SIMULATION STUDY OF STATISTICAL PROCESS CONTROL SCHEMES PERFORMANCE FOR MONITORING VARAITION

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The research objectives are to study evaluate performance of traditional control charts that are *Shewhart* and *EWMA* both .In monitoring small and large process mean shifts and to propose an improved statistical process control charting procedure that effective for monitoring all process mean shifts . In general Process mean shift can be described as unstable patterns. In this research concentration on the shifts pattern Average run length *ARL* in both types *ARL* stable and *ARL* unstable, Type I Error and Type II Error is used as the performance measures The charting procedures were coded in *MATLAB* program and extensive simulation experiments were conducted. Design of Experiment (DOE) methods were applied in selecting the suitable design parameters of control charts before conducting the detail *ARL* simulations. The *ARL* simulation identifies each control chart monitoring advantages and disadvantages . In general *EWMA* control charts are more effective for detecting the variation process in small mean shifts compare with the Shewhart control charts While the *Shewhart* control charts were more effective for detecting the variation process in large mean shift . Specifically, *EWMA* with (λ=0. 05, L=2. 615) and (λ=0. 1 , L=2. 81) were identified produced a small Type II error, so effective for monitoring small and process mean shift, more effective than *Shwehart* control chart . But at large mean shift 3σ Shwehart gives more effective to detect the variation in the process .

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CHAPTER I

INTRODUCTION

1.1 Introduction:

In recent years, Statistical Process Control tools in have been widely implemented manufacturing industries in all industrialized countries examples In Malaysia, the application is increasing especially in discrete part industries. Selection of Statistical Process Control is critical in quality control improvement. For example, *Shewhart* Control Charting Scheme Shewhart is effective for quality control in monitoring large shift process variation. Inversely with the *EWMA* control chart is effective with small shift process variation (Montgomery 2001) . Generally the Control charts are an essential tool of continuous quality control. Control charts monitor processes to show how the process is performing and how the process and capabilities are affected by changes in the process. This information is then used to make quality improvements Control charts are also used to determine the capability of the process. They can help identify special or assignable causes for factors that impede peak performance. Control charts show if a process is in control or out of control (Montgomery2005). They show the variance of the output of a process over time, such as a measurement of width, upper and lower limits to see if it fits within the expected, specific, predictable and normal variation If so, however, the variance falls outside the limits, or has a run of non-natural points, the process is considered out of control.

1.2 Statement of the Problem :

There is possibility that Industrial Practiceness incorrectly selected the suitable Statistical Process Control tools due to lack of fundamental knowledge in Statistical Process Control. Especially since the manufacturing process influenced by many factors direct and indirect inside the factory, which may Create to a variation in the operation , Hence , this will affect the quality of product that being manufactured, Therefore, it is necessary to investigate the performance of Statistical Process Control tools in monitoring process variation. In particular, this study focus on *Shewhart* and *EWMA* control charting scheme. The findings of this study could be a reference which is useful for Industrial Practice ness to correctly select the specific Statistical Process Control tools in dealing with process variation.

1.3 Objectives :

i. To study evaluated the performance of Statistical Process Control charting scheme in monitoring process variation. In particular, this study focuses on *Shewhart* chart $\mp 3\sigma$ and *EWMA* chart control .

ii. To propose a guideline for choosing suitable Statistical Process Control tools in monitoring process variation. In particular this study focus on optimal design parameters for *Shewhart* chart and *EWMA* control chart.

2.4 Scope and Key Assumptions:

The scope of this research involves three items as follow:

i. Process variables to be monitored are limited to sudden mean shifts.

ii. The performance of the statistical process control charting schemes is evaluated based computer simulation using synthetic and real process data streams.

iii. The design parameters for the *Sewhart* control chart ∓3σ and *EWMA* control harts

2.5 Definition of Terms

In conduct in this project . Some of the terms as shown in the table are used to simplify the meaning of techniques as shown in the table (1-1).

Table (1.1): simplify the meaning of technique

Process Mean Shift	
Small mean shift	Mean of unstable process data, shifted from the mean of stable process less than 1.5σ.
Large mean shift	Mean of unstable process data, shifted from the mean of stable process equal or more than 1.5σ.

1.6 Research Activity Plan:

the research activities conducted within two semesters. It was divided into four phases. As shown in the figure (1.1)

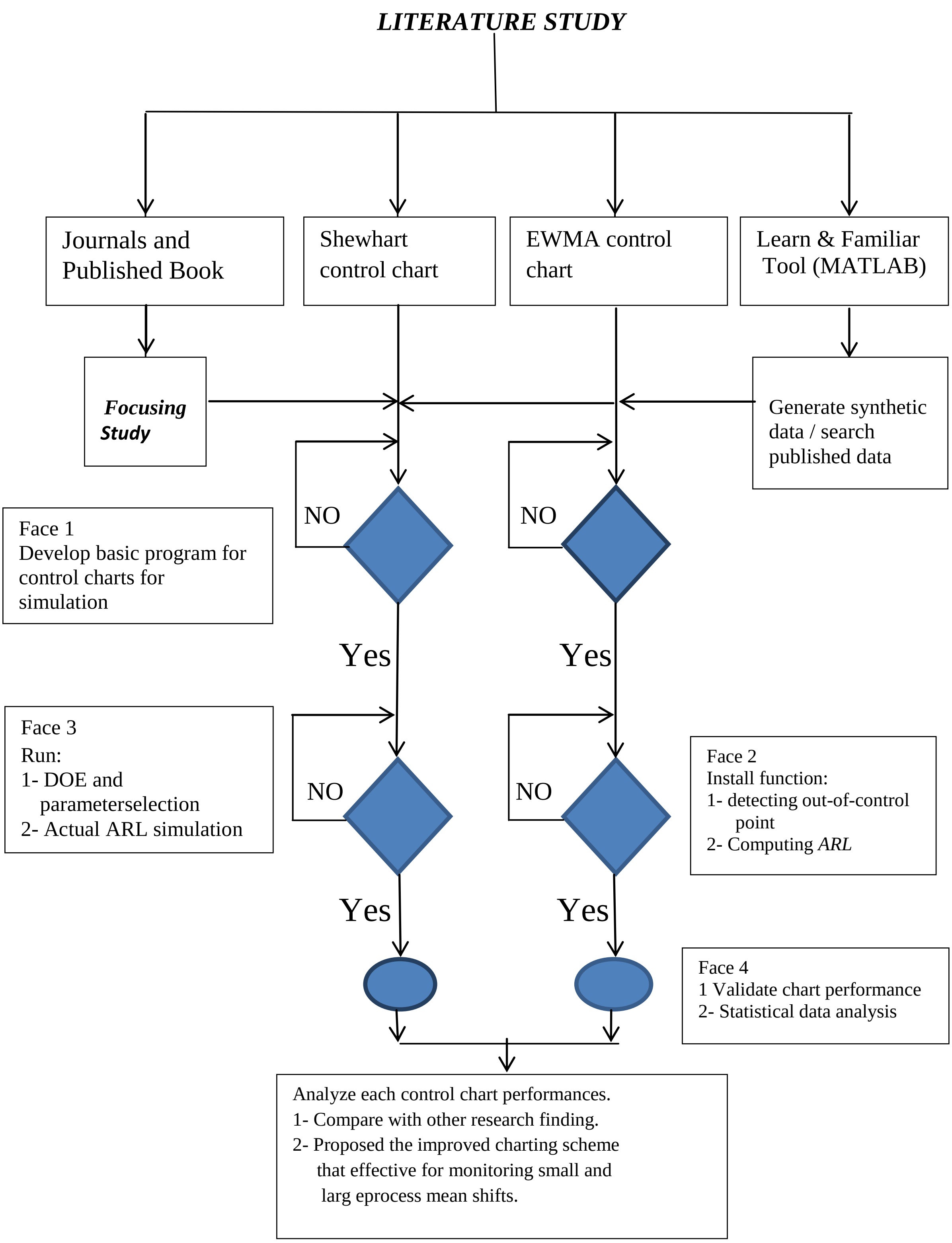


figure (1.1) : Research Activity Plan

In the first semester. Research activity it was studying a research published and books that are related to performance of control schemes Focus on study the performance of *Shewha*t control chart and *EWMA* to monitor the production process to detect possible variation that occurs in the process. Then learning the *MATLAB* program , which was developed to study the control charts. By Using simulation Synthetic Data in the program. Drawn the charts and Analysis to detect the performance of control charts. After each of the simulations for She what control chart and *EWMA* charts. We get the Results and then compared with published results.

1.7 **Summary:**

This chapter Included the background of control charts and the statement of the problem. Find targets. And the scope and key assumption definition of terms of research and research activities in monitoring the variance process. *Shewart* control chart is insensitive in the detection of small shift while the performance of the *EWMA* is more sensitive in detecting small shifts. In the production process problem is that the difference of the average process usually either unexpectedly it will deform to shifts small or large. In this research to evaluate the performance of Shewart control chart and *EWMA* chart . And suggest any suitable process control. This chapter presented on a preliminary basis for this study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction:

Statistical Process Control (SPC) is a tool that measures and achieves quality. Is an Effective method of monitoring the production Processes (Jordan Journal of Mechanical and Industrial Engineering 2012) . That allows for maintaining certain standards without inspecting and regulating every step and product of the process by applying statistical techniques (a series of steps designed to produce a repeated and consistent result) to determine whether the output of a process conforms to the product or service design (MIKEL J. Harry & Prem S . MANN 2010). The basic idea in statistical process control (SPC) is to take random samples of products from manufacturing line and examine the products to ensure that certain criteria of quality are satisfied (Montgomery, 1991). And then study the Statistics for Search for out assignable causes of inferior quality to bring the process back to control. Statistical process control is a powerful collection of problem-solving tools useful in achieving process stability and improving capability (Dale H. Besterfield 2001).
Problem-solving tools useful in achieving process stability and improving capability through the reduction of variability. These tools, often called magnificent seven are; histogram, check sheet, Pareto chart, Scatter diagram, Cause and effect diagrams (Fishbone Diagram) (Jordan Journal of Mechanical and Industrial Engineering 2012) , in1920s by Dr. *Walter Shewhart* Which is one of the most important and powerful tools for *SPC* . Then in 1950 s Enter the *EWMA* control chart, the EWNA chart is more sensitive than the *Shewhart* control chart in the small shifts (Montgomery2005) .

2.2 Tools of statistical process control:

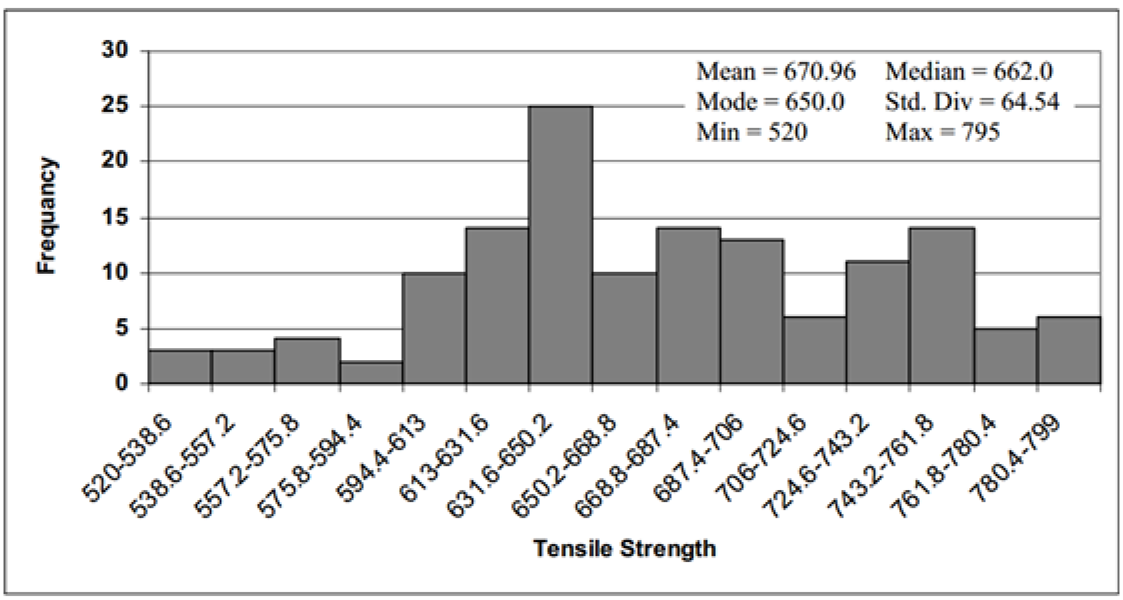
2.2.1 Histogram:

The tool is a special bar chart to measure data. Charts used to draw the frequency of events in the production process. The data are grouped in neighboring numerical categories The Minitab software can be organizing the data into groups. And plot the histogram (Jordan Journal of Mechanical and Industrial Engineering 2012)

Example:

Data concerning the tensile strength test is shown in Table (2.1) and used to illustrate the histogram in Figure (2.1).

Figure (2.1): Histogram diagram



2.2.2 check sheets:

In general the check sheets are tables simply used for data collection and include a list of nonconformities and the tally of nonconformities . And must contain the name of the project and the dates of data collection. And the location of data collection (e.g., in house or at customer's).

Example :

In the Table (2.2) shows the results of the visit by a quality improvement team at a manufacturing of wood components. After checking the elemental ingredients (scrap. Rework bins) And speak with customers. The team is agreed on categories of nonconforming and developed precise definitions of nonconformities and developed precise definitions for each category. The created a check sheet. Then inspected each item and tallied the number of frequencies for each case of nonconformity(Jordan Journal of Mechanical and Industrial Engineering 2012).

Table (2.2) shows the results

Project Quality Improvement Project **Location** Customer A	**Name** QIT **Dates** January 2002	**Shift** All
Reason		**Freq.**
Size out of specification	卌 ////	194
Loose knots	卌 卌 卌 ///	18
Raised grain	////	4
Dents	///	3
Stain/rot	卌 卌 卌 卌 卌 卌 /	31
Fuzzy grain	卌 卌	105
Splits	卌 卌 /	11
Machine tear-out	卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 /	61
Burn marks	卌 卌 卌 卌 卌 卌 卌 卌 ////	44
Oil/grease marks	//	2
Total		473

2. 2.3 Pareto chart:

A Pareto chart, named after Vilfredo Pareto, is a type of chart that contains both bars and a line graph, where individual values are represented in descending order by bars, and the cumulative total is represented by the line. (Jordan Journal of Mechanical and Industrial Engineering 2012)

Example:

Pareto chart was constructed based upon data collected by check sheet for the main tests performed on steel and shown in the following Table (2.3) and Figure (2.2)

Table (2.3) data collected by check sheet

Category	*Repetition*	*Frequency*	Cumulative Frequency	Percentage	Cumulative percent
Tensile strength	𝍸 𝍸 𝍸 𝍸 𝍸 |||	28	28	72%	72%
Yield Strength	𝍸	5	33	85%	85%
Elongation Percent	|||	3	36	92%	92%
Effective diameter	||	2	38	97%	97%
Effective Weight	|	1	39	100%	100%

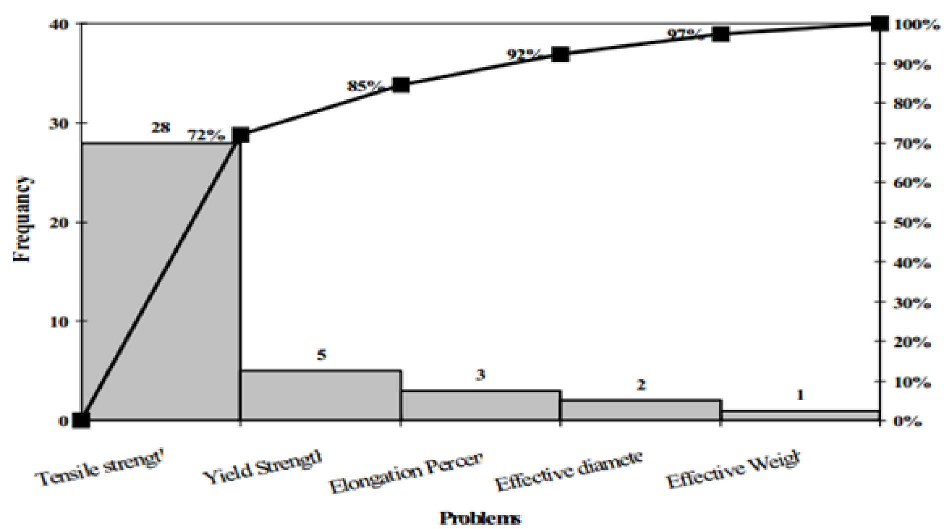


Figure (2.2): as shown Pareto chart

2.2.4 Scatter Diagram :

The scatter diagram is the simplest of the seven tools and one of the most useful. The scatter diagram is used to determine the correlation (relationship between two characteristics (variables) Goetsch).

Example:

Figure (2.3) shows who we can use Scatter Diagram to find the relationship between the flow of water to cool the steel through the stages of production and the tensile strength of steel by applying the data that have been collected, which represents the average reading per hour of water flow and tensile strength. The scatter diagrams clarify that there is no direct relationship exists between tensile strength and water flow. (Jordan Journal of Mechanical and Industrial Engineering 2012).

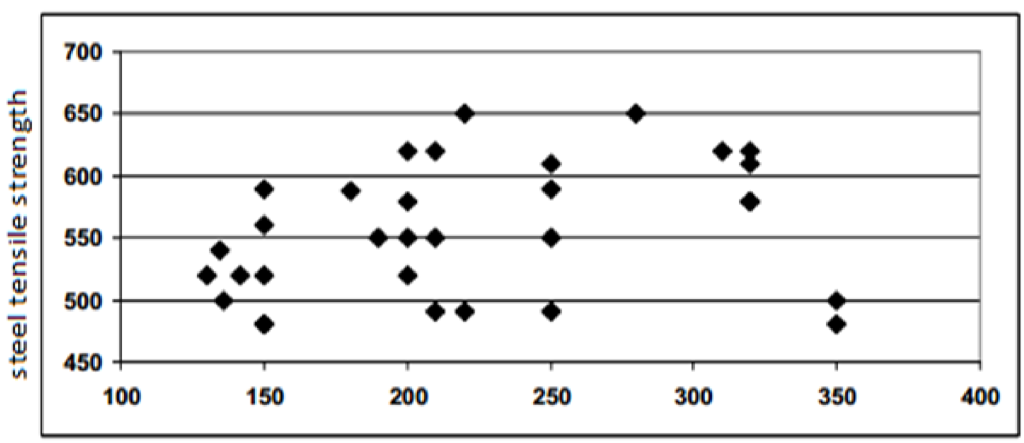


Figure (2.3) Scatter Diagram

2.2.5 Cause and Effect Diagrams (Fishbone Diagram):

Generally the Cause and Effect Diagrams (Fishbone Diagram) as shown in the figure (2.4) consists of two parts backbone , which represents the problem and the five major categories (machines, people, the environment, materials, and style). The scheme is completed by adding extra thorns, which represent the potential causes of the problem under each category. (Jordan Journal of Mechanical and Industrial Engineering 2012).

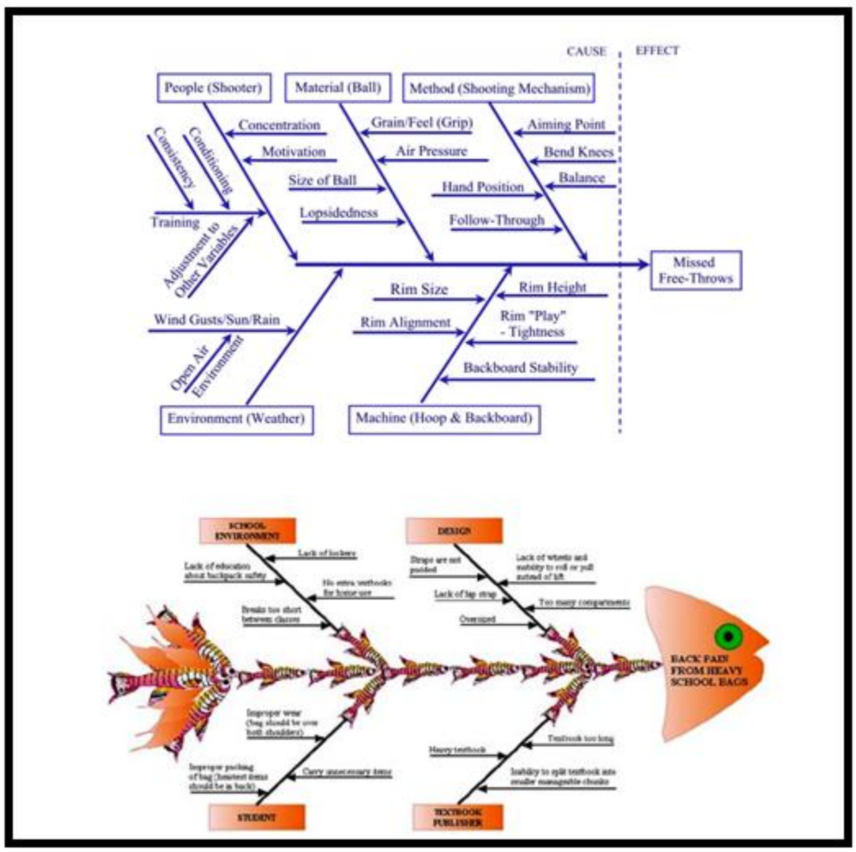
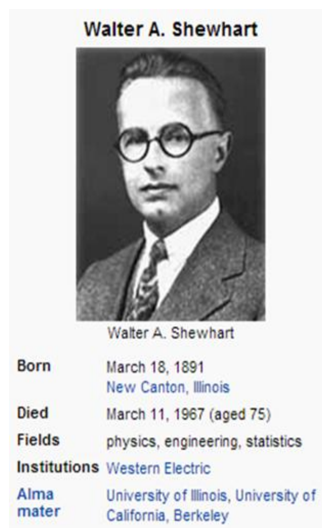


Figure (2.4) Cause and Effect Diagrams (Fishbone Diagram)

2.2.6 Control chart:

Control charts were used to monitor the variable and attribute data .Control charts the most use of the data for variables are mean and range charts which are used together (Gerald m. Smith , 2001) . Dr. Walter Shewhart is the first to introduce a statistical process for quality control of the production process about 60 years ago .He has written a book titled (economic control of the quality of products manufactured) in 1931(PeterW.M.johan1990) . 1928 saw the introduction of the first Statistical Process Control (SPC) Charts. Commissioned by Bell Laboratories to improve the quality of telephones manufactured, a simple graphical method developed a simple graphical method the first of a growing range of SPC Charts as shown in the figure (2-5) Understanding the causes of variation within an industrial process proved. Indispensable as actions could be taken to improve the process and output. (By David Howard 2003)



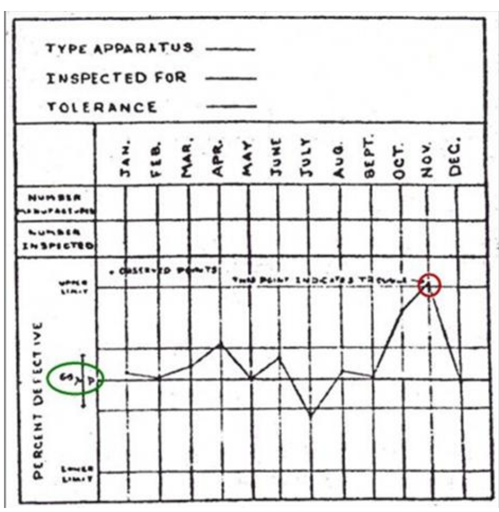


Figure (2.5) simple graphical method.

2.3 Types of Control Charts:

The Control charts are divided into two main types The first type is called variables control charts .The second type is called attributes control charts. The control charts to monitor the variables are more useful from attribute control charts . But attributes control charts works best to give the best results in some cases, such as when tracking paint defects. Characterized for variables control charts using the number of samples less than when we compared with attribute control charts . The attribute control chart used the number of samples more than (100 sample) . Variable control charts use Number of pieces of less use means to reduce the cost and time required to take measures to correct the production process compared with the attribute control chart (Gerald M. Smith 2001) In essence, is a statistical limit applied to a set of points which represent the sequential production process under observation or study .Plot the points in random chat. Each Tamer random point . Through the distribution of points in the chart can characterize the process. They are going the right way. The emergence of points outside the boundaries of control indicates the presence of confusion or a series of errors in the procedure, which refers to taking appropriate action. Control charts Represents a roadmap to monitor and improve the production process of discovering the Defects and take the necessary (MIKEL J. Harry & Prem S . MANN 2010) .

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2.3.1 Variable control charts

Is a chart which uses the standard deviation measure to control for the production process and is used to deal with the variable data (such as speed, temperature, humidity, etc.). (Montgomery 2005). Has a powerful set of charts used to monitor the production process. (MIKEL j. HARRY and PREM S. MANN , 2010)

I. 1-X Chart
II. 2-R Chart (Range chart)
III. 3-X-R CART
IV. 4-Moving Range (MR) Chart
V. 5-Stander deviation
VI. 6-EWMA Chart

2.3.2 Attribute control chart:

Measurements are classified in attribute control charts as acceptable or unacceptable (fail corridor, or go or do not go). Uses attribute control chart when decision-making is difficult (when the user variables control charts). When measurements do not apply to the situation (such as visual verification). Or when the cost of the measurements is expensive because of the time lost. Graphic attributes generally not more sensitive compared with the variables control charts Attribute control charts have a set of control charts . (Gerald M. Smith 2001).

I. P Chart
II. C Chart
III. Np Chart
IV. U Chart

In this chapter we will focus on the variable control chart identification on (Shewhart control chart x-bar chart) and (exponentially weighted moving average (*EWMA*)) which represent a search point in this project.

2.4 Shewhart control chart (X- bar and R - bar):

Control chart was invented by Dr. American Walter Shewhart in the 1920s. When he was working at Bell Telephone lab , (the research arm of American Telephone and Telegraph Company). The most popular schemes used on a large scale. Historically. For several reasons uses the range as a measure of the volatility in the data is that it is easy to calculate by hand. It also provides a good statistical data for small and that the sample size is less than (8 samples). While it is difficult to calculate the standard deviation. It represents a good measure of the variance of the data. Especially for large projects (large sample sizes) (James R. Evans 1991). In General the chart consists of two separate parts. The Xbar plot is a plot of averages on a control chart. The R-bar is a plot of ranges of groups or responses across by time. And display my often together (Jim Waite . Om 380 . 10/14/2004).

2.4.1 X- bar Chart:

Used to monitor the average or mean value of the production process with time For each sub-group . In general The chart consists of three horizontal lines (Jim Waite . Om 380 . 10/14/2004) . Best use with sub-group smaller sample size (each the size of a sub-group of three to four data points) .It is usually used with an R-chart or with the deviations-chart . Control limits in a chart depends on the type of planned joint with control charts (R- Chart or S-Chart) (MIKEL J. Harry & Prem S . MANN 2010) Better to use the R-chart with the X-bar chart if we do not know the standard deviation for this process .Because the limits of the graph will depend on the estimate of the standard deviation. And this must be done properly (AchesonJ.

Duncan 1986). In general is a chart sensitive to determine the variations in the process . And gives a vision of the differences in the process in the short term The chart consists of three horizontal lines as shown in the figure (2-6) . And the Y-axis title (sample mean) and X-axis title for the time or the number of subgroups. Center line (CL) Represents the average line in the chart (center line displays the average of the statistic) . Mediates the limits of the chart and represents the target line. And points are plotted whenever the nearest was referring to the quality of the process. Lower control limited (LCL) Represents the minimum of the expected difference . Points that fall outside the line be outside the control limits. Which may indicate problems in the production process . This line is the bottom the center line . Upper control limited (UCL) Represents the upper limit of the variation . Points that fall outside the limit is out of control (MIKEL J. Harry & Prem S . MANN 2010)

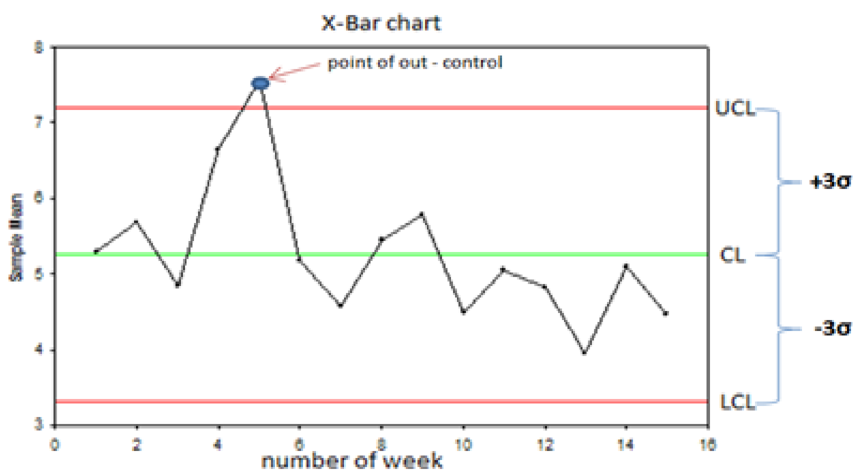

Figure (2-6) Shewhart X-bar chart control

2.4.2 R-bar chart (range chart) :

Is a measure of the regularity of the data set . And can be accessed by taking the largest and smallest values of group variations . R- Chart (range chart) give a clear vision of the limits of control through the presentation of the variability in the process with the passage of time . Is usually chart sync with the X-Bar chart (mean chart) R-Bar (rang chart) Consists of three horizontal lines, as is the case with the chart (X-Bar), as shown in Figure (8). But the y-axis represents (sample range). (MIKEL J. Harry & Prem S . MANN 2010

2.5 compute and establish an X - Bar chart and R-chart :

To compute and establish an X- Bar chart and R-Chart control must follow these steps

2.5. 1 identify Quality characteristics:

Quality characteristics that can be expressed using X- bar chart and R-chart can be summarized in seven units President a (unit length, temperature, material density occasion, mass, time, electric current), as well as any of the units derivative (such as energy, speed, power, density, and pressure). This property is measurable and can be represented by using the numbers. (Dale .H.Besterfiled 2001)

2.5.2 Choose a sub-group rational:

Data that is used within the scheme to monitor the production process are consists of rational subgroup. The data that is collected at random groups are not rational. Definition of the sub group rational as a set of elements have a difference within only due to chance. (Dale. H. Besterfiled 2001).

There are two charts for selecting the subgroup samples:

i. The first chart uses sub-group taken in one period of time.

ii. The second chart uses sub-group taken over periods of time.

2.5.3 collect the data:

The next step is to compile the data. Usually collected the data is in the factory by technician assigned the task of data collection. Data is collected in a vertical way as shown in the table (2.3). And be in the form of sub-groups .And samples. Sometimes remembers the time of sampling in the table. (Dale. H. Besterfiled 2001).

Table (2.3) : data collected in a vertical way

Number of subgroups	DETA	TIME	Simple size (No. Observation)				AVERAGE $\overline{X}$	RANGE R
			X_1	X_2	X_3	X_4		
1	12/6	**8:50**	6.35	6.40	6.32	6.37		
2		**11:30**	6.46	6.37	6.36	6.41		
3		**1: 45**	6.34	6.40	6.34	6.36		
4		**3:45**	6.69	6.64	6.68	6.59		
5		**4:20**	6.38	6.34	6.44	6.40		
6	12/8	**8:35**	6.42	6.41	6.43	6.34		
7		**9:00**	6.44	6.41	6.41	6.46		
8		**9:40**	6.33	6.41	6.38	6.36		
9		**1:30**	6.48	6.44	6.47	6.45		
10		**2:50**	6.47	6.43	6.36	6.42		
							$\sum \overline{X}=$	$\sum R=$

After plotting the data inside the table now we have calculated the chart

Can calculate the $\overline{X}$ from the data by using the formula

$$\overline{X} = \frac{\sum_{i=1}^{n} Xi}{n} \text{ ---------------------- } (2.1)$$

Where

$\overline{x}$=average of the subgroup

n= Simple size (No. observation)

xi= sample

And can find the R (range) from the data by using the formula

$$Ri = \frac{Xmax - Xmin}{2} \text{ ----------------}(2.2)$$

Ri = range of the sub-group

From the data in the table and the number of simple (n) is Equals (4)

$$\overline{X} = \frac{6.35+6.40+6.32+6.37}{4} = 6.36\text{mm} \; , \; R = \frac{6.40-6.32}{2} = 0.08\text{mm}$$

Number of subgroups	DETA	TIME	Simple size (No. Observation) X_1	X_2	X_3	X_4	AVERAGE $\overline{X}$	RANGE R
1	12/6	**8:50**	6.35	6.40	6.32	6.37	**6.36**	**0.08**
2		**11:30**	6.46	6.37	6.36	6.41	**6.40**	**0.1**
3		**1: 45**	6.34	6.40	6.34	6.36	**6.36**	**0.06**
4		**3:45**	6.69	6.64	6.68	6.59	**6.65**	**0.1**
5		**4:20**	6.38	6.34	6.44	6.40	**6.39**	**0.1**
6	12/8	**8:35**	6.42	6.41	6.43	6.34	**6.40**	**0.09**
7		**9:00**	6.44	6.41	6.41	6.46	**6.43**	**0.05**
8		**9:40**	6.33	6.41	6.38	6.36	**6.37**	**0.08**
9		**1:30**	6.48	6.44	6.47	6.45	**6.42**	**0.04**
10		**2:50**	6.47	6.43	6.36	6.42	**6.39**	**0.11**
							$\sum\overline{X}$= **64.17**	$\sum R$= **0.81**

So after finishing

To find the central line for the $\bar{\bar{X}}$ and R they are obtained using the formulas

$$\bar{\bar{X}} = \frac{\sum_{i=1}^{g} Xi}{g} \quad , \quad R = \frac{\sum_{i=1}^{g} Ri}{g}$$ ---------(2.3)

Sinse

$\bar{\bar{X}}$= average of the subgroup average = CL for the x - bar chart

g = number of subgroups

$\bar{R}$= average of subgroup ranges (Dale. H. Besterfiled 2001).

By applying the data from the table on the formula

$\bar{\bar{X}} = \frac{64.17}{10}$ =6.417mm= CL for x-bar chart

$R = \frac{0.81}{10}$ = 0.081mm = CL for R-chart

And to fined the stander deviation .

$$3*\sigma_{\bar{x}} = A_2 * \bar{R} \quad \text{since } A_2 = \frac{3}{d2\sqrt{N}} \quad \text{And } \sigma_X = \sigma' \div \sqrt{n}$$ --- (2-4)

There for the

$$\sigma_{\bar{x}} = \frac{3\sigma}{\sqrt{n}} = \frac{3}{d2\sqrt{n}} * \bar{R}$$ --------------(2.5)

Where

n = NO. For sample .

$\sigma_{\bar{x}}$ = population stander deviation of the subgroup averages.

(A2 , d2) = value of factors for computing central line and standard Deviation for x- chart and R- chart. (Dale H. Besterfield 2001. Table (2-4))

σ'= actually the process standard deviation.

And all so can calculate the (UCL) AND (LCL) for X-bar chart by estimate the process standard deviation from the formula. Is not correct to estimate the process standard deviation from all the data .Just can estimate by using (historical data) . If the number of sample size more than (5) sample than can use the S - chart with an X - bar chart (AchesonJ.Duncan . 1986)

$$s = \frac{\sqrt{\sum(x-\bar{x})^2}}{n-1} = \sigma' \text{------------} (2.6)$$

(S , σ')=estimate process standard deviation

Where $\sigma\bar{x} = \sigma' * \sqrt{n}$ --------------------- (2.7)

$UCL = \bar{\bar{X}} + 3*\sigma\bar{x}$ --------------------------(2.8)

$CL = \bar{\bar{x}}$

$LCL = \bar{\bar{X}} - 3*\sigma\bar{x}$ ---------------------------(2.9)

To find the (UCL) and (LCL) for x-bar chart and R chart using the formula

For x-bar chart

$UCL\bar{x} = \bar{\bar{X}} + A2 * \bar{R}$ -----------------------(2.10)

$CL\bar{x} = \bar{\bar{X}}$ -------------------------------------(2.11)

$LCL\bar{x} = \bar{\bar{X}} - A2 * \bar{R}$ ---------------------------(2.12)

For R-chart

$UCLR = D4 * \bar{R}$ ---------------------------(2.13)

$CLR = \bar{R}$ -----------------------------(2.14)

$LCLR = D3 * \bar{R}$ ---------------------(2.15)

Where

$UCL\bar{X}$=Upper control limits for the X - bar chart

$CL\bar{X}$= Central line for X-bar chart = X

$LCL\bar{x}$= Lower control limit for the X - bar chart

UCL_R= Upper control limit for R-chart

CL_R=central line for R chart = R

LCL_R= Lower control limit for R-Chart

(A2, D2 , D3) = value of factors for computing central line and standard Deviation for x- chart and R- chart. (Dale H. Besterfield 2001. Table B)

By applying the data from the table (9) in the formula can find the limits for x-bar chart and R chart. And from the table (B) find (A2=0.729, D3=0, D4=2.282) as show in figure(5) .

Table (2.4): for factors (Dale H. Besterfield 2001. Table B)

TABLE B Factors for Computing Central Lines and 3σ Control Limits for $\bar{X}$, s, and R Charts.

OBSERVATIONS IN SAMPLE, n	CHART FOR AVERAGES: FACTORS FOR CONTROL LIMITS			CHART FOR STANDARD DEVIATIONS: FACTOR FOR CENTRAL LINE	CHART FOR STANDARD DEVIATIONS: FACTORS FOR CONTROL LIMITS				CHART FOR RANGES: FACTOR FOR CENTRAL LINE	CHART FOR RANGES: FACTORS FOR CONTROL LIMITS				
	A	A_2	A_3	c_4	B_3	B_4	B_5	B_6	d_2	d_3	D_1	D_2	D_3	D_4
2	2.121	1.880	2.659	0.7979	0	3.267	0	2.606	1.128	0.853	0	3.686	0	3.267
3	1.732	1.023	1.954	0.8862	0	2.568	0	2.276	1.693	0.888	0	4.358	0	2.574
4	1.500	0.729	1.628	0.9213	0	2.266	0	2.088	2.059	0.880	0	4.698	0	2.282
5	1.342	0.577	1.427	0.9400	0	2.089	0	1.964	2.326	0.864	0	4.918	0	2.114
6	1.225	0.483	1.287	0.9515	0.030	1.970	0.029	1.874	2.534	0.848	0	5.078	0	2.004
7	1.134	0.419	1.182	0.9594	0.118	1.882	0.113	1.806	2.704	0.833	0.204	5.204	0.076	1.924
8	1.061	0.373	1.099	0.9650	0.185	1.815	0.179	1.751	2.847	0.820	0.388	5.306	0.136	1.864
9	1.000	0.337	1.032	0.9693	0.239	1.761	0.232	1.707	2.970	0.808	0.547	5.393	0.184	1.816
10	0.949	0.308	0.975	0.9727	0.284	1.716	0.276	1.669	3.078	0.797	0.687	5.469	0.223	1.777
11	0.905	0.285	0.927	0.9754	0.321	1.679	0.313	1.637	3.173	0.787	0.811	5.535	0.256	1.744
12	0.866	0.266	0.886	0.9776	0.354	1.646	0.346	1.610	3.258	0.778	0.922	5.594	0.283	1.717
13	0.832	0.249	0.850	0.9794	0.382	1.618	0.374	1.585	3.336	0.770	1.025	5.647	0.307	1.693
14	0.802	0.235	0.817	0.9810	0.406	1.594	0.399	1.563	3.407	0.763	1.118	5.696	0.328	1.672
15	0.775	0.223	0.789	0.9823	0.428	1.572	0.421	1.544	3.472	0.756	1.203	5.741	0.347	1.653
16	0.750	0.212	0.763	0.9835	0.448	1.552	0.440	1.526	3.532	0.750	1.282	5.782	0.363	1.637
17	0.728	0.203	0.739	0.9845	0.466	1.534	0.458	1.511	3.588	0.744	1.356	5.820	0.378	1.622
18	0.707	0.194	0.718	0.9854	0.482	1.518	0.475	1.496	3.640	0.739	1.424	5.856	0.391	1.608
19	0.688	0.187	0.698	0.9862	0.497	1.503	0.490	1.483	3.689	0.734	1.487	5.891	0.403	1.597
20	0.671	0.180	0.680	0.9869	0.510	1.490	0.504	1.470	3.735	0.729	1.549	5.921	0.415	1.585

Since

$UCL\bar{X} = \bar{\bar{X}} + A2 * R$

$= 6.41 + (0.729) * (0.0876)$

$= 6.47mm$

$CL = \bar{\bar{X}} = 6.41mm$

$LCLX = \bar{\bar{X}} - A2 * R$

$= 6.41 - (0.729) * (0.0876)$

$= 6.35mm$

And for R- char

$UCLR = D4 * \bar{R}$

$= (2.282)*(0.081) = 0.18mm$

$CLR = R = 0.08mm$

$LCLR = D3*\bar{R}$

$=(0*0.081) = 0 mm$

2.5.4 **plot data and establish X-bar and R-chart** :

The first step after finding the limits of the chart is a plot of the data in the table (9) within the (X-bar and R) chart along with the planned limits and the Central Line .Plot the data and analysis are given a clear vision of the process. It is Shown if the in-control or outside the control limits . The chart shows that more points within the control limits. And R- chart is a statement the stability of the schema (x-bar chart) . As shown in figure (2.5) . (Dale. H. Besterfiled 2001)

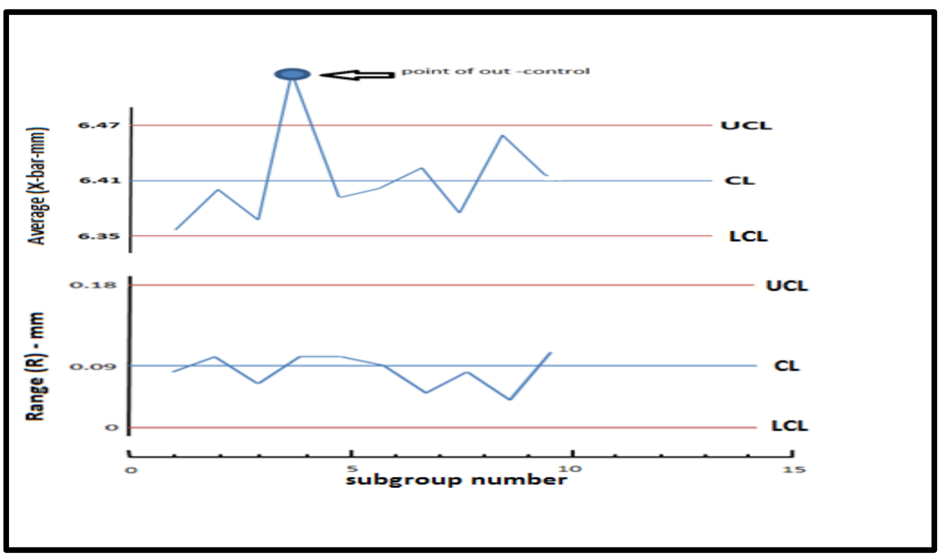

Figure (2.5) : X-bar chart and R-char

2.6 When can apply the X- bar chart :

i. The chart can be applied to subsets of a small sample . If the number of samples (1>n<10). We use an R - chart with the X - bar chart when (n>5) .If the number of samples (n<5) uses S- chart with an X - bar chart .

ii. When you do not know the value of the standard deviation of the process. Or When we know or can estimate the value of the standard deviation . (Quality Technology Company and PC FAB (A Magazine)& (Dale. H. Besterfiled 2002)

2.7 EWAM control chart :

The Exponentially Weighted Moving Average *EWMA* control chart is one of the control charts used to detect shifts in the process. First introduced by Roberts (1959), Of the characteristics of this scheme is quick detection of small and medium-sized shifts in the process therefore is regarded as the best alternative for shear control chart. Is more sensitive in the detection of small-to medium-Wave constant changes in the process. It has three horizontal lines, central line or mean (CL), upper control limit (UCL) and lower control limit (LCL) as shown in figure (11). The two Control limits are not static. Especially at the beginning of the process . This gives more sensitivity to Detect small fluctuations in the process . Making the scheme more effective than planning in small operations. (Montgomery, 1991). The *EWMA* chart for monitoring the process can use with rational subgroups. The *Shewhart* control chart Uses two statistical tests on the process only the immediate data While the EWMA chart uses the previous data after multiplication by a. Weighting factor (λ).

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