Constructing Control Charts in A Printery Company for Monitoring Paper Thickness and Color Shifts

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ABSTRACT
*Assuring the quality of a product is a big problem for all companies. Statistical process control is the main quantitative tool used in TQM. For monitoring the process some statistical process control techniques are used. The most important tool for monitoring the process is quality control chart. Control charts are used in analysis of process changes. Main subject of this study is to construct a quality control chart for offset printing machine in a printery company. Because of the fact that there are some problems in the machines with respect to the color shifting and paper thickness in the output, this study aims at analyzing the production process for decreasing the shifts and the variation in paper thickness. An offset printing machine in the company is selected for constructing the quality control chart. This work focuses on 54*72 Heidelberg offset printing (2 Colors) brand printing machine and paper thickness in Advertising and Printing Company.*
JEL Classification: *M11, L15*
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Bir Basımevinde Kağıt Kalınlığı ve Renk Kaymalarının İzlenmesi İçin Kontrol Kartı Oluşturulması

ÖZET
*Bir ürünün kalitesini sağlamak tüm firmalar için büyük bir problemdir. İstatistiksel süreç kontrolü TKY kapsamında kullanılan temel sayısal araçtır. Süreci izlemede kullanılan en önemli araç ise kontrol kartlarıdır. Kontrol kartları süreçteki değişkenliği analiz etmede kullanılır. Bu çalışmanın ana amacı, bir basımevinde ofset baskı makinesi için kalite kontrol kartı hazırlamaktır. Bu çalışmada amaç bir basım evinde en önemli istatistiksel süreç kontrol aracı olan kontrol kartlarını kullanarak sürecin performansını izlemektir. Makinelerden çıkan ürünlerde renk kayması ve kağıt kalınlıklarındaki değişkenlikleri azaltmak için üretim sürecini analiz etmeyi amaçlamaktadır. Bu çalışma 54*72 Heidelberg ofset baskı makinesine odaklanmaktadır.*
JEL Sınıflaması: *M11, L15*
Anahtar Kelimeler: *İstatistiksel Süreç Kontrolü, Kalite Kontrol Kartlar*

I. STATISTICAL PROCESS CONTROL

Statistical process control is used to maintain and to improve the manufacture in industrial or commercial enterprises. During this control, the process which is constructed with the help of so called Shewhart control graphics is made to be between the calculated control limits. By applying some methods to the out-of-control parts of the process which is monitored with the help of control graphics, the process is made to follow its normal path again. Some definitions about the Statistical Process Control (SPC) in literature is given below:

"In order to better understand and manage the process, this is the follow-up method where analytical, objective and numeric techniques are used." (Oakland, 1993, p.17). "This is the statistical tool that supplies information to avoid process errors and avoids digressing from what is wanted." (Johnson, 1993, p.13).

"SPC is a frequencied control method that is used to meet the demand and expectations of internal and external customers and to carry out the 'consistent improvement model' by examining the values taken from the qualities that affects the product with statistical methods, not after the production, but during the production and by controlling and improving the process." (Sagdıç, 1995, p.9).

Statistical Process Control uses the process information taken from the sample to define the process variations and to take necessary reformative measures in due time. In line with the data collected and analysed with statistical techniques, the services needed for establish and maintain statistical control can be carried out. The productions with defects and poor quality can be avoided and the sufficiency of the process can be improved. Statistical Process Control keeps the production costs at the lowest level by improving the process quality as well as helps the optimum process working in order to keep the deviation from the product quality during the production process at the very least (Chen, 1996,p.108). Statistical techniques show how a process acted in the past and enable to anticipate about the future performance of the process. Consequently, SPC presents the basic activities to assess the current process, to improve the process performance and to meet the demands of customers. In countries which solved these kinds of problems, the design of products that will never cause any trouble during the production is considered (Özer, 1990, p.16)

According to Shewhart, the essential point to focus on in the process is the tools and techniques to satisfy the demands of the customer; the aim that comprises all activities is to make process work economically. If the committed activities are economic, then the results of the activities are expected to fall down to control limits. The deviation in performance seen out of the limits proves that there has been problems in process that puts the economic success of the process in jeopardy. If the variation in the process is out of limits, it is stated that the committed activities are gone away from the demanded level and the process will not continue unless the reason behind the problem is removed. In order to determine and remove the reasons that avoids the studies of quality and efficiency improvement, the process is needed to be examined closely. When there is a deviation in the activities, the process will not work economically as long as the reason of the problem is not determined and not removed (Devor et al, 1992, p.122-125).

II. CONTROL CHARTS

Control charts first developed by W. A Shewhart in 1924. Control charts are graphs visually if sample is within statistical control limits. They have two purpose, to establish the control limits for a process and then to monitor the process to indicate when it is out of control.control charts exist for attributes and variables;within each category there are several diffrent types of control charts (Russell and Taylor, 2000, 136). There are two broad groups of control charts:

process control and product control, two in each category; c-charts and p-charts for attributes (such as number of complaints per order, order from errors, pass or fail, good or bad) and mean (X) and range (R) control charts for variables (for instance, temperature, size, weight, or shipments).

Control charts are used in analysis of process changes. Determination of the process, capability and the differences between customer requirements and performance of these variables are the statistical tools. These charts prevent the error and control the process instead of debugging (Montgomery, 1997).

A. Control Chart Patterns

Even though a control chart may indicate that a process is in control, it is possible the sample variations within the control limits are not random. If the sample values display a consistent pattern, even within the control limits, it suggests that this pattern has a nonrandom cause that might warrant investigation (Russell & Taylor, 2003, 688).

One type of patterrn test divides the control chart into three "zones" on each side of the center line , where each zone is one standard deviation wide. These are often referred to as 1-sigma, 2-sigma, and 3-sigma limits. The pattern of sample observations in these zones is then uesd to determine if any nonrandom pattern exist. Recall that the formula for computing an X-chart uses A_2 from standard factor table, which assume 3-standard deviation control limits (or 3-sigma limits). Thus, to compute the deviding lines between each of the three zones for an X-chart, we use $1/3\ A_2$. The formulas to compute these zone boundaries are shown below (Russell & Taylor, 2000, 151).

The formulas for determining sigmas are;

Zone C: 1 sigma = $\bar{\bar{X}} + \frac{1}{3}(A_2\bar{R})$ 1 sigma = $\bar{\bar{X}} \quad \frac{1}{3}(A_2\bar{R})$

Zone B: 2 sigma = $\bar{\bar{X}} + \frac{2}{3}(A_2\bar{R})$ 2 sigma = $\bar{\bar{X}} - \frac{2}{3}(A_2\bar{R})$

Zone A: 3 sigma = $\bar{\bar{X}} + A_2\bar{R}$ 3 sigma = $\bar{\bar{X}} - A_2\bar{R}$

There are several guidelines associated with the zones for identifying patterns in a control chart, where none of the observations are beyond the control limits. The following cases are out of control process (Russell & Taylor, 2003, 689);

- Eight consecutive points on one side of the center line.
- Eight consecutive points up or down
- Fourteen points alternating up or down
- Two out of three consecutive points in zone A (on one side of the center line)
- Four out of five consecutive points in zone A or B on one side of the center line

III. LITERATURE REVIEW

A statistical model for the design of a hierarchy of adaptive X control charts was developed. It is assumed that the distribution the time the process remains in control is exponentially distributed. The proposed model was developed using a Markov chain approach (DeMagalhaes et al., 2009). A control scheme for the quality control chart that considered learning curve is proposed (Yang et al., 2009). A statistical process control system that optimizes the deployment of manpower so as to minimize the expected total cost associated with the monitoring of a multistage manufacturing system is proposed (Wu et al., 2007). A model for the economic design of an adaptive X chart for short production runs that are subject to the occurrence of assignable causes, which may either increase or decrease the mean of the quality characteristic is studied (Nenes & Tagaras, 2007). Control charts for variation play a key role in the overall statistical process control regime. Popular Shewhart-type R control chart when the mean and the variance of a normally distributed process are both unknown and are estimated from m independent samples (subgroups) each of size n is studied (Human et al, 2010). The major function of control chart is to detect the occurrence of assignable causes so that the necessary corrective action can be taken before a large quantity of nonconforming product is manufactured. The control chart for averages dominates the use of any other control chart technique if quality is measured on a continuous scale. An illustrative example is provided and the genetic algorithm is employed to search for the solution of the economic design. A sensitivity analysis is carried out to study the effects of cost and model parameters on the solution of the economic design (Lin et al, 2009). An economical design of an X chart for a short-run production is presented. The monitoring procedure consists of inspecting a single item at every m produced ones. If the measurement of the quality characteristic does not meet the control limits, the process is stopped, adjusted, and additional items are inspected retrospectively. The probabilistic model was developed considering only shifts in the process mean. A direct search technique is applied to find the optimum parameters which minimize the expected cost function (Ho & Trindade, 2009). There are real industrial cases where small shifts in the quality of a productive process do not need to be detected, but, at the same time, it is necessary to maintain the performance of the control chart to detect large shifts which are considered important. The optimization of the synthetic- X control chart is studied. Genetic algorithms have been employed to solve this optimization problem and user-friendly software has been developed with the objective of helping users to select the best synthetic-X chart for the process (Aparisi & De Luna, 2009). The implementation of control chart has been made with a real data example from chemical process control (Zhou et al., 2010). Integrated systems approach to Statistical Process Control (SPC) and Maintenance Management (MM) has been created (Charongrattanasakul & Pongpullponsak, 2011). Owing to the fact that, automatic recognition of abnormal patterns in control charts has seen increasing demands nowadays in the manufacturing processes, a novel hybrid intelligent method has been proposed (Ranaee & Ebrahimzadeh, 2011). In order to overcome the ambiguities and vagueness in relating the chart patterns to assignable causes, a fuzzy causal relationship between chart patterns and assignable causes has been established through fuzzy inference systems (Demirli & Vijayakumar, 2010). For detecting changes in psycho-physiological signals that are induced by varying cognitive load with high accuracy and relatively few false alarms control charting methods have been used instead of pattern recognition methods (Cannon et al., 2011).

IV. APPLICATION

A. COMPANY PRODUCTION PROCESS

Firstly, design and graphics work is done. At this stage text and photos are transferred to the computer. There are three design programs the firm uses. These are Photoshop, CorelDraw and illustrator. The visual elements which are transferred to the computer are bought together in the computer software and design suitable for the print is generated. The company produces designs according to customer expectations as well as offering their own designs. When presenting their own designs to the customer they make changes according to the customers' requests. Later the film output of the work is taken. The film is used to create molds for printing. After the film outputs have been taken the design image is extracted on aluminum plates (mold). The company's raw material is paper. The paper is primarily processed in the machine called guillotine. The paper is cut to sizes which are set in this machine. This process is done in order not to be reduced by wastage. For example if the paper is to be turned into a box it enters the box shaped cutting machine. After that bonding, quality control, packing and shipping is done.

B. METHODOLOGY

Statistic process control is a quality control method to provide continues supervision of a process and control process variability. It is used as a tool in deciding whether customer requirements are being fulfilled and whether the process is within the limits of variability that it has produced. The company production process is experiencing mistakes that result in 54*72 Heidelberg offset printing (2 Colors) brand printing machine sittings. During the production process molds are mounted to the printing machine according to the colors and dyes are placed. These molds are sensitive to water and alcohol mixtures. Printing takes place with the help of water and alcohol as paint is embroiled. In this process there are color percentages. If the machine deviates from these percentages color shifting occurs in the output product. Until the master understands that the machine has failure the machine is reduced by waste and the company suffers loss.

The methodology of this study incorporates both qualitative and quantitative approaches. First of all measurements will be made via the scale lupa by taking samples at random from the production line printing machine. These values will be processed to the x quality control card. Then the X-chart attached to the machine will be processed in Ms-Excel program and assessments will be made whether the process is under control or not. This study aims at minimizing production errors by developing a process control cards.

C. DATA COLLECTION

Two different evaluations are made with two different instruments in this activity. One of them is for color flows and the other one is for paper thickness. To understand the problems caused by the color flows and to reduce this problem to the least point some calculations are made through the products of x machine. The measurements of color flows and paper thickness are made in 03.04.2010 and in 05.04.2010 by taking 10 samples in 15 minute- periods. Color flows are evaluated with scaled kernel and paper thickness is evaluated with micrometer. These results are saved in Ms-Excel and x and R cards are prepared. The values for color shifts are listed in Table 1.

Table-1: Measurements color shift

Day	Sample	shift value (scale lupa)	shift value (scale lupa)	shift value (scale lupa)	shift value (scale lupa)	shift value (scale lupa)	shift value (scale lupa)	shift value (scale lupa)	shift value (scale lupa)	shift value (scale lupa)	Shiftvalue (scale lupa)
03.04.2010	9:00-9:15	0	0,4	0,1	0,4	0,6	0	0	0	0	1,1
03.04.2010	9:15-9:30	1,5	2,1	1,4	0	2	0	0	0	0,7	2,2
03.04.2010	9:30-9:45	1	1,9	0	2	2,3	0	1,8	0	0	0
03.04.2010	9:45-10:00	0	1,8	2,3	2,1	3,9	3,2	0	3,7	0	0
03.04.2010	10:00-10:15	3,2	3,6	3,5	3,5	1,7	0	0,4	0,3	2,9	3,1
03.04.2010	10:15-10:30	3,4	3,8	4,1	4	0,5	4	0	0	1	0,9
03.04.2010	10:30-10:45	0	2,9	3	3	0	2,1	2	1	1,2	0
03.04.2010	10:45-11:00	1	1	0,9	0,6	0	0	0	1,4	1,7	0,3
05.04.2010	13:00-13:15	0	1,2	1,1	0	2,4	1,7	0	3,1	3,1	3,1
05.04.2010	13:20-13:35	2,7	2	0	0	0	1,3	1,2	0	1	0,9
05.04.2010	13:40-13:55	0	2,1	2	2	2,7	2,1	2,1	2	0	0
05.04.2010	14:00-14:15	1	0,7	0	0	0	0,4	0	1,5	1,2	1,2
05.04.2010	14:20-14:35	1,8	0	1	1	1,3	1,7	0	0	0	0
05.04.2010	14:40-14:55	0	0	0,3	0,7	0,3	0,1	0	1,1	0	0
05.04.2010	15:00-15:15	0,7	0,9	0,1	0	0	0	1	1,1	1,3	1,1
05.04.2010	15:20-15:35	0	0	1,4	1,2	2,1	2	0	0	0	0
05.04.2010	15:40-15:55	1,6	1,1	0	1,6	0	0	0	1	1,5	1,5
05.04.2010	16:00-16:15	3	2,7	2,7	2,7	2,7	0	3,2	3,6	0	0
05.04.2010	16:20-16:35	2,4	2	0	0	0	0,9	0,9	0	0	0
05.04.2010	16:40-16:55	0	0	0	0	0	0	0,9	0,4	1,5	1,2
5.04.2010	17:00-17:15	0,1	0,5	0	0	1,2	0	0	0	0	0

Table-2: Measurements paper thickness

Day	Sample	Thickness value (micrometer)	Thickness value (micrometer)	Thickness value (micrometer)	Thickness value (micrometer)	Thickness value (micrometer)	Thickness value (micrometer)	Thickness value (micrometer)	Thickness value (micrometer)	Thickness value (micrometer)	Thickness value (micrometer)
03.04.2010	9:00-9:15	12	30	10	9	9	9	32	35	12	10
03.04.2010	9:15-9:30	10	10	15	13	20	9	7	7	21	10
03.04.2010	9:30-9:45	15	30	30	32	40	45	10	10	10	12
03.04.2010	9:45-10:00	10	10	15	5	7	18	25	10	20	25
03.04.2010	10:00-10:15	10	15	17	10	10	10	20	25	25	20
03.04.2010	10:15-10:30	20	12	10	10	10	10	10	10	10	10
03.04.2010	10:30-10:45	10	25	25	10	12	9	9	7	10	10
03.04.2010	10:45-11:00	9	5	10	21	10	10	10	10	9	10
05.04.2010	13:00-13:15	10	12	10	10	14	10	9	7	15	14
05.04.2010	13:20-13:35	10	10	20	17	10	10	10	15	10	10
05.04.2010	13:40-13:55	20	10	23	20	7	9	14	21	10	10
05.04.2010	14:00-14:15	9	10	20	27	24	30	10	7	10	10
05.04.2010	14:20-14:35	10	9	21	10	10	10	10	10	10	15
05.04.2010	14:40-14:55	35	30	10	31	34	15	17	35	30	9
05.04.2010	15:00-15:15	20	20	14	20	15	17	23	20	32	30
05.04.2010	15:20-15:35	10	8	21	23	18	20	20	10	10	10
05.04.2010	15:40-15:55	12	10	7	35	10	10	10	28	21	32
05.04.2010	16:00-16:15	10	41	10	10	36	36	42	40	35	35
05.04.2010	16:20-16:35	37	10	10	10	10	21	20	9	9	10
05.04.2010	16:40-16:55	12	14	14	10	10	11	12	14	25	23
05.04.2010	17:00-17:15	15	23	20	24	28	20	20	10	10	10

Table-3: X control chart calculations for color shift

Day	Sample	**R**	$\bar{X}$	**Above / below**	**Up / down**	**Zone**
03.04.2010	9:00-9:15	1,1	0,260	b		x
03.04.2010	9:15-9:30	2,2	0,990	b	u	c
03.04.2010	9:30-9:45	2,3	0,900	b	d	c
03.04.2010	9:45-10:00	3,9	1,700	a	u	a
03.04.2010	10:00-10:15	3,6	2,220	a	u	x
03.04.2010	10:15-10:30	4,1	2,170	a	d	x
03.04.2010	10:30-10:45	3	1,520	a	d	a
03.04.2010	10:45-11:00	1,7	0,690	b	d	b
05.04.2010	13:00-13:15	3,1	1,570	a	u	a
05.04.2010	13:20-13:35	2,7	0,910	b	d	c
05.04.2010	13:40-13:55	2,7	1,500	a	u	a
05.04.2010	14:00-14:15	1,5	0,600	b	d	b
05.04.2010	14:20-14:35	1,8	0,680	b	u	b
05.04.2010	14:40-14:55	1,1	0,250	b	d	x
05.04.2010	15:00-15:15	1,3	0,620	b	u	b
05.04.2010	15:20-15:35	2,1	0,670	b	u	b
05.04.2010	15:40-15:55	1,6	0,830	b	u	c
05.04.2010	16:00-16:15	3,6	2,060	a	u	x
05.04.2010	16:20-16:35	2,4	0,620	b	d	b
05.04.2010	16:40-16:55	1,5	0,400	b	d	a
05.04.2010	17:00-17:15	1,2	0,180	b	d	x

For finding the R and $\bar{X}$ values in Table 3, Table 1 measurement values for color shifts are used. First sample R and $\bar{X}$ calculations have been given as an example.

R = max{0; 0,4; 0,1; 0,4; 0,6; 0; 0; 0; 0; 1,1} - min{0; 0,4; 0,1; 0,4; 0,6; 0; 0; 0; 0; 1,1} = 1,1 - 0 = 1,1

$$\bar{X} = \frac{0+0{,}4+0{,}1+0{,}4+0{,}6+0+0+0+0+1{,}1}{10} = 0{,}260$$

Sum of these values give $\bar{\bar{X}}$ and $\bar{R}$.

$$\bar{\bar{X}} = \frac{\sum \bar{x}}{n} = \frac{21{,}340}{21} = 1{,}016$$

$$\bar{R} = \frac{\sum R}{n} = \frac{48{,}5}{21} = 2{,}309524$$

Then, upper control limit and lower control limit values can be calculated for constructing $\bar{X}$ control chart.

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

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

A_2 factor only depends on n (sample size). It can be seen from the standard table. (n=10)

$A_2 = 0{,}31$ for n=10

UCL = 1,016 + 0,31*2,309524 = 1,727524
LCL = 1,016 - 0,31*2,309524 = 0,304857

$$1u = \bar{\bar{X}} + \frac{1}{3}(A_2\bar{R}) = 1{,}016 + \frac{1}{3}(0{,}31 * 2{,}309524) = 1{,}253302$$

$$1l = \bar{\bar{X}} - \frac{1}{3}(A_2\bar{R}) = 1{,}016 - \frac{1}{3}(0{,}31 * 2{,}309524) = 0{,}779079$$

$$2u = \bar{\bar{X}} + \frac{2}{3}(A_2\bar{R}) = 1{,}016 + \frac{2}{3}(0{,}31 * 2{,}309524) = 1{,}490413$$

$$2l = \bar{\bar{X}} - \frac{2}{3}(A_2\bar{R}) = 1{,}016 - \frac{2}{3}(0{,}31 * 2{,}309524) = 0{,}541968$$

For finding the above/below result $\bar{x}$ value in the first row is compared with the $\bar{\bar{x}}$ values.

0,260<1,016 => first result in the above/below column is "b".

In up/down column, $\bar{x}$ value is compared with the previous $\bar{x}$ value. For the second row,

0,990>0,260 => result in the up/down column is "u".

For determining the zone in $\bar{x}$ control chart for color shift, this conditional function has been used.

$$\begin{cases} 0{,}779079 < \bar{x} < 1{,}253302 \Rightarrow zone\ "c" \\ 0{,}541968 < \bar{x} < 0{,}779079 \ or\ 1{,}253302 < \bar{x} < 1{,}490413 \Rightarrow zone\ "b" \\ 0{,}304857 < \bar{x} < 0{,}541968 \ or\ 1{,}490413 < \bar{x} < 1{,}727524 \Rightarrow zone\ "a" \\ \bar{x} < 0{,}304857 \ or\ \bar{x} > 1{,}727524 \Rightarrow out\ of\ control\ limits\ "x" \end{cases}$$

In zone column, "x" means $\bar{x}$ value is out of control limits.

For example, for the first $\bar{x}$ value in Table 3, (0,260 < 0,304857), it is out of control limits. For the second $\bar{x}$ value, (0,779079 < 0,990 < 1,253302), it is in zone "c".

When Table 3 is examined for the color flow, there is no problem in up/down parts. But, there are 6 consecutive "b" terms in above/below column and in the zone part there are some "x" terms in zone column. This shows that the process is out of control. These are shown in Table 3 and 4. In Table 3, it can be seen that the out-of-control situation appeared in 03.04.2010, between 9:00-9:15; 10:00-10:15; 10:15-10:30. Also it can be seen that in 05.04.2010 between 14:40-14:55; 16:00-16:15; 17:00-17:15 the process grew out of control limits. There are sudden risings or decreases during the process.

By using the data in Table 1; $\bar{R}$, UCL and LCL values can be calculated.

UCL = $D_4\bar{R}$ LCL = $D_3\bar{R}$

D_4 and D_3 values from the standard factor table can be found. From n=10;

D_4 = 1,78 D_3= 0,22

UCL = 1,78*2,309524 = 4,104024
LCL = 0,22*2,309524 = 0,515024

When Table 4 is examined, there is no problem in above/below and up/down parts. But in the zone part, 2 of 3 sequential values are in b column and 4 of 5 sequential values are in b column. This situation shows that process is out of control. In Table 4, it can be seen that these out-of-control situations occurred in 03.04.2010 between 9:45-13:15. In this interval, 6 consecutive values are in zone A or B. Furthermore it is obvious that in 03.04.2010 between 9:00-9:15; and in 05.04.2010 between 14:40-14:55 the process was not continuing according to the limits of control. There are abrupt changes throughout the process.

Table-4: R control chart calculations for color shift

Day	Sample	**R**	**Above / below**	**Up / down**	**Zone**
03.04.2010	9:00-9:15	1,1	b		x
03.04.2010	9:15-9:30	2,2	b	u	c
03.04.2010	9:30-9:45	2,3	b	u	c
03.04.2010	9:45-10:00	3,9	a	u	a
03.04.2010	10:00-10:15	3,6	a	d	a
03.04.2010	10:15-10:30	4,1	a	u	a
03.04.2010	10:30-10:45	3	a	d	b
03.04.2010	10:45-11:00	1,7	b	d	b
05.04.2010	13:00-13:15	3,1	a	u	b
05.04.2010	13:20-13:35	2,7	a	d	c
05.04.2010	13:40-13:55	2,7	a	d	c
05.04.2010	14:00-14:15	1,5	b	d	b
05.04.2010	14:20-14:35	1,8	b	u	c
05.04.2010	14:40-14:55	1,1	b	d	x
05.04.2010	15:00-15:15	1,3	b	u	b
05.04.2010	15:20-15:35	2,1	b	u	c
05.04.2010	15:40-15:55	1,6	b	d	b
05.04.2010	16:00-16:15	3,6	a	u	a
05.04.2010	16:20-16:35	2,4	a	d	c
05.04.2010	16:40-16:55	1,5	b	d	b
05.04.2010	17:00-17:15	1,2	b	d	b

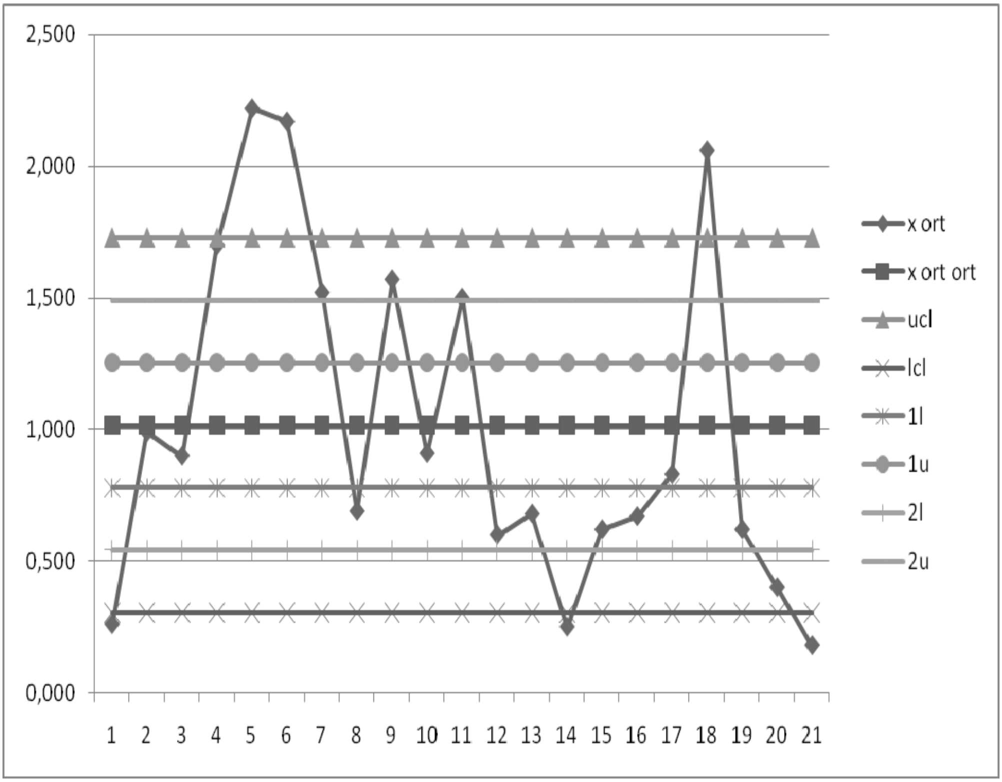

Figure-1: X control chart for color shift

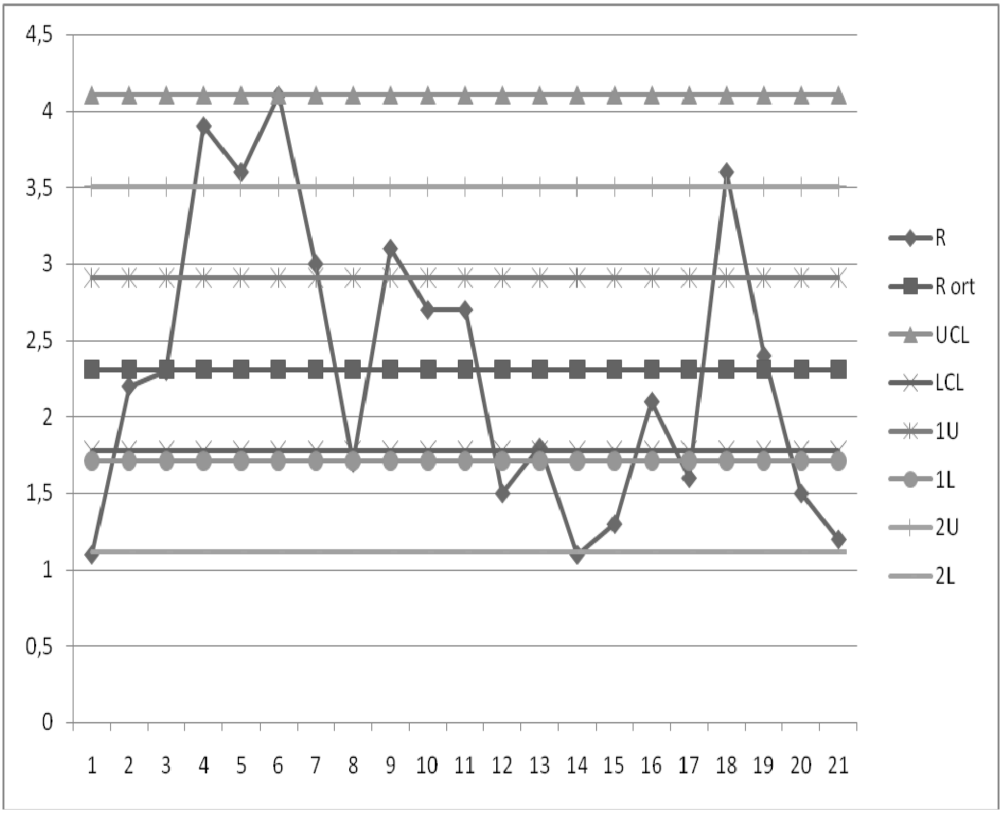

Figure-2: R control chart for color shift

Table-5: X control chart calculations for paper thickness

Day	Sample	**R**	$\bar{X}$	**Above / below**	**Up / down**	**Zone**
03.04.2010	9:00-9:15	26	16,800	a		c
03.04.2010	9:15-9:30	14	12,200	b	d	b
03.04.2010	9:30-9:45	35	23,400	a	u	x
03.04.2010	9:45-10:00	20	14,500	b	d	c
03.04.2010	10:00-10:15	15	16,200	a	u	c
03.04.2010	10:15-10:30	10	11,200	b	d	a
03.04.2010	10:30-10:45	18	12,700	b	u	b
03.04.2010	10:45-11:00	16	10,400	b	d	a
05.04.2010	13:00-13:15	8	11,100	b	u	a
05.04.2010	13:20-13:35	10	12,200	b	u	b
05.04.2010	13:40-13:55	16	14,400	b	u	c
05.04.2010	14:00-14:15	23	15,700	b	u	c
05.04.2010	14:20-14:35	12	11,500	b	d	a
05.04.2010	14:40-14:55	26	24,600	a	u	x
05.04.2010	15:00-15:15	18	21,100	a	d	a
05.04.2010	15:20-15:35	15	15,000	b	d	c
05.04.2010	15:40-15:55	28	17,500	a	u	c
05.04.2010	16:00-16:15	32	29,500	a	u	x
05.04.2010	16:20-16:35	28	14,600	b	d	c
05.04.2010	16:40-16:55	15	14,500	b	d	c
05.04.2010	17:00-17:15	18	18,000	a	u	c

$\bar{\bar{X}}$ and $\bar{R}$ calculations for paper thickness have been shown below by using Table 2 data.

$$\bar{\bar{X}} = \frac{\sum \bar{x}}{n} = \frac{337{,}100}{21} = 16{,}052$$

$$\bar{R} = \frac{\sum R}{n} = \frac{403}{21} = 19{,}19048$$

Then, upper control limit and lower control limit values can be calculated for constructing $\bar{X}$ control chart.

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

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

A_2 factor only depends on n (sample size). It can be seen from the standard table. (n=10)

$A_2 = 0{,}31$ for n=10

UCL = 16,052 + 0,31*19,19048 = 21,96305

LCL = 16,052 - 0,31*19,19048 = 10,14171

$$1u = \bar{\bar{X}} + \frac{1}{3}(A_2\bar{R}) = 16{,}052 + \frac{1}{3}(0{,}31 * 19{,}19048) = 18{,}0226$$

$$1l = \bar{\bar{X}} - \frac{1}{3}(A_2\bar{R}) = 16{,}052 - \frac{1}{3}(0{,}31 * 19{,}19048) = 14{,}08216$$

$$2u = \bar{\bar{X}} + \frac{2}{3}(A_2\bar{R}) = 16{,}052 + \frac{2}{3}(0{,}31 * 19{,}19048) = 19{,}99283$$

$$2l = \bar{\bar{X}} - \frac{2}{3}(A_2\bar{R}) = 16{,}052 - \frac{2}{3}(0{,}31 * 19{,}19048) = 12{,}11194$$

For finding the above/below result $\bar{x}$ value in the first row is compared with the $\bar{\bar{x}}$ values.

16,800<16,052 => first result in the above/below column is “a”.

In up/down column, $\bar{x}$ value is compared with the previous $\bar{x}$ value. For the second row,

12,200>16,800 => result in the up/down column is “d”.

In zone column, “x” means $\bar{x}$ value is out of control limits.

The evaluation of the out-of-control situations from the above/below/up/down and zone aspects which are calculated on the board:

1. If 8 points are in succession or if 8 points are “b” in succession, no matter they are in the process limit in above/below column, they should be checked.
2. If 8 points increases in succession (in other words, if they are “u”) or decreases (in other words, if they are “d”) in up/down column.
3. If 14 points are scattered between “u” and “d”.
4. If two of three sequential values are in “a” column zone (a, b, c) information in the last column.
5. Four of five sequential values are in “a” or “b” column zone (a, b, c) information in the last column.

When Table 5 is examined for the paper thickness, there is no problem in above/below and up/down parts. But in the zone part 2 of 3 sequential values are in a column. This shows that the process is out of control. These are shown in Table 5 and 6. In the Table 5, it can be seen that the out-of-control situation appeared in 03.04.2010, between 9:30-9:45. Also it can be seen that in 05.04.2010 between 14:40-14:55 and 16:00-16:15 the process grew out of control limits. There are sudden risings or decreases during the process.

By using the data in Table 2, $\bar{R}$, UCL and LCL values can be calculated.

D_4 and D_3 values from the standard factor table can be found. From n=10;

D_4 = 1,78 D_3= 0,22

UCL = 1,78*19,19048 = 34,101476

LCL = 0,22*19,19048 = 4,279476

When Table 6 is examined, there is no problem in above/below and up/down parts. But in the zone part, it can be seen that these out-of-control situations occurred in 03.04.2010 between 9:30-9:45. Process is out of control according the charts.

Table-6: R control chart calculations for paper thickness

Day	Sample	**R**	**Above / below**	**Up / down**	**Zone**
03.04.2010	9:00-9:15	26	a		b
03.04.2010	9:15-9:30	14	b	d	b
03.04.2010	9:30-9:45	35	a	u	x
03.04.2010	9:45-10:00	20	a	d	c
03.04.2010	10:00-10:15	15	b	d	c
03.04.2010	10:15-10:30	10	b	d	b
03.04.2010	10:30-10:45	18	b	u	c
03.04.2010	10:45-11:00	16	b	d	c
05.04.2010	13:00-13:15	8	b	d	a
05.04.2010	13:20-13:35	10	b	u	b
05.04.2010	13:40-13:55	16	b	u	c
05.04.2010	14:00-14:15	23	a	u	c
05.04.2010	14:20-14:35	12	b	d	b
05.04.2010	14:40-14:55	26	a	u	b
05.04.2010	15:00-15:15	18	b	d	c
05.04.2010	15:20-15:35	15	b	d	c
05.04.2010	15:40-15:55	28	a	u	b
05.04.2010	16:00-16:15	32	a	u	a
05.04.2010	16:20-16:35	28	a	d	b
05.04.2010	16:40-16:55	15	b	d	c
05.04.2010	17:00-17:15	18	b	u	c

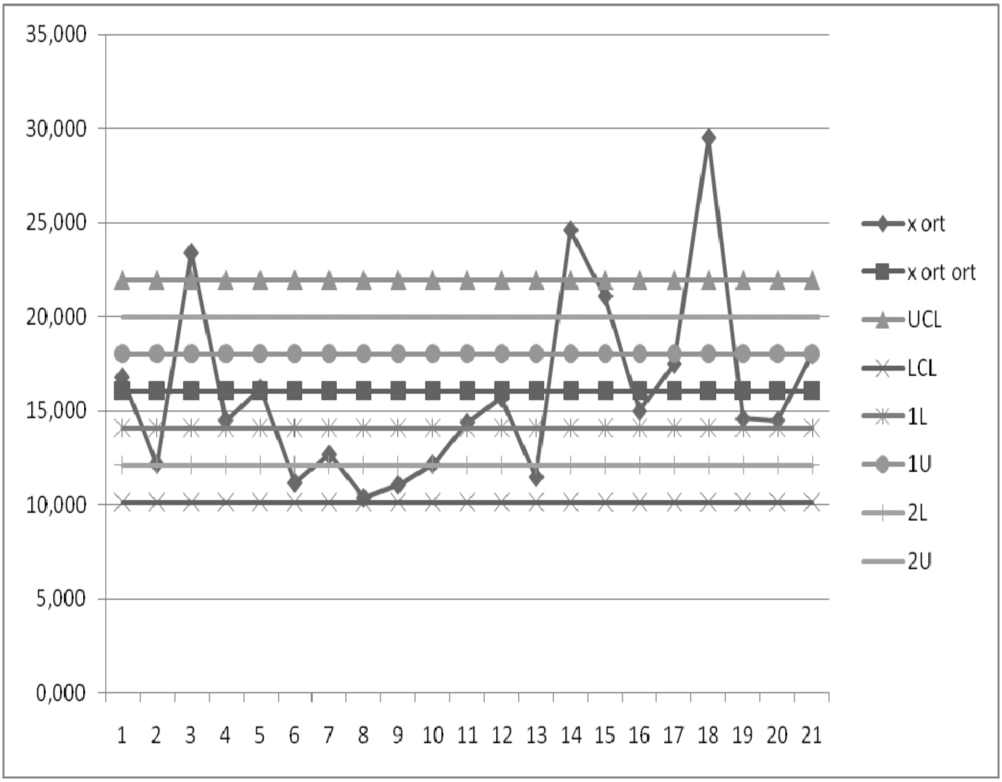

Figure-3: X control chart for paper thickness

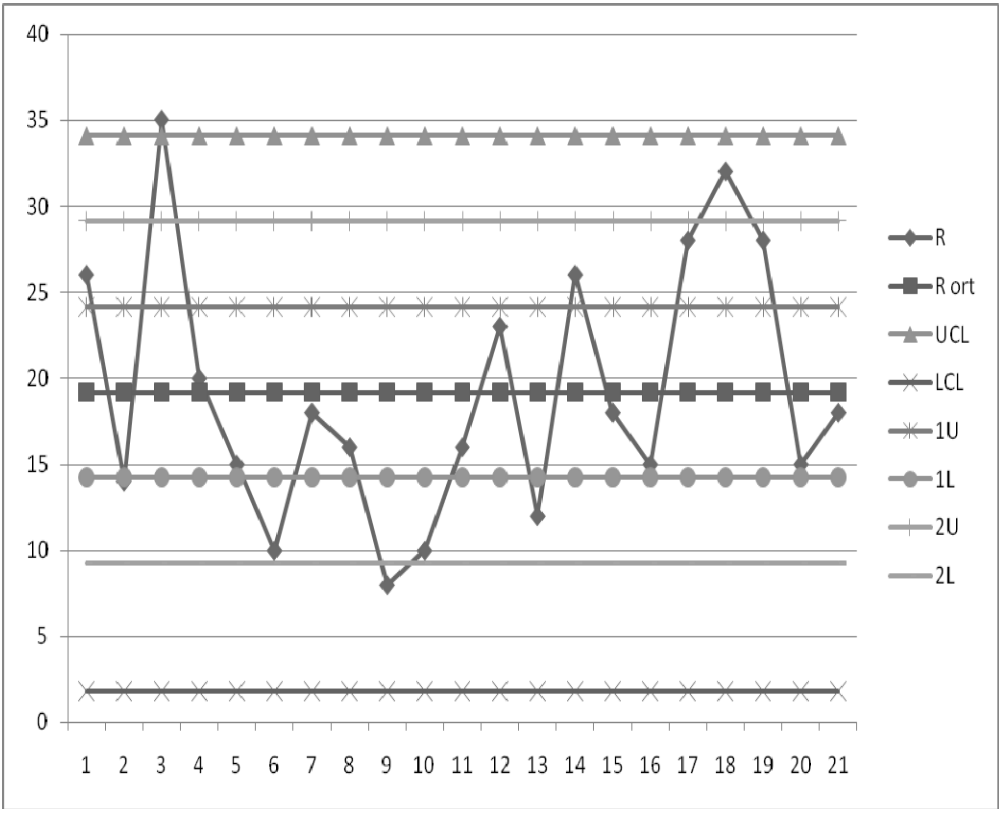

Figure-4: R control chart for paper thickness

RESULT

In the company where the process takes place it is evaluated that in the solution of a defined problem if Statistical Quality Control methods can be used or if it was used how they could benefit from it. When the solution is searched without the use of Statistical Quality Control methods it is inevitable to encounter with deficient and illusory conclusions. Making reformatory activities without defining the reason of the problem will not end up with improving activities; also it will cause unnecessary loss of time and money. It is vital to know the reason of the problem and it can be done by the use of Statistical Quality Control methods.

There is no problem in all X and R charts above/below and up/down parts. But there is some problem in zone part. This proves that the process is out of control. The out-of-control situations for color flows are like these:

When Table 3 is examined for the color flow, there is no problem in up/down parts. But, there are 6 consecutive "b" terms in above/below column and in the zone part there are some "x" terms in zone column. This shows that the process is out of control. These are shown in Table 3 and 4. In Table 3, it can be seen that the out-of-control situation appeared in 03.04.2010, between 9:00-9:15; 10:00-10:15; 10:15-10:30. Also it can be seen that in 05.04.2010 between 14:40-14:55; 16:00-16:15; 17:00-17:15 the process grew out of control limits. There are sudden risings or decreases during the process. When Table 4 is examined, there is no problem in above/below and up/down parts. But in the zone part, 2 of 3 sequential values are in b column and 4 of 5 sequential values are in b column. This situation shows that process is out of control. In Table 4, it can be seen that these out-of-control situations occurred in 03.04.2010 between 9:45-13:15. In this interval, 6 consecutive values are in zone A or B. Furthermore it is obvious that in 03.04.2010 between 9:00-9:15; and in 05.04.2010 between 14:40-14:55 the process was not continuing according to the limits of control. There are abrupt changes throughout the process.

The out-of-control situations for paper thickness are like these: When Table 5 is examined for the paper thickness; there is no problem in above/below and up/down parts. But in the zone part 2 of 3 sequential values are in a column. This shows that the process is out of control. These are shown in Table 5 and 6. In the Table 5, it can be seen that the out-of-control situation appeared in 03.04.2010, between 9:30-9:45. Also it can be seen that in 05.04.2010 between 14:40-14:55 and 16:00-16:15 the process grew out of control limits. There are sudden risings or decreases during the process. When Table 6 is examined, there is no problem in above/below and up/down parts. But in the zone part, it can be seen that these out-of-control situations occurred in 03.04.2010 between 9:30-9:45. Process is out of control according the charts.

When evaluation was made the worker in the schedule did not move from his place during his working hours. When there is a problem in the machine's regulations, it is reduced by wastage. The preventive time of this machine in the company is once a month. But for decreasing the defects caused by the color flows, for improving the process, preventive maintenance activities should be scheduled according the control chart results. For the change of the thickness of the papers, the relations with the suppliers should be improved. First of all, a sample should be taken from the supplier and then it should be evaluated. As a result of this, materials can be purchased by minimizing the faulty property and customer's satisfaction can be increased. Also productivity of manufacture will increase and production cost will be decreased by preventing the loss caused by production fouls.

The mission of Statistical Process Control will not end with getting the process under control. After this step, random reasons in the process should be determined and improving tries should be done. Improvement of the process is managed by the reduction of variability.

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