CHAPTER 4

Developed Model

The developed model is created to overcome the problem of the old system that is using in the electrical testing machine control chart. As described above in the chapter of problem analysis, the current system changed the control limit every shift of operation, this means every 8 hours of working. This is not a good way of control the process because not every 8 hours is the most suitable point of time to change the control limit.

The new control chart will be constructed every shift. This new model will show the way to find the most suitable point of time to recalculate the control limits and center line of the control chart for p-chart. This model can also applied for using with the fraction conforming control chart which is the chart that is currently used in electrical testing machine.

This model was constructed to overcome the problems above. the procedure of constructing model is listed below.

- Data Collection
- Create model
- Test model with random generated data to see the ability of the model to detect the process shift even in the point that has to be detected by eyes. This step is created to ensure that the model works in the right way because if the model cannot detect the process shift even in the shift that can be detected by eyes, it can be sure that this model does not work properly. So, this step is very important. If there is something wrong with the model, it has to be corrected before go further to the next step.
- Test model with actual data to ensure that the model is working in the right way.
- If the model pass the test process, it will be conclude that it is the right model.

- If the model does not pass the test, it will be corrected until it pass all the tests.

For better understanding of these procedure, the flowchart of these procedure is shown below.

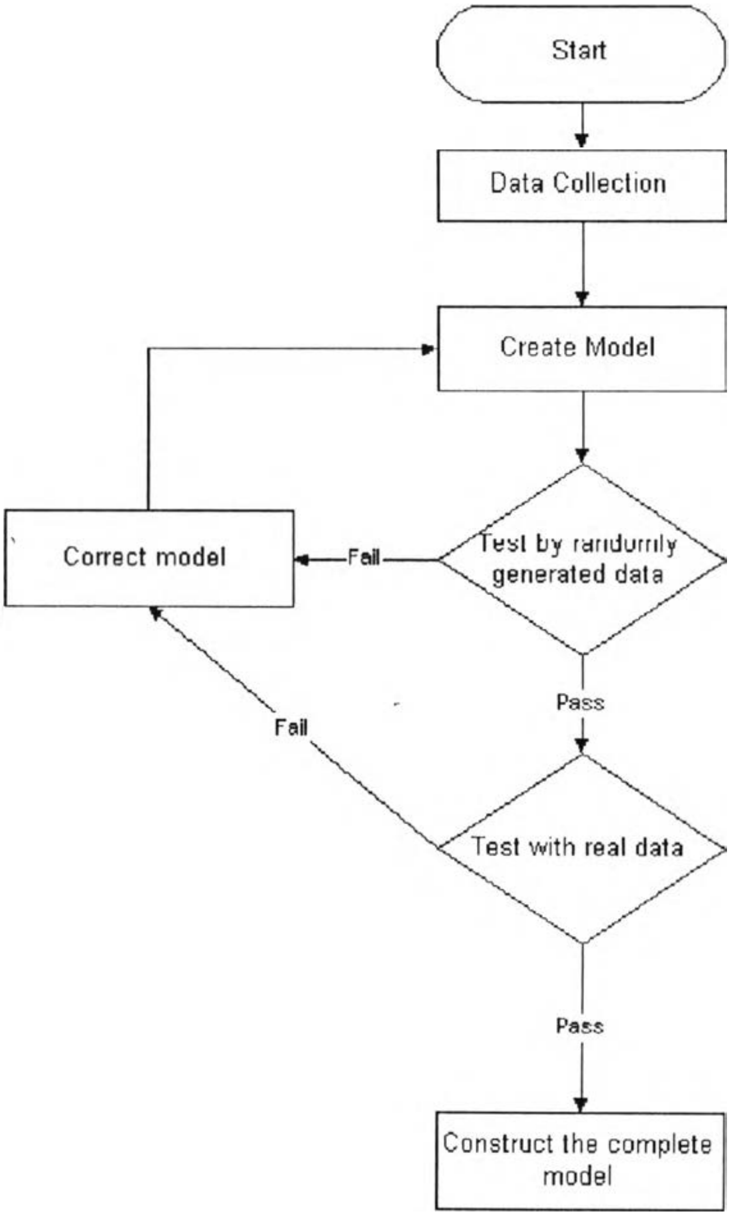


Figure 4-1 Procedure of construct the model

After this procedure, the complete model is constructed. The figure below is the flowchart for this model.

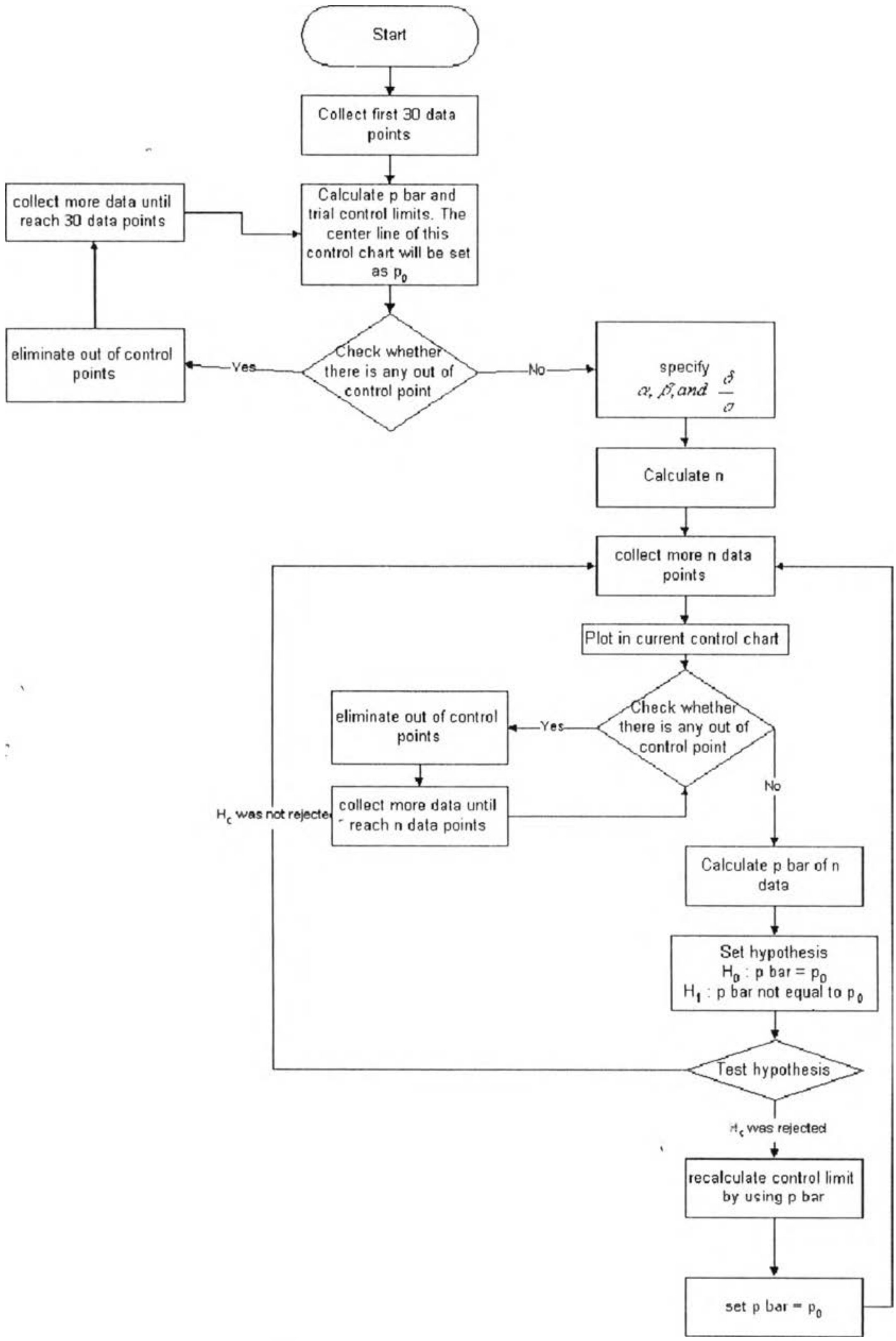


Figure 4-2 The flowchart shows how the developed model work

4.1 Logic behind this developed model.

This developed model has the theories and logic supported as shown below

The approximation of binomial to normal distribution. The requirement for this parts is the value of p is not too close to either 0 or 1 and n is large. To find if the requirement were met or not, typically, we will calculate from np and n(1-p) be greater of equal to 5.

The hypothesis tests on a Binomial Proportion for single sample. The test in this model is the test whether the first 30 sample and the next n sample has significantly difference in process mean or not.

The way to prove the hypothesis is to use the normal approximation to test that binomial parameter are not significantly different to the standard. That is

H_0: $p = p_0$

H_1: $p \neq p_0$

If the null hypothesis is true, then $p = p_0$, this means this group of data has not significantly different from the standard value

The statistic testing H_0 is

$$Z_0 = \frac{p - p_0}{\sqrt{p_0(1 - p_0)/n}}$$

The H_0 will be rejected when $|Z_0| > Z_{\alpha/2}$

From the equation above, we can see that the value that we have to specify is the α value which is the confident level of this hypothesis test. Before going further, the description of this α value will be described. This α value is called type I error, which means we reject H_0 when, in fact, H_0 is really true.

Another type of error that has to be concerned is called type II error or β. This error is the error that is the possibility to reject H_0 when it is really false. So, we can see from the above description that there are 4 different situations determine whether the final decision is correct or error. This will be shown in the table below.

Table 4-1 decision in hypothesis testing

Decision	H_0 is true	H_0 is false
Fail to reject H_0	No error	Type II error (β)
Reject H_0	Type I error (α)	No error

After looking at these 2 types of error, there is another important factor that has to be specified before the hypothesis testing process, which is n or the sample size of the calculation. To find n, we need to know the range of the shift in process mean. This range of mean shift will be calculated in terms of $x\sigma$ which will be equal to $p - \bar{p}$ or δ that has to be specified by the user who wants to detect the shift. This is because when we say process mean shift, we have to specify how much of the change in process mean we will consider it as a change.

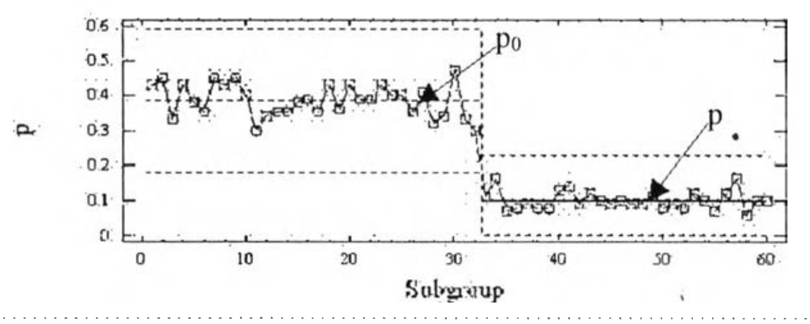


Figure 4-3 The example of control chart that has the process mean shift

After we know these 3 value, α, β, and δ which is all the necessary factors we should know before any further calculation, we will calculate the sample size or n that needs to be collect to detect the process mean shift in this manufacturing process.

The calculation of sample size is based on the value α, β and the target p value that has mentioned above. To detect the process mean shift, we have to know that how much of the range of the shift we will consider to be process mean shift. The calculation formula for two sided testing is shown below.

$$n = \left(\frac{z_{\alpha/2}\sqrt{p_0(1-p_0)} + z_{\beta}\sqrt{p(1-p)}}{p - p_0} \right)^2$$

4.2 Detail description of each process in model

Start

This is the start stage of this model

Collect first 30 data points

This process will collect the first set of data which will be useful in the next process.

Calculate $\bar{p}$ and trial control limits. The center line of this control chart will be set as p_0

After we have this set of the first 30 data, we will calculate the average value of p in this stage which will be used to calculate the trial control limits of this p-chart. The calculation formula is shown below.

$$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$
$$CL = \bar{p}$$
$$LCL = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

Check whether there is any out of control point

This process will check the point that is plotted beyond the control limits. If there is no any points that plotted outside the control limits, we will continue the next process to the detection of the process mean shift. On the other hand, if there is some points that located out of the control limits, we will go to the next process to eliminate it.

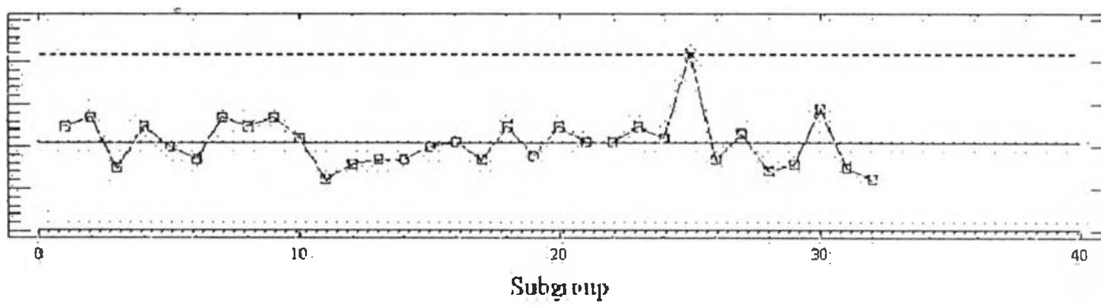


Figure 4-4 Control chart of the data that out of control point before eliminate point

Eliminate out of control points

If the out of control points were found and we assume since the beginning that our process is in approximately normal distribution, we will figure out if this out of control points came from assignable cause or not. If assignable causes for these points are discovered, they should be discarded and new trial control limits will be calculated.

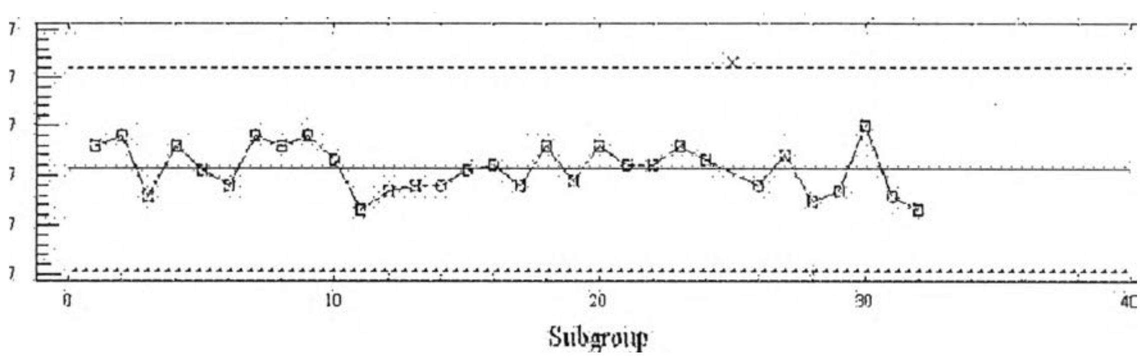


Figure 4-5 Control chart of the data that out of control point after eliminate point

Collect more data until reach 30 data points

After the elimination of the points that came from assignable cause, we will continue collect more data until it reaches 30 data points and will go back to recalculate the control limits. If there is any out of control points shown again, the process will continue in this loop until there is no out of control point that came from assignable cause shown.

From the 3 above stages, Check whether there is any out of control point, Eliminate out of control points, and Collect more data until reach 30 data points, the algorithm for these stages is shown below

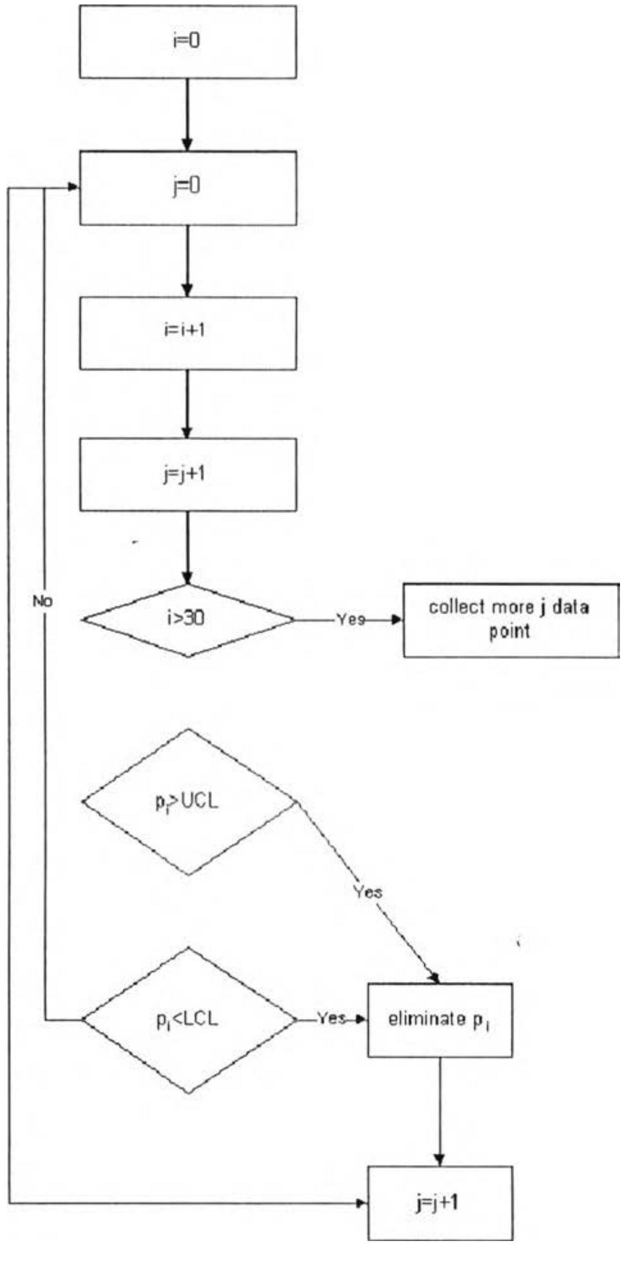


Figure 4-6 Algorithm for the Check whether there is any out of control point, Eliminate out of control points, and Collect more data until reach 30 data points stages

Specify $\alpha, \beta, and\ \frac{\delta}{\sigma}$

At this stage, the user have to specify the confidence level of both type I and type II error, and the $\frac{\delta}{\sigma}$ ratio which means the distance from p_0 and the new set sample to calculate the change in process mean shift.

Calculate n

This process will calculate the sample size of the set of data that is suitable for detect the process mean shift at the specified confident level. The calculation formula is introduced in above will be shown again in this stage.

$$n = \left(\frac{z_{\alpha/2}\sqrt{p_0(1-p_0)} + z_{\beta}\sqrt{p(1-p)}}{p - p_0} \right)^2$$

This formula has to be used for 2 sided testing. Due to the detect in the process mean shift wants to detect both the upward and downward shift, the 2 sided hypothesis testing is used.

Collect more n data points

After the calculation of suitable sample size, we will continue collect n data points, which will be used to be a group of data in the next hypothesis testing.

Plot in current control chart

This stage is to plot this group of data into the control chart that has the control limits calculated above. From this point, we can see if there is any out of control points occurred in this group of data.

Check whether there is any out of control point

As mentioned above, the checking of any out of control points will be done to make sure that the points from assignable cause will not be calculated in this control chart.

Eliminate out of control points

As mentioned above, this stage is the elimination from the calculation of any points that came from assignable cause.

Collect more data until reach n data points

This stage is the collect of more data points and will be back to the checking process again. This is to make sure that the points that will be used to calculate in the next process are not the out of control points. For these above 3 stages, the algorithm also shown below for further understanding.

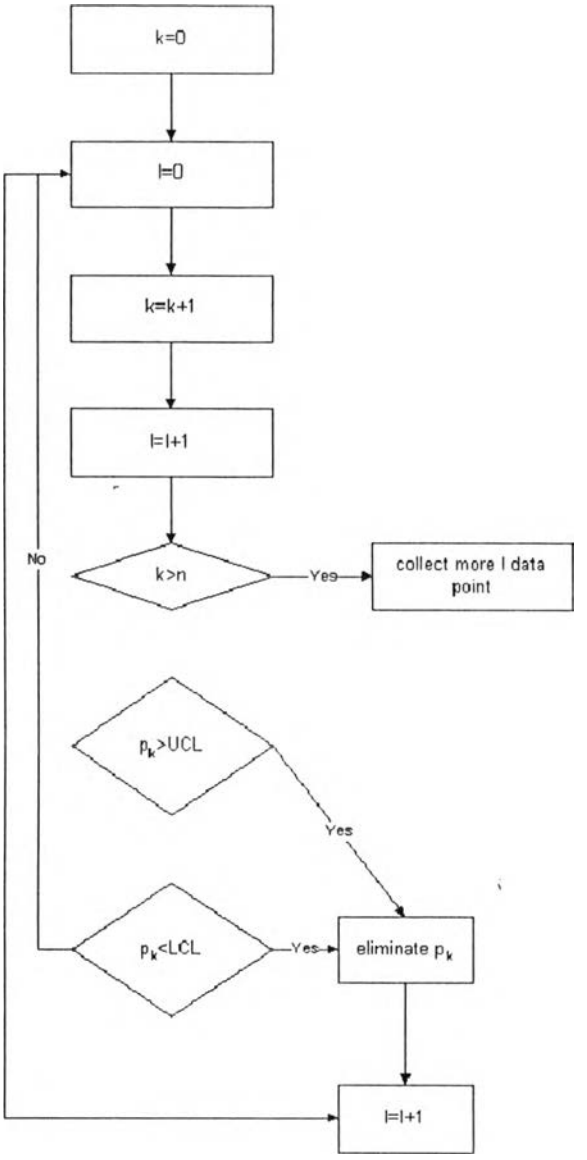


Figure 4-7 Algorithm for the Check whether there is any out of control point, Eliminate out of control points, and Collect more data until reach n data points stages

Calculate p bar of n data

This process will calculate the average value of the fraction nonconforming of n data points which will be useful in the next hypothesis testing process.

Set hypothesis

H_0 : $\bar{p} = p_0$

H_1 : $\bar{p} \neq p_0$

This is the process of the hypothesis testing, this is to test whether the set of data with n sample size has significantly difference in process mean with the standard value or not. The standard value of p or p_0 is calculated from the use of trial control limit.

Test hypothesis

From this hypothesis testing, there are 2 ways to go, reject or not reject the null hypothesis.

If the null hypothesis is not rejected.

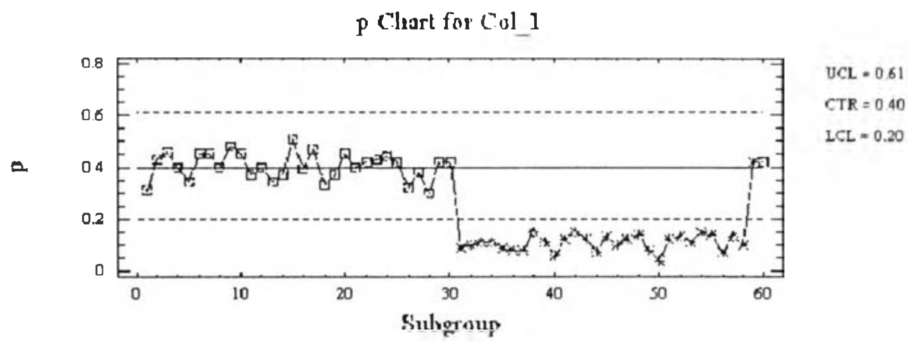
This mean this set of data and the standard set of data has not significantly difference in mean. So, the next process is to continue using the current control limits for this set of data with n sample size. The calculation loop will begin again at the point that more n data points come into the process and if the null hypothesis is still not rejected, the latest control limit will be continue in use until we find the significantly shift in the process mean.

If the null hypothesis is rejected

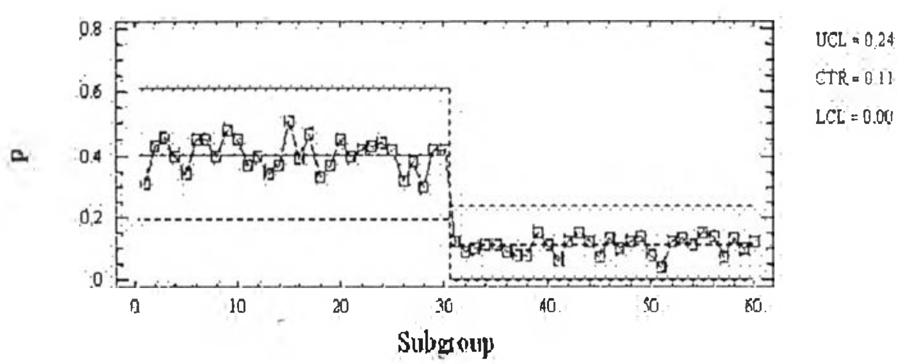
This means there is the significantly difference in process mean of this operation. So, the center line of the control chart has to be shifted, and also the control limits.

Recalculate control limit by using p bar

This process is done after the hypothesis testing result shows that the process mean of this set of data and the standard set has significantly difference. The calculation of control limits will be changed due to the change of process mean which is the center line of the control chart. From the calculation of the control chart that is shown above, the control limits calculation are based on mean. At this stage, the mean has changed, so the control limits will be changed.



(a)



(b)

Figure 4-8 The sample control chart (a) if there is no this hypothesis testing. (b) if there is this hypothesis testing.

Set $\bar{p} = p_0$

This is the process that set the prior control limits that just is calculated to be new trial control limits. This new control limits will be the reference for the next data that enter the process. The $\bar{p}$ will be set as p_0 and the control limits will be set as a new control limits for the rest of data until we can find the difference in process mean again.

From the description of the process above, we can see that the value n or sample size will be changed if there is any changed in process mean, we have to recalculate the sample size every time. That makes this model create continuous control chart in this manufacturing process.

4.3 Advantages of this developed model

- The propose model allow p-chart to be automatically detected the shift in process mean at a given confident interval.
- The algorithm can be easily implemented in the actual manufacturing system since it is based on the widely use Shewhart p-chart.
- This model can be developed further to be a computer software to control the process. This is due to the model is a algorithm, which is nearly the computer software logical thinking.
- Due to similarity assumptions between the $\overline{x}$ -R ($\overline{x}$ -S) chart and p-chart, the proposed model can be applied to the $\overline{x}$ -R ($\overline{x}$ -S) by replacing the proportion hypothesis test with the one-sample t (or 1 sample Z) test

4.4 Disadvantages of this developed model

- Because the study is based on p-chart, therefore, it inherits the same limitation of the chart. Such as, it cannot detect the shift in process mean just after the input of the shifted point.
- To get a reasonable confidence in doing hypothesis test for mean, it may requires large number of data point (specially, for p-chart due to the nature of proportional testing). However, it is working well with the manufacturing system that can produce product in relatively large quantity combine with the state of art in Data/ Networking system.