

IMPLEMENTATION OF SIX SIGMA METHODOLOGY IN THE PACKAGING MANUFACTURING PROCESS

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Abstract — Six Sigma methodology is the quality technique that eliminates or reduce the defects by focusing on the output of the process and improve the existing process. The objectives of this study were to implement the Six Sigma methodology in the packaging manufacturing process and also to find and eliminate the root causes of the problem that effect the critical to quality (CtQ) of the product. The study had been conducted in Company X for two weeks, which the data had been collected for 2 to 3 times per day. The parameter considered in this study was the speed of the sheet per minutes of packaging produced. The data was collected to find the problem of the measurement of the glue gap. The collected data was analysed by using capability analysis in Minitab statistical software. The result obtained from the analysis indicate that the process was improved from the old process. The Sigma level had shown the improvement from level between 1 and 2 to level between 3 and 4. Although it is impossible to achieve the perfect process and reduce the defects to the level of 3.4 ppm, the improvement in the process show that Six Sigma methodology can increase the quality and decrease the defects of the product.

Keywords - Six Sigma, DMAIC, Minitab statistical software, glue gap measurement, capability analysis.

I. INTRODUCTION

Throughout over decades, manufacturing sector in Malaysia had been increased rapidly due to the natural resources, increasing in investors or clients, development of technology and well-educated population. The growth in manufacturing industry has increase the competitive environment between the companies, where they need to compete with each other to increase the productivity, and at the same time maintain the quality of the products. The product quality is critical to control as the customers usually choose the best quality of the products. Therefore, the companies need to prepare and introduce a good quality management system, where it aims these vital elements which are quality control, quality assurance and quality improvement.

Six Sigma methodology consists of define, measure, analyse, improve and control (DMAIC) phases, where the phases are called problem solving technique as the DMAIC phase is used to find the root cause of the problem in the product process flow and eliminate it to readjust and improve the process flow permanently.

However, the implementation of Six Sigma methodology in Malaysia is still lacking and the existence of Six Sigma initiatives in the country are inadequate compared to other countries [1], including Company X. Company X is the professional and experienced company of corrugated packaging worldwide

including Malaysia and Southeast Asian region. As the packaging manufacturer, Company X usually faced with continually growing demands from miscellaneous type of customers, basically on the production speed and the quality of the packaging. Company X had experienced a number of problems and the complaint of the customers regarding the production of packaging including the measurement of glue gap.

The significant and relevancy of this study is to prove the validity and capability of Six Sigma implementation in the packaging process. Although Six Sigma had displayed an excellent result on quality improvement and achievement of implementation, there are also abundant of reviews and studies that pointed out the failure of Six Sigma adoption [2][3]. But, the range of Six Sigma implementation had been developed from time to time and evolve into a business angle, where it is concentrating on enhance the demand of customers, business work rate and financial efficiency [4]. Besides, Six Sigma can be used in variety type of circumstance and processes, from human relation to product design [5].

Motorola Inc., were originally invented the approach of Six Sigma business management. Then, Honeywell International and General Electric had attained astounding effect from Six Sigma when it had been introduced by Jack Welch [6]. The range of Six Sigma implementation had been developed from time to time, not only in manufacturing industry but also had evolved into a business angle, where it is concentrating on enhance the demand of customers, business work rate and financial efficiency [4][7]. In the last century, many organization had developed and transformed a lot of ideas to improve the quality of products and customers satisfaction. Six Sigma had shown a lot of improvement compared to others quality technique [2]. Six Sigma strategy was focused on design, eliminating defects, driving out process variability as well as reducing costs, whereas the lean strategy only focused on speed and time [5][8].

There are several studies that show the achievement of Six Sigma application in worldwide. For examples, in India, there are various studies in Six Sigma such as automobile manufacturing industries [3], foundry industry [4], and farm equipment sector (FES) [7]. In addition, the application of Six Sigma methodology was also applied to a diagnostic imaging process in private hospital in Turkey. As the result of implementation, their study manage to eliminate the causes of failure, improve the workflow and achieving optimal efficiency, service quality, customer satisfaction and financial success in medical imaging department [9].

The main objective of this study is to implement Six Sigma methodology in a packaging manufacturing process. The second objective is to find the root causes of the defects in the process and also to prove the validity and capability of Six Sigma. The data collected was analysed by using process capability analysis in Minitab Statistical Software. The parameter used in this study is

the speed of the sheet per minute of the packaging produced by Company X. the different types of speed is used in this study.

II. METHODOLOGY

The Six Sigma implementation will use the DMAIC methodology, which consists of Define, Measure, Analyse, Improve and Control phases. The following sections will discuss in details about the DMAIC methodology, which include and combining the different types of techniques and tools used for each phases.

i. Define

Define phase is the first step of the DMAIC methodology. The selection of the project and the target framework must be set appropriately as to avoid the problem and the project failure as the aims of define phase is to define and describe a Six Sigma project with all necessary details including the objectives, scope, team composition, schedule, etc. the process mapping tool is used the define phase in order to understand the overall process flow completely. In the define phase, the critical to quality (CtQ) of the product was defined, where mostly from the customer's complaints and satisfaction.

ii. Measure

Measure phase is the second phase in the DMAIC methodology, which it is the phase for data collection. The data and information from the current process is gathered and the standard performance of process is evaluated. This entails the following key tasks: identifying the characteristics were data to be collected, studying the accuracy of the measurement system, collecting and recording the data and establishing a baseline performance of the process. The glue gap measurement of the packaging was measured and the data was collected. Both top and bottom gap at the glue gap were measured and recorded in the table.

iii. Analyse

The objective of the analyse phase in a Six Sigma methodology is to clarify and identify the potential causes for the process problem being studied and then select the root causes with the help of the data and their analysis. During this phase, data was analysed to seek explanation for the data collected during the measure. The tool used during phase is process capability analysis using Minitab statistical software is used to analyse the data. The values of process capability ratio, Cp and process capability index were observed. Also, the value of performance of the process in part per million, ppm was observed to find the Sigma level of the process. Figure 1 below show how the Sigma level was defined from the value of ppm from the capability analysis diagram.

Sigma Levels and DPMOs

Sigma Level	DPMO
1	690,000
2	308,000
3	66,800
4	6,210
5	233
6	3.4

Figure 1: the Sigma level and Defects per million opportunity, DPMO

iv. Improve and Control

During the improve phase, the solutions for the root causes of the problem are to be identified and implemented to observe the result. The process is improved after the data was measured and analysed. Then, the new process is being controlled and keep ongoing and the prevent reverting to the old process.

III. RESULT AND DISCUSSION

i. Define Phase

The first step of DMAIC phase is define phase. Define phase is the phase to identify the root causes of the problem in the process. Company X is emphasized in term of critical to quality (CtQ), where their focus is on the satisfaction of the customers. The critical to quality (CtQ) characteristic in this study is the measurement of the glue gap for both top and bottom part.

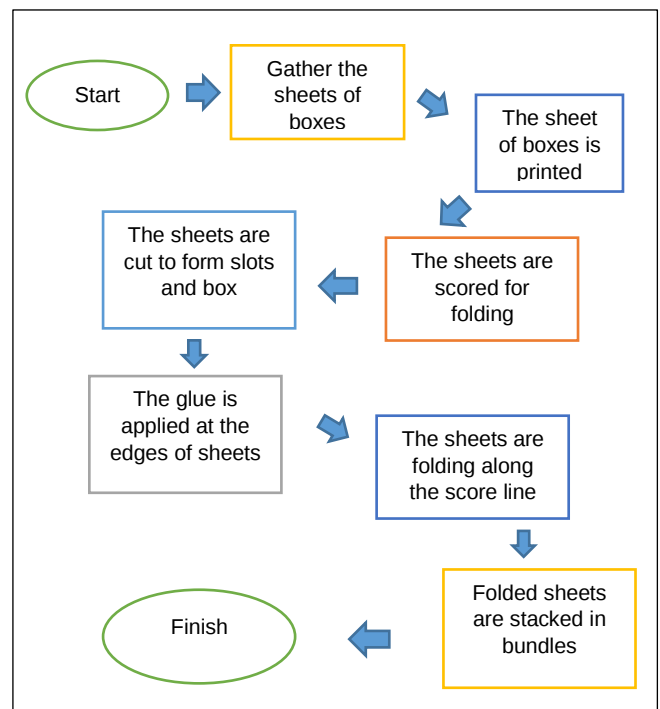


Fig 1: The overall workflow of the production of packaging in Company X

Figure 1 shows the overall process flow of the production of the boxes at Company X. The process start when the sheet of the boxes are gathered in the bundles. Then, the sheets is sent to the machine for the printing step, where the sheet is printed correspondingly to the specific brands/logo that designed by the customer. After that, the sheet is scored/marked for folding and sent to the cutting part to form slot and box. The dimension specification of the boxes, such as height, width of the boxes and panels are solely based on the customer's requirement. Next, the cut sheet is sent to the gluing part of the machine. After glued, the sheet is folded along the scored line forming folded sheet. Lastly, the folded sheet is stacked together in bundles by using the rope and send to the warehouse for further shipment.

The study that had been conducted was to find the causes of the defects of the measurement of glue gap of the boxes. In the overall workflow, the part that being stressed out was at the phase where the glue was applied to the sheets. The glue gap measurement was selected as it was the least obvious defects that cannot be seen by the naked eye compared with the print defects. The width of the gap must be measured manually by using ruler.

ii. Measure Phase

After understanding the overall process in the define phase, the data and information is gathered and collected. The objective of measure phase is to evaluate the baseline status of the existing process. Table 1 shows the example how the data was collected for glue gap measurement. The top mean the width of the top at the glue gap flap, while the bottom mean the width of the bottom at the glue gap flap. The difference is the subtraction of top and bottom gap. All the measurement is in millimeter (mm). The glue gap for both top and bottom should be 6 mm width with the tolerance of ± 3 mm.

Speed: 100 sheets/minutes			
NO.	TOP(mm)	BOTTOM(mm)	DIFFERENCES(mm)
1	7	3.5	3.5
2	1.5	3	-1.5
3	3	3.5	-0.5
4	7	6.5	0.5
5	4.5	11	-6.5
6	3.5	5	-1.5
7	7.5	4	3.5
8	6	4	2
9	5.5	3.5	2
10	6	5	1
11	6	5	1
12	2	5	-3
13	1.5	2	-0.5
14	3.5	2	1.5
15	2	0	2

Table 1: Examples of Glue Gap Measurement Data

The speed of sheet per minute (sheet/minute) production of the boxes is the factor that affecting the glue gap measurement. In order to verify the factor, different types of speed is conducted. The speed of 100, 120 and 150 sheet per minute of production of boxes are used and the data was collected and recorded to be analyzed. The total of data collected were 150 samples for each speeds, which mean the overall total of the samples were 450 samples that was collected randomly, 2 or 3 times a day in the period of 2 weeks.

iii. Analyzed Phase

The data were analysed one by one, where the data of speed of 100 sheets per minutes of boxes produced were the first that being analysed using process capability analysis. Then, the speed of 120 sheets per minutes and then, the speed of 150 sheets per minutes of boxes produced. The total samples used for each analysis was 150 samples.

Figure 3(a) show the result of the glue gap measurement at the top part for speed of 100 sheet per minutes. As shown in the figure 3(a), the value of sample mean is 3.34667 show that the process is shift to the left as the process mean should be around 6 (target). Besides, the value of process capability ratio, Cp and process capability index, Cpk are 0.61 and 0.07 respectively and this is indicated that the process is not capable meeting its specification as the value of Cp must be equal or greater than 1 to make the process is capable [10]. In addition, within and overall performances are indicated, namely that approximately 416,535 parts per million (ppm) would be nonconforming if only common causes of variability were present in the current process, and approximately 441,917 ppm in overall. The Sigma level of this process is between level 1 and 2[11].

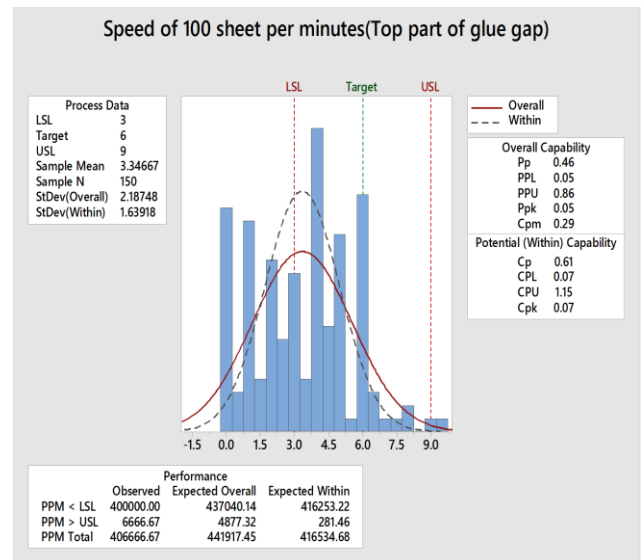


Fig 3(a): Process capability analysis diagram at Top part of glue gap

For the bottom part of the glue gap measurement, the Figure 3(b) shown the capability analysis of the process. The value of sample mean is 4.17333, show that the process is shift toward the left. The value of Cp and Cpk are 0.48 and 0.19 respectively, indicated that the process is not capable meeting its specification as the value of Cp must approach or greater than 1. The value of Cpk is less than 1 indicated that the improvement in the process is warranted [10]. Correspondingly, within performance in the Figure 3(b) indicates that the proportion of defect is approximately 299,340 of total ppm, while the proportion of defects for the overall performance is approximately 359,739 of total ppm. The sigma level of the current process is between 1 and 2[11].

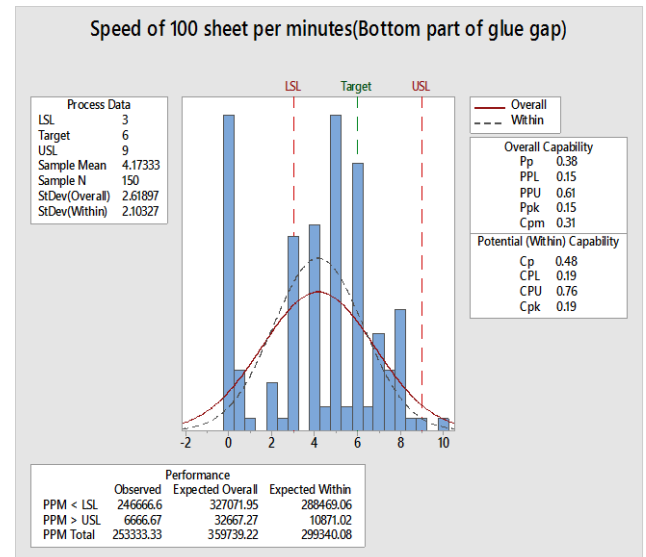


Fig 3(b): Process capability analysis diagram at Bottom part of glue gap

For the second part of analysis, the speed of 120 sheet per minute of the production of boxes is analyzed. The total samples used is 150 samples.

The sample mean is 4.15333 show that the process is slightly move toward to the left side of the graph in figure 4(a). The value of Cp and Cpk are 0.59 and 0.23 respectively. The value of Cpk is increases from the previous one and this show that the

process improved a little, but the process is still not capable meeting its specification as the value of C_p is not equally or greater than 1. Also noted that the value of C_{pk} is less than 1 demonstrated the improvement is needed in the process. Excluding, the within and overall performance of the current process had illustrated that the percentages of the defect side has been slightly decreased compared with the previous analysis. The Sigma level of the current process is between 2 and 3, which show the improvement from the earlier one.

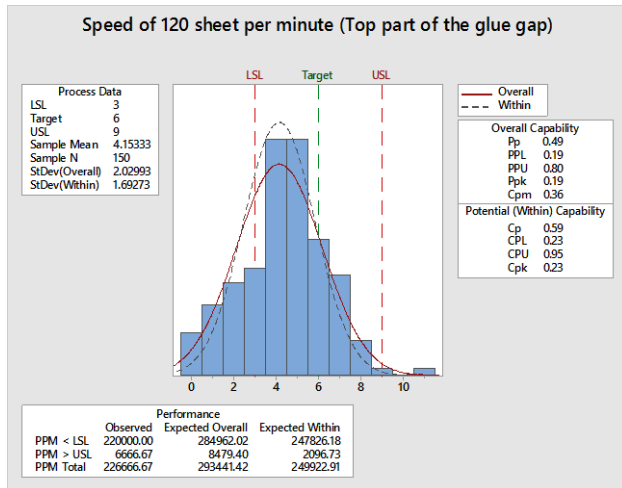


Fig 4(a): Process capability analysis diagram at Top part of glue gap

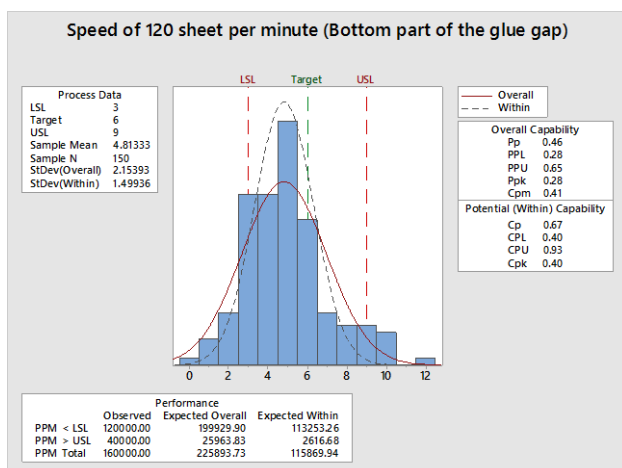


Fig 4(b): Process capability analysis diagram at Bottom part of glue gap

The next analysis is the capability analysis for the bottom part of the glue gap shown in the Figure 4(b). The sample mean of 4.1533 show that the process is move toward the left side of the graph but also move closer to the center. Besides, the value of C_p and C_{pk} for current process is 0.67 and 0.40 respectively, which is much better than earlier one. The higher the value of C_p , the better the process and the process is more capable meeting its specification. Additionally, the within and overall performance also shown the slightly decrease compared with the previous speed, where the value for within performance is 115,869 ppm and the value of overall performance is 225,893 ppm. The level of Sigma for current process is between 2 and 3, which is enhanced from the previous one.

For the third part of analysis, the speed of 150 sheet per minute of the production of boxes is analyzed, where number of samples was 150 samples that taken randomly.

The sample mean of 5.78 in figure 5(a) shows that the current process is more toward the center. This result is better than

the previous two samples. The value of C_p for the current process is 0.57 and the value of C_{pk} is 0.53. The process is not capable meeting its specification as the value of C_p is not equally or greater than 1. On the other hand, the value of C_{pk} is less than 1 illustrated that the improvement is needed in the current process. The values of overall and within performance of current process also show that the proportion of defects are decreased and signified the improvement from the previous two samples. The level of Sigma for the current process is approaching level 3.

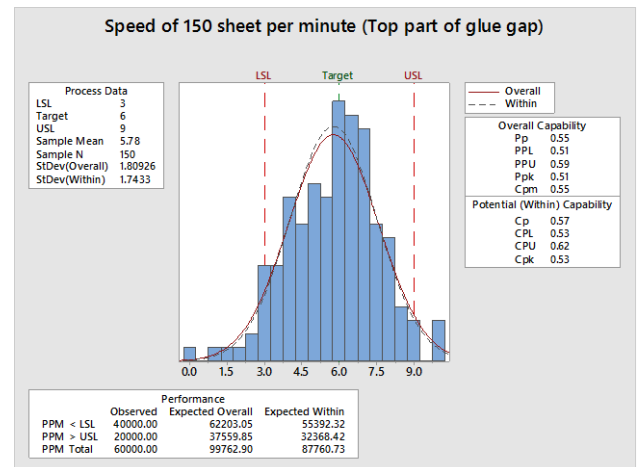


Fig 5(a): Process capability analysis diagram at Top part of glue gap

The sample mean of 5.78 in figure 5(b) displayed the improvement compared with the previous two samples for the bottom part of glue gap measurement. The value of C_p for the current process is 0.55 and the value of C_{pk} is 0.51. This indicated that the process is not capable meeting its specification as the value of C_p is not equally or greater than 1. Nevertheless, the value of C_{pk} is less than 1 indicated that the current process still need to be improved. The values of overall and within performances of current process illuminated that nonconforming region of the current process had been improved from the previous two samples. Level of Sigma of current process is between level 2 and 3.

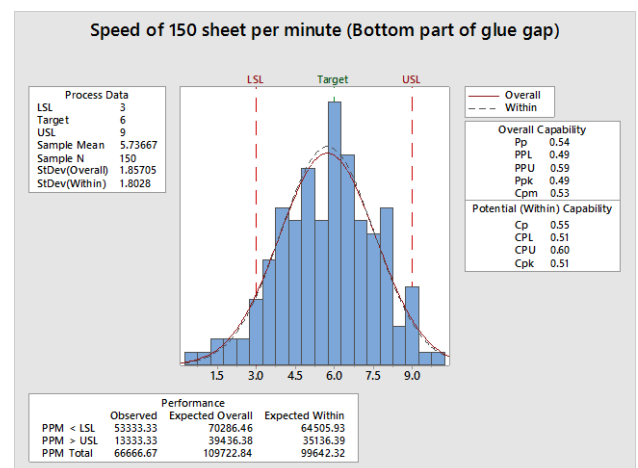


Fig 5(b): Process capability analysis diagram at Bottom part of glue gap

iv. Improve and Control Phases

The improvement of the process is taken place after the analyzed phase. Figure 6(a) show the capability analysis diagram after improvement for the top part of the glue gap. The speed used is 150 sheet per minute of production of boxes. Due to time limitations, the total number of sample collected and used is 30 samples that was taken randomly.

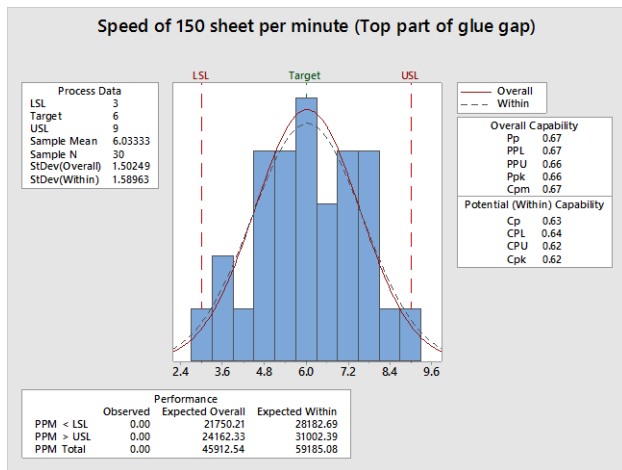


Fig 6(a): Process capability analysis diagram after the improvement for top part of glue gap

The sample mean from the diagram is 6.033, which is almost approaching the target of 6 mm. This result indicates that the process had been improved from the previous one. Besides, the value of Cp and Cpk are almost equal, which is 0.63 and 0.62 respectively, demonstrated that the new improvement process is almost centered. The overall and within performance of the process show an impressive improvement and the level of Sigma for current process is between 3 and 4, which is had shown the improvement in the process.

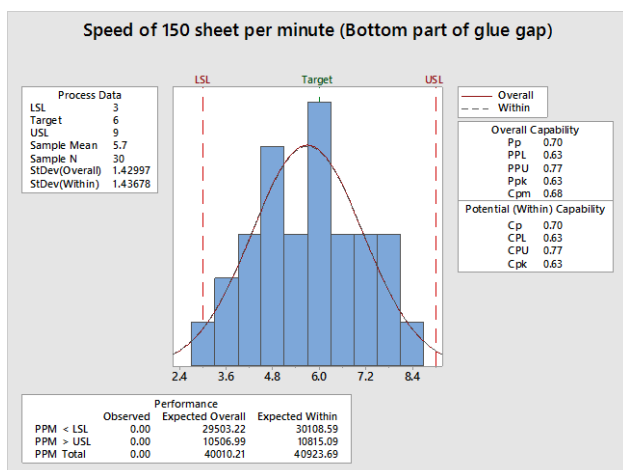


Fig 6(b): Process capability analysis diagram after the improvement for bottom part of glue gap

The sample mean for the bottom part in the figure 6(b) is 5.7, which is slightly toward the left of the graph but almost centered and approach target. Besides, the value of Cp is 0.70 and the value of Cpk is 0.63. These values had shown the significant improvement from the previous one and the proportion of defect had been decreasing. The new level of Sigma for the improvement process is between 3 and 4.

IV. CONCLUSION

The goal of this study is to implement the Six Sigma methodology for improving the measurement of glue gap in the packaging production. The result of the study is quite successful as the new process had shown considerable improvement compared with the old one. It is difficult and need the enormous amount of time and resources to achieve the level of Sigma of 6 where the defects is decreasing to 3.4 ppm from the process. In conclusion, the

implementation of Six Sigma methodology in manufacturing process is proven and successful.

V. RECOMMENDATIONS

There are several recommendation that can be made to improve the outcomes and the understanding of the Six Sigma methodology. For the future references, the following recommendations are proposed.

- 1) It is recommend to have the sufficient time and sources when conducting the study
- 2) The understanding and fundamental knowledge of Six Sigma should be studied from the previous case studies of the Six Sigma application.
- 3) It is encourage to use another approach or others quality technique or combine them together.

VI. ACKNOWLEDGEMENT

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VII. REFERENCES

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