BONNET CABLE DEFECT ANALYSIS USING SIX SIGMA DMAIC TECHNIQUES

Dina DIGA[1], Irina SEVERIN[2]

Study presents the implementation of Six-sigma techniques to identify the root cause of bonnet cable problem at the customer's request. The process was developed in detail, using five main (DMAIC) steps: Define, Measure, Analyze, Improve and Control. In this research, Quality Management tools such as SPD – Standard Problem Definition analysis, Data Analysis, Quality Assurance Part Inspection, Data Collection Plan, Process Capability Study - DPMO, Initial Verification Diagnosis, Visual and Control Charts etc. are used in defining the problems to find the root causes for the problem and carrying out experiments in order to suggest improvements, through which the company could bring in quality and reliability in their process.

Keywords: Six sigma, DMAIC, defects, quality techniques, automotive industry, market, bonnet cable, customer satisfaction.

1. Introduction

The presence of quality in the automotive industry is fundamental. Since conception to product delivery to the end customer, all the steps are followed in detail to avoid failures [1]. The paper develops the DMAIC methodology to analyze and detect the root cause that generated the failure of the bonnet cable.

Six sigma provides a rigorous disciplined, organization-wide approach to improve products and services based upon customer expectations, by reducing process variation, only 3.4 defects per million opportunities (DPMO) or 99.9997% defect-free. Six sigma uses a wide variety of tools to help teams to identify the customer, define the customers understanding of value and visualize our process, products and services from a customer's point of view [2].

Jack Welch [3] (1995) called six sigma the most ambitious undertaking the company had even taken on. He stated: "Work-Out defined how we behave, Six Sigma defines how we work and has set the stage for making our customers feel Six Sigma". The similar ideas had the authors Bill Smith and Dr. Mikel J. Harry, who would become the "Founders of Six Sigma". Smith and Harry came up with the Six Sigma concept for quality control improvement using the foundational Lean

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principles created by W. Edwards Deming, Joseph Juran, Philip Crosby, Kaoru Ishikawa, and Genichi Taguchi [3, 4].

Through the research, the approach of this paper is to go through each stage of the improvement project research from defining the bonnet cable problem and understanding the current process to evaluating and tracking the effectiveness of solutions [5]. This work aims to identify the root cause of bonnet cable and apply a rigorous six sigma DMAIC approach using a mix of process analysis and data analysis tool.

Implementation of six sigma DMAIC (Define, Measure, Analyze, Improve and Control) took place through the following stages where problem identification and definition takes place in define phase. After identifying main processes, their performance is calculated in measure phase with the help of data collection. Root causes of the problem were found out in analysis phase. Solutions to solve problem were implemented in improve phase. Improvement is maintained and assured in control phase [6].

2. DMAIC Process

The case is part of a study held in an automotive company in the United Kingdom, the company manufactures various bonnet cables used to assemble the bonnet release system. The requirement of the study is to analyze and evaluate the bonnet cable problem using six sigma DMAIC techniques. The problem will be passed through the whole DMAIC approach, having 70 days to identify the root cause and the possible solution. The study was attended by: the body quality team, the engineering team – Lids and the team responsible for the problems reported on the world markets – Market Service.

The paper is divided into 5 main subchapters. The first subchapter defines and describes the "bonnet cannot be opened" problem, identified and reported by the customers. In the Measure subchapter, the Data Collection Plan is presented, a plan necessary in presenting the data identified during the visual inspection [7]. The third subchapter describes the verification analysis used to identify the symptom. The Improve subchapter identifies the solution to reduce release lever free play. The last subchapter shows the improvements brought after the implementation of the proposed solution.

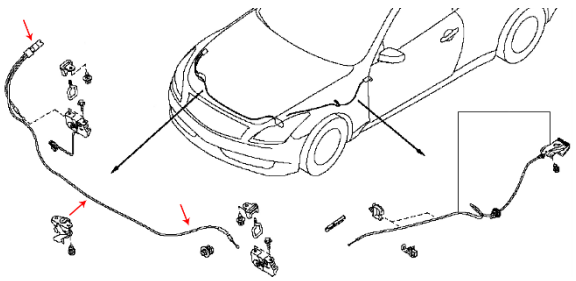
2.1. Define

The bonnet release system consists of an interior bonnet latch handle, bonnet release cable and bonnet latch assembly. The bonnet latch handle is usually located below the steering wheel, beside the driver's seat or set into the door frame. A bonnet cable carries the signal from the hand-operated lever inside the car to the lock on bonnet to open it.

During the period from July 2019 to January 2020, 143 complaints from consumers and dealers related to the bonnet cable were collected by the quality team in the markets [8]. The failure has been observed on bonnet release mechanism and the problem were identified in several markets around the world (China, Russian Federation and United States). Customers reported bonnet issues, bonnet cannot be opened and requested the normal functioning of the bonnet and cable, as presented in SPD - standard problem definition, in Table 1.

Table 1

Standard problem definition analyses

<table>
<tr><td>Lead name: Dina Diga</td><td>Revision Date:30/01/2020</td><td>Voice of the Customer: Customers reported bonnet issues, bonnet cannot be opened.</td></tr>
<tr><td colspan="3">Customer Requirement:
The normal functioning of the bonnet and cable – bonnet should open when release lever pulled.</td></tr>
<tr><td colspan="2">Initial Scope / Business Case: bonnet will not open, Reference Project research P232813</td><td>Refined Problem Scope: bonnet will not open, all vehicle models from 2019. Dealers’ states cable will not open bonnet and conduct parts replacement in 80% of cases.</td></tr>
<tr><td colspan="2">Symptom: Customer report not being able to open the bonnet when lifting the release lever. These are also 8 cases raised from Road Side Assistance.</td><td>Detailed Problem Statement:
Cable bonnet does not exercise the required pull length when lever is at 90 degrees position. Lever is mechanically prevented from exceeding 90 degrees which results in latching mechanism staying engaged.</td></tr>
<tr><td colspan="2" rowspan="2">Is / Is not Summary:
 
What:
▪ Vehicle bonnet realise cable
▪ Supplier cables

Where:
▪ Front of bonnet along LHS - Left hand side/ RHS – Right hand side up to lower driver door side
▪ Major markets affected: USA, UK, China, Canada</td><td>In-House Measure of Customer Requirement:
Bonnet is opened for various reasons during CAL (Customer Acceptance Line) and other health checks. When noticed, bonnets have been re-worked in plant.</td></tr>
<tr><td>Developed Project research opportunity :
25 EPQR (Electronic Product Quality Reporting)
101 Claims,
13 RSA’s (Road Side Assistance)
Total cost € 6,974.40.
Increased customer satisfaction and confidence.</td></tr>
<tr><td colspan="2"></td><td>Resources Required / Enablers (People / Equipment):
Lids – K. W. & M. B.;
MS(Market service) – J. K.,
Body Quality – E. S. & Dina Diga.</td></tr>
</table>

When: ▪ Build month: Dec 2018 to Jan 2019 ▪ Repair date: Jun 2019 to Feb 2020 ▪ Increasing number of repairs since launch ▪ Repair Mean TiS (Time in service) – 5 MiS (Month in service); 10203 Km **How big/ many :** ▪ How many claims: 143 claims, 51 EPQR, 22 RSA (IQM- Intelligent Quality System data) ▪ Warranty: R/1000 : 3.362	**Action based on Project research Opportunity**: ■ Proceed with project research □ Not proceed with project research **Issue / Project research Ref Number**: P232813 **Champion Name / Signature / Date**: **Project research Start Date**: 30/01/2020 **Expected Close Date**:

Once the data has been obtained, the issue requires a more detailed analysis. Thus, the quality team performed an internal audit in the cable production line. During the inspection, a part inspection report was made, as shown in Table 2.

Table 2

Quality Assurance Part Inspection Report

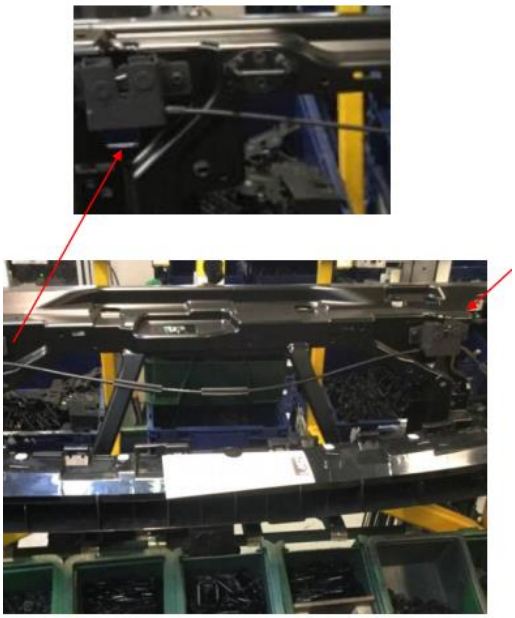
Project research no. & Title : P232813 Bonnet - Will not open	**Problem investigator:** Dina Diga / P. P.	**Date: 07/02/2020**
What/Why/Where/Who/When		
Part no.: (Eng. / Service)	**Part description**: Bonnet cable	Supplier, Code & Contact details
Visual Inspection evidences: i.e. photos etc. 		
Other supporting evidences: 1. **VIN** (Vehicle Identification Number): SLRA2BV9HA022 TIS: 4 months / 1503 Km 2. **Customer Verbatim**: Unable to open Bonnet 3. **Technician Verbatim**: Customer concern confirmed. Bonnet opening lock cable failed renewed. Issue still the same. Bonnet right hand latch failed renewed.		
Conclusion: There is evidence of a kink in the cable which may cause a tight spot. ABA – (Applied Behavior Analysis) test to vehicle to test operation.		

When the data were concluded, it was decided to perform the measurements on the bonnet cables identified in the production line and those received from the supplier according to the Work instruction.

2.2. Measure

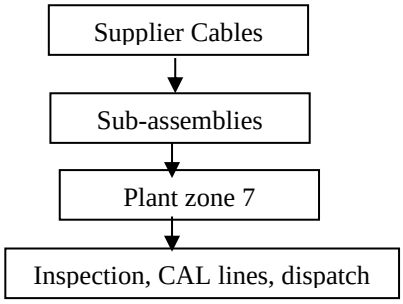
Once the problem has been fully defined the next step is to collect data to further understand and quantify the problem and the possible causes. To support the evidence, a Data Collection Plan from the Standardized Problem Definition will be provided. A Data Collection Plan is a summary of the data collection requirements for the Critical to Quality characteristics and relevant stratified input process measures relating to improvement project research [9]. The Data Collection Plan will support the graphical evidence, as shown in Fig.1.

What (Part Details)?

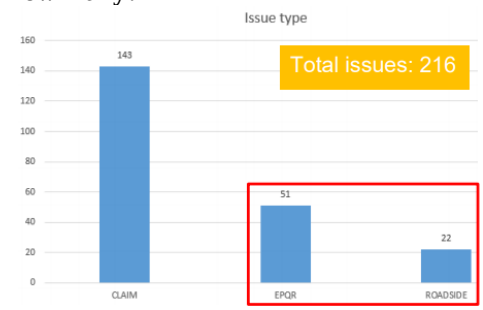


Description: Bonnet control cable

What (Supply/Assembly Chain)?



How many?



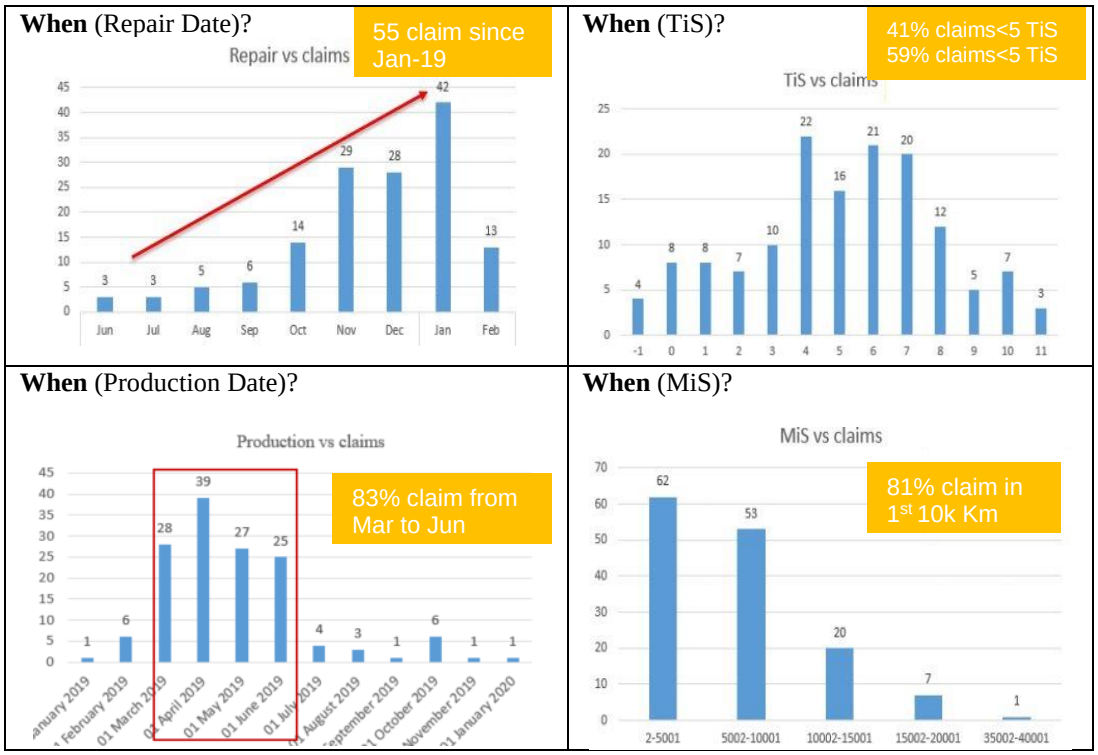


Fig.1. Data Collection Plan

Following the data analysis, 300 complaints were identified from customers and dealers regarding the bonnet cable problem. From this a total of 143 claims, 51 EPQR and 22 RSA are found. Based on the above data, DPMO was calculated using the following formula:

$$\text{DPMO} = \frac{D}{NxO} \text{ x } 10^6 \quad (1)$$

DPMO - Defects per million opportunities
D - Defects N - Number of items/documents sampled
O - Opportunities used

$$\text{DPMO (for defects)} = \frac{216}{(300x3)} \text{ x } 1{,}000{,}000 = 240{,}000 \text{ DPMO} \quad (2)$$

The specification limits must accurately reflect the true requirement of the customer. The process must be stable and the number of defects lower.

2.3. Analysis

Six sigma approach necessary to analyze the problem depends on the data collected. A wide range of tool and techniques are available to analyze both the process and the data collected. In all cases it is key to drill down from the symptom to find and address the real root cause of the problem [10]. Table 3 shows a first step in verifying and analyzing plant data.

Table 3

1st and 2nd Initial Verification Diagnosis

<table>
<tr><td colspan="3">Validation/ Observation/ Conclusion - 1st Initial Verification Diagnosis - IVD</td></tr>
<tr><td colspan="2">IV&D What/Why/Where/Who/when</td><td>IVD evidence: Highlight any non-conformance found during verification</td></tr>
<tr><td>Project research title</td><td>Cable - bonnet control</td><td rowspan="6">There are no non-conformities to process found during inspection. However the fault is being reworked at early MiS but no recent repairs were highlighted by the rectification team.

Additionally, operators at Zone 1 say grommet in vehicle1 is causing problems in comparison with vehicle2, where vehicle1 is "soft" and can pass the BIW- Body in White. To be followed up with PVT - Production Validation Test team.</td></tr>
<tr><td>IV&D scope & target:</td><td>To understand supply chain of parts assembly and detection points for low TiS in plant.</td></tr>
<tr><td>Component description</td><td>Cable - bonnet control</td></tr>
<tr><td>Supplier/Plant/ Dealership name</td><td>M. Cables</td></tr>
<tr><td>Problem verifier/investigator</td><td>S. G.</td></tr>
<tr><td>Date verification carried out</td><td>06/11/2019</td></tr>
<tr><td colspan="2">IVD evidence: i.e. Photos, documents etc.
  </td><td>Conclusion Please highlight the major non-conformance i.e. Drawings, Control Plan, FMEA – failure mode and effect analysis etc.

Although failure can be witnessed on plant, it is not understood at this stage what causes the fault. Parts required for measurements and further investigation on grommet material required.</td></tr>
<tr><td colspan="3">2nd Initial Verification Diagnosis</td></tr>
<tr><td colspan="2">  </td><td>  </td></tr>
</table>

Conclusions from 2nd IVD: Correct routing and consistency of bonnet cables to be adhered in manufacturing. Some variation was noticed in routing of bonnet cable in a subsequent visit to Plant. Cable not clipped. Associates also stated lever does not always fully return on some vehicles [10, 11].

During the document inspection, it was noted: Drawings specify several SC - sharp corners. The length of cable exposed to the latch (relevant to the failure mode) is an SC. See drawings in Fig.2.

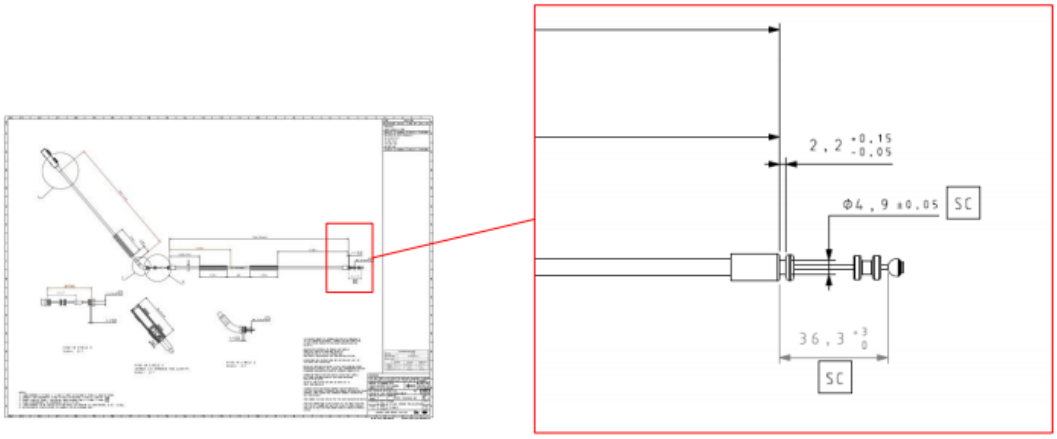


Fig. 2. Bonnet cable drawings

DFMEA - Design failure mode and effect analysis and PFMEA - Process Failure Mode Effects Analysis contain failure mode of cable being too long or short but no reference to quality inspection or prevention of failure mode.

Table 3

Plant cable measurements

Cable Identification	L 36.3+3-0mm	Actual Size	Total Deviation From Nominal	Deviation from Specification
SAMPLE 1	L 36.3+3-0mm	41.8mm	5.5mm	3.5mm o/s
SAMPLE 2	L 36.3+3-0mm	42.2mm	5.9mm	2.9mm o/s
SAMPLE 3	L 36.3+3-0mm	42.3mm	6.0mm	3.0mm o/s
SAMPLE 4	L 36.3+3-0mm	40.9mm	4.6mm	1.6mm o/s
SAMPLE 5	L 36.3+3-0mm	41.8mm	5.5mm	2.5mm o/s

Five samples were measured, as presented in Table 3, in terms of cable length produced in the company's plant and it was concluded that the parts returned for measurement and new cables are out of tolerance. Similar measurements were performed at the supplier, as shown in Table 4.

Table 4

Supplier Results

Cable Identification	Stud Position= 40.00- 41.50mm		Protrusion =36.30 -39.30mm	
	Before Temp. Chamber	After Temp. Chamber	Before Temp. Chamber	After Temp. Chamber
SAMPLE 1	40.78		36.88	
SAMPLE 2	41.20	40.34	39.89	37.40
SAMPLE 3	41.91	40.65	39.27	37.96
SAMPLE 4	41.74	40.65	38.82	37.34
SAMPLE 5	41.34	41.04	39.87	39.13
SAMPLE 6	41.44	40.57	39.45	38.94
SAMPLE 7	41.96	41.11	39.64	38.22
SAMPLE 8	41.76	40.67	39.15	37.72

The drawings in Fig. 3, shows the bonnet cable stud dimension and protrusion compared to supplier results.

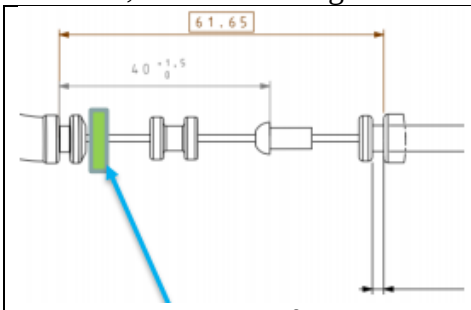
Fig. 3. Cable drawings

Conclusion: following the measurements performed and the straightening of the cables, it was included in the specifications.

2.4. Improve

The goal of the Six sigma improve phase is to identify a solution to the problem that the project research aims to address [12]. This involves brainstorming potential solutions, selection solutions to test and evaluating the results of the implemented solutions. Such a solution has been identified and implemented, after measurements showed that there is a difference in tolerances between the cables.
The design of the system allows for excess free movement where the failure mode can be produced when coupled with other factors such as routing and bonnet alignment [13]. During the cable assembling process inspection, there were evidences wherein the cable was out of its position and not clipped at timing marks. Bonnet lever specification is from 10°C - 90°C which allows for considerable free play leading to the lever reaching its end of travel before enabling the bonnet to be

open. Following the final tests, the solution to reduce release lever free play was identified, as shown in Fig.4.



Nut used as a spacer fitted to cable at point shown. Nut added to act as spacer between Left-hand latch and outer cable collar.

Spacer shown fitted to remove cable slack.

Fig.4. Bonnet cable modification test

Conclusion: This reduced release lever free play and thus overall travel.

2.5. Control

In the control phase of the project research, the solution was developed and validated and the goal is to make sure that the problems have been eliminated and that the method is improving [14]. A training was performed on the correct mounting of the bonnet cable because the cable was out of its position and not clipped at timing marks, as shown in Fig. 5.

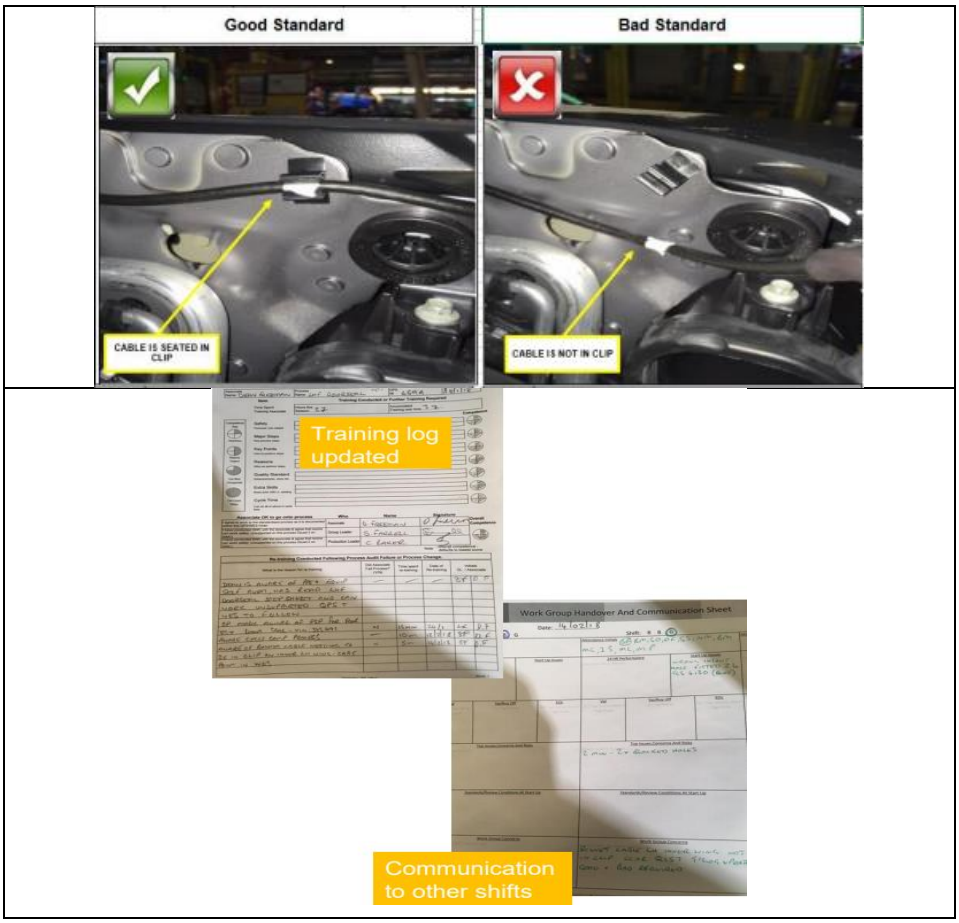


Fig.5. Standardization method of installation and training

3. Conclusions

This research is concerned with the analysis of the problem of bonnet release cable that will not open. During the Define, Measure and Analyse phases, two major problems were identified.

1. Measurements made at the plant and at suppliers show that there is a difference in tolerances between cables.
2. During the cable assembling process inspection, there were evidences wherein the cable was out of its position and not clipped at timing marks.

Following improvements were obtained by six sigma implementation and finding the best solutions to the bonnet cable problem.

The solution found for the difference in tolerances between the cables is to add a nut to act as a spacer between the left-hand latch and the outer cable collar. The solution for improper cable assembly is to standardize the assembly method and perform operator training.

The results of this study reveal that the implementation of Six Sigma can provide a significant improvement in the process of assembling the bonnet cable and eliminating possible defects.

Acknowledgement

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