State of The Art Review of Quality Control Method in Automotive Manufacturing Industry

M Hafizi1*, S N S Jamaludin2 and A H Shamil3

1 Master Student DRB-Hicom University of Automotive Malaysia
2 Research and Innovation Head DRB-Hicom University of Automotive Malaysia
3 Advance and Distance Learning Dean DRB-Hicom University of Automotive Malaysia

Corresponding author *: mejmohdhafizi@gmail.com

Abstract. Quality control plays a vital role in automotive industry to ensure the standard of the end product are accepted by customer and stay competitive in this industry. Company must remain updated to enhance and improve method in defining their product quality and maintain the continuous quality improvement. The purpose of this paper is to provide an overview of implementation quality control method used in automotive industry in reducing defects. Methodology used for this paper is extensive review of existing paper and literature. This paper provides an overview of quality control method, advantages and disadvantages of the method. The literature in this subject is fairly limited. There are very limited discussions of quality control method in the automotive industry. Therefore, great effort to carry out the study was done on the manufacturing environment particularly in the automotive part.

1. Introduction
Quality control in the automotive industry played a significant role in an ever growing need to implement continuous improvement methodologies in automotive companies. Every companies setting up higher quality standard to attract customer into purchase their product and maintain the customer expectation. The selection and application of quality control and continuous improvement method depends on companies structuring of the quality system, classification of faultless operation methods and techniques. Each company need to establish and follow quality system methodologies to help ensure their product consistently meet applicable requirement and specifications.

In order to remain competence and survive in the business, each company focus on improving product quality and reduce rework to save time and cost subsequently fulfils customer needs. From product development to final product delivery to the customer, the application of quality tools remains vital in manufacturing as a standard monitoring [1-2] and increasing productivity and profitability. How industries evolve in managing customer quality perfection demand using quality tools? In fulfilling customer demand on quality, it is important step in each manufacturing process to make sure the quality of product are above expectations. Manufacturing industries are required to be able to give quality guarantee of the manufactured products and services. This quality guarantee to the highest is able to retain competitiveness in the consumers markets [3]. Poor handling of quality issue and
procedure and below par performance of quality personnel neglecting quality effort is the main culprit for most of the defect in the manufacturing [2].

2. Review on previous research

In Product Reject Analysis using Weibull Distribution Model - A Case Study in Automotive Parts Manufacturing Industry [4], author proposed product analysis method using application of Weibull Distribution in analyzing characteristics pattern of product reject data. This method aim is to pinpoint the root cause of the defect product and providing statistical value and distribution plotting graph from analysis to determine level of production performance. This method divides the most common root cause into four groups. This group are design reject, manufacturing reject, lack of warning and instruction reject. Material, design and processing method is the most common factor contributing to product defect in every manufacturing. The result from this method could identify the inconsistency and abnormality practice in the production line. This inconsistency of working mostly caused by human error [4]. However, the Weibull Distribution models are considered as too complex and esoteric. The accuracy of Weibull analysis depends on the quality of the data. Weibull distribution generally provides a good fit to data when the data quality is understood. The data must include item-specific failure (times to failure) for the population being analyzed, data for all item that did not fail must also included and the analyst must know all experienced failure-mode root cause and be able to segregate them.

In produce conforming product, the other way is using Statistical Process Control (SPC). By using statistical tools, this method monitors the performance level of manufacturing process. It will be able to predict if any significant deviations occurred that can lead to defect product [5-7]. It is statistical method regularly used in monitoring and control of a process to ensure it operates at full capabilities. By using a process behaves predictably, it able to produce as much conforming product with the least waste. This method can be applied to any process using measureable output even though it is usually applied to controlling manufacturing lines. The main tools in SPC methods are control charts and cause and effect diagrams. This tool usually focuses on quality continuous improvement. In order to prevent problematic product passed on to the customer as well as reducing waste product, variation in the process that may affect the quality of the end product need to be detected and corrected. Implementation of SPC Techniques in Automotive Industry: A Case Study by [5] conclude, SPC analysis have the capabilities in improving the efficiency of the production process. The improved manufacturing process resulted in decreasing number of defective end product thus reduce rework cost and time. However, SPC can only detect abnormality. If the process is consistently in bad zone, SPC will consider the process in good order and will not trigger early warning.

Japanese using Quality Assurance (QA) Network method to achieve 100% defect free product in the manufacturing process. This method create a network that traps manufacturing defects effectively thus resulting in free variation in end product [8]. [8] in Reduction of Defect through Quality Assurance research stated, this method can be implement in a few condition, when there is introduction of new car model, newer version of existing cars or any change in any of the operations or processes. This QA Network main aim is to achieve 100% defect free vehicle and one of the most important part to achieve that is maintaining the documentations process of the network created. QA Network method uses 5 stages of defect detection system. These 5 stages was design to make sure zero defect outflows. Stage 1 is, In Process with the aid of Pokayokes, Templates, Karakuri, Magic Checks and QC gates. Stage 2 is successive process which also involves Templates, Karakuri, Interdependency, Visual Checks and QC gates. Stage 3 is Within Group involving Interdependency, Visual, Functional and QC gates and the 4th stage is Within Shop involving Interdependent, Fitting, Functional and QC gates. The last stages are Outflow. When the defect is not detected anywhere, it outflows to the customer that result in degradation of company brand.

Figure 1 show how the implementation of QA Network in four stages indicated by the colour coding in the figure. The colour coding of this method start with the green line indicates the process, the blue line indicates process group, yellow line indicates process shop and the red line indicate the
customer. The first stage of this method is to evaluating the process management sheet to verify the entire defect that occurred. The second step is to evaluate the check sheet very detail. This step introduces four group of occurrence prevention that is Facilities (Tools), Materials (Parts), Method, Person group. The third step in this implementation is filling and keeping this created document for further reference. The last stages will be to take counter measure to improve the condition of products.

![QA Network Web Diagram](image)

**Figure 1.** QA Network Web Diagram [8]

The QA Network when implemented with maximum accuracy capable in finding the origin of the specific kind of defects within a region in a very short time. However it needs to be updated when certain changes are made. This network is hard to maintain when some information is missed because manipulating the information is worse than no information. The difficulty in the implementation of QA Network is as good as its effectiveness as shown in figure 2. The blue line is before QA applied and red line after QA applied.

![Defects per Vehicle (DPV) before and after QA application](image)

**Figure 2.** Defects per Vehicle (DPV) before and after QA application [8]

[9] discussing about the application of Six Sigma using Taguchi approach to minimize defect In Application of Six Sigma in Automobile Industry. This research using automobile casting process at a foundry in North India as a subject to analyzes various significant process parameters. The objectives of [9] research are to develop a novel approach in creating Six Sigma projects and identify the critical parameters needed. Taguchi method used in testing the optimized parameters in an industrial case study and a trade off made to finalize the recommended process parameters used in manufacture automobile parts. [9] concluded, data have been collected and analyzed shows that their
standard deviation, represented by the Greek symbol $\sigma$ value laid in between 3.0-3.16 generally. Therefore to increase the $\sigma$ value of processes, most influencing parameters need to be identified. The effective range of the parameters identified to be studied for its effects on the $\sigma$ performance of the processes. Further analysis to identify the levels of influencing parameters need to be conducted to increase the $\sigma$ value of the processes and thereby result in the lower rejection of the components or parts. However, this method is too extreme which can slow down the production leaving customer waiting for the product delivery.

Reduction of Rework in Bearing End Plate Using Six Sigma Methodology: A Case Study by [10] discussing the implementation of Six Sigma in reducing manufacturing defect of bearing end plate which occurred after machining process. Defect on the bearing end plate detected when there is variation in thickness and diameter of the bearing end plate thus a need of rework. The subject company use casting which is the raw material form supplier. When the machining process started, defects sign starting to show up. Because of the casting are supplied by the supplier, company just complain to the supplier for a new one. However, the reduction of the casting defects is not company responsibilities, so the focus of this project is to reduce the rework due to bearing end plate problem.

The first step of implementation of Six Sigma method is definition phase. Through this phase, project team selected, project charter created, project scope and project goal identify. Follow with problem statement definition, business case development and lastly the preparation of project schedule to be carried out. The second phase is measure phase. This phase is the project base lining including the identification of measurements factors which is vital in improving Critical to Quality (CTQ) characteristics, assessment of measurement system if required and quantification of the current status of the CTQ characteristics [10]. The third phase is analysis phase. In this phase, focus will be to identify the probable or potential causes of the problem. From this list, the root cause will be shortlisted using Gemba investigation. Gemba is a technique to verify whether a potential cause is a root cause or not through the physical observation of the process. The aim of this phase in the Six Sigma methodology is purely to come out with a list of root causes of the problem. The fourth phase is the improving phase. This phase is to identify the best resolution to overcome the root causes or minimizing it. The last phase is the control phase. In this phase, the process performance is evaluated after the implementation of the solution and compared with that at the start of the project. The achieved improvements are verified. The steps are taken to ensure that the improvements will be sustained in the process. However, Gemba investigation need a lot of time consuming to observe the whole production process thus limiting the application of this method to a very short production process or line.

A research conducted by [11] investigate suitable effective tools based on Define-Measure-Analyze-Improve-Control (DMAIC) using car audio product manufacturing as a model. For the time being, each industry has different versions implementation of DMAIC for every phase. Practitioners are using different tools for each phase of DMAIC and there are no standard in defining the verification phase. The implementation of DMAIC in case study and production reject rate in industry had been study to the detail. Research also included detailed adaptation process which being verify by publish literature.

This research focus is final assembly of the production of XXX product where the reject rate is analyzed. This company production shop floor consists of three different sections which is part preparation, surface mounting process and final assembly. The process of this product is sequential process, in batch, multi-patch and asynchronous involving Front of Line (FOL), End of Line (EOL) and Final Inspection process. This research conducted by monitoring reject rate for twelve months in the Final Inspection. By analyzing the data collected within that period, the solution to reduce the parts defect found.

DMAIC method used in solving this quality issue by divided into five phases. The first phase start by defining the status of quality issue process and the expected outcome after the completion of the improvement activity is derived. Define phase consists of the four tools which are Voice of Customer (VOC) or Voice of Process (VOP), Cross functional team forming, 5W1H (Why, When,
Who, Where, What and How) and scatter plot. This phase begins with solving the customer issues. VOC means the feedback from customer about the quality of the product, while, VOP means the process feedback about the previous process which is normally inspected by quality control (QC). This phase ends by applying the scatter plot to visualize the current situation of the reject rate. The plotting of the line chart will show the trend of the reject rate based on the observation time. From the scatter plot, setting the goals or objective of the improvement activity will then be initiated.

Second phase will be the measuring the defect of the product through application of the selected quality tools to determine and visualize the current quality issue. This phase consists of applying the Pareto chart, process mapping and process capability. Several types of defects captured and identified during observing the data and focusing on the problem solution. The Pareto chart is used to define and visualize the main contributing elements that contribute to the reject rate. Type of defect, defect quantity and cumulative percentages of defect quantity are usually used in plotting the Pareto diagram. Through the charting mechanism, it shows the weightage on how much effort need to be ratified which resulting in better use of limited resources by application of the 80/20 rules. Next, process mapping is applied as a tool by using basic concept of the process flow chart to mapping the potential processes contributing to the partial failure. Once the potential processes area has been detected, the process capability study will be conducted to calculate the process capability (Cp) and process capability index (Cpk). The purpose of this analysis is to identify the stability and accuracy of the process. Based on the quality standard, the value of Cp and Cpk more than 1.0 representing the process is stable.

Analyze phase consists of application of the quality tools to determine the possible causes of the defects and analyze all the possible causes to determine the main root causes. This phase consists of brainstorming by using Ishikawa diagram and a selection of the possible root causes through multi-voting to identify the possible root-causes of the potential causes as identified in Measure Phase. The brainstorming session using Ishikawa diagram involves cross functional team members to ensure all possible root causes will be recorded based on the four factors which are man, method, material and machine. The Ishikawa diagram can also allow the possible causes or problem to be identified structurally and can also determine the relationships between potential causes of problems.

Since the possible root-causes have been brainstormed and the possible root causes were recorded, the multi-voting analysis has been adopted to select the root causes based on mutual agreement among team members. From the all possible root causes from the Ishikawa diagram for stuck pins, three potential root causes have been selected based on the highest number of ratings according voting from the team members and the listed potential root causes according to the ranking one to three is a processes contributing into the defects.

Improve phase is the stage of implementation as a counter measure to solve the quality issues. The potential countermeasures will be identified through the observation and discussion, the hypothesis test conducted to ensure the counter measure really solves the quality issue. Once the process of improvement was validated by hypothesis test, the improvement activity will be implemented as per project planning.

The last phase is Control phase where this phase is about controlling the process and ensure the defects will not occur in future. This control phase completes an improvement activity ensures day to day processes stay in the meeting quality specification and become standard. This phase includes establishing a scatter plot, monitoring the process capability to ensure always meeting the specification and provide the proper training into workers to ensure the problem will not appear again in the future and highlighted the lesson learned in production floor to ensure workers not make the mistake. Scatter plot is the technique to monitor any abnormality of the data based on trend of the graph. Instability of the data can be recognized and process capability will be applied to monitor the consistency of the assembly processes. At the end of the improvements, visual of the lesson learned of defects will publish in production work station to alert the workers and ensure the defects will not happen again in future. The implementation of DMAIC with consist of 5 stages and must be supported by various quality tools may render the method becoming too complex and bound to overlook.
[12] in their paper title Defects Reduction in Manufacturing of Automobile Piston Ring Using Six Sigma, propose a method to reduce defects. It involves identifying the factors causing rejection of piston rings in the Automobile Piston Ring Manufacturing industry using a Six Sigma Methodology for problem solving and control. In the define phase, the aim is to identify the problems in the manufacturing line of the Molybdenum coated Piston rings which comprises of around 20 stations that each ring passes through to take form of the final product. By using Cost of Poor Quality (COPQ) analysis, each machine data in the production line is analyzed to find out the contribution of each machine in the rejection. Analyze also been made in term of process capabilities and all factors lead to defect product are listed. The measure phase helps in measuring the existing system and establish valid and reliable metrics to help monitor progress towards the goals defined in the previous step. Measurement System Analysis of the Manufacturing Process is carried out to compare the Standard Operating Procedures (SOP’s) with the actual procedures being followed, the reason for deviation if any, sampling details, measuring instruments and their Calibration frequencies. In the analyze phase, Failure Mode and Effect Analysis (FMEA) is carried out for both the processes to find out the vital causes among the many causes listed in the cause and effect analysis. The vital causes for plasma spraying are listed as per its descending order of Risk Priority Number (RPN). Based on the finding in the analyze phase, improvements are carried out in this improve phase. This phase use all finding by quality tools in the previous phase to sort out solutions for the problems found out through the Analyse phase. But the most widely used tool is the Design of Experiments (DOE). It is a test or a series of tests which are intentionally performed on input variables in a system to see the effect in response variable. In the last phase, this control phase used to develop and implement process control plan to ensure sustenance of the improved process. This step to make sure that process stays in control after the solutions have been implemented. Control phase will detecting the out of control state and determines associated special causes so that actions can be taken to correct the problem before non-conformances are produced. This method also suffer the same consequence as [9] which require too many quality tools that will render the process to becoming too complex.

In Improving Quality of Light Commercial Vehicle using PDCA Approach by [13], author study about the bits defect on the electrodeposited body is investigated. This research suggests a systematic quality improvement plan and optimization are performed. The application of the PDCA cycle improved 65% of bits and reduced 34% of sanding man hour. Quality improvement methods focus on reducing, defects or errors by eliminating variation in both manufacturing and service operations; hence, quality tools are often used to investigate problems and develop appropriate solutions to address these problems. The electrodeposition (ED) in the light commercial vehicle is a special coating method where the ED paint that is dispersed in water is electrically deposited on the substrate to form a uniform and water-insoluble. In order to coordinate continuous improvement effort, the PDCA cycle has been utilized. Figure 3 below show the propose implementation of PDCA methodology.
Figure 3. PDCA Methodology [13]

Result show that the main defect of the electrodeposited body was generation of bits. The systematic application of PDCA-cycle improved the generation of the bits. The average number of bits reduced was by 65%. This improvement shows the successful of this method in improving quality and reducing bits defect. However, this method may slow down process and do not allow variable that routinely crop up in a project.

3. Conclusion
A total of 5 basic quality systems have been reviewed ranging from Weibull Distribution Model, SPC, Six Sigma, Quality Assurance and PDCA. Researcher also using combination of quality tools in hybrid form to achieve optimum outcome in order to reduce defect of product manufacturing. Every method of quality management and continuous improvement has their own strength and weaknesses as detailed on table 1.

Table 1. Quality System Comparison

| Type of Quality Tool           | Advantages                                      | Disadvantages                                      |
|-------------------------------|-------------------------------------------------|----------------------------------------------------|
| Weibull Distribution Model    | Able to pin point root cause of defect.         | Too complex and isoterix                           |
|                               | Scientific problem solving technique            | The accuracy of Weibull analysis depends on the     |
|                               |                                                 | quality of the data.                               |
| Statistical Process Control (SPC) | Able to predict if any significant deviations occurred that can lead to defect or rejected product | SPC can only detect abnormality. If the process is consistently in bad zone, SPC will consider the process in good order and will not trigger early warning. |
| Quality Assurance (QA)        | Achieve 100% defect free product in the manufacturing process | Did not discuss the combination with other quality tools. |
Scientific problem solving technique

Hard to maintain when some information is missed.

Six Sigma

Able to reduce defect in each cases of case study

Able to cooperate with various quality tools

Scientific problem solving technique

This method is too extreme which can slow down the production leaving customer waiting for the product delivery

PDCA Cycle

A well know method for improvement of quality

Scientific problem solving technique

This method may slow down process and do not allow variable that routinely crop up in a project

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