IDEA STUDIES Journal
Open Access Refereed E-Journal & Indexed & Puplishing

Subject Area
Management and Organization
Article Type
Research Article

e-ISSN:2587-2168
Year: 2022
Vol: 8 Issue: 45
pp 627-638

Article ID
64369
Arrival
31 July 2022
Published
30 September 2022

DOİ NUMBER
http://dx.doi.org/10.29228/ideas.64369

How to Cite This Article
Erdoğan, A. (2022). "Practices on the Structure and Operation of Quality Control Charts", International Journal of Disciplines Economics & Administrative Scienves Studies, (e-ISSN:2587-2168), Vol:8, Issue:45; pp: 627-638

Practices on the Structure and Operation of Quality Control Charts

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ABSTRACT

Statistical Process Control is regarded as a field that provides statistical instruments to detect changes in processes and monitor data flows. By means of Statistical Process Control, which has a dynamic structure, possible problems are determined by following the process; the factors causing the problem are established and solutions are produced. Quality Control, as the control process applied in the production stages, is a crucial function in order to maximize consumer satisfaction and it is used in all phases of statistical methods; design, production and service activities. The primary goal of quality control is to maintain the rate of defective products at a minimum level. Being one of the most effective tools in quality control, Control Charts are a significant method of statistical process control, which is referred to in the phase of improving the production process. Fundamentally, Control Charts are used to specify the factors that cause variability.

In this study, it is presented by which methods possible deviations from the center line are detected, the structure and types of Control Charts used to improve the process are evaluated; thereby the Quantitative and Qualitative Control Charts are explained theoretically.

Additionally, applications on Quantitative and Qualitative Control Charts are performed and control methods used for control charts are explained and an application for calculating acceptance probabilities are included.

Keywords: Shewhart Control Charts, Lower Control Limit, Upper Control Limit, Acceptance Sampling, Acceptance Probability

1. INTRODUCTION

The process consists of elements namely; operation (machine/equipment), material, environmental conditions, operator, inspection and all these elements lead to variability in the process. The variability that arises in any process is assessed in two groups as random variability and systematic variability. Random variability includes factors whose effects on the event cannot be ruled out and are impossible to detect. Systematic variability, on the other hand, is the changes that push the production process in a certain direction, take it out of control and the cause of which can be determined, and which are effective only on a certain part of the event. Only a variable that is under the influence of random factors corresponds to the ordinary distribution (Şahin, 2013).

The responsibility for the quality of any process rests with the operators of that process, in a word the manufacturers. In case appropriate statistical instruments are provided to fulfill said responsibility, operators achieve success on the following issues (Oakland, 2003):

- ✓ To know whether the process meets the requirements,
- ✓ To know whether the process meets the requirements at any given moment,
- ✓ Correcting the process or its inputs unless they meet the requirements.

In order to solve the problems in Statistical Process Control; Flowchart Diagram, Fishbone Diagram, Pareto Diagram, Checklist, Histogram, Scatter Diagram and Control Charts are used. The main objective of Control Charts, which is the most widely used among these methods, is to improve the process (Montgomery, 2009).

2. QUALITY CONTROL CHARTS

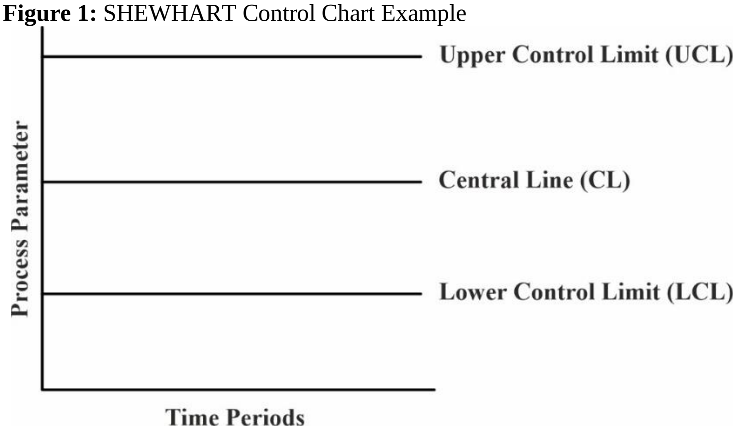
Quality is simply defined as meeting consumer requirements (Oakland, 2003). Quality control is a series of check-out operations performed at every stage of production in order to maximize consumer satisfaction. By dint of quality control, it is analyzed to what extent the standards determined during the planning phase are complied with (Barutçugil, 1988). Statistical Quality Control techniques are utilized to examine the quality levels of the products and to determine the quality change in the product. Above-mentioned techniques are used at each stage of production to determine whether the process is under control. Statistical techniques are the most significant evaluation tools in the process of quality control. The most effective one among these techniques is the control charts developed to determine the variability in the process and the out-of-control situations that reduce the product quality (Noorossana and Vaghefi, 2006).

Statistical Process Monitoring is considered a field that provides statistical tools to monitor data flows to detect changes in processes. In 1924, SHEWHART developed the first statistical tool, which he called the "Control Chart", to solve problems in this area. The Control Chart is basically a diagram based on Three Sigma limits (Does, Goedhart, Woodall, 2019). Shewhart's overall approach to process control is to take a subset of the data and use the results of that subgroup, the sample, to make estimates for the population. The two elements of the sample in which the control is applied are the mean and the range (Knowles, 2011).

Control Charts are an integral part of statistical process monitoring used to follow up and improve the manufacturing process in industry. Among the Control Charts, SHEWHART Control Charts are preferred due to their ease of use in the industry. Said charts are generally designed under the assumption that the studied variable applies to the ordinary distribution (Arif and Aslam, 2018).

Control Charts demonstrate the changes over time of measurement values obtained from samples taken from production at certain and equal time intervals. Control charts created from sequential samples taken from the process provide information about the process by revealing whether the process performance is at an acceptable level. The operation of the Control Charts is based on the principle that in case the last product produced is within the control limits, the process is under control, and in case at least one of them is outside the control limits, detection of the error by examining the operations (Pekmezci). In Figure 1 an example of the SHEWHART Control Chart is presented.

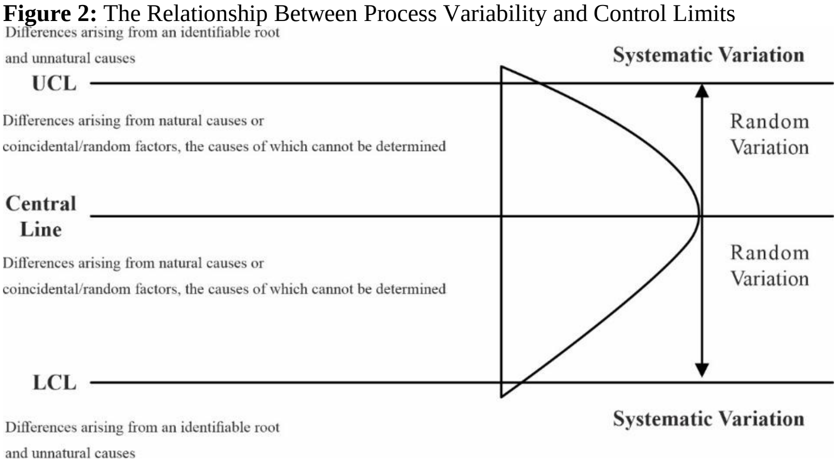
Figure 1: SHEWHART Control Chart Example



Reference: Yavuz, 2010.

The relationship between the types of variability and control limits pertaining to a process is given in Figure 2.

Figure 2: The Relationship Between Process Variability and Control Limits



Reference: Şahin, 2013.

Quality Control Charts, according to the type of data in terms of application area, are divided into two groups as Quantitative Control Charts and Qualitative Control Charts. Provided that the quality feature is measurable; arithmetic mean, range of variation and standard deviation are calculated and Quantitative Control Charts are used. Unless the quality feature is possible to be measured numerically, Qualitative Control Charts are used.

Although more costly than Qualitative Control Charts, Quantitative Control Charts that are frequently used because they provide more information about process performance are:

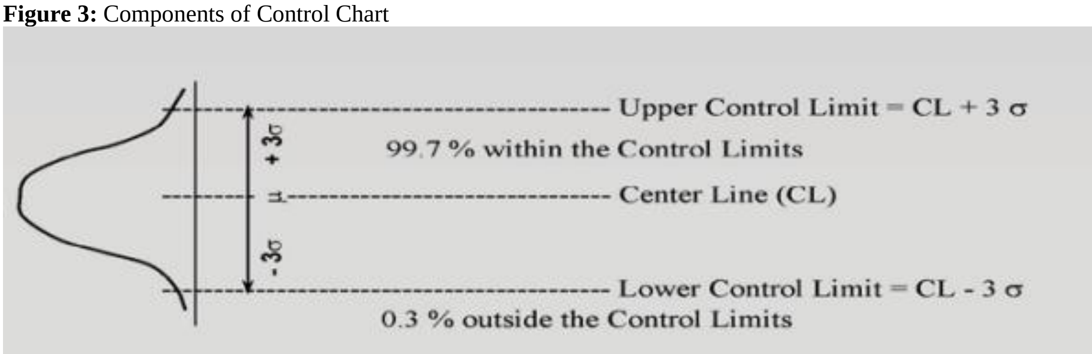
- ✓ $\overline{X}$ -Chart (Average/Mean Chart)
- ✓ R-Chart (Range Chart)
- ✓ S-Chart (Standard Deviation Chart)

Qualitative Control Charts, which are defined as control charts used for features, variations of which cannot be measured numerically, are as follows (TÜİK-Turkish Statistical Institute, 2011):

- ✓ p (fraction defective) Chart
- ✓ c (number of defects per sample) Chart
- ✓ np (number of defects) Chart
- ✓ d Control Chart
- ✓ u (number of defects per unit) Chart

A control chart is composed of three components: Lower Control Limit (LCL), Upper Control Limit (UCL) and Center Line. The mean value of the quality attribute is represented by the centerline and is the target value of the control. The lower and upper limits represent the control area.

Figure 3: Components of Control Chart



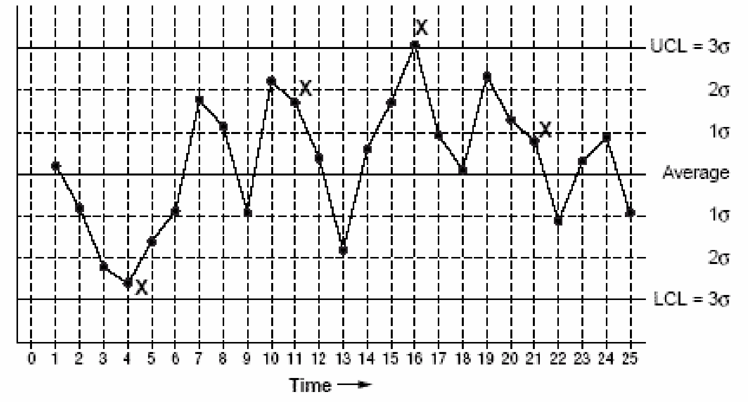
Reference: Erdoğan and Canatan, 2015.

The $\mp 3\sigma$ width is termed as the control area width. In the process that can create a normal distribution model, 99.7% of the observation values are expected to be within the control limits. The probability that the values observed in the process are outside the control limits, on the other hand, will be 0.3%.

While preparing control charts, first of all, the quality attribute to be inspected is determined. Following the selection of the control chart type, the sample mass is selected and the measurement values are recorded. After calculating the center line and control limits, the observations outside the limits are detected and the causes of defects are specified then precautions are taken.

The limits in the 3 sigma dimension are the ones that constitute the control area and reveal the necessity of taking corrective measures when it comes to the points outside this area. Limits in two sigma dimensions on the other hand, are defined as Out of Control Signals. If any observation is in a close position to the Out of Control Signals, it can be interpreted as an indication that the process is not working properly.

Figure 4: Out of Control Signals



Reference: www.asq.org

In Figure 4, observation number 16 has exceeded the upper control limit. For instance, two of three consecutive points on the same side of the centerline have exceeded the length of two sigma defined as the out of control signals, and observation 4 is considered an indication that the process is not working properly. In general, out-of-control criteria, which indicate that the process is not under control, can be listed as follows (Duncan, 1986):

- ✓ One or more observations are out of control limits.
- ✓ Two out of three consecutive observations are out of control signals.
- ✓ Four out of five consecutive observations are out of the one sigma limit.
- ✓ Display of a non-random distribution by observed values around the centerline.

3. SHEWHART CONTROL CARDS (CHARTS) MODEL

For example, let the average value of any quality attribute in a production process be 100 mm and its standard deviation 0.01 mm. Assuming that a sample mass of 5 samples is selected every hour and the average is recorded on the card, the standard deviation of the sample mass mean is calculated as follows:

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}} = \frac{0.01}{\sqrt{5}} \cong 0.00447 \ mm$$

Then, UCL and the LCL values as three sigma control limits are obtained as follows:

$$UCL = 100 + 3.(0.00447) = 100.01341 \ mm$$

$$LCL = 100 - 3.(0.00447) = 99.98659 \ mm$$

Selection of the control limits is supposed to mean determining the critical region for hypothesis testing. The hypotheses are established as follows:

$$H_0 : \mu = 100 \, mm$$

$$H_1 : \mu \neq 100 \, mm$$

The critical region is identified by the following formula:

$$\mu \mp z_{\alpha/2} \left(\frac{\sigma}{\sqrt{n}} \right)$$

If $z_{\alpha/2} = 3$, a control chart having three sigma control limits is obtained. Thus, a general model for control charts, also known as Shewhart Control Charts, can be created as follows (Montgomery, 2009):

$$UCL = \mu_K + L.\sigma_K$$

$$LCL = \mu_K - L.\sigma_K$$

K : Analyzed quality attribute

μ_K : Analyzed average of attribute

σ_K : Standard deviation of analyzed attribute

L : Distance of control limits from center line

4. AVERAGE/MEAN AND RANGE CONTROL CHARTS

$\bar{X} - R$ Control Charts are used for variables of which quality characteristics can be measured and are preferred when the sample mass size is less than 10. The sample mass average of n size taken from a population is as follows (Kartal, 1999):

$$\bar{X} = \frac{X_1 + X_2 + ... + X_n}{n}$$

Assuming that there are m samples, each with n observations, the mean of the sample mass averages (process mean) is found as follows:

$$\bar{\bar{X}} = \frac{\bar{X}_1 + \bar{X}_2 + ... + \bar{X}_m}{m}$$

Assuming that variation range (symbolized as R) is $R = X_{\max} - X_{\min}$, then the mean of the variation range is calculated by the formula:

$$\bar{R} = \frac{R_1 + R_2 + ... + R_m}{m}$$

By the help of this information, the UCL and LCL values pertaining to the $\bar{X}$ control chart are obtained as follows (Small, 1956):

$$UCL = \bar{\bar{X}} + A_2.\bar{R}$$

$$LCL = \bar{\bar{X}} - A_2.\bar{R}$$

On the other hand, it is possible to demonstrate control limits of the R control chart as follows:

$$UCL = D_4.\bar{R}$$

$$LCL = D_3.\bar{R}$$

The $\bar{X}$ Control Chart detects deviations from the mean whereas the R Control Chart detects deviations from homogeneity.

5. AVERAGE/MEAN AND STANDARD DEVIATION CONTROL CHARTS

Mean and Standard Deviation Control Charts demonstrate whether the process mean and process variability are under control. In cases where the sample size varies, the standard deviation control chart is used. Provided that the variance of the probability distribution is unknown, the standard deviation value can be estimated using the sample mass variance. The sample mass variance is found by the following formula (Aydın and Kargı, 2018):

$$s^2 = \frac{\sum_{i=1}^{n} \left(X_i - \bar{X}\right)^2}{n-1}$$

and the limits of the s control chart are obtained as follows:

$$UCL = B_6.\sigma$$

$$LCL = B_5.\sigma$$

$$Central\ Line = C_4.\sigma$$

In case the process parameters are unknown, the σ magnitude is found by analyzing past data. If the sample mass number is m, the mean of the standard deviation values is calculated through the following formula:

$$\bar{s} = \frac{\sum_{i=1}^{m} s_i}{m}$$

At that rate, the limits of the s-control chart are found using the following formulas:

$$UCL = \bar{\bar{X}} + A_3.\bar{s}$$

$$LCL = \bar{\bar{X}} - A_3.\bar{s}$$

The $A_2, A_3, B_5, B_6, C_4, D_3, D_4$ values included in the equations are the coefficients used in the calculation of the control limits and depend on the sample size (Pekmezci). The coefficient values used in the control charts, which vary depending on the number of observations in the sample mass, are given in Table 1.

Table 1: Table of Coefficients for Control Charts

n	$\bar{X}$ Chart		Standard Deviation Chart				R Chart				
	A_2	A_3	c_2 ***Central Line***	c_4	B_3	B_4	d_2 ***Central Line***	d_3	D_2	D_3	D_4
2	1.880	2.659	0.5642	0.7979	0	3.267	1.128	0.853	3.686	0	3.267
3	1.023	1.954	0.7236	0.8862	0	2.568	1.693	0.888	4.358	0	2.575
4	0.729	1.628	0.7979	0.9213	0	2.266	2.059	0.880	4.698	0	2.282
5	0.577	1.427	0.8407	0.9400	0	2.089	2.326	0.864	4.918	0	2.115
6	0.483	1.287	0.8686	0.9525	0.030	1.970	2.534	0.848	5.078	0	2.004
7	0.419	1.182	0.8882	0.9594	0.118	1.882	2.704	0.833	5.203	0.076	1.924
8	0.373	1.099	0.9027	0.9650	0.185	1.815	2.847	0.820	5.307	0.136	1.864
9	0.337	1.032	0.9139	0.9693	0.239	1.761	2.970	0.808	5.394	0.184	1.816
10	0.308	0.975	0.9227	0.9727	0.284	1.716	3.078	0.797	5.469	0.223	1.777
11	0.285	0.927	0.9300	0.9754	0.321	1.679	3.173	0.787	5.534	0.256	1.744
12	0.266	0.886	0.9359	0.9776	0.354	1.646	3.258	0.778	5.592	0.283	1.717
13	0.249	0.850	0.9410	0.9794	0.382	1.618	3.336	0.770	5.646	0.307	1.693
14	0.235	0.817	0.9453	0.9810	0.406	1.594	3.407	0.763	5.693	0.328	1.672
15	0.223	0.789	0.9490	0.9823	0.428	1.572	3.472	0.756	5.737	0.347	1.653
16	0.212	0.763	0.9523	0.9835	0.448	1.552	3.532	0.750	5.779	0.363	1.637
17	0.203	0.739	0.9551	0.9845	0.466	1.534	3.588	0.744	5.817	0.378	1.622
18	0.194	0.718	0.9576	0.9854	0.482	1.518	3.640	0.739	5.854	0.391	1.608
19	0.187	0.698	0.9599	0.9862	0.497	1.503	3.689	0.734	5.888	0.403	1.597
20	0.180	0.680	0.9619	0.9869	0.510	1.490	3.735	0.729	5.922	0.415	1.585
21	0.173	0.663	0.9638	0.9876	0.523	1.477	3.778	0.724	5.950	0.425	1.575
22	0.167	0.647	0.9655	0.9882	0.534	1.466	3.819	0.720	5.979	0.434	1.566
23	0.162	0.633	0.9670	0.9887	0.545	1.455	3.858	0.716	6.006	0.443	1.557
24	0.157	0.619	0.9684	0.9892	0.555	1.445	3.895	0.712	6.031	0.451	1.548
25	0.153	0.606	0.9696	0.9896	0.565	1.435	3.931	0.708	6.058	0.459	1.541

Reference: (Benbow, Kubiak, 2017), (Öztürk, 2017).

6. AN APPLICATION CONCERNING QUANTITATIVE CONTROL CHARTS

Sample #	X_1	X_2	X_3	X_4	X_5	**Total**	$\bar{X}_i$	R_i
1	101.5	100.6	100.1	99.2	101.5	502.9	100.58	5.2
2	99.6	100.7	102.8	100.9	101.6	505.6	101.12	4.3
3	98.7	100.4	98.3	99.8	99.1	496.3	99.26	6.2
4	100.7	100.1	99.5	99.4	98.3	498.0	99.60	4.1

$$\bar{\bar{X}} = \frac{(100.58)+(101.12)+(99.26)+(99.60)}{4} = 100.14$$

$$\bar{R} = \frac{5.2+4.3+6.2+4.1}{4} = 4.95$$

The values of $A_2 = 0.577$, $D_3 = 0$ and $D_4 = 2.115$ are found out from the coefficients table. In this case, the UCL and LCL values pertaining to $\overline{X}$ the control chart are obtained as follows:

$$UCL = \overline{\overline{X}} + A_2.\overline{R} \quad \Rightarrow \quad UCL = 100.14 + (0.577).(4.95) \cong 102.996$$

$$LCL = \overline{\overline{X}} - A_2.\overline{R} \quad \Rightarrow \quad LCL = 100.14 - (0.577).(4.95) \cong 97.284$$

On the other hand, the control limits of the R-control chart are calculated as follows:

$$UCL = D_4.\overline{R} \quad \Rightarrow \quad UCL = (2.115).(4.95) \cong 10.469$$

$$LCL = D_3.\overline{R} \quad \Rightarrow \quad LCL = 0.(4.95) = 0$$

7. QUALITATIVE CONTROL CHARTS

Qualitative Control Charts are created using the Binomial Distribution and Poisson Distribution, which have only one parameter. The Binomial Distribution and Poisson Distribution are discrete/truncated probability distributions.

The Binomial Distribution is a series of trials in which each trial has only two possible outcomes. The rules of the Binomial Distribution were mooted by NEWTON. This distribution is based on the hypothesis that if a two-probability event is repeated many times, the probabilities will always remain constant. The Binomial Distribution, in which the probability of an event occurring and not occurring is constant, is formulated as:

$$P(X = x) = \binom{n}{x} p^x . q^{n-x} = C_x^n . p^x . q^{n-x}$$

$$p + q = 1$$

The Poisson Distribution is a type of distribution that occurs over a certain period of time. The expected value is gotten through $\lambda = np$. This is also the mean of the distribution. In this distribution, the random variable X takes values between 0 and $+\infty$. The Poisson Distribution, also known as the small probabilities distribution (law of small numbers), is used to calculate the probabilities of rarely occurring events and is formulated as follows (Erdoğan, 2021):

$$P\left(X = x\right) = e^{-\lambda} . \frac{\lambda^x}{x!}$$

The control limits of the p (Fractions Defective) Chart and np (Number of Defects) Chart, which are among the Qualitative Control Charts, are presented in Table 2.

Table 2: Control Limits of p and np Control Charts

	np Chart	**p Chart**
Upper Control Limit (UCL)	$n.\overline{p} + 3\sqrt{n.\overline{p}.\overline{q}}$	$\overline{p} + 3\sqrt{\overline{p}.\overline{q} / n}$
Central Line	$n.\overline{p}$	$\overline{p}$
Lower Control Limit (LCL)	$n.\overline{p} - 3\sqrt{n.\overline{p}.\overline{q}}$	$\overline{p} - 3\sqrt{\overline{p}.\overline{q} / n}$

Reference: Bircan and Gedik, 2003.

The mean number of defects per unit in the sample mass (center line), which satisfies the assumptions of the Poisson Distribution, and the control limits of the u Control Chart used to control the center line (UCL and LCL) are calculated using the following formulas:

$$\overline{u} = \frac{\sum c_i}{n}$$

$$UCL = \overline{u} + 3\sqrt{\overline{u} / n}$$

$$LCL = \bar{u} - 3\sqrt{\bar{u}/n}$$

7.1. An Application Concerning Qualitative Control Charts

For instance, let a sample mass containing 10 televisions be randomly selected for the television (TV) production process, and the surface defects for each selected television are detected as follows.

Table 3: Determination of UCL and LCL Values

TV Number	*Surface Defect*
1	1
2	3
3	1
4	2
5	0
6	0
7	1
8	2
9	1
10	1

In the circumstances, the centerline (midline) is found as follows:

$$\bar{u} = \frac{\sum c_i}{n} \quad \Rightarrow \quad \bar{u} = \frac{12}{10} = 1.2$$

After the center line has been determined, the UCL and LCL values are calculated by the following operations:

$$UCL = 1.2 + 3\left(\sqrt{\frac{1.2}{10}}\right) \cong 2.24$$

$$LCL = 1.2 - 3\left(\sqrt{\frac{1.2}{10}}\right) \cong 0.16$$

The presence of values exceeding the control limits indicates that the process is out of control. If the control chart presents a non-normal distribution even though there is no value exceeding the control limits, the presence of systematic factors is in question.

c-Control Chart, on the other hand, uses the defect number of the product and converges to the Poisson Distribution. The control limits of the c-Chart are calculated by using the following formulas:

$$UCL = \bar{c} + 3\sqrt{\bar{c}}$$

$$LCL = \bar{c} - 3\sqrt{\bar{c}}$$

8. CONTROL METHODS FOR CONTROL CHARTS

Two different control methods are applied for control charts. The first method is the complete- enumeration control technique, in which products are checked one by one. In complete enumeration technique, the control costs are high and the time interval during which the control is performed is quite long, but the control reliability is very high. The second method used in control charts, on the other hand, is the Acceptance Sampling method. Acceptance sampling is used to decide whether to accept the lot or not, as a result of examining the sample mass randomly selected from a lot of products (Özcan and Aykanat, 2017). Acceptance sampling plans are evaluated in four different groups (TÜİK):

8.1. One-stage sampling plan:

It is a sampling plan in which n products from a lot are selected and the acceptance or rejection decision is taken in regards of the acceptability of the said lot**.** In order to express the number of products in n lot, the number of products in n samples, and the number of acceptable defective products in c samples, the sampling plan is demonstrated in the following form:

$$\begin{bmatrix} N \\ n \\ c \end{bmatrix}$$

The mathematical demonstration of the acceptance or rejection condition, where k is the number of defectives in the sample examined, is as follows:

If $k \leq c$, then lot is accepted.

If $k > c$, then lot is rejected.

8.2. Two-stage sampling plan

First of all, a unit product sample is selected from n_1 unit lot of products. If a decision of acceptance or rejection cannot be made, quality control is performed by selecting a second n_2 unit sample. Considering the combined sample of $(n_1 + n_2)$ units, a decision is made on whether to accept the lot in question. The two-stage sampling plan is expressed as follows, where c_1 is the acceptable number of defective items in the first sample and c_2 is the acceptable number of defective items in the second sample:

$$\begin{bmatrix} N & \\ n_1 & c_1 \\ n_2 & c_2 \end{bmatrix}$$

If $k_1 + k_2 \leq c_2$, then lot is accepted.

If $k_1 + k_2 > c_2$ then lot is rejected.

8.3. Multi-stage sampling plan

It is a sampling plan in which more than two samples are taken from the same lot of product, quality control is performed and it is decided whether to accept the product in question based on the results of the combined samples. In the multi-stage sampling plan, 7 samples are often taken from a lot of products and the acceptance/rejection conditions are given in wide range until the last sample. The demonstration of the plan is figured in Table 4.

Table 4:

Sample Number	***Sample Size***	***Number of Acceptance***	***Number of Rejection***
1	n_1	-	c_1
2	n_2	a_2	c_2
3	n_3	a_3	c_3
4	n_4	a_4	c_4
5	n_5	a_5	c_5
6	n_6	a_6	c_6
7	n_7	a_7	c_7

8.4. Sequential sampling plan

It is a combination of a two-stage sampling plan and a multi-stage sampling plan. Samples are sequentially taken from a lot and inspected. Depending on the results, a decision is made whether to accept the lot product in question. The sequential sampling plan is based on the sequential probability ratios test. In this method, one product from a lot is sequentially sampled and subjected to inspection.

9. AN APPLICATION CONCERNING ACCEPTANCE PROBABILITIES

The normal distribution is used in the case of $n.p > 5$, where p is the defective ratio and the Poisson distribution is used in the other case, the binomial distribution is another type of distribution used in calculation of probabilities.

How the acceptance probability is calculated according to a two-stage sampling plan is explicated with an application below.

$$\begin{bmatrix} N = 100 & \\ n_1 = 5 & c_1 = 0 \\ n_2 = 11 & c_2 = 2 \end{bmatrix}$$

Supposing we would like to calculate the probability of acceptance for the 2% defective rate, according to the plan given in the above form. According to this plan, let us calculate the acceptance probability, taking into account the 2% defective rate. According to the plan, 5 products from a lot of 100 units will be selected and inspected. Among the products inspected, if no defects are found, the lot will be accepted; If 1 or 2 products are found to be defective, 11 products from the said lot will be selected as a second sample and inspected.

Table 5:

Acceptance Way	Acceptance Way Probability
The first way: $k_1 = 0$	$P_1 = P(k_1 = 0)$
The second way: $k_1 = 1$, $k_2 \le 1$	$P_2 = P(k_1 = 1)\, P(k_2 \le 1) = P(k_1 = 1)\left[P(k_2 = 0) + P(k_2 = 1)\right]$
The third way: $k_1 = 2$, $k_2 = 0$	$P_3 = P(k_1 = 2)\, P(k_2 = 0)$

$$\lambda = np \quad ; \quad P(k) = \frac{e^{-\lambda}.\lambda^k}{k!}$$

$$\lambda_1 = 5.(0.02) = 0.10 \quad , \quad \lambda_2 = 11.(0.02) = 0.22$$

$$P(k_1 = 0) = \frac{(2.718)^{-0.10}.(0.10)^0}{0!} \cong 0.905$$

$$P(k_2 = 0) = \frac{(2.718)^{-0.22}.(0.22)^0}{0!} \cong 0.803$$

$$P(k_1 = 1) = \frac{(2.718)^{-0.10}.(0.10)^1}{1!} \cong 0.09$$

$$P(k_2 = 1) = \frac{(2.718)^{-0.22}.(0.22)^1}{1!} \cong 0.177$$

$$P(k_1 = 2) = \frac{(2.718)^{-0.10}.(0.10)^2}{2!} \cong 0.005$$

In the next step, the acceptance way probabilities are obtained as follows:

$$P_1 = P(k_1 = 0) = 0.905$$

$$P_2 = P(k_1 = 1)\left[P(k_2 = 0) + P(k_2 = 1)\right] \Rightarrow P_2 = (0.09).\left[0.803 + 0.177\right] \cong 0.088$$

$$P_3 = P(k_1 = 2).P(k_2 = 0) \Rightarrow P_3 = (0.005).(0.803) \cong 0.004$$

In the view of said information, the probability of acceptance for the lot in question is obtained as follows:

$$P = P_1 + P_2 + P_3 \quad \Rightarrow \quad P = (0.905) + (0.088) + (0.004) = 0.997$$

10. CONCLUSION

Quality has a dynamic attribute in terms of its nature. Business enterprises use statistical methods intended for measuring activity efficiency to maximize product quality and consumer satisfaction. Quality Control Charts are the most widely used method among these methods, and it is an important method that allows detecting and adjusting variations.

In this study; the structure and function of the quality control charts are explained and it is specified that possible deviations from the center line in the production processes are determined by methods. Applications were made on quantitative and qualitative control charts; the control methods applied are explained and an application about acceptance probabilities is given.

By dint of control charts, business enterprises find the opportunity to assess their production processes and can determine whether possible errors are under control. During these activities, which aim to reduce the level of error, the first and most important issue that businesses should pay attention to is to use the type of quality control chart that is most suitable for the production processes and the quality of the outputs. All and only by this means the quality level can be increased while minimizing errors.

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