Modifying Integrated Model for Manufacturing Process Improvement

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Abstract

Yung (1996) has investigated the intimate relationship between Statistical Process Control (SPC), the seven basic tools (histogram, check sheet, cause-and-effect diagram, control chart, Pareto Chart, flow process chart, scatter diagram), KAIZEN (Japanese term of continuous improvement) and Total Quality Management (TQM) principles and proposed an integrated model that shows significantly improvement on both quality and productivity of the product and process. However, this is a very time-consuming and bulky method. This paper proposes a new method to improve the manufacturing process performance by modifying the time-consuming integrated model of Yung (1996). We re-arrange the sequence of tools and techniques by considering the coordination of information flow and selecting only the suitable tools for the specialized problems.

1. Introduction

Statistical Process Control (SPC), the seven basic tools (histogram, check sheet, cause-and-effect diagram, control chart, Pareto Chart, flow process chart, scatter diagram), KAIZEN and Total Quality Management (TQM) are perhaps the most frequently used tools and techniques in the manufacturing industries today. In order to survive in a competitive market, the organizations have to consider on the improving quality and productivity of the products and processes. Integrated model is the valuable method for this objective. This method combines with the Total Quality Management (TQM) methods to cover the quality consideration and KAIZEN teams to achieve the better overall performance of the manufacturing. Statistical Process Control (SPC) was proved to be an effective means to improve quality and productivity; while the basic seven tools are powerful for problem solving. The KAIZEN team is formed for the sole purpose of inspection. However, to integrate them successful and effective in

practice, management and planner has to pay a lot of efforts and time in training staff, preparing the plans, coordinating the process, etc. The main drawback of manufacturers is the lack of highly trained experienced officers who are capable of using the seven basic tools and SPC, TQM techniques to its full potential in order to detect and solve various kinds of obstacles. On the other hand, vast amount of time are presumably wasted on all the tools and techniques to solve the occurred problem because some tools and/or techniques are redundant when the problem has been detected and/or solved by the previous used tools/techniques. Thus, it is better to modify the original integrated model to re-arrange the sequence of tools and techniques by considering the coordination of information flow and selecting only the suitable tools for the specialized problems. By such modification, we can save time and improve the process more effectively. In the following section, the seven basic tools and techniques

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are described briefly with the short review on the related works before developing the modified model for process improvement.

2. Literature Reviews

2.1. Background

Total Quality Management (TQM) is a strategy for implementing and managing quality improvement activities on an organization-wide basis. Typically, organizations that have implemented a TQM approach to quality improvement have quality councils or high-level teams that deal with strategic quality initiatives, workforce-level teams that focus on routine production or business activities, and cross-functional teams that address specific quality improvement issues. TQM has only had moderate success for a variety of reasons, but frequently because there is insufficient effort devoted to widespread utilization of the technical tools of variability reduction.

Statistical Process Control (SPC) is a powerful collection of problem-solving tools useful in achieving process stability and improving capability through the reduction of variability. SPC can be applied to any process. Its seven basic tools, often called "the magnificent seven," are Histogram, Check sheet, Pareto chart, Cause-and-effect diagram, Process flow charting, Scatter diagram and Control chart.

Histogram is a graph of the observed frequencies versus range of the data. It represents a visual display of the data in which one may more easily see three properties: Shape, Location or central tendency, Scatter or spread.

In the early stages of an SPC implementation, it will often become necessary to collect either historical or current operating data about the process under investigation. A check sheet can be very useful in this data collection activity. The engineer designed this check sheet to facilitate summarizing all the historical defect data available. The time-orient summary is particularly valuable in looking for trends or other meaningful patterns. When designing a check sheet, it is important to clearly specify the type of data to be collected, the part or operation number, the date, the

analyst, and any other information useful in diagnosing the cause of poor performance.

The Pareto chart is simply a frequency distribution of attribute data arranged by category. We produce the Pareto chart by plot the total frequency of occurrence of each defect type against the various defect types to produce. Through the chart the user can quickly and visually identify the most frequently occurring types of defects. Note that the Pareto chart does not automatically identify the most important defects, but rather only those that occur most frequently. In general, the Pareto chart is one of the most useful of the "magnificent seven." Its applications to quality improvement are limited only by the ingenuity of the analyst.

Once the defect, error, or problem has been identified and isolated for further study, we must begin to analyze potential causes of this undesirable effect. In situations where causes are not obvious, the cause-and-effect diagram is a formal tool frequently useful in un-layering potential causes. The cause-and-effect diagram constructed by a quality-improvement team assigned to identify potential problem areas.

Cause-and-effect analysis is an extremely powerful tool. A highly detailed cause-and-effect diagram can serve as an effective troubleshooting aid. Furthermore, the construction of a cause-and-effect diagram as a team experience tends to get people involved in attacking a problem rather than in affixing blame.

The scatter diagram is a useful plot for identifying a potential relationship between two variables. Data are collected in pairs on the two variable, say (x_i, y_i) for i=1, 2,3,…,n. Then y_i is plotted against the corresponding x_i. The shape of the scatter diagram often indicates what type of relationship may exist between the two variables. The scatter diagram is useful for identifying potential relationships.

The flow process chart is especially valuable in recording non-production hidden costs, such as distances traveled, delays, and temporary storages. Once these non-production periods are highlighted, analysts can take steps to minimize them and hence their costs. In addition to recording operations and inspections, flow process charts show all the moves and storages delays encountered by an

item as it goes through the plant. Flow process charts therefore need several symbols in addition to the operation and inspection symbols used in operation process charts.

Control charts are the simplest type of on-line statistical process control (SPC). A major objective of control chart is to quickly detect the occurrence of assignable causes of process shifts so that investigation of the process and corrective action may be undertaken before many nonconforming units are manufactured. Control charts may also be used to estimate the parameters of a production process, and, through this information useful in improving the process. The control chart is an effective tool in reducing variability as much as possible.

To estimate process capability, process capability ratio (C_p, C_{pk}) *is* a necessary tool. The estimation of process capability may be in the form of a probability distribution having a specific shape, center (mean) and spread (standard deviation). A process capability study usually measures functional parameters on the product, not the process itself.

$$C_p = (USL-LSL)/6\sigma$$

C_p does not take into account where the process mean is located relative to the specification. C_p simply measures the spread of the specification relative to the six-sigma spread in the process. This situation may be more accurately reflected by defining a new process capability ratio that takes process centering into account. Note that C_{pk} is simply the one-sided PCR for the specification limit nearest to the process average.

$$C_{pk} = \min (C_{pu}, C_{pl})$$

We usually say that C_p measures potential capability in the process, whereas C_{pk} measures actual capability.

2.2. Related Works

Terwiesch and Bohn (1999) proposed learning and process improvement during production ramp-up. Many large industries tried to decreases the production lifecycle which consist of development time (time-to-market) and time to reach full capacity utilization (time-to-volume). And the processes of producing that have to work-in-process (WIP) in order to increase total output. In this point of view, we can see that there are some

problem occurred while increasing operating speed which decrease the precision assembly and many defect will occurred. In order to improve the process, they proposed the production ramp-up to solve the problem. Production ramp-up is the period between the end of product development and full capacity utilization. The goal of this technique is to improve the quality and raise the production rate.

Schippers (1998) has conducted the research on the application of the Process Control Technique (PCT) to determine the total success of process control. The Process Control Technique (PCT) is used for all company that can be used to improve and control the technical performance of the production process. For this technique they use Best Practice to apply the control charts on some major characteristic of the product parts and using framework to gives an overview of the situation which activities that put in to the control of production process can be performed. The reason of using the Best Practice is to prevent the company from trying to implement unsuitable PCTs. However, they conclude that the main reasons for these problems are caused by lack of vision, initially to understand SPC, lack of education and training and lack of team work.

Forza and Filippini (1997) proposed the total quality management (TQM) model considerable success in term of its implementation in companies. The total quality management (TQM) model that constructed on the basis of established theory and on well-known criteria of evaluation of contribution. The model tested on data collected on a random sample of manufacturing plant through a reliable measure. The great attention has been paid to sampling and testing measurement instrument since each one of these can directly influence the result.

Born (1995) shown that business re-engineering and quality management are not often conflict. Quality management needs a process–oriented view of the world, to achieve true customer focus. And business re-engineering can build on the achievements of the total quality revolution. He tried to link between these two points. Neither business process re-engineering nor quality management can work ideally by themselves,

but together they provide a vital tool in the competitive environment. The author develops a modeling language, called Quality Process Language (QPL), a notation for describing the process in an organization, along with a framework for quality management. QPL is based on information, processes, and the interactions between them. It is a diagrammatic language, which makes it easier to understand how processes affect quality and vice versa.

Chan and Spedding (2003) formulated an integrated multidimensional process improvement methodology (IMPIM) to address the yield management, process control and cost management problems of a manufacturing system. The enabling technologies for IMPIM are management concepts, information technology, artificial intelligent techniques and mathematical models. Simulation is used as a platform to implement the integrated multidimensional process methodology by incorporating the productivity, quality and cost dimension in a unified, systematic and holistic manner.

From the practical application of IMPIM in two studied cases, the result shows that the appropriate combination of difference control charts in the system can achieve the conditional optimal process control. The result of the second case shows that the using of NNM as an on-line quality improvement tool can achieve optimal performance without costly intervention and complex analytical tools.

Dogdu and Santos (1998) was indicated that in the development of the computer technology, although the Statistic Process Control (SPC) technique and theories remain unchanged, the implementation and the characteristics of SPC are changing due to the rapid developments in software and hardware industry.

Many of software tools perform the SPC analysis. Computer integrated SPC systems enable process manager to simultaneously monitor many shop floor operations and find the interrelations between the processes. In data collection and management part nowadays, there are numerous methods to collect data. Data can be imported to the software thus eliminating the time-consuming data entry step. For example, once data is entered, it is available to a host of analyses

without the need of reentry. Now the use of software programs X-bar and standard deviation charts or other hard to construct charts can be used easily. The developments in computer technology lead the way to more sophisticated tools such as DOE and data mining. In the training section, two training programs developed and used in PCB. Employees were learning the basics and explain the philosophy behind the control charts instead of learning only how to plot it.

Voros (19990 developed a model that considers process quality improvement and set up cost reduction. The distinctive characteristics of his model are embodied in the assumptions that production rate is finite and cost of attaining close to zero setup time is not finite. Additionally, the process layout makes possible spotting problems at the place of appearance and these problems can be fixed. The outcome of his analysis under these assumptions supports the popular operations paradigm that reducing response time and increasing process reliability are parallel processes. A simple mapping procedure is also suggested to find the minimum value of total cost function.

Consider the inferior quality products are normally either reworked or scrapped to assure good outgoing quality. When the quality of product exceeds the limit, remedial action is taken to restore in-control state while taking a learning action would improve the mean value of the product's quality which produced from out-of-control state. Assumptions are made in order to be proved by the statistical method from the quadratic quality cost function. The cost model is proposed to determine the optimal number of learning actions to be taken and the optimal action limit. Also examine the effect of both the learning action and remedial action.

Since quality has become a key determinant for success in modern industry, services and also manufacturing. This paper reviews the contribution of statistical analysis and methods to modern quality control and improvement. Major areas are statistical process control and industrial experimentation. For example, the Shewhart control charts, economically optimal control chart, multivariate control chart, statistical and automatic process control, acceptance

sampling etc. Experimentation for quality improvement and quality management are also significant factors. This paper argues that only through the broader perspective of a total quality approach can fullest recompense of SPC and other statistical techniques be realized.

Improving performance in manufacturing is the basic objective of operations management approaches. Benchmarking, reengineering and TQM rely on the hypothesis that critical success factors may be improved. Although several approaches have proved their usefulness, the relationship between improvement and learning is not properly established. This paper gives an overview of the theoretical background of processes, the most components involved, the noticed effects and also the relationship among the system.

3. The proposed model

In this section, we developed a new integrated model for process improvement by using sequencing proper tools for the appropriate problems. This arrangement will reduce the implementation time. It also helps the manufacturer to reduce the scrap rate, improve quality, gain the productivity through the improvement process and reduce the number of the employees in the KAIZEN team.

To coordinate the information flow of the process properly, we need to re-organize the sequence of the tools. The sequence begins with the check sheet to collect all the data even in the historical or the current situation and focus on the bottle neck of the process as a problem. The next tool to be used is the cause-and-effect diagrams which help us to find the problem and its contribution factors. Then the Pareto chart is used to identify the crucial areas of the problem and factors based on the 80-20 rule. Finally, the control chart is implemented to improve the quality of the product, detect and prevent defection. Control chart is also used as an estimating device. After sequencing the proper tools for the appropriate problems, the capability indices are finally computed to evaluate the performance of the process. Here histogram is out of consideration because the check sheet could replace its functions completely. The scatter diagram and the flow process chart are also used as optional tools for the specific proposed. Thus, the main tools that we normally use are check sheet, Pareto chart, cause-and-effect diagram, control chart, scatter diagram and flow process chart. The general framework of the proposed model is represented in Figure 1.
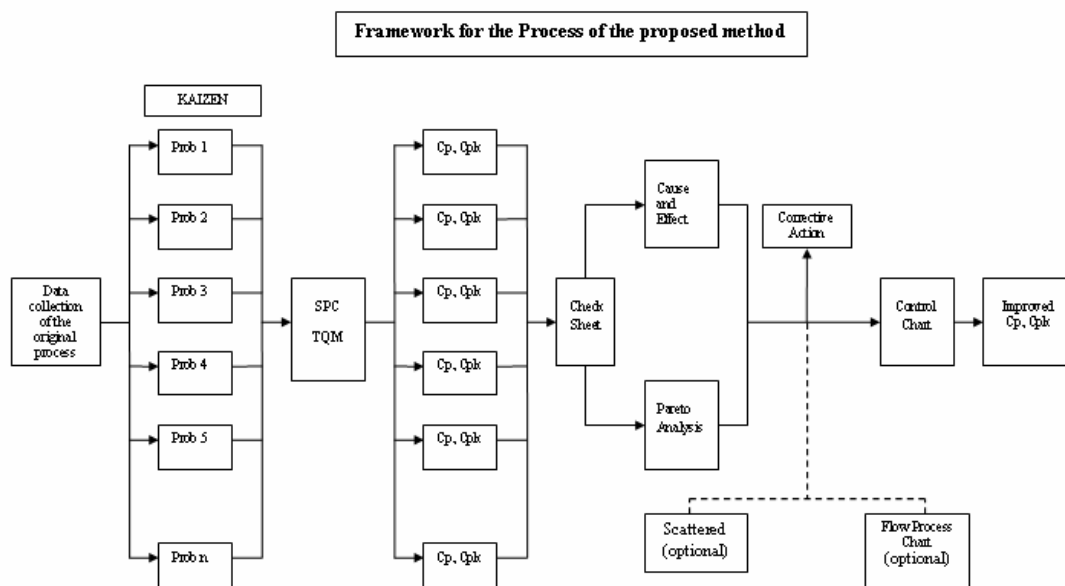

Figure 1: The framework of the proposed method

4. Experimental Results

In order to evaluate the performance of the proposed method, we compare our model with the integrated model of Yung (1996). The capability indices are the indicators for evaluation. The experiments are conducted with data collected from the real life manufacturing system of speaker assembly. The following is the summary of collected data and the obtained results.

Table 1: Check sheet from data collection

Month	July				August				
Date	1	2	26	27	18	21	25	30	Total
Open circuit	6		5	4		4	3	3	25
Defected input	1	1	1		2			1	6
Switch breakdown	6	4	7	8	2	5	3	2	37
Sound interuption	1								1
Scratched bass line		1							1
Peeled-out PVC		1	2	1		2	1	1	8
Distortioned speaker			1	1					2
Transformer breakdown			1					2	3
Speaker worked improperly							1		1
Total	14	7	17	14	4	11	8	9	84

The defects in July are 52 times and in August are 32 times. The overall of two-month defects are 84 times. This summarize also shows us the outstanding reason for defects which are the switch breakdown and the open circuit. We will use these two reasons for further analysis. From the check sheet, we can see that the switch breakdown and the open circuit are the main problem in the speaker assembly line. For such a case, we choose the switch break down to be an example for developing the cause and effect diagram as shown in Figure 3. We considered switch breakdown to be the cause (the head of the chart) and the effects are classified into 5 topics which are the environment, method of assembly, machines, material and worker.
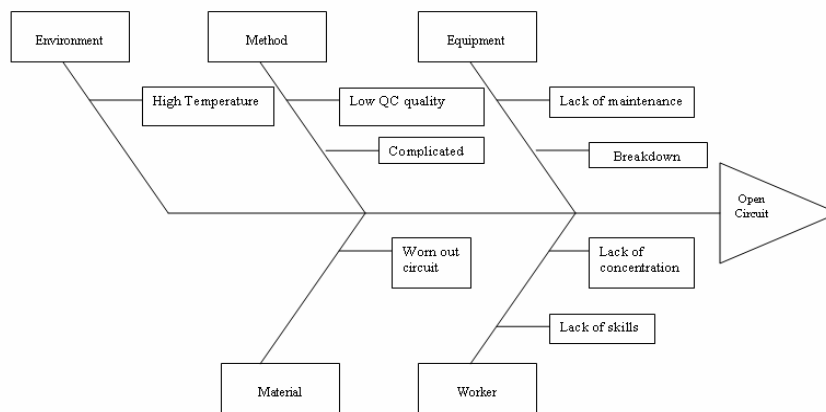

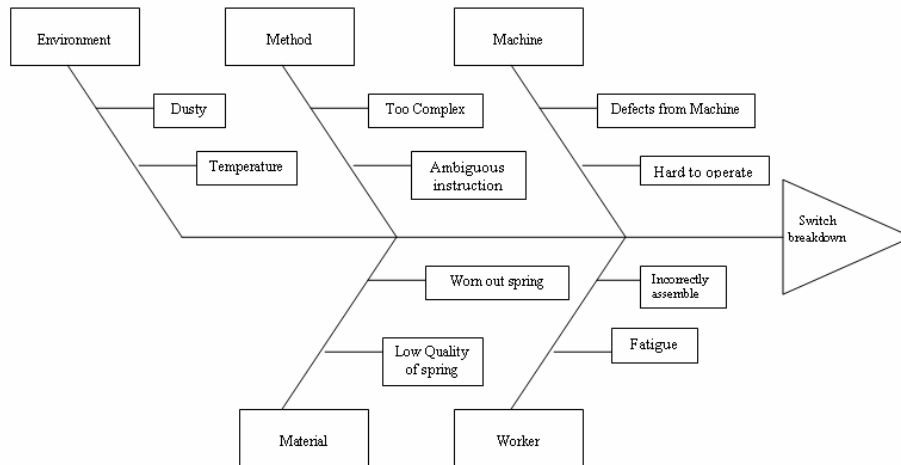Figure 2: Cause and Effect Diagram of Open Circuit

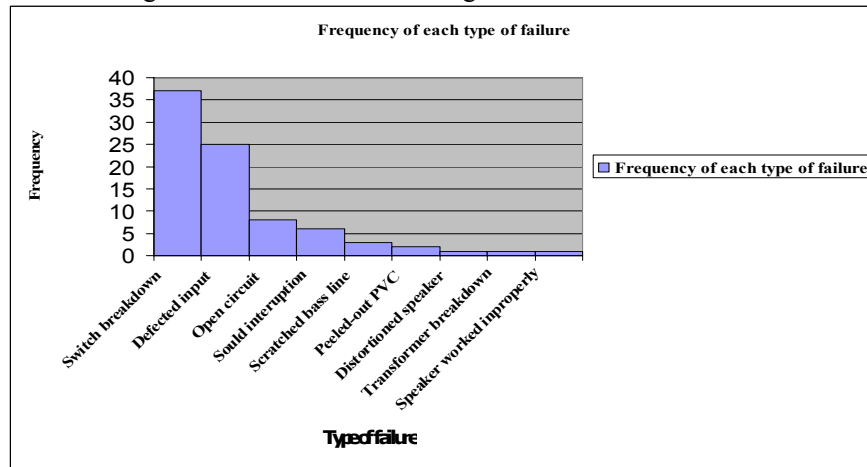Figure 3: Cause and Effect Diagram of Switch Breakdown

Figure 4: Pareto Chart

According to the check sheet, we used these failures to create the Pareto chart as shown in Figure 4. Using the statistical data of failure, we filled up the chart and arrange in sequence of descending order. The obtained data from Pareto chart is approximately match with the 20-80 theory which is the 73.8% of the cause came from the 20% of the type of failure. From the production area, we also recognize that the edge cutting machine is required the accurate width of the work piece. Ten samples of data and three time observations for each sample have been taken. The requirement of the width for this work piece is 18±0.1 (Table 2). In order to evaluate the performance of the process, we construct the R-Chart and the $\overline{X}$ Chart and calculate the values of C_p(potential capability)and C_{pk} (actual capability)

Table 2. Collected Data

sample number	Observation			Average	Ri
1	17.82	17.96	17.96	17.91	0.14
2	17.98	17.94	18.00	17.97	0.06
3	18.05	18.03	18.14	18.07	0.11
4	18.08	18.00	18.08	18.05	0.08
5	17.98	17.91	17.95	17.95	0.07
6	17.89	17.95	17.92	17.92	0.06
7	17.80	17.90	17.95	17.88	0.15
8	17.92	17.83	17.97	17.91	0.14
9	18.00	17.88	17.93	17.94	0.12
10	17.98	17.82	17.87	17.89	0.16
11	17.85	17.84	17.92	17.87	0.08
12	18.03	18.10	18.07	18.07	0.07
13	18.11	18.09	18.01	18.07	0.10
14	17.80	17.92	17.89	17.87	0.12
15	17.88	17.95	17.86	17.90	0.09
16	17.90	18.00	18.05	17.98	0.15
17	18.11	18.05	18.08	18.08	0.06
18	17.91	18.04	18.04	18.00	0.13
19	18.00	18.14	18.12	18.09	0.14
20	17.95	18.08	18.10	18.04	0.15
21	18.07	18.02	18.08	18.06	0.06
22	17.98	17.90	17.75	17.88	0.23
23	18.15	18.11	18.07	18.11	0.08
24	17.81	17.96	17.90	17.89	0.15
25	18.12	18.09	18.07	18.09	0.05

$\overline{R}$ **Chart**
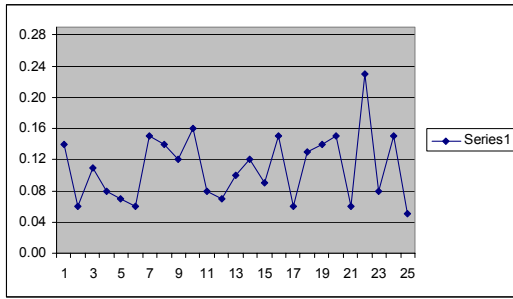
$\overline{X}$ **Chart**
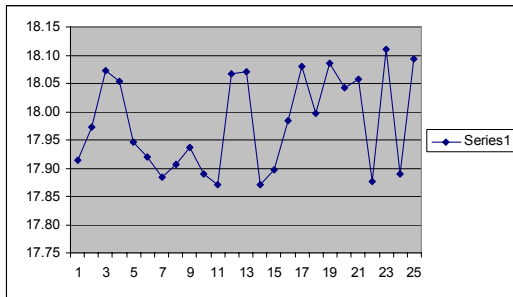
R Chart:

Lower Control Limit $\quad = \overline{R}\,\text{D3}$
$$= (0.11 \times 0)$$
$$= 0$$

Upper Control Limit $\quad = \overline{R}\,\text{D4}$
$$= (0.11 \times 2.575)$$
$$= 0.283$$

$\overline{X}$ Chart:

Lower Control Limit $\quad = \overline{X}\, \text{-}\, \overline{R}\,\text{A2}$
$$= 17.97 - (0.11$$
$$\times 1.023)$$
$$= 17.85$$

Upper Control Limit $\quad = \overline{X}\, + \, \overline{R}\,\text{A2}$
$$= 17.97 +$$
$$(0.11 \times 1.023)$$
$$= 18.08$$

Cp value:

$$\hat{\sigma} = \frac{\overline{R}}{d_2} = \frac{0.11}{1.693} = 0.065$$

$$\hat{C}_p = \frac{USL - LSL}{6\sigma} =$$

$$\frac{18.10 - 17.90}{6(0.065)} = 0.513$$

$$\hat{P} = \left(\frac{1}{\hat{C}_p} \right) 100\% =$$

$$\left(\frac{1}{0.513} \right) 100\% = 195\%$$

Cpk value:

$$C_{pk} = \min\left(C_{pu}, C_{pl} \right)$$

$$C_{pu} = \frac{(USL - \overline{X})}{3\sigma} = \frac{(18.10 - 17.98)}{3(0.065)} = 0.615$$

$$C_{pl} = \frac{(\overline{X} - LSL)}{3\sigma} = \frac{(17.98 - 17.90)}{3(0.065)} = 0.41$$

$$\therefore C_{pk} = 0.41$$

The result shows that the process is normally out of control (*Both C_p and C_{pk} are lower than 1*) but the C_p and C_{pk} values are still relatively similar which mean the data is very close to the specification limits. Thus the process is needed to be improved.

After we test the improvement methods with the random data, it shows that the numerical results are the same. However with the improved methods, the steps are reduced from using 7 tools to 4 tools (Check sheet, Cause-and Effect-Diagram Pareto Chart and Control Chart while Scatter and flow process chart are optional) in stated sequences which consume less time to perform. In addition, with the real situation, if there is any travel time concerned, we would use the flow process chart in order to improve both quality and productivity.

5. Corrective actions

From our investigation, all the problem areas can be improved by the corrective actions presented in Figure 5.
In addition, we may use optional tool as the Flow Process Chart to identify some more problems such as

- Too many delay intervals (141 min)
- Time-consumed transportation (24.75 min)

Corrective Action		
Equipment	Using more preventive & predictive maintenance	/
Method	Improve the QC quality	/
Environment	Use more ventilation fans	
	Clean more often	/
Worker	Reduce the annoyance	/
	Perform more training	/
	Encourage the workers to wear masks	/
Material	Apply better inspection	/
Handling Device	Apply conveyor to the appropriate workstation	
	Apply our material handling	

		Original method	Improved method
1	Cp	0.513	2.564
2	Cpk	0.41	2.441
3	Transportation time	24.75 min	-
4	delay	141 min	-
5	scrap rate	14%	11%

Figure 5 : Corrective actions and results

We can conclude that the existing production line has many bottle neck stations. Therefore we can reduce both delay intervals and transportation time by;

1. Apply Kanban system to the line
2. Re-sequencing the process
3. Design the material handling device

After the corrective actions are implemented, the control chart is revised in order to check the Cp and Cpk, and then compared with the performance of the process before implementing the corrective actions.

Table 3: Revised data

Sample No.	Observation 1	Observation 2	Observation 3	Avg	Ri
1	18.00	17.97	17.99	17.9867	0.03
2	18.02	18.01	18.01	18.0133	0.01
3	18.02	18.01	17.99	18.0067	0.03
4	17.98	17.97	18.01	17.9867	0.04
5	17.98	18.00	17.99	17.9900	0.02
6	17.98	17.97	17.98	17.9767	0.01
7	17.98	17.96	17.98	17.9733	0.02
8	18.02	18.01	18.03	18.0200	0.02
9	18.00	18.02	18.01	18.0100	0.02
10	18.00	17.98	18.01	17.9967	0.03
11	17.98	17.98	17.96	17.9733	0.02
12	17.98	17.97	17.97	17.9733	0.01
13	17.99	18.04	18.03	18.0200	0.05
14	18.02	18.01	18.00	18.0100	0.02
15	17.98	18.01	17.98	17.9900	0.03
16	18.00	18.00	18.01	18.0033	0.01
17	17.98	17.98	17.96	17.9733	0.02
18	18.00	17.98	18.01	17.9967	0.03
19	18.02	18.02	18.00	18.0133	0.02
20	18.01	18.02	18.00	18.0100	0.02
21	17.97	18.00	17.99	17.9867	0.03
22	17.98	17.98	17.99	17.9833	0.01
23	17.98	17.99	18.00	17.9900	0.02
24	18.01	18.03	18.01	18.0167	0.02
25	17.98	17.97	18.00	17.9833	0.03

$\overline{R}$ Chart
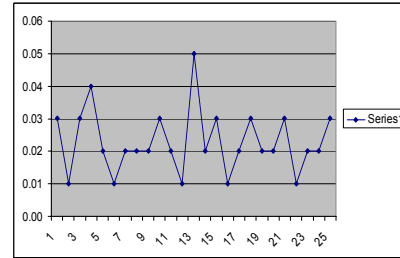
$\overline{X}$ Chart
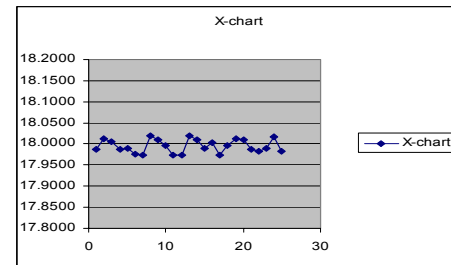
Calculation

R Chart:

Lower Control Limit $= \overline{R}$ D3
$= (0.0228 \times 0)$
$= 0$

Upper Control Limit $= \overline{R}$ D4
$= (0.0228 \times 2.575)$
$= 0.0587$

$\overline{X}$ Chart:

Lower Control Limit $= \overline{X} - \overline{R}$ A2
$= 17.9953 - (0.0228 \times 1.023)$
$= 17.972$

Upper Control Limit $= \overline{X} + \overline{R}$ A2
$= 17.9953 + (0.0228 \times 1.023)$
$= 18.019$

Cp value:

$$\hat{\sigma} = \frac{\overline{R}}{d_2} = \frac{0.0228}{1.693} = 0.013$$

$$\hat{C}_p = \frac{USL - LSL}{6\sigma} = \frac{18.10 - 17.90}{6(0.013)} = 2.564$$

$$\hat{P} = \left(\frac{1}{\hat{C}_p}\right)100\% = \left(\frac{1}{2.564}\right)100\% = 39\%$$

Cpk value:

$$C_{pk} = \min(C_{pu}, C_{pl})$$

$$C_{pu} = \frac{(USL - \bar{X})}{3\sigma} = \frac{(18.10 - 17.9953)}{3(0.013)} = 2.687$$

$$C_{pl} = \frac{(\bar{X} - LSL)}{3\sigma} = \frac{(17.9953 - 17.90)}{3(0.013)} = 2.441$$

$$\therefore C_{pk} = 2.441$$

From the obtained results, it seems to be dramatically improved. Both Cp and Cpk are more than 1. Both Cp and the Cpk also show that mean of the data are close to the accurate one. It proves that the improved method is very effective than the original one.

6. Conclusions

This paper has modified the integrated model of Yung for process improvement. The proposed model tries to sequencing the proper tools/techniques for appropriate problem. The improvement could be more effectively at lower cost and required shorter implementation time. The real life speaker assembly process has been test to verify the performance of the proposed model. The obtained results confirm that the process improvement has been achieved in the more effectively way.

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