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Root Cause Analysis of Refinement Engineering for Automobile M

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for Automobile M

by

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Abstract

This project focused on finding the solutions for tiny flaws that appeared on auto M due to the production process. The core problem was discovering the root cause of tiny flaws and proposing on how to solve them. Brainstorming, data collection and analysis, measurement and material test, Gage R&R project and other methods were used to look for the root causes. During the project, the defect of production was confirmed. With the root cause defined, the quality of auto M improved and the problem solved observably.

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Chapter I: Introduction

Introduction

Because of the increased requirement of production quality, providing satisfied and stable products, reducing the cost during the produce process had become effective approaches to seize the opportunities in the market for companies. Numbers of companies focused on the result of the production, and devoted themselves to getting excellent products. As competition existed everywhere, improving the quality of products became more and more important. The devil was in the details. It meant details decided success and failure. As a result, eliminating all the tiny flaws or defects helped customer got higher level experience of the product they purchased. On the other hand, focusing on the details of products made company had a high competitiveness.

Refinement management was a kind of theory and culture, it was the necessary requirement and the result of modernized management. As the concept of scientific management, there were three degrees include standardization, refinement and individuation. Refinement management required company controlled the characters of product’s quality well, disposed the relationship between qualities with zero defect. In order to increase the competitiveness and found advanced impression of the company, refinement management was an important and useful path to success.

The plant of ABC limited Company in Changsha, China was an automobile company, and keeping high quality level was always the tenet of their production.

This project hammered at the refinement engineering of one major type of the automobiles they product. As the production line was not automation completed, manual work could lead more errors. Because of several of tolerance accumulation during the whole process line, flaws appeared on the final product easily. Refinement project for this automobile was to eliminate all the flaws of the exterior and upholstery, for example, reducing the gap between two adjacent components, and then improved the quality level of the automobile finally.

Problem Statement

The flaws appeared on the exterior and upholstery of automobile M had a negative effect on sales. This problem weakened the competitiveness of automobile M in the market. As a result, the profit of company got decreased.

Nature and Significance of the Problem

As mentioned above, details decided the success and failure of a company. By comparing with higher level automobile company, there were numbers of problems appear on ABC's production. Although ABC Company's production already had a strong competitiveness with other same level companies, but no progress simply meant regression. Be part of the world market, ABC Company should keep advancing and improving to catch up with the enhancing pace of the world. Quality was the life, as the result, refinement project was important because it was one part of the quality engineering. For the refinement project, it aspired to make products more delicate to satisfied increased requirement of customers. Automobile M was the major product of production plan this year, as a result, qualified driving performance was not enough for today’s market any more. Refinement project for automobile M was focusing on the improvement of the exterior and upholstery, which could realize modernized production.

Objective of the Project

a. Analyze the causes of flaws on automobile M.
b. Detect the ability and accuracy of production process of related plants.
c. Reduce or eliminate flaws and defects on the exterior and upholstery to complete the refinement project.

Project Questions

The following questions were answered at the end of the project:

a. What related plants leaded to the flaws on automobile M?
b. What possible steps affected the accuracy of production?
c. What effect of material using in related parts?
d. What were the real causes of the flaws?
e. What were the approaches to collect data, analyze data, and figure out the solution?
f. What were the orientation to improve production quality in the future?

Limitations of the Project

Due to the characteristics of automobile company and the size of Company ABC, production could not be automatic completely. Manual work in welding, assembling, and detecting process made tolerance accumulation easily. Though the project reduced the gap of adjacent units to embellish and improve the appearance of auto M, the problems still existed on parts of the products. The solution of the problem in this project could improve the quality of products, but it was impossible to realize standardized production. As a result, improvement of the company was limited.

Definition of Terms

Root cause analysis. The method of problem solving used for identifying the root causes of faults or problems. A factor is considered a root cause if removal thereof from the problem-fault-sequence prevents the final undesirable event from recurring; whereas a causal factor is one that affects an event's outcome, but is not a root cause. Though removing a causal factor can benefit an outcome, it does not prevent its recurrence within certainty.

Refinement engineering. The project focus on reducing the amount or remove disqualified index and appearance of the automobile.

MSA analysis. Measurement system analysis. A specially designed experiment that seeks to identify the components of variation in the measurement.

Kappa test. When two binary variables are attempts by two individuals to measure the same thing, you can use Cohen's Kappa (often simply called Kappa) as a measure of agreement between the two individuals.

CMM measurement. A coordinate measuring machine (CMM) is a device for measuring the physical geometrical characteristics of an object. A machine which takes readings in six degrees of freedom and displays these readings in mathematical form is known as a CMM.

Summary

In this chapter, author introduced the importance of quality engineering for company and the effect to the world market. Based on the requirements, the refinement project came out. This part also described the problem statement, the objective, and the questions of the project. It provided a brief acknowledge of how the project would be worked and what were the limits of the project. After the introduction part, background and review of literature gave a more detailed description of the project.

Chapter II: Background and Review of Literature

Introduction

In this part, the reason and the effect of the project would be described more detailed. As the marketing philosophy of Company ABC, improving quality of product was an important method to make the company growth. Besides on the innovation of production, present products provided huge profit to the company and basis to innovate. As a result, solving the existing problem was most important for ABC. Refinement engineering is part of the improvement plan for Company ABC, furthermore, the achievement of the project would be useful experience for future production.

Literature related to the project would also be posted in this part to prove and support the idea and concept of the project.

Background Related to the Problem

ABC Company Ltd. was founded in 1995, and it was an advanced technology company listed in Hong Kong. ABC Company had built 11 industrial sub-companies in Beijing, Shanghai, Guangdong, Shanxi and Changsha. Furthermore, it also founded sub-companies in America, Japan, Korea, and India. As one branch company of ABC, Changsha ABC Automobile Company Ltd. was founded in 2009. The main products of it were electric bus, auto M, auto F and so on. ABC Company thought highly of technology and innovation, and improving quality was always the objective of their production.

As one part of main products, auto M needed to be improved because of the gaps between two adjacent parts of the appearance. To reduce the gap and unitize it, root cause analysis was necessary. This project was working on finding out the cause lead to the gaps and solve them. On the other hand, refined the defects of auto M appearance was the target of this project.

Literature Related to the Problem

Refinement engineering on vehicle mainly worked on solving noise and vibration problems. The article below introduced how refinement engineering worked.

Refinement helps manufacturers sell their vehicles. Brandl, Biermayer, Thomann, Pfluger, and von Hofe (2000) published the results of a formal investigation of customer attitudes to vehicle refinement. Customers were asked to complete a questionnaire relating to their own vehicle. They were asked questions relating to their attitudes on vehicle prestige (brand by another name), performance, convenience, family friendliness, noise quality and cost. Although there was scatter in the result obtained, there was evidence of clustering with certain classes of customer showing predictable tastes with vehicle-refinement issues helping to define that taste.

The traditional vehicle manufacturer is organized according to functional divisions being typically: Design, Engineering, Manufacturing, Marketing and Sales. Each division might be divided further into groups. For simplicity, an Engineering Division shall be divided into three groups: Powertrain, Vehicle and the Suppliers of components to the engineering effort as shown in Figure 1.

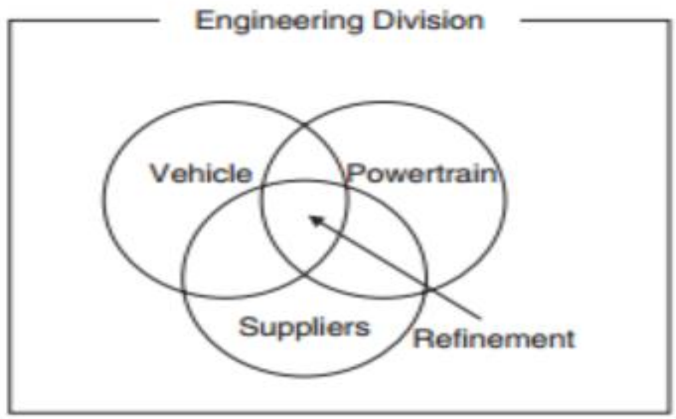

Figure 1. Refinement within the Traditional Vehicle Manufacturer

The refinement sub-group straddles the interface between the three main groups, having influence on each one in turn but not enjoying any decision-making authority. For example, consider the engine mounts: they are attached to both the powertrain and the vehicle and they are manufactured by a third party supplier. The refinement sub-group has an interest in their performance in order to improve NVH but no over-riding authority to broker compromises between the three main groups (Bies & Hansen, 1996). Management of such an interface is never going to be easy, and inefficiencies, misunderstandings, mistakes or arguments that result may delay the development program.

An alternative organizational structure is that of the 'Extended Enterprise' (Ashley, 1997) where suppliers assume greater responsibility for the design and development of their particular contribution to the whole vehicle. Such organizations are more fluid as illustrated in Figure 2.

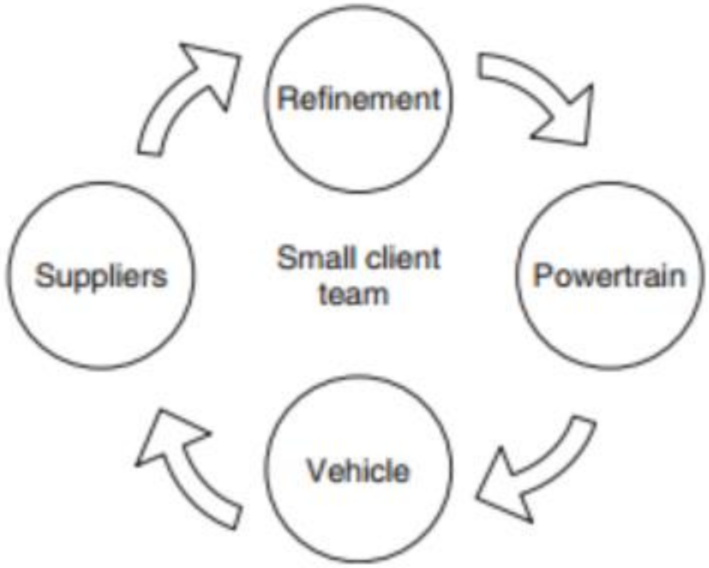

Figure 2. Refinement in the ‘Extended Enterprise’

The wider adoption of the Extended Enterprise structure within the global automotive industry has led to new opportunities for refinement engineers, particularly within component supply organizations used to manufacture but now required to design and engineer as well.

The Extended Enterprise also leads to consolidation in the industry, with the big organizations getting bigger by acquisition (Hibbert, 1999).

Refinement engineering also helped improve driving environment on roads.

The advanced situation awareness of the driver in the road environment is very important for vehicle safety application, especially for mitigating the harmful effects of collisions. Nowadays, advanced driver assistance systems are based on on-board sensors (Panagiotis Lytrivis, 2010). The evolution of wireless networks lead to the exploitation of cooperation among vehicles to enhance road safety.

Vehicle design and surface refine are also one aspect of refinement engineering. It satisfied the requirement of nowadays' customers.

Today's innovative vehicle designs are much more than functional, they can be an extension of their drivers' personal style and enhance their transportation experience. Surface Refinement Industry Process Experience of the Target Zero Defect Industry Solution Experience provides industry-leading capabilities to enable designers to readily craft and optimize vehicle style to peak consumer appeal, while collaborating with engineering to optimize function to form (The 3D Experience Company, n.d.).

Boukehili and Zhang (2012) gave an example of refinement engineering working on the improvement of power management on Hybrid vehicle.

The power management strategy in many hybrid vehicles is based on expert rules and thresholds. These rule-based strategies can result in good efficiency in term of fuel economy and emission if their thresholds and rules are accurate. However, due to the complexity and the non-linearity of the hybrid powertrain, determining accurate thresholds and rules is neither explicit nor straightforward, and experts in most cases fail to define these thresholds and rules with enough accuracy. To achieve the objective, we used an optimization method (dynamic programming) to calculate the optimal power management, determine the optimal control signals, and extract efficient thresholds and rules that can be used in real time. Finally, simulation results for the three strategies (optimal, simple and refined strategy) are shown and discussed (Boukehili & Zhang, 2012).

Literature Related to the Methodology

Root Cause Analysis (RCA) is a popular and often-used technique that helps people answer the question of why the problem occurred in the first place. It seeks to identify the origin of a problem using a specific set of steps, with associated tools, to find the primary cause of the problem, so that you can:

1. Determine what happened.
2. Determine why it happened.
3. Figure out what to do to reduce the likelihood that it will happen again (ThinkReliability, 2015).

Simply stated, RCA is a tool designed to help identify not only what and how an event occurred, but also why it happened (Ferry, 1988).

RCA assumes that systems and events are interrelated. An action in one area triggers an action in another, and another, and so on. By tracing back these actions, researcher can discover where the problem started and how it grew into the symptom they are now facing.

Three basic types of causes exist:

1. Physical causes–Tangible, material items failed in some way (for example, a car's brakes stopped working).
2. Human causes–People did something wrong, or did not do something that was needed. Human causes typically lead to physical causes (for example, no one filled the brake fluid, which led to the brakes failing).

3. Organizational causes–A system, process, or policy that people use to make decisions or do their work is faulty (for example, no one person was responsible for vehicle maintenance, and everyone assumed someone else had filled the brake fluid) (Mind tools, 2015).

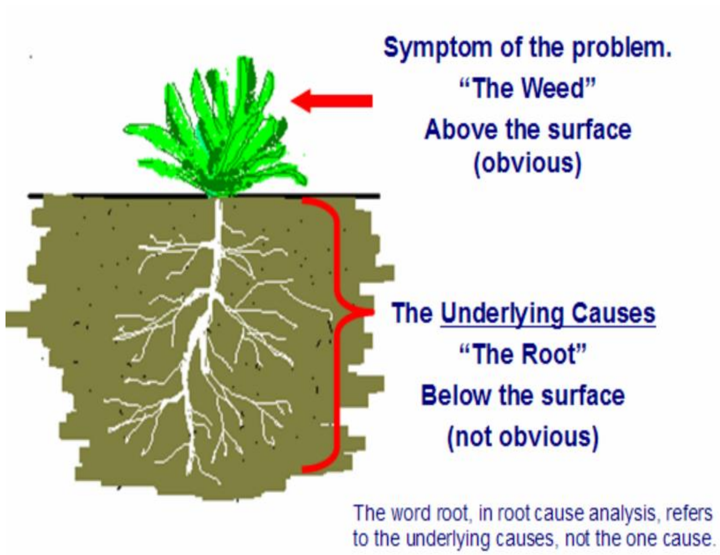

Figure 3. Root Cause Analysis Basis

There are three basic steps to the Cause Mapping method:

1. Define the issue by its impact to overall goals
2. Analyze the causes in a visual map
3. Prevent or mitigate any negative impact to the goals by selecting the most effective solutions (ThinkReliability, 2015).

Gage R&R analysis also helped solving the confirmation of responsibility in this project.

Measurement system analysis of uncertainty is one topic in lean Six Sigma training that is too often ignored or under-taught. I believe that it is under-taught because most instructors have never used or understood it. Therefore, this column will dive deep into what it is and why you should learn about it. Keep in mind that this methodology is not for destructive sampling or attribute or classification gauges. It only works on measurement systems that allow re-measuring of the same sample and reporting a continuous value for the measurement output (Haynes, 2013).

We frequently do not realize how our decisions depend on the results of a measurement system. We also do not adequately understand the consequences of incorrect results of a measurement system. Imagine that a doctor prescribes medicines to reduce blood pressure (BP) when it is actually normal! Doctors use BP measuring apparatus with mercury column or with a dial type gauge. If the mercury column type BP apparatus is used, it is vulnerable to “cosine error” when it is kept tilted instead of vertical. Result can artificially “increase” the BP of the person and can result in to incorrect prescription. This looks like a simple example but the incorrect decision can create major problem for the patient. In statistical terms, the doctor is making a “type I” error. Many of us may have more than one clock in our houses. We know that each clock shows a different time! This may not be a serious problem in routine decisions. However, we will not like such differences when critical decisions are made (Urdhwareshe, 2006).

The least count of our wrist watches is one second. But this is not the accuracy with which we can estimate time elapsed between events. If we want to find time taken for an athlete to run a distance of 100 meters, error using a wrist watch may be about a second. Thus we will use a stop watch instead. If we want to decide winner of an Olympic race, our stop watch also may be unacceptable measurement system. We will then need a more precise system and a fast video camera to decide winner in case of very narrow difference in time. Thus we need to use a measurement system that is appropriate for the objective and is able to adequately resolve “process variation” to take correct decisions (Urdhwareshe, 2006).

The gage study consists of several parts that are repeatedly measured by multiple appraisers. While the numbers can vary, most studies use 10 parts and three appraisers who measure the parts at least three times each (Sloop, 2009).

The repeated measurements are called trials. Calculations are then made to determine the level of variation between the appraisers, parts and across the trials. It is not necessary to go into the actual calculations here since there are numerous software programs and templates available to assist operators (Sloop, 2009).

Kappa test was a tool used in detecting the measurement accuracy in qualitative system. Kappa coefficient is a statistic which measures inter-rater agreement for qualitative (categorical) items. It is generally thought to be a more robust measure than simple percent agreement calculation, since κ takes into account the agreement occurring by chance (Kappa test, 2015).

The kappa statistic is frequently used to test interrater reliability. The importance of rater reliability lies in the fact that it represents the extent to which the data collected in the study are correct representations of the variables measured. Measurement of the extent to which data collectors (raters) assign the same score to the same variable is called interrater reliability (McHugh, 2012).

There are a number of statistics that have been used to measure interrater and intrarater reliability. A partial list includes percent agreement, Cohen’s kappa (for two raters), the Fleiss kappa (adaptation of Cohen’s kappa for three or more raters) the contingency coefficient, the Pearson r and the Spearman Rho, the intra-class correlation coefficient, the concordance correlation coefficient, and Krippendorff’s alpha (useful when there are multiple raters and multiple possible ratings). Use of correlation coefficients such as Pearson’s r may be a poor reflection of the amount of agreement between raters resulting in extreme over or underestimates of the true level of rater agreement (Stemler, 2004).

Summary

This chapter introduced the background of Changsha ABC Automobile Company, Ltd. and the refinement engineering project they were processing, and it also explained the reason of this project. In additional, literature related to the project and method used in the project were also posted to support the opinions. For the next chapter, it entered into the main project to describe how the project was designed and processed.

Chapter III: Methodology

Introduction

This chapter would give a brief description about how the project processed including the design of the study, data collection and analysis. By observing the problems on auto M, planning the project and setting detailed process is most important. Here material test and MSA analysis and other methods might needed to support the project. In additional, root cause analysis would be the main content about the project and the improvement steps would support to complete the program. For this part of the report, introduction of the whole process was the main objective.

Design of the Study

As the main question about the project was figuring out the reason why gaps appeared on auto M, qualitative and quantitative approaches would be used everywhere. Actually automobile was a kind of completed product, and in general it included four steps to assembly one automobile. They were stamping, welding, spraying and assembling. It was more difficult to solve the problems on an automobile than other single component or part. Qualitative analysis was a way to decide the orientation of the research. After finding out the related steps in whole production process of automobile about the problems, quantitative analysis would be the approach to solve them.

To confirm the related steps about the problems, root cause analysis should be the first procedure. As the basic principle of root cause analysis, determining what happened started the project. Here was the gaps between skylights with plafonds and the gaps between front lights with bumpers. Group meeting was the first step to understand the roughly situation of automobile M. Team would assign refinement tasks to each group. Within the scope of each issue, engineer would discuss about the potential causes. After personal analysis to the exist problems, preliminary summary would make a research orientation to carry out next assignments. Above was the process to determine why the problem happened. In solving steps, measurement and size adjusting were quantitative analysis to meet the requirements of the improvement. This is the procedure to figure out the way to eliminate the flaws.

Data Collection

To make sure the problematic parts leaded to flaws on automobile M, group detected each related parts separately. Collected data from related plants and made MSA analysis which meant measurement system analysis by Gage R&R analysis or Kappa test based on the type of the system. It inspected the accuracy and ability of production process.

Material test should be proceed to exclude the effect of material deformation.

Measuring the size of related parts and comparing with design. It helped to find out root causes.

Data Analysis

In detecting procedure, MSA analysis confirmed if the problems of the plants existed. Comparison with design helped get rid of the effect about wrong sizes. Material testing also needed to observe the potential effect of the material they used.

Based on the data collected, group analyzed available approaches to adjust core measurements to fix flaws. To reduce or eliminate tolerance accumulation, related plants had to rebuild some parts to meet the request of adjustment.

Figured out effective approaches to manage plants and company to meet higher quality requirement based on the project.

Budget

All the cost in this project covered by Changsha ABC Company, Ltd.

Timeline

Table 1: Timeline

Activity	Purpose	Start Date	Finish Date
1.Tour in the plant	Acknowledged the process of automobile production	5.11	5.15
2.Observing automobile M	Collected flaws and defects data	5.19	5.22
3.Meeting	Discussed and analyzed the flaws should be fixed and assign tasks	5.25	5.25
3.1 Group meeting	Analyzed the potential causes of the two issues on automobile M	5.26	5.26
4. Deformation experience	For issue of gap between front lamps with bumper, tested the deformation potential of the bumper.	5.28	7.1
5. Collecting data from stamping, welding and assembling plants	Analyzed the accuracy of detection system, analyzed the details about the issues	6.1	6.18
5.1 Collecting data from plafond stamping plant	Analyzed Gage R&R, figure out issues in production process	6.1	6.4
5.2 Analyzing the process of skylight assembly	Analyzed the tolerance in process	6.9	6.10
5.3 Observing the process of automobile assembly, focus on skylight assembly, front lamps and bumper assembly	Analyzed the tolerance in process	6.10	6.12
5.4 Analyzing the data of front lamps and bumper	Got rid of the size error of component	6.15	6.18
6. Group meeting	Discussed the data analysis	6.19	6.19
7. Meeting with designing department	Reported the issue progress and figure out the potential causes	6.24	6.24
8. Experience	To make sure the root cause and figure out solution	6.29	
8.1 Rebuilding the plafond		6.29	7.8

8.2 Measuring and analyzing the altitude intercept of components		7.6	7.7
8.3 Rebuilding the automobile body to adjust the core measurements		7.1	
8.4 Adjusting the altitude intercept on skylight		7.8	
8.5 Assembling new components		7.16	
9. Group meeting	Discuss the result of experience Figure out solutions	7.20	
10. Detecting the levelness of skylight	Seek new solution for eliminating the gap	7.21	
11. Detecting gaps between lamps and bumper after frame rebuilding	Confirmed the problems	7.22	
12. Completing the project	Confirmed the causes leaded to the gaps, made report and summary.	7.27	7.31

Summary

This part introduced how the project was designed and what procedures were planned. By brief description about the methods and data analysis about the project, timeline showed the whole process of the project. Though it gave an understanding about this refinement engineering, how it worked would be provided in the next part.

Chapter IV: Data Presentation and Analysis

Introduction

In this chapter, data collected in this project would be showed and described in detail. In additional, what the data meant and how to use the data to analyze the problem would be provided. Furthermore, this part would describe the whole process of this refinement engineering. As the design of the project, MSA analysis were two main data analysis in this part. Pictures and photos also supported to explain the problem and the project.

Data Presentation

1. Photo introduction of parts related to the problem.

   1.1 The gap between the skylight and the plafond. The position showed as the red arrows in Figure 4 and Figure 5. When the skylight closed, the left and right edges of skylight could not cling to the plafond.

Figure 4: Gap between Skylight and Plafond

Figure 5: Gap between Skylight and Plafond

1.2 Production process of skylight and plafond. Framework of skylight was assembly by other plant, and plafond was produced through stamping. The key component showed by red arrow on plafond connected to skylight was assembly manually. Showed as Figure 6 and Figure 7. Figure 8 showed the detecting mold of plafond. The lines on the mold were the standard of qualified plafond.

Figure 6: Production Machine of Plafond

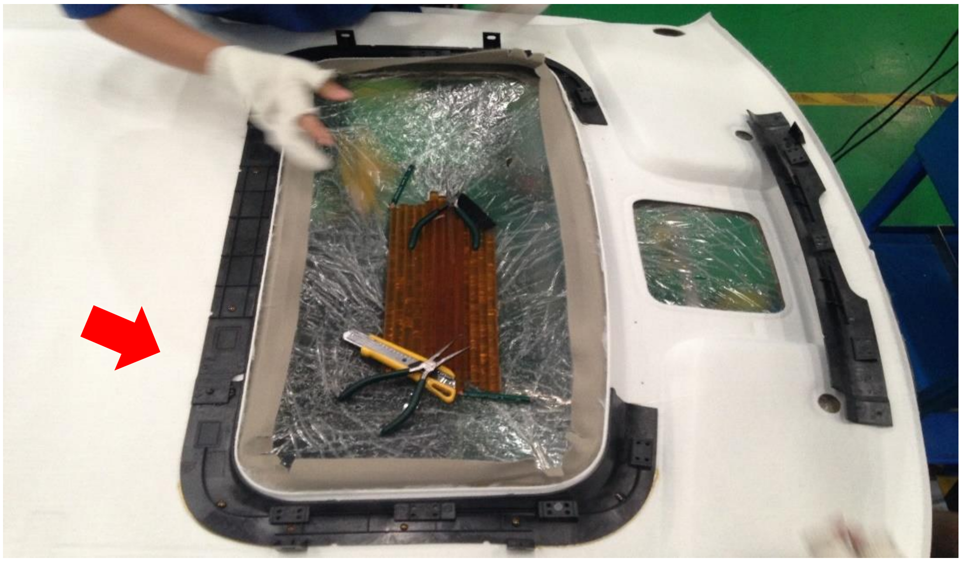

Figure 7: Connected Part Assembly

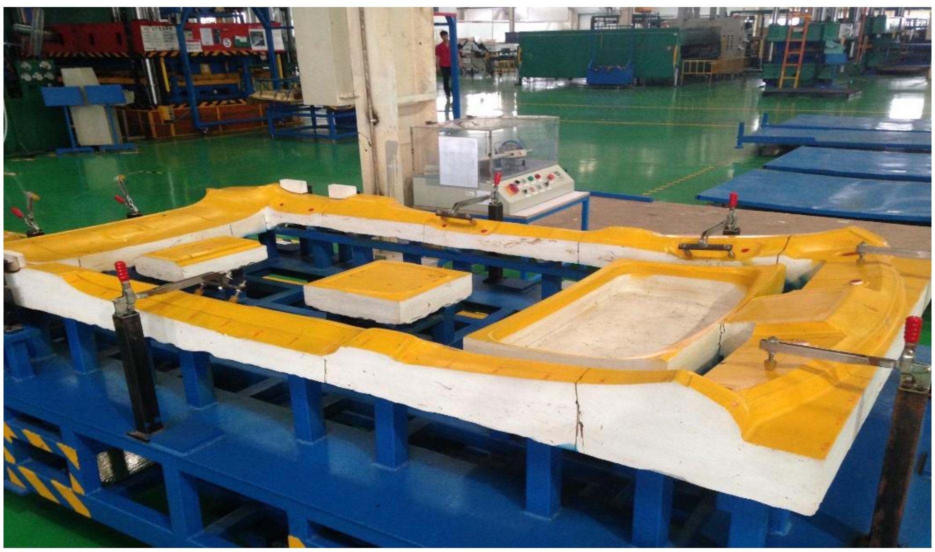

Figure 8: Detection Mold of Plafond

1.3 The gap between the front lamp and the bumper. Showed as red arrow in Figure 9.

Figure 9: Gap between Lamp and Bumper

1.4 Assembly of skylight. Figure 10 showed the moment before plafond mounted and the skylight had been installed. The positions of red arrows showed the hasps on skylight that connected to plafond.

Figure 10: Connected Hasps on Skylight

1.5 Framework of front side. In order to analyze the reason of gap between lamp and bumper, observing of bodywork frame is necessary. Red arrows in Figure 11 showed the important install position of lamp and bumper.

Figure 11: Part of Framework for Auto M

2. Data collected for detection. As part of the project, detecting accuracy of production was very important because it was the premise for next assignment. Here were data collected from related plants to prove the accuracy of production.

   2.1 Acceptability of plafond. To confirm the accuracy of detecting system, MSA analysis was necessary. As the mold detecting method, an acceptability data form was collected from plafond plant. In Table 2, 1 meant acceptable and 0 meant unacceptable.

Table 2: Acceptability of Plafond

	operator A			operator B			operator C			
No.	test 1	test 2	test 3	test 1	test 2	test 3	test 1	test 2	test 3	standard
1	0	0	0	0	0	0	0	0	0	0
2	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1
16	1	1	1	1	1	1	1	1	1	1
17	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1	1
19	1	1	1	1	1	1	1	1	1	1
20	0	0	0	0	0	0	0	0	0	0
21	1	1	1	1	1	1	1	1	1	1
22	0	0	0	0	0	0	0	0	0	0
23	1	1	1	1	1	1	1	1	1	1
24	1	1	1	1	1	1	1	1	1	1
25	1	1	1	1	1	1	1	1	1	1
26	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1
28	1	1	1	1	1	1	1	1	1	1
29	1	0	1	1	1	1	1	1	1	1
30	1	1	1	1	1	1	1	1	1	1
31	1	1	1	1	1	1	1	1	1	1
32	1	1	1	1	1	1	1	1	1	1
33	1	1	1	1	1	1	1	1	1	1
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39	1	1	1	1	1	1	1	1	1	1
40	1	1	1	1	1	1	1	1	0	1
41	1	1	1	1	1	1	1	1	1	1
42	1	1	1	1	1	1	1	1	1	1
43	1	1	1	1	1	1	1	1	1	1
44	1	1	1	1	1	1	1	1	1	1
45	1	1	1	1	1	1	1	1	1	1
46	1	1	1	1	1	1	1	1	1	1
47	1	1	1	1	1	1	1	1	1	1
48	1	1	1	1	1	1	1	1	1	1
49	1	1	1	1	1	1	1	1	1	1
50	1	1	1	1	1	1	1	1	1	1

2.2 Measurement accuracy of body plant (bumper). To detect the accuracy of measurement system in body plant, and data collected from the production of core part size showed in Table 3. A, B, C were three operators and each operator measured 3 times for each part. Ten parts were picked randomly from production process in this experience.

Table 3: MSA Analysis Data of Body Plant

		1	2	3	4	5	6	7	8	9	10
	1	10.24	10.12	10.25	10.32	10.25	10.46	10.53	10.46	10.64	10.57
	2	10.20	10.19	10.20	10.35	10.30	10.42	10.52	10.40	10.60	10.59
A	3	10.18	10.09	10.21	10.35	10.32	10.47	10.54	10.42	10.63	10.54
	1	10.23	10.19	10.19	10.35	10.28	10.42	10.50	10.43	10.65	10.58
	2	10.23	10.18	10.20	10.34	10.26	10.47	10.51	10.47	10.69	10.57
B	3	10.21	10.10	10.22	10.35	10.27	10.46	10.51	10.45	10.64	10.58
	1	10.24	10.09	10.29	10.33	10.30	10.49	10.52	10.48	10.63	10.58
	2	10.23	10.11	10.25	10.38	10.28	10.45	10.54	10.49	10.58	10.58
C	3	10.25	10.08	10.27	10.36	10.27	10.46	10.55	10.49	10.59	10.59

(Standard: 10±1 mm)

2.3 Measurement accuracy of welding plant (skylight).

Table 4: MSA Analysis Data of Welding Plant

		1	2	3	4	5	6	7	8	9	10
	1	6.33	6.60	6.52	6.39	6.33	6.24	6.27	6.43	6.37	6.27
	2	6.30	6.64	6.50	6.37	6.30	6.25	6.25	6.40	6.32	6.26
A	3	6.28	6.59	6.48	6.38	6.28	6.27	6.26	6.41	6.35	6.28
	1	6.30	6.59	6.50	6.38	6.30	6.24	6.23	6.44	6.36	6.38
	2	6.31	6.57	6.53	6.39	6.31	6.26	6.27	6.41	6.35	6.36
B	3	6.31	6.57	6.52	6.37	6.33	6.25	6.28	6.42	6.36	6.38
	1	6.33	6.60	6.51	6.37	6.33	6.27	6.28	6.43	6.37	6.32
	2	6.33	6.61	6.48	6.36	6.35	6.23	6.26	6.42	6.35	6.30
C	3	6.31	6.61	6.50	6.38	6.31	6.23	6.21	6.43	6.38	6.28

(Standard: 6±1 mm)

3. Data collected for problem analysis.

3.1 CMM (coordinate measuring machine) of plafond. Figure 12 showed the 5 points on plafond tested by CMM. To detect if the connected points were qualified comparing with standard design.

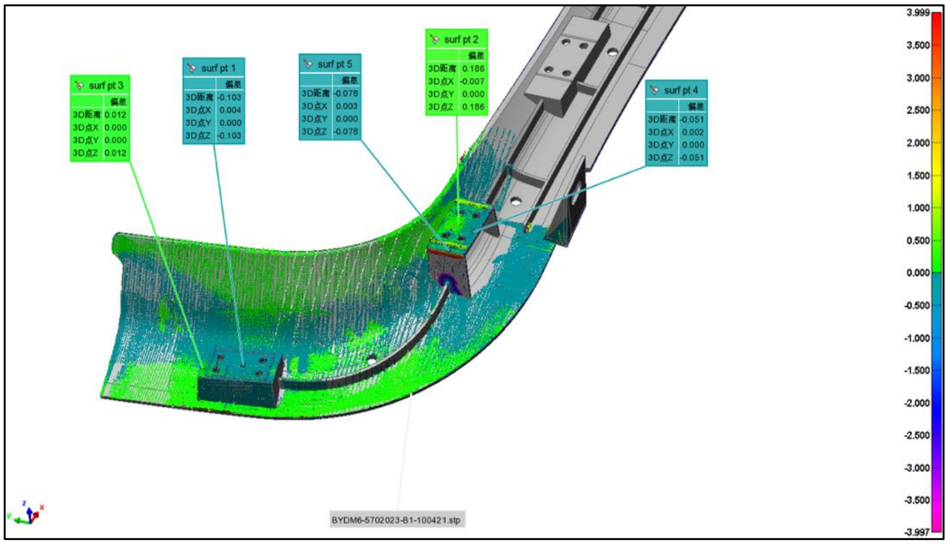

Figure 12: CMM Test of Plafond

3.2 Data of CMM test.

Table 5: CMM Test Data

	pt 1	pt 2	pt 3	pt 4	pt 5
3D distance	-0.104	-0.071	0.041	-0.025	-0.099
X	0.004	0.002	-0.002	0.001	0.004
Y	0	0	0	0.001	0
Z	-0.104	-0.072	0.041	-0.025	-0.099

Table 6: CMM Test Data

	pt 1	pt 2	pt 3	pt 4	pt 5
3D distance	-0.071	-0.093	-0.06	0.225	-0.03
X	0.002	0.003	0.003	-0.008	0.001
Y	0	0	0	0	0
Z	-0.071	-0.092	-0.06	0.224	-0.03

Table 7: CMM Test Data

	pt 1	pt 2	pt 3	pt 4	pt 5
3D distance	-0.103	0.186	0.012	-0.051	-0.078
X	0.004	-0.007	0	0.002	0.003
Y	0	0	0	0	0
Z	-0.103	0.186	0.012	-0.051	-0.078

3.3 Manual measurement altitude intercept of connected hasps on plafond.

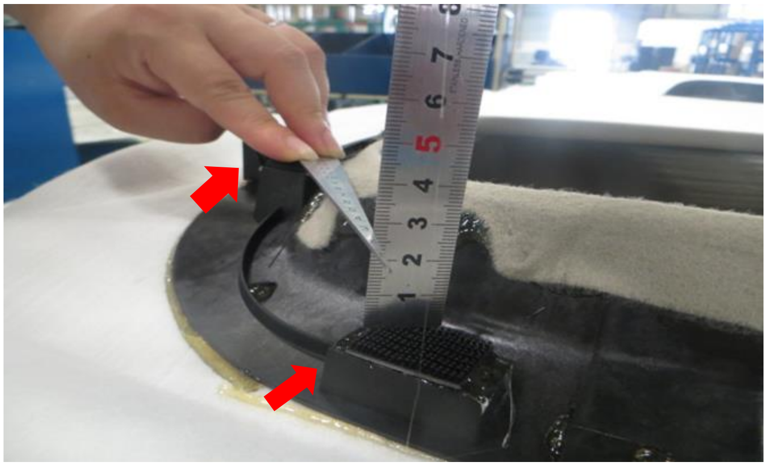

Figure 13: Altitude Intercept Measuring

Table 8 showed the value of altitude intercept between two red arrows hasps on left and right sides.

Table 8: Altitude Intercept of Hasps on Plafond

	1	2	3	4	5
let side	25	24	24	25	26
right side	26	26	26.5	26	26.5

3.4 Body data from body plant. Figure 14 and Figure 15 showed the mounting point values tested by CMM. Q59, Q65, Q11, Q05, and Q15 were mounting points of lamp.

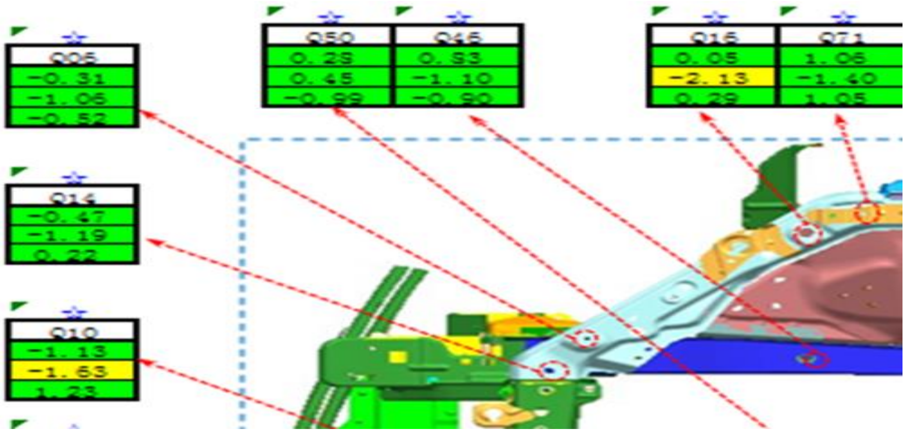

Figure 14: CMM Data of Lamp

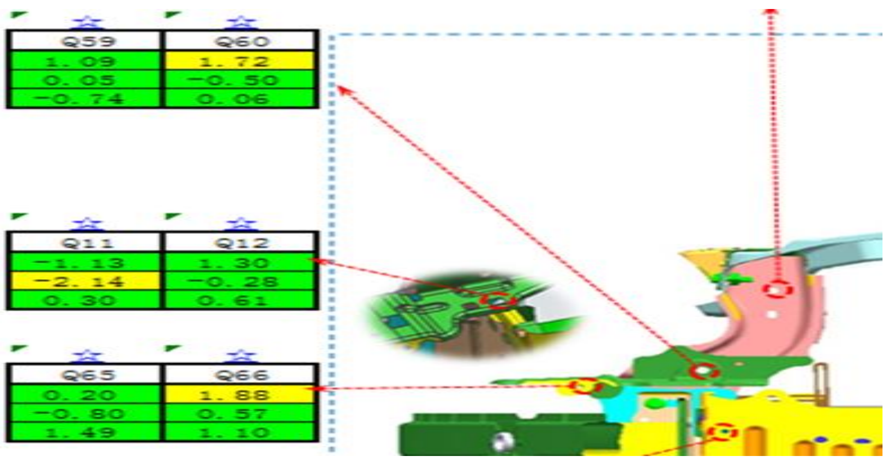

Figure 15: CMM Data of Lamp

3.5 Mounting point value of bumper tested by CMM. In Figure 13, red circle 1 showed the value of bumper and red circle 2 showed the mounting point value of fender.

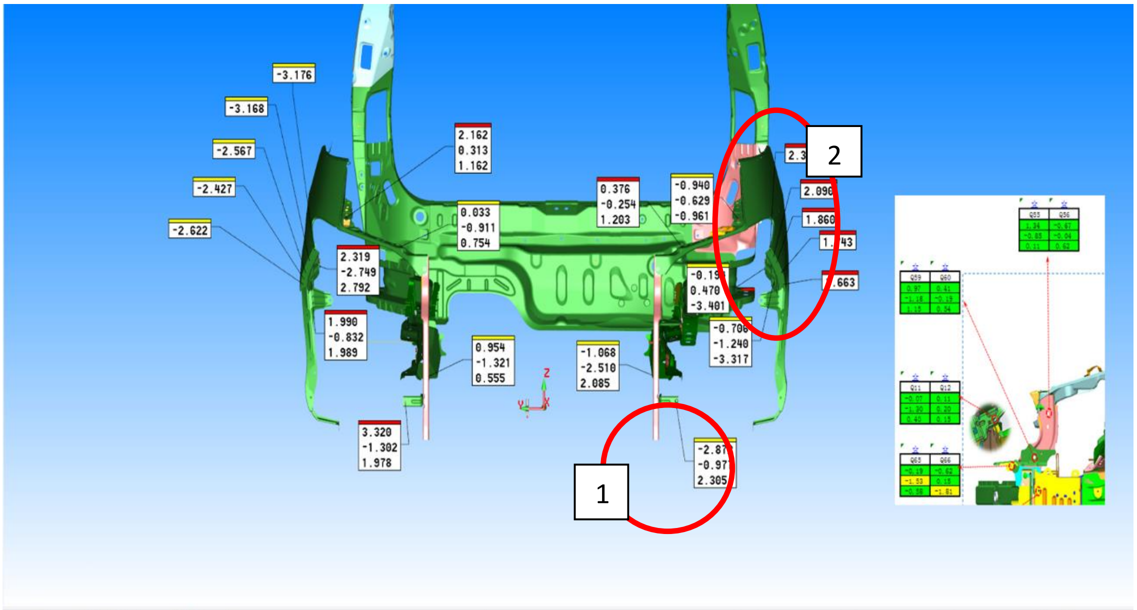

Figure 16: CMM Data of Bumper

Data Analysis

After observing the problems existed on auto M and designing the project, a rough procedure of root cause analysis was proposed. In order to make clear why it happened, detecting related plants was implemented. In the analysis, Kappa test, Gage R&R analysis were used to confirm the accuracy of the measurement system of each plants.

1. Acceptability of plafond. Based on the production and detecting methods of plafond, Kappa test was used as MSA analysis for the plafond. After typing all data in Table 2 into Minitab and made attribute agreement analysis, figures and results provided for detecting.

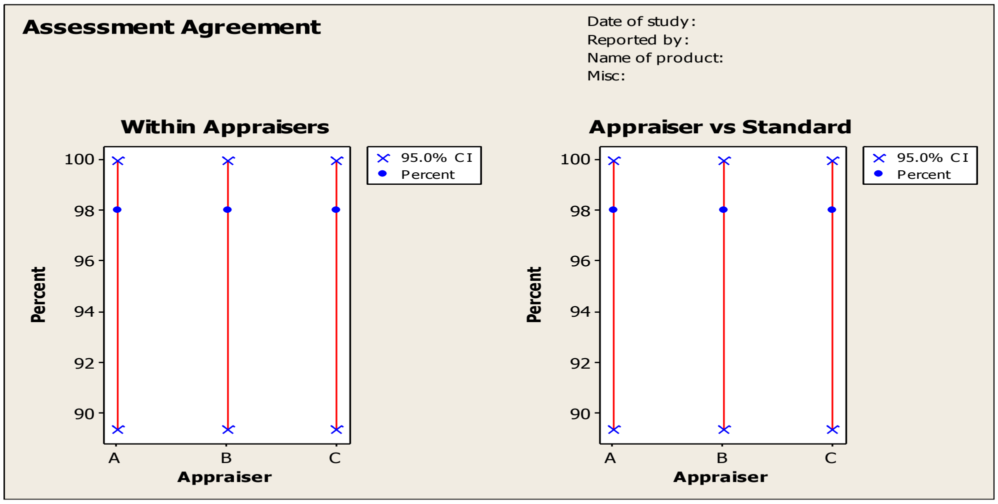

Figure 17: Assessment Agreement Analysis

Table 9: Attribute Agreement Analysis by Minitab

Attribute Agreement Analysis for A1, A2, A3, B1, B2, B3, C1, C2, C3

Within Appraisers

Assessment Agreement

Appraiser	# Inspected	# Matched	Percent	95% CI
1	50	49	98.00	(89.35, 99.95)
2	50	49	98.00	(89.35, 99.95)
3	50	49	98.00	(89.35, 99.95)

Matched: Appraiser agrees with him/herself across trials.

Fleiss' Kappa Statistics

Appraiser	Response	Kappa	SE Kappa	Z	P(vs > 0)
1	0	0.892857	0.0816497	10.9352	0.0000
	1	0.892857	0.0816497	10.9352	0.0000
2	0	0.892857	0.0816497	10.9352	0.0000
	1	0.892857	0.0816497	10.9352	0.0000
3	0	0.892857	0.0816497	10.9352	0.0000
	1	0.892857	0.0816497	10.9352	0.0000

Table 10: Attribute Agreement Analysis by Minitab

Each Appraiser vs Standard

Assessment Agreement

Appraiser	# Inspected	# Matched	Percent	95% CI
1	50	49	98.00	(89.35, 99.95)
2	50	49	98.00	(89.35, 99.95)
3	50	49	98.00	(89.35, 99.95)

Matched: Appraiser's assessment across trials agrees with the known standard.

Assessment Disagreement

Appraiser	# 1 / 0	Percent	# 0 / 1	Percent	# Mixed	Percent
1	0	0.00	0	0.00	1	2.00
2	0	0.00	0	0.00	1	2.00
3	0	0.00	0	0.00	1	2.00

1 / 0: Assessments across trials = 1 / standard = 0.
0 / 1: Assessments across trials = 0 / standard = 1.
Mixed: Assessments across trials are not identical.

Fleiss' Kappa Statistics

Appraiser	Response	Kappa	SE Kappa	Z	P(vs > 0)
1	0	0.948797	0.0816497	11.6203	0.0000
	1	0.948797	0.0816497	11.6203	0.0000
2	0	0.948797	0.0816497	11.6203	0.0000
	1	0.948797	0.0816497	11.6203	0.0000
3	0	0.948797	0.0816497	11.6203	0.0000

From Figure 17, the 95% confidence interval (CI) was showed for A, B, and C. That meant it was 95% that the result of agreement for A, B and C fell within the interval. Detailed results were got from Table 9 and Table 10. They told the data collected from this system had 98% validity for A, B and C, and it was within the 95% CI of 89.35%-99.95%. In additional, the Kappa value of within appraisers was 89.3% for A, B and C, and the Kappa value of appraisers vs standard was 94.9% for A, B and C. Based on the requirement of the industry, the measurement system for plafond was acceptable because the validity was 98% larger than 80%, and Kappa value were larger than 75%.

2. Gage R&R analysis for body and welding plants. To make sure the accuracy of data collect from related plants, Gage R&R analysis was made for body plant and welding plant.

   2.1 Body plant. Using Minitab as the tool to analyze Gage R&R. After typing in the data in table 3, then chose Stat, Quality tools, Gage study, and then made Crossed Gage R&R study. Reading Figure 18 and Table 11 got from Minitab helped confirm the accuracy of the measurement system.

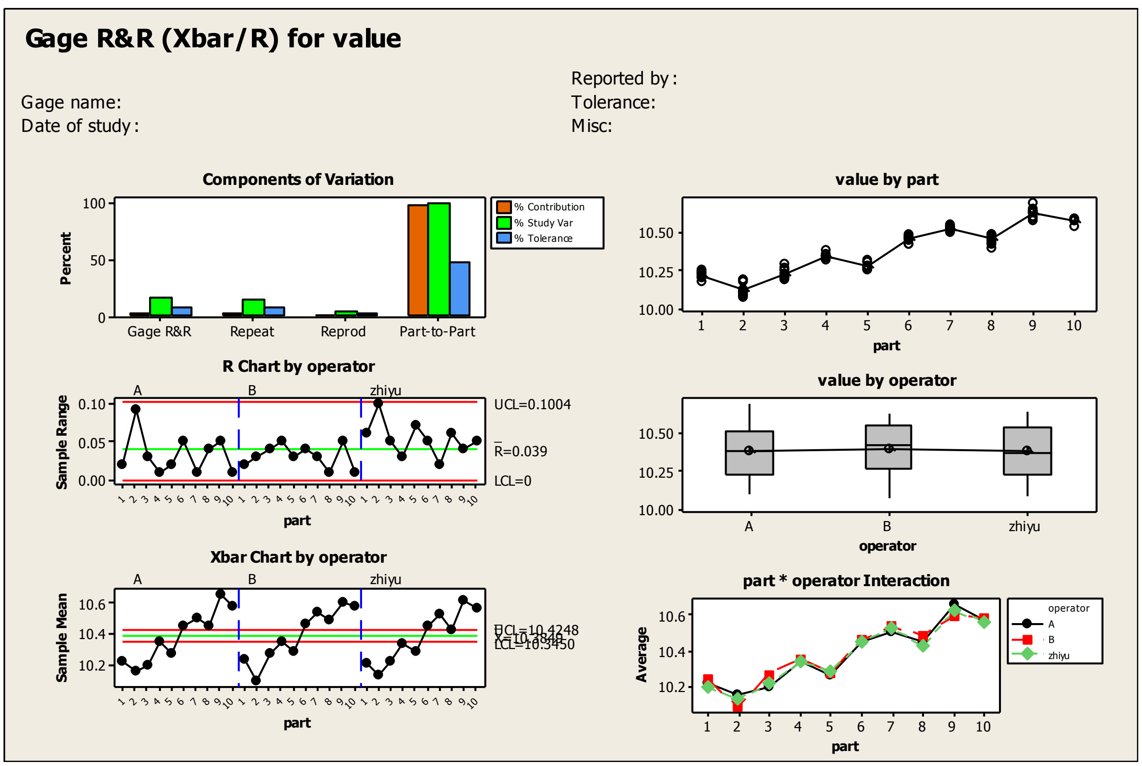

Figure 18: Gage R&R Analysis of Body Plant

In Figure 19, the components of variation chart was a graphical summary of the results of a gage R&R study. In a good measurement system, the largest component of variation was part-to-part variation. If, instead, large variation was attributed to the measurement system, the measurement system might need correcting.

Using an R chart to determine whether operators measure parts consistently:

Plotted points, which represented, for each operator, the difference between the largest and smallest measurements of each part. If the measurements were the same, the range = 0. Minitab plotted the points by operator so that could compare the consistency of each operator.

Center line, which was the grand average of the ranges (the average of all the subgroup ranges).

Control limits (UCL and LCL) for the subgroup ranges. Minitab used the within-subgroup variation to calculate these limits. A point that was higher than the upper control limit (UCL) indicated that the operator did not measure parts consistently. It was acceptable in Figure 18.

Using an X-bar chart to determine whether the measurement system was acceptable:

Plotted points, which represented, for each operator, the average measurement of each part.

Center line, which was the overall average for all part measurements by all operators.

Control limits (UCL and LCL), which were based on the number of measurements in each average and the repeatability estimate. Because the parts chosen for a Gage R&R study should represent the entire range of possible parts, this graph should ideally show lack-of-control. Lack-of-control existed when many points were higher than the upper control limit and/or lower than the lower control limit. As a result, it was acceptable.

Using the By Part chart to display all the measurements taken in the study, arranged by part. Ideally, the multiple measurements for each individual part varied as minimally as possible (the dots for one part would be close together), and the averages varied enough that differences between parts were clear.

Using the By Operator chart to display all the measurements taken in the study, arranged by operator. As measurements collected for each operator was greater than 9, Minitab display a boxplot. There were total six important values represented in each box, they were minimum value, first quartile value, median value, mean value, third quartile value and maximum value for all the measurements taken by each operator. The horizontal line inside box indicated median value and the circle meant mean value. Ideally, the measurements for each operator varied an equal amount and the part averages varied as minimally as possible.

Using the Operator * Part Interaction chart to display the average measurements taken by each operator on each part in the study, arranged by part. Ideally, the lines followed the same pattern and the part averages varied enough that differences between parts are clear.

Table 11: Gage R&R Analysis of Body Plant by Minitab

Gage R&R Study - XBar/R Method

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.0005593	2.21
Repeatability	0.0005307	2.10
Reproducibility	0.0000286	0.11
Part-To-Part	0.0247221	97.79
Total Variation	0.0252814	100.00

Process tolerance = 2

Source	StdDev (SD)	Study Var (6 * SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	0.023649	0.141897	14.87	7.09
Repeatability	0.023036	0.138216	14.49	6.91
Reproducibility	0.005351	0.032108	3.37	1.61
Part-To-Part	0.157233	0.943396	98.89	47.17
Total Variation	0.159001	0.954008	100.00	47.70

Number of Distinct Categories = 9

Gage R&R for value

In Table 11, variance component calculated by expected mean squares indicated % contribution to total variation for each source of variance. The result was 2.21% as total Gage R&R. It was different with the result based on standard deviation which was the root square of each variance component. Typically, process variation was defined as 6s, where s was the standard deviation, as an estimate of σ. When data was normally distributed, approximately 99.73% of the data fell within 6 standard deviations. As a result, %study variance indicated each source of variation's six sigma spread divided by the total six sigma spread, and total Gage R&R was 14.87%. Furthermore, the number of distinct categories value estimated how many separate groups of parts the system can distinguish which should greater than 5. As the standard of part is 10±1, the process tolerance is equal to 2.

Normally the measurement system was acceptable if Gage R&R less than 10%, and 14.87% which was between 10% with 30% was also acceptable based on the requirement of auto plants.

2.2 Welding plant.

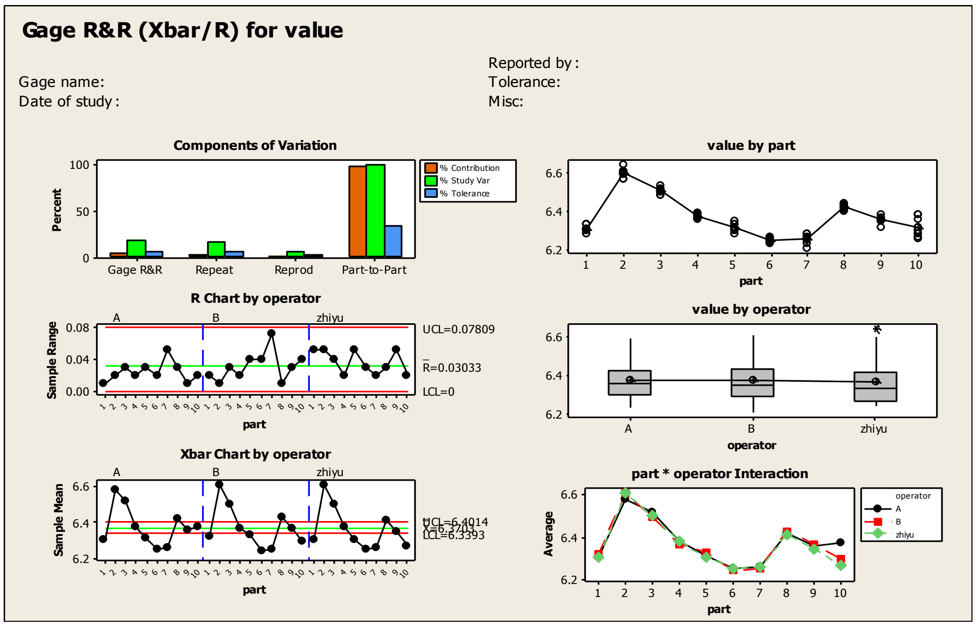

Figure 19: Gage R&R Analysis of Welding Plant

Table 12: Gage R&R Analysis of Welding Plant

Gage R&R Study - XBar/R Method

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.0003476	2.81
Repeatability	0.0003210	2.59
Reproducibility	0.0000266	0.21
Part-To-Part	0.0120370	97.19
Total Variation	0.0123847	100.00

Process tolerance = 2

Source	StdDev (SD)	Study Var (6 * SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	0.018645	0.111868	16.75	5.59
Repeatability	0.017917	0.107501	16.10	5.38
Reproducibility	0.005158	0.030951	4.64	1.55
Part-To-Part	0.109713	0.658281	98.59	32.91
Total Variation	0.111286	0.667719	100.00	33.39

Number of Distinct Categories = 8

Gage R&R for value

Figure 19 and Table 12 were the results of welding plant got from Minitab. Through the similar analyze with body plant, the measurement accuracy of welding plant was acceptable as Gage R&R value was 16.75%.

3. Process of cause analysis.

    3.1 Gap between skylight and plafond. After the basic measurement system analysis, the reason of flaws on skylight was seeking. As the assembly process of plafond and skylight, it was focusing on the connected hasp on plafond and skylight.

Figure 20: Connected Hasps on Skylight

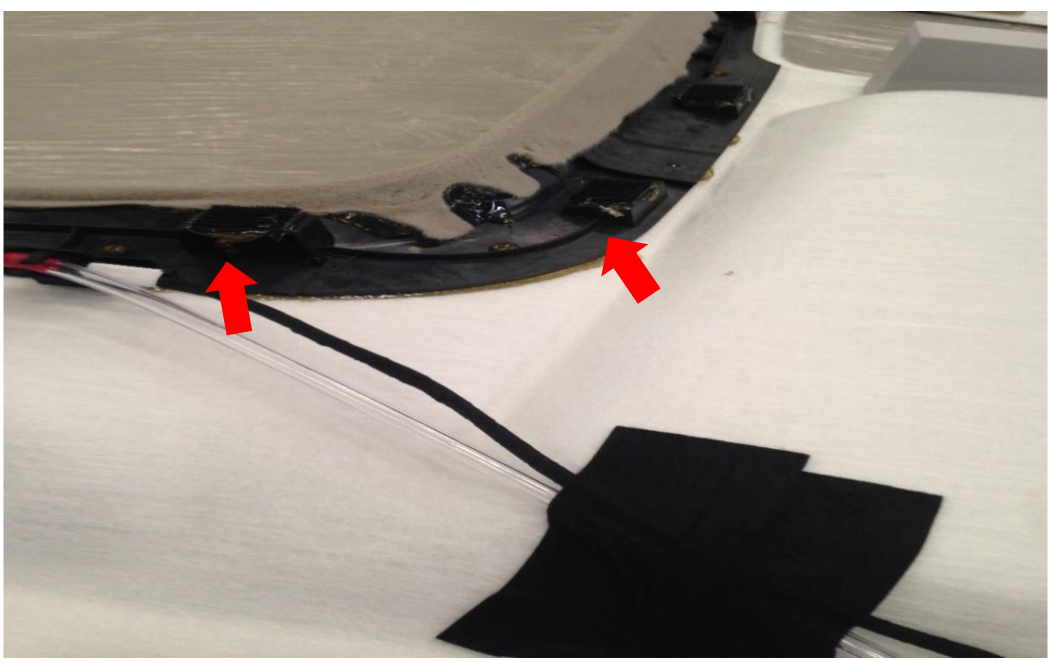

Figure 21: Connected Hasps on Plafond

Comparing the characteristics of plafond and skylight, a higher error potential existed on plafond because of the production process. As a result, research on plafond was most important. The CMM detecting method of plafond showed as Figure 12 was a way to detect if the product qualified as design. After analysis by engineer, the altitude intercept of two hasps on plafond showed as red arrows in Figure 21 was acceptable.

By measured the altitude intercept of two sides separately on plafond, result showed in Table 13 below. From Table 13, left side altitude intercept was between 24mm-26mm, and right side altitude intercept was between 26mm-26.5mm. Comparing with standard 25±2mm, these data showed plafond was acceptable. However, because of the disparity on two sides, errors might come and resulted in the gap between skylight and plafond.

Table 13: Altitude Intercept of Hasps on Plafond

	1	2	3	4	5
let side	25	24	24	25	26
right side	26	26	26.5	26	26.5

3.2 Gap between lamp and bumper.

3.2.1 Deformation experience. Because of the process of production, high temperature or pressure might result in bumper deformation. In order to get rid of this reason, deformation experience was taken on bumper.

3.2.2 Structure strengthen. As the deformation might exist, engineer also made a plan of structure strengthen to seek the reason. In

Figure 22, blue lines showed the position need to be strengthened and trial-produce could show the result.

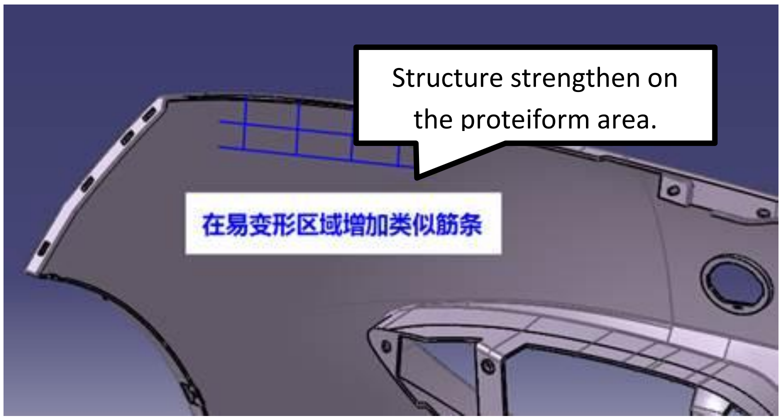

Figure 22: Structure Strengthen for Bumper

3.2.3 Body analysis. After analysis the mounting point data (showed as Figures 14 and 15), the average deviation of lamp mounting point showed in Figure 23 below. As it said, all deviations were under 1.5mm and it was qualified, it should not lead to the gap between lamp and bumper.

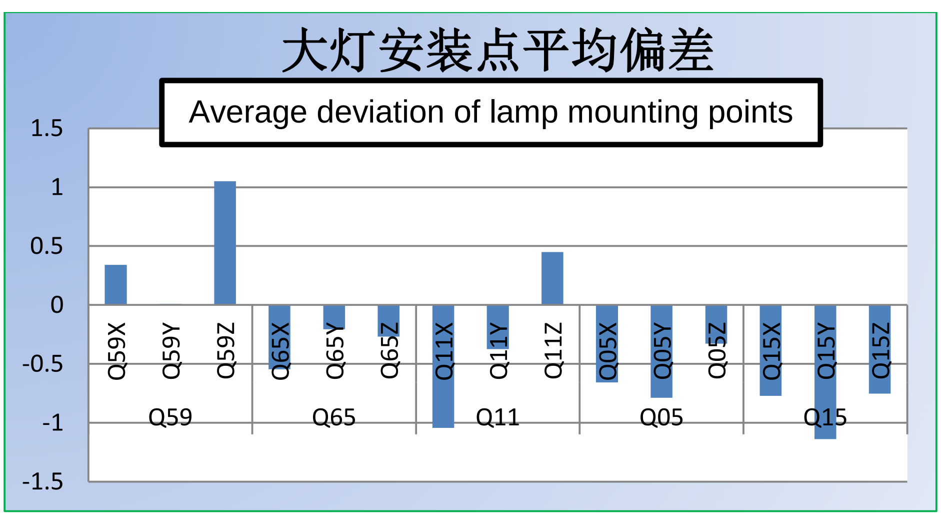

Figure 23: Average Deviation of Lamp Mounting Points

In Figure 16, the mounting point value of bumper and fender were bad and there was a 2.3mm error existed on mounting point value of fender. As a result, adjustment of the mounting point was a method to eliminate the gap between lamp and bumper.

Summary

This chapter was focusing on data analysis. In this chapter, data collected in project was presented and how to analyze and seek the root cause of the problems by these data. Through step by step explanation and description, the detailed process of the project was provided. For next chapter, all the result and conclusion would be given. It would also introduce what was learnt and what should be recommended in this project.

Chapter V: Results, Conclusion, and Recommendations

Introduction

As the last chapter of this report, it introduced the results and conclusion of the project. In this chapter, how the project worked and what was the reason of the problems would be given. In additional, the questions presented would be answered as part of the conclusion. What the project brought to company and what recommendation provided to the company also mentioned below.

Results

By observing and discussing the problem, figure out the problematic and related parts and then focusing on researching them. Confirming the accuracy of the measurement system was the first step before data collection and it helped make sure the validity of the whole project.

a. What related plants leaded to the flaws on automobile M?

As the problems were the gap between skylight and plafond, and the gap between lamp and bumper, the related plants were stamping plant, welding plant and body plant.

b. What possible steps affected the accuracy of production?

During the production process, most manual work would affect the accuracy of it. For example, when mount the part connected the skylight on plafond, the thickness of glue would affect the altitude intercept of connected points on plafond. In additional, the manual welding work also affect the accuracy of car body. Furthermore, because many production procedures were taken by workers, it was impossible to require a really high accuracy in production. As a vehicle was assembled by parts, the errors blew up when parts were assembled together. As a result, problem came out and it was difficult to figure out the real reason leaded to the problem.

c. What effect of material using in related parts?

The only deformation experience on bumper was a plan to inspect if the material used for bumper had negative deformation during production. This could be the cause of gap between lamp and bumper.

d. What were the real causes of the flaws?

For the gap between skylight and plafond, the loose error range of plafond leaded to the problem. Skylight was assembly by welding plant and it was detected by measuring tool, so it had a higher accuracy than plafond. After detecting and analysis, the different altitude intercepts on the two sides of plafond was the cause of the problem. It was proved by rebuilding the plafond and mounting the connected part on plafond within a limited error range, and the gap was eliminated observably.

For the gap between lamp and bumper, negative deformation was excluded by the experience. As a result of car body analysis, the mounting point of fender and bumper were focused. After adjusting the mounting point of bumper, the problem still existed. However, the gap was eliminated by adjusting the position of fender. Assumed the orientation of front wheel to rare wheel was X axis, move the mounting point of fender to front wheel orientation on X axis by about 2-3mm could solve the gap. It was proved by trail-produced.

e. What were the approaches to collect data, analyze data, and figure out the solution?

Following the procedure of root cause analysis to seek the reasons and collect the data necessary. All the data collected from related plant were random to ensure the validity of the result. And data of CMM test and deformation experience were collected by engineers.

f. What were the orientation to improve production quality in the future?

The most effective method to improve production quality was realizing standardized production. Most error accumulation was happened in manual work. Considering the dimension and the cost of the company, higher training requirement of workers and importing more automatic production lines could help improve production quality.

Conclusion

As the project was going to refine and improve the quality of auto M of ABC Company, the task assigned was eliminating the gap had negative effect on upholster and exterior of auto M. Because of the problematic parts, stamping, welding, and car body plants were related plants needed to be researched and detected. In order to ensure the accuracy of data collected, MSA analysis was very fist procedure.

Brainstorming and guessing were the ways to confirm the study orientation. Focusing on problematic position and assembly process of auto M, engineer drew white pigment on the connected hasps on skylight, and then observing the hasps on plafond when the car assembled completely. After disassemble the plafond on the completed vehicle, engineer found the hasp on the right side did not stain the white pigment on skylight. By detecting the altitude intercept of key point and analyzed data, reason was figured out.

To solve the problem on the lamp and the bumper, deformation experience and structure strengthening were the consideration of the material used in building the bumper. Meanwhile, analyzing car body was the main method to figure out the root cause. By reading the data of CMM detection and trail-producing, reason was confirmed. Because of the loose error range requirement, tolerance accumulation leaded to quality problem on final products.

Recommendations

By working on the refining and improving project of auto M, some problems of production in ABC Company were exposed. Realizing standard production was the purpose of vehicle industry, and automatic production line was the method. For ABC Company, considering the cost, higher training requirement was the method to improve the skills and abilities of the worker, and it helped to allow the production within a smaller error range. Importing automatic lines for some key parts production was also necessary to improve quality of product. It was a good way to keep 5S management method for a high quality production process, but the abilities and the skills were the key to a higher quality product. That was the recommendation for Changsha ABC Automobile Company, Ltd.

References

Ashley, S. (1997, November). Keys to Chrysler's comeback. *Mechanical Engineering—CIME.*

Bies, D. A., & Hansen, C. H. (1996). Engineering noise control–theory and practice 2nd ed.). London: E&FN Spon.

Boukehili, A., & Zhang, Y. T. (2012, October). Hybrid vehicle power management modeling and refinement. *International Journal of Automotive Technology*, *13*(6), 987-998.

Brandl, F. K., Biermayer, W., Thomann, S., Pfluger, M., von Hofe, R. (2000). Objective description of the required interior sound character for exclusive passenger cars. *IMechE Paper No. C577/013/2000*.

Ferry, T. S. (1988). Modern accident investigation and analysis (2nd ed.). John Wiley and Sons.

Haynes, R. (2013, September 10). How to understand a measurement system analysis. *Quality Digest*. Retrieved from http://www.qualitydigest.com/inside/quality-insider-article/how-understand-measurement-system-analysis.html#.

Hibbert, L. (1999, November 3). Last ones standing are the winners. *Professional Engineering.*

Kappa test. (2015). Retrieved from https://en.wikipedia.org.

McHugh, M. L. (2012, October 22). Interrater reliability: the kappa statistic. *Biochemia Medica, 22*(3), 276-282.

Mind tools. (2015). Retrieved from http://www.mindtools.com.

Panagiotis Lytrivis, G. T. (2010). Situation refinement for in-vehicle platforms in vehicular networks. In *Proceedings of the 13th International IEEE Conference on Intelligent Transportation Systems*, pp. 204-209.

Sloop, R. (2009, September 1). Understand gage R&R. *Quality Magazine*. Retrieved from http://www.qualitymag.com/articles/86819-understand-gage-r-r.

Stemler, S. E. (2004). A comparison of consensus, consistency, and measurement approaches to estimating interrater reliability. *Practical Research, Assessment and Evaluation, 9*(4).

The 3D Experience Company. Retrieved from http://www.3ds.com.

ThinkReliabillity. (2015). The problem solving discipline for your business. Retrieved from http://www.thinkreliability.com.

Urdhwareshe, H. (2006, December). Validating measurement system using measurement systems analysis (MSA). *Quality World*.