Improvement of the customer satisfaction through Quality Assurance Matrix and QC-Story methods: A case study from automotive industry

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Abstract. Presently, in the automotive industry, the tendency is to adapt permanently to the changes and introduce the market tendency in the new products that leads of the customer satisfaction. Many quality techniques were adopted in this field to continuous improvement of product and process quality and advantages were also gained. The present paper has focused on possibilities that offers the use of Quality Assurance Matrix (QAM) and Quality Control Story (QC Story) to provide largest protection against nonconformities in the production process, throughout a case study in the automotive industry. There is a direct relationship from the QAM to a QC Story analysis. The failures identified using QAM are treated with QC Story methodology. Using this methods, will help to decrease the PPM values and will increase the quality performance and the customer satisfaction.

1. Introduction
In automotive industry the development of new products, involve complex engineering processes subject to time pressures and fierce competition on the automotive market. The companies have to adapt their products precisely to customer needs, and therefore parameters of manufactured products are adjusted to the individual requirements of customers [1]. An important role in the development of such projects is user of the modern quality tools in the development of new products. Existing tools and methods have become inadequate because they do not meet all additional requirements [2, 3]. It is therefore necessary to look for new solutions or improve old and trusted methods. In this context, the use of modern quality methods such as the Quality Assurance Matrix (QAM) and the Quality Control Story (QC Story) is opportune.

QAM and QC Story are tools of IATF 16949. In October 2016, the IATF will publish a revised automotive industry standard, and the first edition will be referred to as IATF 16949. This new standard will supersede and replace the current ISO/TS 16949:2009, defining the requirements of a quality management system for organizations in the automotive industry. IATF 16949 is aligned with and refers to the most recent version of ISO’s quality management systems standard, ISO 9001:2015, fully respecting its structure and requirements. According IATF, 10.2.3 Problem solving: The organization shall have a documented process (es) for problem solving: c) root cause analysis, methodology used, analysis, and results. Where the customer has specific prescribed processes, tools, or systems for problem solving, the organization shall use those processes, tools, or systems unless otherwise approved by the customer [4]. In this paper, we present the solution of a quality problem by...
applying the QAM and QC Story methods for the manufacturing-assembly process of a subassembly-axle for vehicles. Using QAM we identify the failures, then these are treated with QC Story.

2. Quality Assurance Matrix and QC Story - Quality problem solving tools

2.1. Quality Assurance Matrix

Quality Assurance Matrix is a quality tool that is based on the principle that any failure (noncompliance) to a manufacturing process that affects a customer (who may be the next process or final customer) must imperatively be eradicated. The method ranks, for potential and existing defects, the reliability limits of the control systems in the manufacturing process, thus allowing the implementation a necessary corrective measures and achieving in this way a quality objectives [2,5]. Comparing to the Failure Mode and Effects Analysis (FMEA), it can be applicable in already implemented production [6]. QAM permit a periodic quantification of the level of production processes quality, verifying the reliability (in the sense of trust or even effectiveness) of means of control existing in the production process, the necessity and the possibility of implementation of anti-error systems (Poka-Yoke) or other nonconformities protection systems [5]. QAM is built on the Plan-Do-Check-Act (PDCA) cycle structure [5,7,8]: Plan - Establish quality goals and defining the technological process; Do - Making analysis; Check – Verifying the reliability of control set; Act – Implementation of the corrective actions for the operations that do not guarantee the quality level established.

2.2. QC Story

The QC Story originated in the Seisakusho Li Tianjin plant, which is located in Komatsu, Ishikawa in Japan. To improve the performance of the quality control circle - QCC, a structural process for the activity of the QCC is presented. The output of the QCC can be arranged and presented based on the process, namely, the QC Story [9]. The QC Story is a structural process for the presentation of QCC activities. It is frequently used in practical problem-solving procedures and methods [10]. For example, in the literature, QC Story methodology is used to improvement of Kaizen projects in local governments [11]. Also, Sha et al. [12,13] proposed a creative problem-solving quality control story (CPS-QC story) to improve the traditional quality control process. CPS-QC story consists of the combination of the traditional QC story and TRIZ.

In automotive industry, QC Story is a problem solving method based on considering the facts and data, without speculation, for a problem caused by several factors. It is applicable not only to quality problems, but also to problems of productivity, costs, logistics, energy, security etc [14]. Therefore, QC Story, which uses a different standard process and different tools, is applicable to different kinds of problems. The method is applied using nine steps and basic principles of quality by taking into account tools and techniques from various approaches based on the PDCA cycle structure, shown in table 1.

| Table 1. QC Story Method steps. |
|----------------------------------|

| PLAN | DO | CHECK | ACT |
|------|----|-------|-----|
| 1. Choosing the subject | 5. Analysis | 7. Confirming the effects | 8. Standardization |
| 2. Explaining the reasons of the choice | 6. Applying corrective actions | |
| 3. Understanding the current situation | |
| 4. Choosing the targets | |

The approach used by QC Story applies to solving problems both as a group and as individuals. Sometimes using the format is not essential but may be necessary at the beginning or to communicate the results.
3. Quality Assurance Matrix application

QAM application to analyse the manufacturing-assembly process of a subassembly-axle for vehicles is shown in table 4. The main steps of this analysis are to determine the failure modes, the parameters that may influence the occurrence of these failures and the proposed corrective measures to prevent the occurrence of these failures. All failures modes are not given in this table. The proposed measures presented in table 2 take into account the criticality (importance) of the failure for the client, as quoted in table 3 [5,7].

Table 2. Quotations of different levels for quality guarantee.

| Quotation | Quality Guarantee |
|-----------|-------------------|
| 5 points  | 100% Automatic control; Impossibility of assembling or post machining; Interdiction / control Poka Yoke |
| 3 points  | Warning Poka Yoke; Frequency Control (measurements); Manual control 100% in the line; Human control 100% with identification |
| 1 point   | Frequency control; Human control 100% without identification; Periodically audit Human control 100% with or without identification |

Table 3. The criticality of the failure for the client.

| Degree | Client impact | Criteria for assessment | Quotation |
|--------|---------------|-------------------------|-----------|
| A      | Grave         | Failure preventing use your product or creates a strong dissatisfaction, with repair request | 5         |
| B      | Very embarrassing | Fault for the customer expresses dissatisfaction in a survey | 3         |
| C      | Embarrassing  | Discovered fault of the customer, but tolerated | 1         |

Table 4. QAM for manufacturing-assembly process of a subassembly-axle for vehicles.

| Failure modes         | Parameters | Type of control | Control process inside the assembly workshop | Control process outside the assembly workshop |
|-----------------------|------------|-----------------|---------------------------------------------|---------------------------------------------|
| Oxidation of the part | Paint appearance nonconforming: stains, agglomerates, matte paint, orange peel, exfoliated paint | C △ | Visual control 100% |  |
| Oxidation of the part | Contact areas on balance | C △ | Visual control 100% | Control in the workshop cataphoresis with calibre 1/week |
| Lack of articulation and incorrect orientation | Manual articulation load | A ⬜ | Present part in post ensuring the orientation of the part (the missing part and no advance of mobile arm in the work area prevent the table from rotating) |  |
| Lack of security welding cords | Visual inspection and marking of security welding cords | C △ | Visual control and permanent marker marking 10% |  |
| Diversity nonconforming part with the chosen gust | Axle type error | A ⬜ | 100% automatic (read axle grading in the loading station) |  |
Table 4. (continued)

| Failure modes                      | Parameters                      | Importance | Type of control | Control process inside the assembly workshop | Control process outside the workshop |
|------------------------------------|---------------------------------|------------|-----------------|---------------------------------------------|-------------------------------------|
| Pressing articulation nonconforming | Pressing effort nonconforming   | A          |                 | Control 100% automatic                        |                                     |
| Impossibility to fix the strings   | Welding grids fillet nonconforming | C          |                 | Control 100% operator (screwdriver and screw) |                                     |
| Sticking label product             | Reference error                 | A          |                 | 100% automatic SIP MECA (in compliance with Data Matrix post 1) | Control 100% present label |
|                                   | Axle without sticker label      | A          |                 | Control 100% present marked cords            | Control 100% operator in the welding workshop |
| Support shock absorber broken     | Lack of welding grids           | A          |                 |                                            |                                     |
| Mixed parts in box                | Reference error                 | B          |                 | 100% automatic SIP MECA (in compliance with Data Matrix post 1) |                                     |
| Impossibility to read serial number from sticker label | Duplicate sticker labels | B          |                 | Banning key removing labels manually |                                     |
| Reference error Galia             | Reference error                 | B          |                 | Zipping stickers 100%                        |                                     |

All proposed corrective actions aim to ensure a global quality assurance level of 94%. Applying these control measures as a result of QAM analysis did not ensure the protection of customers against the appearance of very embarrassing failures (B). After the start of production and delivery of parts to the customer there was a complaint from a customer who found labelling with the same series of two delivered axles.

Following the QAM analysis, the proposed measures for failure modes with impact on labelling were: 100% automatic SIP MECA (in compliance with Data Matrix post 1), banning key removing labels manually and zipping stickers 100%.

Since the compliant labelling measures initiated following the QAM analysis did not eliminate the possibility of this failure, it moved on to the use of the QC Story method which allows detailed analysis of all the potential causes of a failure and the establishment of corrective and preventive measures.

4. QC Story application

The steps of the QC Story methodology involve the following:

Step 1: Choosing the subject. Removing the failure: Edison axle double labelling, appeared on week 27 at the Hambach customer two axles reference 591R labelled with the same serial number, zero.

Step 2: Explaining the reasons of the choice. Given the company’s quality policy by applying the QC Story method it is aimed to:

1. Eliminate the risk of the emergence of this failure at other customers.
2. Treat the problem quickly; deadline to solve the problem Week 28;
3. Reduce the costs generated by solving quality problems.

Step 3: Understanding the current situation. The current situation shown in table 5.

Step 4: Choosing the targets (objectives). Given the company’s quality policy it was established that the goal of solving the problem would be Week 28.
Table 5. Current situation.

**Personnel**

a. The operator did not respect the Standard Operations Sheet – SOP (took the piece off the presser).
b. The operator did not respect the Standard Operations Sheet (scanned the sticker label of the axle in box and not on the working device).

d. There is no the Standard Operations Sheet roll labels and ribbon change.
d. There is no traceability for the last record and the first series after roll or ribbon change.
e. It is not mentioned in instruction sheet to clean the printer head.
f. Lack of key point in the Standard Operations Sheet (forbidden to apply sticker label with the same serial number on two different axles).
g. Lack of key point in the Standard Operations Sheet (forbidden to unload the part from the presser without the sticker label stuck and scanned).

**Method**

a. The operator did not respect the Standard Operations Sheet – SOP (took the piece off the presser).
b. The operator did not respect the Standard Operations Sheet (scanned the sticker label of the axle in box and not on the working device).

c. There is no the Standard Operations Sheet roll labels and ribbon change.
d. There is no traceability for the last record and the first series after roll or ribbon change.
e. It is not mentioned in instruction sheet to clean the printer head.
f. Lack of key point in the Standard Operations Sheet (forbidden to apply sticker label with the same serial number on two different axles).
g. Lack of key point in the Standard Operations Sheet (forbidden to unload the part from the presser without the sticker label stuck and scanned).

**Means**

i. Printer (allows editing multiple labels with the same serial number).
j. Printer edits (illegible labels).

**Management**

k. Team leader did not explain to the operators what unitary traceability means and what role this traceability has.

**Step 5: Analysis.** The Ishikawa diagram has been used in order to establish the precise causes that led to the nonconformity, shown in figure 1.

![Ishikawa Diagram](image)

**Figure 1.** Ishikawa diagram for: double labelling with the same serial number on two different Edison axles.
**Step 6:** Applying corrective actions. The corrective actions and their efficiency – quality, cost and deadline are shown in table 6.

| No | Problems                                                                 | Action                                                                                                                                                                                                 | Efficiency | Responsible | Deadline |
|----|---------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|-------------|----------|
| A  | Printer allows editing several labels with the same serial number         | Blocking operator access to re-edit labels                                                                                                                                                           | 9          | 6           | 6        | 324      | Resp.1  | W 28     |
| B  | Standard Operations Sheet incomplete                                      | Introducing key point in the Standard Operations Sheet (forbidden to unload the part before applying the sticker label on the axle and scanning it) Introducing key point in the Standard Operations Sheet (forbidden to apply a label with the same serial number on two different axles) Introducing key point in the Standard Operations Sheet (after scanning the label visualize the torch screen and make sure it is recorded) Using it for the pressing articulation connecting rod post too | 6          | 6           | 6        | 216      | Resp.2  | W 28     |
| C  | Lack of the Standard Operations Sheet ribbon and sticker label change     | Editing the Standard Operations Sheet ribbon change, sticker label and using on all posts                                                                                                                                                         | 6          | 6           | 6        | 216      | Resp.3  | W 28     |
| D  | Lack of the Standard Operations Sheet printer head cleaning               | Editing the Standard Operations Sheet printer head cleaning and using on all posts                                                                                                                                                                   | 6          | 6           | 3        | 54       | Resp.4  | W 28     |
| E  | Insufficiently trained operator                                           | Training operator in three stages after the Standard Operations Sheet modified analysis, ribbon change, printer head cleaning                                                                                                                                  | 6          | 6           | 3        | 54       | Resp.5  | W 28     |
| F  | Team leader did not train operators on unitary traceability               | Training operators on unitary traceability                                                                                                                                                         | 6          | 6           | 3        | 54       | Resp.6  | W 28     |
| G  | Lack of action printer head cleaning                                      | Introducing action in the instruction sheet and using it for all printer-equipped posts                                                                                                                                                                   | 6          | 6           | 3        | 54       | Resp.7  | W 28     |

Q = 9 – high quality; Q = 6 medium quality; Q = 3 minimum quality
C = 9 – high costs; C = 6 medium costs; C = 3 minimum costs
D = 9 – time > 5 days; D = 6 - 3 < time < 5 days; D = 3 – time <3 days
Step 7: Confirming the effects
In order to achieve this step the current situation is compared with the initial conditions, using graphs, Pareto diagram, figure 2.

![Figure 2. The number of cases occurred in workstation.](image)

Step 8: Standardization
To avoid other similar cases the following standardizing actions were established:
1. Editing the Standard Operations Sheet and ribbon and sticker labels change.
2. Editing the Standard Operations Sheet and printer head cleaning.
3. Introducing in instruction sheet printer head cleaning.
4. Introducing key point in the Standard Operations Sheet (forbidden to unload the part before applying sticker labels on the axle and scanning it).
5. Introducing key point in the Standard Operations Sheet (forbidden to apply a label with the same serial number on two different axles).
6. Introducing key point in the Standard Operations Sheet (after scanning visualize the torch screen and make sure it is registered).

5. Conclusion
By applying the QC Story method, ten additional corrective measures have been established and implemented in relation to the control plan that emerged as a result of the QAM method, which led to the elimination of the failure: labelling with the same series two delivered axles.

The conclusion of this study confirms the complementarity of the two methods and the need for their separate application. QAM is applied in the process preparation stage and allows the identification of failure modes on the manufacturing flow and the parameters that influence these failure modes. The quantification of the impact of these failures on the customer allows establishing the type of control to ensure the delivery of compliant parts after each operation of the manufacturing stream. These control measures include frequency control for low-impact (embarrassing) failures on the customer up to a 100% automatic control or Poka Yoke system for major impact failures that prevent the operator from making mistakes (to perform a non-compliant operation).

By applying the QC Story method as a result of a failure with a serious impact on the customer, there was identified a series of seven nonconformities that could generate the failure: labelling with the same series two delivered axles, there were established nine corrective measures which were implemented to eliminate the possibility of occurrence of this failure. As well, the corrective actions (documentation preparation) were standardized in order to avoid the occurrence of failures.

In the situation of implementing of a new products line in a company from automotive industry, taking in consideration decorative parts, is necessary a good correlation between Quality Assurance Matrix and QC Story methods.

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