7	782
2	0.92	217.7	770	0.94	218.7	786
3	0.96	212.5	760	0.95	211.6	802
4	0.95	210	775	0.92	214.5	761
5	0.94	212	757	0.96	213.4	756
6	0.93	214.5	769	0.92	213.5	784
7	0.92	209.8	750	0.93	212.2	767
8	0.94	210.4	814	0.95	217.1	813
9	0.92	215.3	770	0.93	218.8	779
10	0.93	218.4	786	0.95	210.7	812
11	0.94	220.8	768	0.92	219.5	810
12	0.93	219.4	758	0.91	217.2	807

Hence, the control charts for variables were used to monitor the quality characteristics of the chipboard as a variable and then the mean (central tendency) and the standard deviation (dispersion or spread) of the board process were calculated using equations (3) and (5) respectively for the selected quality variables (thickness, mass and density) of the process.

Based on equations (6), (7), (8) the average standard deviation or sigma of the pieces, grand average of the thicknesses, masses and densities and as well as two control limits of the selected quality characteristic variables were found and summarized as shown in Table 3.

Table 6: summarized values of the average variables.

Average	Thickness (cm)	Mass (Kg)	Density(Kg/m^3)
$\bar{\bar{X}}$	0.934305556	214.9694444	777.3819444
Average sigma	0.013149898	2.556376725	17.20892312

From available data the control charts for thickness, mass and density of the chipboard were plotted respectively as shown in the following Figure 4(a, b, c).

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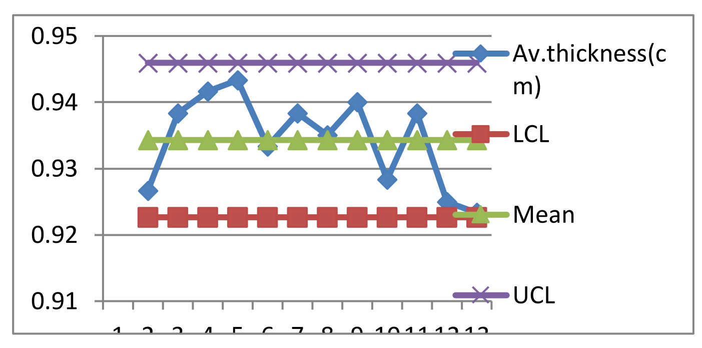

Fig 4a: Average distribution of chipboard thickness

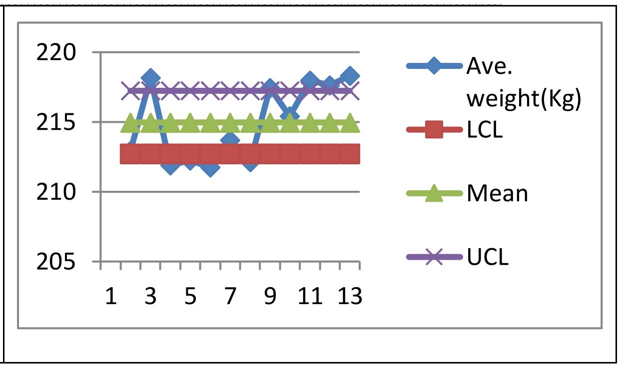

Fig 4b: Average distribution of chipboard mass

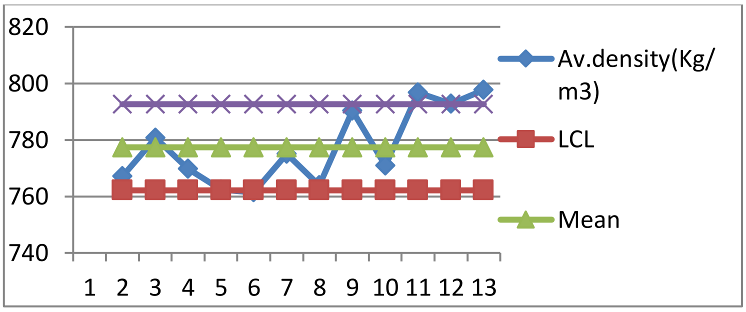

Fig 4c: Average distribution of chipboard density

Thus, as per the control charts used in figure 4 (a, b, c) distribution of the average quality characteristics (mass and density) of the products from the grand mean were beyond the control limits (out of upper control limits). The main factors were due to special causes present during the process such as machine failure, power off, chemical composition (physical observation) and hence as per the test results found the process was far to meet the specification limits.

5. Hawassa Millennium Pepsie Cola Industry

The industry was planted to produce soft drinks of Moha products such as pepsie, mirinda, 7-up & apple mirinda etc. All these products have been passed through complicated mechanisms of automatic machines. The main raw materials used for the process were sugar, flavor and ground water. Before manufactured the beverages, quality of the raw materials and related problems that could be occurred during mixing were checked to reduce the customers' risk and personal health of the users (society) at whole. The finished syrup was inspected related to bricks (percentage of sugar), acidity (PH) and control drink. In addition, the overfilled and undefiled of the bottle from 300mm of volume was checked through physical observation and using automatic sensors and thus over and under filled bottles were rejected. For the study two (2) quality characteristics namely amount of CO_2 and amount of Brix were measured from the samples taken (six shifts) and compared to the standards given by the company (brix of 10.80-10.90 and CO2 of 3.40-3.80).

Table 7: Quality Characteristics of Pepsie Cola industry

Sample	Time	Shift-1	Shift-2			Shift-3	
		Brix	CO_2	Brix	CO_2	Brix	CO_2
1	7:00	10.84	3.68	10.83	3.67	10.86	3.68
2	7:20	10.87	3.71	10.85	3.7	10.83	3.72
3	7:40	10.86	3.72	10.88	3.69	10.89	3.7
4	8:00	10.84	3.68	10.87	3.65	10.86	3.69
5	8:20	10.88	3.67	10.84	3.72	10.85	3.68
6	8:40	10.85	3.66	10.87	3.68	10.84	3.65
7	9:00	10.85	3.72	10.88	3.71	10.87	3.58
8	9:20	10.87	3.7	10.85	3.64	10.88	3.64
9	9:40	10.86	3.68	10.87	3.65	10.85	3.66

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10	10:00	10.87	3.7	10.87	3.72	10.86	3.69
11	10:20	10.86	3.7	10.84	3.68	10.88	3.71
12	10:40	10.87	3.7	10.89	3.65	10.85	3.68

Sample	Time	Shift-4		Shift-5		Shift-6	
		Brix	CO_2	Brix	CO_2	Brix	CO_2
1	7:00	10.85	3.66	10.83	3.7	10.85	3.67
2	7:20	10.86	3.69	10.84	3.68	10.82	3.7
3	7:40	10.87	3.7	10.79	3.67	10.8	3.69
4	8:00	10.86	3.68	10.85	3.72	10.88	3.71
5	8:20	10.87	3.71	10.87	3.72	10.86	3.68
6	8:40	10.84	3.67	10.82	3.74	10.85	3.67
7	9:00	10.86	3.68	10.84	3.7	10.85	3.71
8	9:20	10.88	3.68	10.86	3.68	10.89	3.72
9	9:40	10.86	3.69	10.88	3.72	10.87	3.66
10	10:00	10.85	3.71	10.84	3.68	10.86	3.69
11	10:20	10.88	3.72	10.86	3.69	10.85	3.7
12	10:40	10.86	3.69	10.87	3.7	10.87	3.72

Hence, the control charts for variables were used to monitor the quality characteristics of the cola as a variable and the mean (central tendency) and the standard deviation (dispersion or spread) of the cola process over the time were calculated using equations (3) and (5) respectively for the selected quality characteristic variables (Brix and Carbon dioxide) of the process. Based on the equations (6), (7), and (8) the average standard deviation of the pieces, grand average of the brix and CO_2 and also the two control limits of these variables were found and summarized as shown in Table 8. Control charts for brix and Carbon dioxide of the pepsie Cola were plotted respectively as shown in Fig. 5 (a, b).

Table 8: summarized values of the average variables.

Average	Brix	CO_2
Grand average ($\bar{\bar{X}}$)	10.8572222	3.688333333
Average sigma (σ_x-bar)	0.01663874	0.023854991

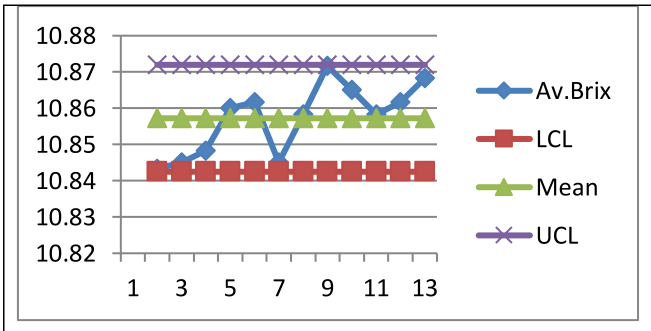

Fig 5a: Average distribution of Cola Brix from mean

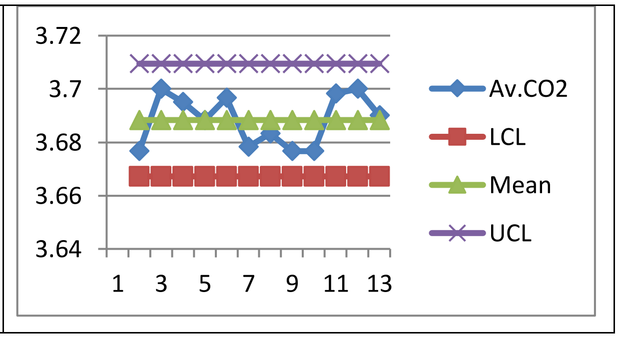

Fig 5b: Average distribution of Cola CO_2 from mean

As per the control charts used distribution of both the brix and CO_2 from the grand mean were within the control limits. Also, process capability of the factory was also considered as one of the quality characteristics of the Pepsie Cola production process. The parameter was evaluated to indicate capability of the industry as per specifications. As per the collected data, the process capability measuring tools of the factory related to brix and CO_2 were evaluated using equations (9), (10) respectively and summarized in Table 9.

Table 9: Summarized estimated values of process capabilities

Factors	**Brix**	**CO_2**
Cp	1.0017	2.795
Cpk	0.8570(i.e <1)	1.56(i.e >1.33)

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Based on equations (9), (10) the process capability (Cp) and the minimum process capability indices of the industry for brix and CO_2 were **Cp**=1.0017 and 2.795 respectively and the minimum Cpk of 0.857 and 1.56 respectively. As per the test results, the process capability indices of the industry were compared to the standard process capability indexes and the process was not capable to meet the brix specification and could be produce a probability of non-conforming cola products more than 2700 PPM but highly capable to give the CO_2 within the specification with less than 64 PPM. As per literature [17], the process capability possible ranges of Cp = 1 indicated that process variability just meets specifications, $Cp \leq 1$ indicated process not capable of producing within specifications and $Cp \geq 1$ is process exceeds minimal specifications). In addition the value of $\mathbf{C_{PK}}$ is simply minimum value of $\mathbf{C_{PU}}$ and $\mathbf{C_{PL}}$ and since the smallest value represents the nearest specification, the value of C_{PK} gives if the process is truly capable of meeting requirements and a $\mathbf{C_{PK}}$ of at least +1 is required and +1.33 is preferred.

6. Wonji Sugar Factory

This factory is one of the biggest and oldest sugar industries of the nation that has been producing sugar for local and export purposes. The raw-material was sugar cane with a theoretical compositions of 65% water, 13% of bagasse, 10-15% of sucrose and 3-5% of non-sugar (other chemicals). Sugar cane was crushed and extracted through five (5) mill units and so bagasse and sugar juice (with low viscosity) were separated. Then, the juice from each mill was piped to the tanks under each mill as per its purity using the designed mechanisms of feed roller, top roller, delivery roller and discharge roller arranged according to their function. The necessary juice purifications have been conducted in each process line using respective sugar additives.

In general, four (4)-types of sugars namely A-type, B_1-type, B_2-type and C-type have been producing in the factory. A-type sugar has been used directly for commercial purpose while the other three types were recycled again by adding some seeds and chemicals to give A-type sugar. The quality characteristics of the sugar such as brix, purity (pty), PH, TOD, TSS, T, Pol and pressure were inspected as per the standards before packed. For the research work A-type of sugar molasses was chosen and also brix and pty were taken as a quality characteristics from three shift shown in Table 10.

Table 10: Am/c quality characteristic checked at 64^0c temperature

Massecuite tpye	Sample	Shift 1		Shift2		Shift 3	
		Bx	Pty	Bx	Pty	Bx	Pty
Am/c	1	85	94.9	91.2	94.3	92.4	94.9
	2	86	96.5	88.4	95	89.5	96.5
	3	89.5	95.8	90.5	95.2	89.5	95.8
	4	87	96.4	88.6	94.4	87	96.4
	5	90.1	95.8	91.3	95	90.1	95.8
	6	87.5	95.8	90.8	95.5	87.5	95.8
	7	87.2	94.6	89.9	94.4	90.2	94.8
	8	90	95.3	91.4	94.3	90	95.3
	9	85.9	96.7	90.2	93.8	85.9	97.6
	10	87.5	95.7	88.6	93	93.5	95.7

Thus, the control charts for variables were used to monitor the quality characteristics of the sugar as a variable and then the mean (central tendency) and the standard deviation (dispersion or spread) of the sugar process over the time were estimated using equations (3) and (5) respectively for the selected quality characteristic variables (Brix and purity) of the process. Based on the equations (6), (7), (8) the average standard deviation of the Am/c, grand averages of the brix and purity and also the two control limits of these variables were found and summarized as shown in Table 11.

Table 11: summarized values of the average variables

	Brix(Bx)	**Purity(pty)**
Grand average ($\bar{\bar{X}}$)	89.0733333	95.36666667
Ave. sigma (σ_x-bar)	1.79979717	0.767061036

From available data the control charts for brix and purity of the sugar were plotted respectively as shown in Figure 6 (a, b) .

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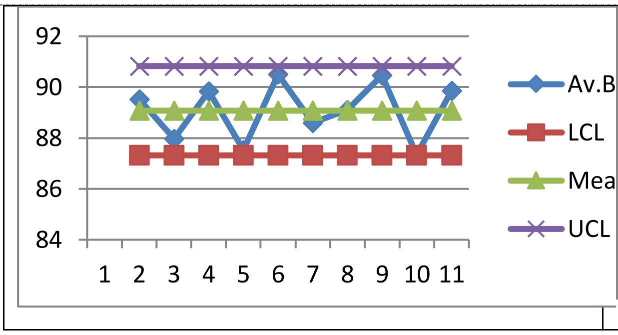

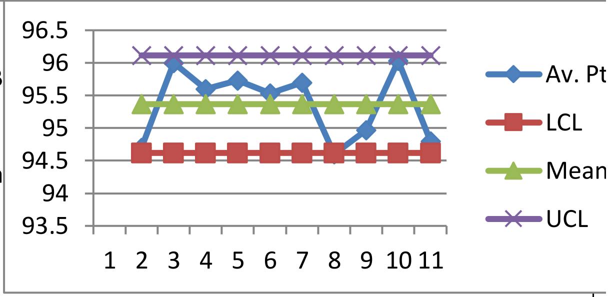

Fig 6a: Distribution of sugar's average brix ***Fig 6b: Distribution of sugar's average purity***

As per the control charts used distribution of both the brix and CO_2 from the grand mean were within the control limits and hence the process is in control.

IV. CONCLUSION

The results shown that the applied quality engineering pillars for determination of quality characteristic distributions and process capabilities of the factories were realized and the following conclusions can be drawn:

1. The numerical calculation results have shown that the non-conforming proportion products produced during the production processes were due to the improper use of quality characteristics (parameters) and hence due to improper use of quality engineering pillars.
2. The experimental results shown that distributions of the quality characteristics were beyond the control limits and hence the processes capabilities used during the production process were incapable to meet the customers' specifications in few industries because of some common causes of variation including unskilled man power employed in the industries.
3. Lastly, it was found that none of the selected manufacturing industries was used statistical quality control method before and concerned only on the quantity of the output products and hence the production systems of the industries as per the design used were not present in a better productive system.

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