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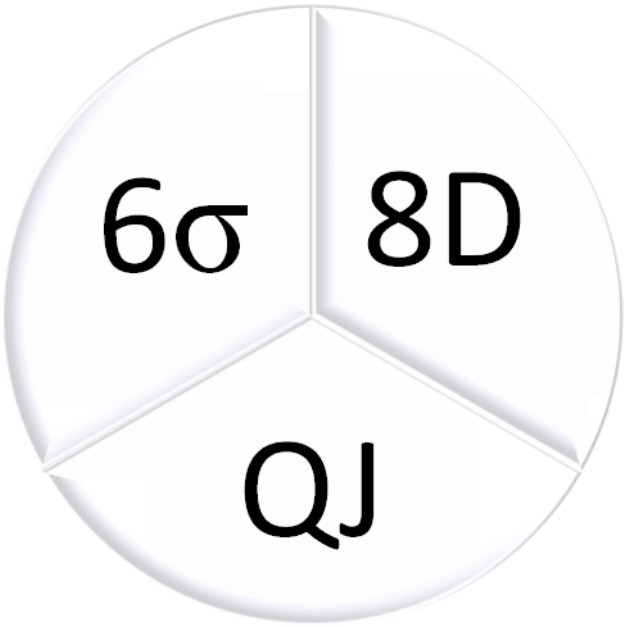

Assessment and improvement of Volvo Powertrain's problem solving process "Quality Journal" vs. "Six Sigma"

Master of Science Thesis in the Master Degree Programme,
Civil Engineering

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Abstract

Volvo Powertrain has a problem solving process called the QJ-process, which is based on the 8D framework. If quality issues occur that are severe or urgent enough, a problem-solving project is initiated, the QJ-process is due to this very important for Volvo Powertrain. This thesis is made to investigate Volvo Powertrains current procedure on solving problems, identify best practice and identify areas of improvement.

The thesis is also made to compare the QJ-process with Six Sigma's DMAIC framework, to distinguish differences and similarities between them, finding out if parts of the DMAIC framework are applicable to use in the process.

Interviews and observations have been made in order to identify Volvo Powertrain's current procedure. A comparative analysis has then been made in order to distinguish differences and similarities between the QJ-process, the 8D framework and Six Sigma's DMAIC framework. Key areas of interest have then been identified and a SWOT-analysis has been performed.

The 8D framework, which the QJ-process is built on, is more suitable for the problems that the QJs are intended for than the DMAIC framework. The current QJ-process could be improved by adopting some of the parts from the original 8D framework in a better way. There are methods used in the DMAIC framework, which are suitable in some QJ cases. The QJ-process should use statistics to a greater extent and could gain by increasing the statistical knowledge level in the QJ-teams. The QJ-process could also improve by being more transparent and traceable, this in combination with always performing thoroughly made root-cause analysis.

Keywords: 8D, 8 Disciplines, Six Sigma, DMAIC, problem solving, root-cause analysis, RCA.

Table of content

Abbreviations

8D	8 Disciplines
ANOVA	Analysis Of Variance
ANOM	Analysis of means
BP-team	Business package team
CM	Case Manager
DCN	Design Change Notice
DD	Design Decision
DMAIC	Define Measure Analyze Implement Control
DPMO	Defects per Million Opportunity
FMEA	Failure Mode and Effects Analysis
FTA	Fault Tree analysis
GCMM	Global Case Manager Meeting
KPI	Key Performance Index
MQR	Market Quality Report
PD	Product Development
PME	Project Manager Engineer
PMQJ	Project Manager Quality Journal
QJ	Quality Journal
RCA	Root-cause Analysis
SWOT	Strength, Weaknesses Opportunities and Threats
VMEA	Variation Mode and Effects Analysis
VPT	Volvo Power Train
CTQ	Critical to Quality

1 Introduction

Background

Volvo Powertrain (VPT) is a company within the Volvo Group, which is responsible to develop, produce and maintain heavy engines, transmissions and axels at customers. Quality and customer satisfaction (QCS) within VPT has the responsibility to address all issues and problems that arise. If faults are accruing that might jeopardize safety or if a bad trend on quality can be seen, a problem-solving project is initiated.

These problem-solving projects are called Quality Journals (QJs). The QJs are being carried out by a cross-functional team, which follows a defined process solving these issues. VPT is a more global organization today than it was before and this has affected the QJ process as well, since the problems and solutions have become of a more global and complex nature. In order to work cross functional and global it is important that the QJ process has procedures that are similar so that employees from different countries can work together and are familiar with the same methods. The QJ-process is partly built on the 8D framework, which is a team-oriented problem solving method, initiated by Ford Motor Company in the early 90's.

Purpose

VPT wants to solve their quality issues as fast as possible, but still with a high accuracy in order to keep the customers satisfied. Volvo Powertrain wants to find out how they best should work in their problem solving process, to achieve both high-quality solutions and customer satisfaction. In order to achieve this, it is important to evaluate their current way of working, find best practice and identify areas of improvement, which is investigated in this thesis. The thesis is also comparing the QJ-process to Six Sigma's DMAIC framework, distinguishing differences and similarities between the two frameworks, in order to find out if some part of the DMAIC framework is applicable to use in the process.

2 Theoretical Framework

The theoretical framework will give a basic understanding of the topics addressed in this report. The difference between vertical and horizontal systems will first be explained, in order to give the reader a better understanding of the systems that usually exist within large organizations and the difference between them. Volvo Powertrain's problem solving process, the QJ-process, is in this thesis compared to Six Sigma's DMAIC framework, which is why the DMAIC framework also is comprehended in this chapter. The original 8D framework will also be described in this chapter because the QJ-process is, as stated in the introduction, partly built on it. How this theory was used will be further explained the methodology, chapter 3.

2.1 Horizontal and Vertical systems

In organizations there is need for two types of systems, horizontal and vertical systems. "Horizontal systems spread a single effective idea across the whole organization. Vertical systems use many proven tools in the most effective sequence to visualize and solve a specific problem" (Bajaria, H. J., 1998). One example of a horizontal system is ISO 9000. Examples of vertical systems are the 8D framework and the DMAIC framework (Velury, J., 2004).

The two systems can be illustrated by an example of using control charting. A company wants to control its processes and therefore decides to apply control charting throughout all processes, this implementation is an example of a horizontal system. Control charting used in a vertical system could instead be used in order to define a problem. In both Six Sigma's DMAIC and 8D, control charting can be used as one part of the vertical system in order for instance to define a problem. The vertical and horizontal systems work most effectively in coherence with each other. (Bajaria, H. J., 1998)

The only difference is that in order for a DMAIC project to be as successful as possible and fit the DMAIC framework, the project should concern clearly identified critical-to-quality-characteristics and "have ongoing measurement and monitoring of the critical-to quality-characteristics" (Bergman , B., et al. 2003), which implies the use of existing horizontal systems.

In an article by Bajaria (1998) the importance of having both horizontal and vertical systems in an organization is discussed. The horizontal systems are needed to be able to control and continuously improve the processes and products. The vertical systems are needed in order to be able to perform effective problem solving. The vertical systems are quickly adoptable and through those, the creation of new horizontal systems can be created, i.e. by finding new critical-to-quality factors, which needs to be monitored. The existing horizontal systems in an

organization can make the vertical problem solving systems more effective by providing them with necessary data for problems that arise ad hoc. (Bajaria, H. J., 1998)

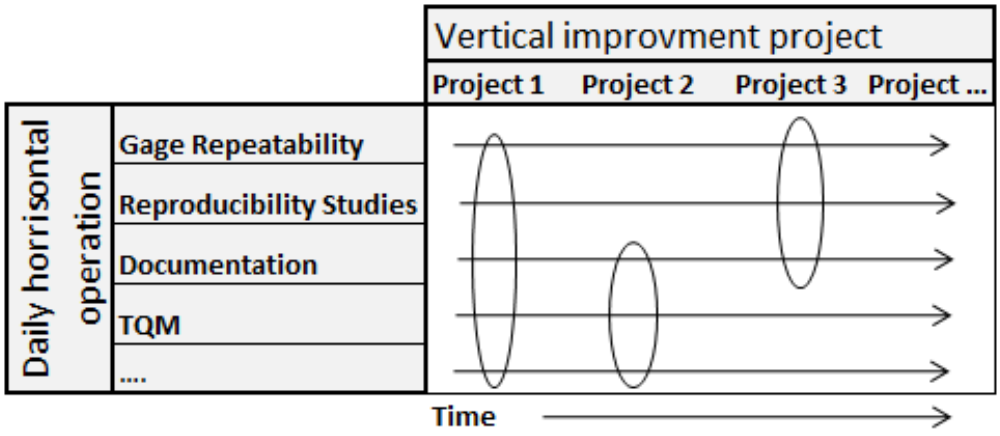

Figure 1: vertical and horizontal systems in correlation

To achieve high quality results an organization needs to have supporting systems that are contributing to that result. These systems cannot be seen, the only thing that can be seen is the results of them.

Velury (2004) stresses the importance of having of both vertical and horizontal systems in order to be competitive on a global market. In his article, Velury (2004) explains quality as an iceberg, where the tip of the iceberg represents the results from quality systems, the result is the only thing that can bee seen. Neither the horizontal nor the vertical systems are above the water level and cannot be seen, only the results of them, *see Figure 2* (Velury, J., 2004). Unfortunately many companies today lack vertical systems and tend to focus mainly on horizontal systems, which inhibit their ability to perform vertical tasks, such as problem solving (Bajaria, H. J., 1998).

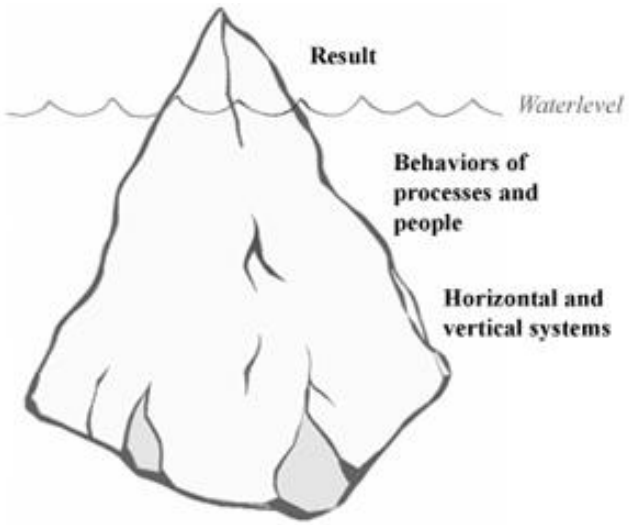

Figure 2: Iceberg (Velury, J., 2007)

2.2 Six Sigma's DMAIC framework

Six Sigma is a framework that was created by Motorola in the 1980's. Six Sigma is a systematic approach in order to reduce defects in an organization's processes, products and services, through the use of analytical and statistical methods. Six Sigma is also growing to become a business strategy that focuses on improving business productivity, financial performance and the understanding of customer requirements (Kwak, Y. H. and Anbari, F. T., 2006, see Tjahjono, B., et al., 2010).

Six Sigma is an improvement initiative that needs senior management commitment, this is regardless of in what scope or at what level in the company it is launched. It is a strategic decision and the success of the initiative highly depends on the senior management's ability to provide its long-term commitment. The commitment by all stakeholders that are affected by the Six Sigma initiative is of course also important in order to successfully implement it. It requires a mindset, with a customer focus, statistical thinking and knowledge. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

In order to involve employees one key element is to, at all levels, give them roles and responsibilities. A common approach to assign these roles, adapted by many companies, is to rank employees by the martial art, "belt rank system", based on their knowledge and responsibilities within the framework and company. The competence and knowledge needed for these roles is of course not gained over night, it takes a lot of time, training and education. The roles and responsibilities within the "belt rank system" is according to Bergman, et al. (2003):

- **Champion** – Member of senior management team – *Driver and advocator*
- **Master Black Belt** – Full-time breakthrough expert – *Trainer and coach*
- **Black Belt** – Full-time improvement expert – *Project manager and specialist*
- **Green Belt** – Middle management, supervisor –*Project manager and team member*
- **White Belt** – Operators, front-line staff –*Team member*
  (Bergman, B., Korslid, D. and Magnusson, K., 2003)

One common approach when using the Six Sigma methodology is to use the DMAIC structure, which contains the following phases; Define, Measure, Analyze, Improve and Control, which later will be explained according to Bergman, et al. (2003).

2.2.1 Define

1. Generate projects to be improved and prioritize them

To be able to start a Six Sigma DMAIC project, possible improvement opportunities have to be localized within the organization. There are different ways to find information in order to

generate projects but according to Bergman, et al. (2003) there are different sources of information; from systems that continuously measure changes in critical-to-quality-characteristics, suggestions from Green Belts or Black Belts, supplier problems, from a suggestion system, or through customer complaints. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

According to Banuelas, R., et al. (2006) the Six Sigma projects are opened based on the voice of their customers, but many new Six Sigma project arise from other ongoing Six Sigma projects. From the survey made by Banuelas, et al. (2006) companies were asked which tools or methods they use to identify potential Six Sigma projects. The most common method were Brainstorming, other popular tools used were, CTQ (Critical-to-quality) tree, focus groups, interviews, customer visits, QFD, Kano model and surveys (Banuelas, R., Tennant, C., Tuersley, I. and Tang, S., 2006).

In order for the project to be suitable for the DMAIC framework and be successful, the environment of the process, which is the target of the project, should be transparent, developed and structured according to Bergman, et al. (2003)

Four criterions are specifically mentioned:

- The ownership and goal of the process should be clearly defined.
- The process should be mapped to an appropriate level of detail.
- The CTQs should be clearly defined.
- The CTQs should already be measured and monitored continuously.
  (Bergman, B., Korslid, D. and Magnusson, K., 2003)

After generating potential projects they need to be prioritized. This can also be done in different ways, but to base decisions on facts is something that is advocated in the DMAIC methodology. To choose projects on a hunch is therefore not a recommended way of selecting projects, it is instead of importance to use appropriate tools and routines. The projects can be evaluated in different criterions and then weighted against each other. Typical criteria to consider are according to Bergman, et al. (2003):

- Process performance
- Cost saving potential
- Impact on customer satisfaction
- Technical complexity
- Organizational Complexity
- Availability of human resources
  (Bergman, B., Korslid, D. and Magnusson, K., 2003)

In order to prioritize between projects it can be good to create an evaluation scorecard or to make an affinity-diagram to systematically choose the right project.

2. Develop project and team character

Every project is of different nature, it is because of that important to formalize the team and the project, by allocating resources, and ensure that everything and everyone that are needed is included in the project. According to Bergman, et al. (2003) this is often done by creating a project and team charter, where the; business case, problem formulation, the project scope, team members, roles, project plan and project tollgates are written down.

It is important that everyone who is included has the same understanding of the project, the scope and the problem before going further. It enables a focus within the team when striving towards the same goal. It is important to have a rather detailed project plan with activities and tollgates. Having deliverables connected to all the phases within the project is also important, these should all be accepted by senior management before proceeding. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

3. Identify the outcome to be improved

Six Sigma has another important step in the define phase, which is to define the output of the process, which needs to be improved. Six Sigma describes the output of the process as *y*. The output should be the characteristic or characteristics that are critical-to-quality (CTQ) and should be the focus of improvement. The CTQ charactaristics need to be identified before going further with the investigation. It is also important that the team fully understands the customer requirements connected to each characteristic. Especially what the customer defines as a defect. On several occasions a customer can experience a defect, but the product might

not be broken. The customers can as an example perceive a non-familiar sound from an engine as a defect, but the engine might be perfect. This is why an understanding of these characteristics is important in an early stage of the project. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

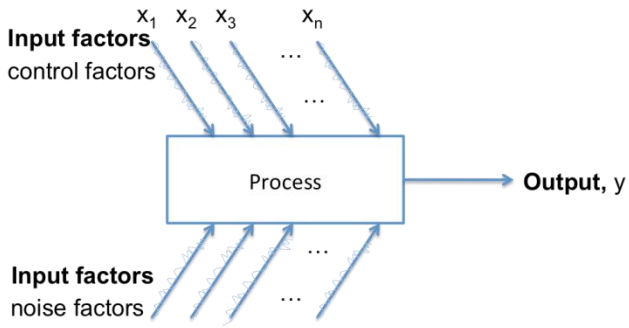

Figure 3: Process Input and Output, by (Bergman, B., Korslid, D. and Magnusson, K., 2003)

The process is influenced by input factors. The input consists of two different kinds of factors, the control factors that are described as *x*s and the noise factors. These factors are explained more thoroughly in the measure phase of the Six Sigma process, were they should be identified. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

4. Determine performance/map process

It is also important to assure that the group shares a common understanding of the process and to know the current performance of *y* before continuing to the measure phase. It is important to be aware of the current performance to be able to evaluate the project afterwards, to determine if and by how much it has improved. An effective way of getting the current performance of a process is to perform a capability analysis. In order to get a common understanding of the process a process map can be made. This should include not only activities but also what the input and output of every activity is, which can be good in order to communicate through the organization. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

2.2.2 Measure

5. For each output, indentify input signals

In the measure phase it is important to identify input factors that could possibly affect output, this procedure should be done for each of the outputs identified. The input factors are as explained earlier consisting of control factors and noise factors. The control factors affect the process and can be controlled physically. The noise factors on the other hand are the factors that; cannot be controlled, are too costly to control, or are not desirable to control. These noise factors are important to be aware of even though they are considered uncontrollable in order to achieve a robust product or process. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

A good way in order to visualize and generate input factors are to make a cause-effect diagram or an Ishikawa diagram for each output, *y*. To make a cause-effect diagram also enables a focus within the team. To first identify as many *x*s as possible and then prioritize the most important ones is the best way to perform this. After generating potential causes they should be broken down into lower level causes or sub-causes, this to be able to get an even more detailed picture. The causes, sub-causes and sub-sub-causes then indicate different levels of detail. It is important to identify if the factors are control factors or noise factors and check so that they are in the same level of detail, usually, the more detailed level the better. It is often good to break the causes down until they are measurable. Measuring them is recommended in order to be able to verify the cause or causes that are believed to be the root-cause or root-causes of the problem. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

6. Develop measurement plan

To be able to measure the right thing a measurement plan has to be established. It should contain which factors that should be measured and how to measure them. It is important to consider the sample size of each test, the measurement intervals and the duration of each test. To design how to perform the measurements is also of importance. In which order they should be measured and to ensure that enough data is collected in order to get a significant result and at the same time demand as little resources as possible. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

Bergman, et al. (2003) writes that a rule of thumb is to have at least 30 observations when the *y* and *x*s are of continues characteristics and at least 300 observations when they are discreet numbers in order get a significant result. In order to make the results useful the input and output has to be recorded simultaneously in order to see how they correspond. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

7. Data collection of input- and output-signals

This step is to ensure that data is recorded according to the measurement. It is important to document how the measurements are performed, to detect when the measurement is not performed according to the plan, to be able interpret the result of it in the right way. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

2.2.3 Analyze

8. Get to know the output based on the new data

When the measurements have been performed it is time to get to know the output better based on the results of them. Firstly understanding how the output works by looking into the size and variation of it. The distribution of the output is of importance, because if statistics models should be used, there is a significant difference between normal-, weibull- and exponential distribution. If a lot of data has been collected it can be checked if the data represents a normal distribution with a Normal probability plot. In the plot deviations can also be detected, which can be due to special cause variation or that the data does not represent a Normal distribution. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

It is important that the performance of the output (y) is examined, this in order to check if the process is capable. The performance can be examined through a capability analysis. Capability Analysis is a method used to analyze the capability of a process by comparing the output of an in-control process to the specification limits through the use of capability indices. The important issue here is that the process should be in-control. The analysis is built on comparing the common cause variation with its specification limits, in order to analyze how well it is meeting the specifications. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

It is also important to check if the output (y) is predictable in performance. Applying control charts is one of the best ways in order to look at the predictability. The control charts are best used in pairs, one for variance and one for the location (mean). These are often done by carefully using samples from the process in intervals, which should be selected differently depending on what type of process that is examined. The most common charts used for sampling is the X-bar chart for location, the s chart for sample standard deviation and R chart for variation. These charts can be used to detect if a process is unpredictable. To understand the sources of variation is important in order to be able to improve a process. The part-to-part variation could be due to many reasons. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

Before taking actions the measurement error and variation is important to look at and understand, this can be done by performing a gage R&R. The repeatability, variation due to measurement the measuring device, and the reproducibility, variation due to the measurement system, is two types of variations that are quantified through a gage R&R study. The measurement variation is something that has to be small in order to be able to continue with the project. A rule of thumb is that the variation due to measurement system error has to be less than 10 % of the total variation in Six Sigma projects to be neglected. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

9. Identify input signals that influence the output signal

If the process is unpredictable the cause or causes of this need to be addressed first through a logical improvement action. If the process is predictable and the measurement error is small, the data gathered from measurements can be used in order to find out which of the *x*s influence the *y*. In order to identify which factors influence the output, a number of tools can be used, these are some examples of both graphical and numerical, which Bergman, et al. (2003) thinks are very useful:

- Pareto chart or pie chart
- Cause-effect diagram
- Tree diagram
- Stratification
- Relationship chart
- Correlation analysis
- Regression analysis
- Analysis of means (ANOM) and analysis of variance (ANOVA)
- Factorial experiment
- Standardization
- Waste analysis
- Variation mode effect analysis (VMEA)

Another set of tools, which are useful in order to detect areas of improvement are according to Bergman, et al. (2003) the seven lean tools. If no influencing factors can be identified among the *x*s that has been measured, the project goes back to the measure phase in order to generate more and look deeper into possible causes and factors. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

10. Establish improvement targets

Once influencing factors has been identified the improvement targets can be set. Improvements can be made in three different ways according to Bergman, et al. (2003), "by gaining predictability, reducing variation and/or improving location (mean)." What method to apply or prioritize first is depending on what has been found through the measurement analysis. If the process is found to be unpredictable in the previous step, best way to start achieving process improvement is by gaining predictability eliminating or reducing the special causes' influence on *y*. If their influence is on location or variance on a predictable process, it has to be considered whether both variance and location needs to be improved or just one of them. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

2.2.4 Improve

With the knowledge gained through the other steps, it is in this phase time to implement a solution or solutions and get a sustainable result. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

11. Design solution(s)

The target here is to indentify one or more ways to improve the performance with the knowledge gained about the *x*s and *y*. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

12. Cost/benefit analysis

As a second step the solution or solutions should be evaluated in the terms of costs and benefits. If many solutions are generated from the prior step they could also be compared. The cost/benefit analysis is done by identifying direct costs associated with the solution and costs associated with project. The cost savings included should only be direct ones, which is the actual contributions, not speculations. A best-, most likely- and worst-case scenario could also be made. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

13. Implement best solution

In this phase the implementation should be carried out based on the cost/benefit analysis. An important thing here is to make and stick to an implementation plan. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

2.2.5 Control

14. Verify the planned improvements in the output

In this phase the result of the implementation is going to be verified. The output (*y*) is monitored in order to make sure that the target has been achieved. It can although take a while before the process has stabilized. The output should be predictable before the mean and standard deviation can be calculated. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

15. Estimate the cost saving

When the output has become predictable it is time to estimate the actual saving. This can be done in various ways, including or excluding indirect costs and benefits. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

16. Institutionalize and document

This is a very important step, where the result should be institutionalized; this can include new or updated drawings of the product, updating process procedures etc. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

17. Communicate and visualize

The result from the project also needs to be communicated and visualized to all involved parties. Information about the project and result should be distributed and shared throughout the organization, gained experiences should also be included. This should preferably be done by an internal system in the company, where the main findings from all DMAIC projects should be found. (Bergman, B., Korslid, D. and Magnusson, K., 2003)

In the DMAIC framework there is although more descriptions over applicable methods and tools used to continuously monitor the improved output. Then again the DMAIC framework are adapted to fit measurable problems.

2.3 The 8D framework

2.3.1 Background of 8D

The 8D framework has historical roots back in the MIL-STD 1520 “Corrective Action and Disposition System for Nonconforming Material” quality standard used by the US military. It was introduced in 1974 and used by the military suppliers until 1995. The main goal was to indentify errors, make root cause analysis, limitation of waste, prevent reoccurrence, cost reduction and raise the quality in general (Behrens, B. -A., Wilde, I. and Hoffmann, M., 2007). Based on what the military had done, the Ford Motor Company developed “team oriented problem solving” (TOPS), also called 8D (8 Disciplines), to enhance their problem solving processes. TOPS 8D was also campaigned by Ford to their suppliers (N N, 1992 see Behrens, B. -A., Wilde, I. and Hoffmann, M., 2007)

Ford later introduced their 8D framework to Motorola in 1989, and required that Motorola used it to resolve all problems involving Ford products (Whitfield, R. C. and Kwok, K. -M., 1996). The 8D framework was later adopted by especially the automotive industry in order to solve problems (Punnakitikashem, P., Somsuk, N., McLean, M. W. and Laosirihongthong, T., 2010).

2.3.2 What is 8D

Team Oriented Problem Solving (8D) is a multi-disciplined approached that has integrated the traditional approach with structures for supporting and enhancing teamwork. One major part of the 8D methodology is concerning how the team should work in order to get a good result. What mindset the team members should have and what key ingredients that is required in order to perform well as a team. (Connolly, C., 1992) The 8D can also be described as a problem solving methodology similar to Six Sigma. It incorporates the whole scope of problem management, such as; mapping the problem, root cause analysis, problem correction and robust design (Quality-One International, 2009-2011). When companies decide to use 8D in their processes it is common that they adopt the framework differently to fit their processes better (Behrens, B. -A., Wilde, I. and Hoffmann, M., 2007).

In the 8D framework working in cross-functional teams is emphasized as very important. The methods used often make the awareness of the team members higher, which often results in that they gain a deeper understanding and have eye-opening revelations. The approach used in the 8D framework often provides a detailed awareness about problems and long-lasting solutions. (Ehie, I. C. and Sawhney, R., 2006)

> *"Whereas Six Sigma focuses on data and process variables, the 8D-TOPS uses cross-functional teams, looks for root causes, and implements and test permanent corrections or improvements."* (Ehie, I. C. and Sawhney, R., 2006)

2.3.3 The 8 Disciplines

The 8D framework comprises Eight Disciplines (steps), which are described according to Whitfield and Kwok (1996) as follows:

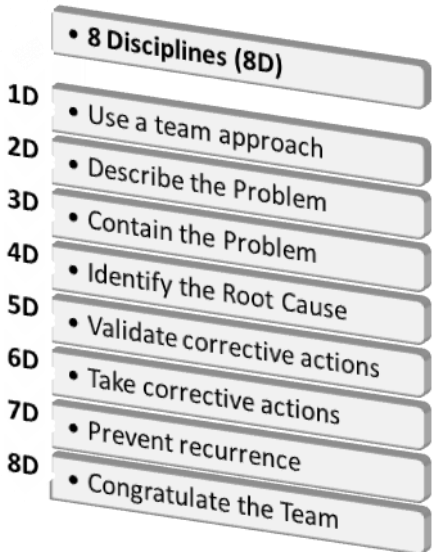

Figure 4: The eight steps in 8D

2.3.3.1 1D – Use a team approach

In this step the team is established, it is important that the team is cross-functional. The persons selected should have key competence connected to the problem and be from different areas of expertise. They should also have enough authority in order to make the project a success. The team should also be well defined and have continuous meetings until the problem is resolved.

2.3.3.2 2D – Describe the Problem

In is in this phase important to understand and map the problem. The problem can be characterized by 5W2H (Who, What, When, Where, Why, How and How many), in order to describe it in quantitative terms. "The problem should be defined in terms of *whose* product is affected, *what* is wrong with it, *when* the problem arose, *where* the problem occurs, *why* it is a problem, *how* do you measure the defects, and *how many* units are defective". (Whitfield, R. C. and Kwok, K. -M., 1996) The team should look into historical data to find reasons behind the failure and to why the problem exists, in order to resolve it.

2.3.3.3 3D – Contain the Problem

In order to prevent the problem from getting bigger or spreading, preliminary actions have to be taken. When "containing the problem" it is important to find affected areas quickly, to minimize the impact that may cause on the market or in production. Depending on what the problem may cause, the actions required are of different proportions. In some cases a containment action could be to only inform the customers, but in other cases it might be necessary to stop the production and to recall all products on the market.

2.3.3.4 4D – Identify the Root Cause

In this step potential root-causes to the problem should be generated, structured and prioritized for further investigation. A structured brainstorming session should be held with the support of applicable tools such as Ishikawa, fishbone or cause and effect diagrams. The Nominal Group Technique is one applicable method in order to perform constructive session. It is essential to separate solution thinking from this phase and to look deeper than symptoms to be able to later address the problem in the right way. The potential causes are in the end prioritized for further investigation.

2.3.3.5 5D – Validate corrective actions

The potential main causes are in this phase being investigated and verified. Potential solutions are also being generated for each cause. The corrective actions generated for each cause should then be evaluated, to make sure that the solutions solves the problems without causing new problems. It is an advantage to have multiple solutions that can be compared, since some of them might not work or are causing new problems.

2.3.3.6 6D – Take corrective actions

In this step the aim is to implement the actions that were chosen in the previous step. The team should develop an implementation strategy, so that it is clear what is going to change and who is responsible.

2.3.3.7 7D – Prevent recurrence

It is important to monitor the problem afterwards to detect any possible re-occurrence of the problem. It is also important to evaluate the implementation, ensuring that the corrective actions are solving the root cause without causing new problems.

2.3.3.8 8D – Congratulate the Team

Once the problem is successfully resolved it is important to distinguish what the team has accomplished and give them credit for their collective efforts.

2.4 The QJ process

The QJ process is a process within Volvo Powertrain and is applied to solve Market Quality Problems (MQRs). It should be applied when there is an urgency or severity that motivates one of the following:

- To meet Fault-, Breakdown- and Unplanned stop frequency.
- To meet Warranty cost target
- Problem related to Safety
- Non conformity to legal requirements
- Red card opened
- External campaigns recommended

The QJ process is constructed to identify, solve, implement and follow-up solutions on product quality problem that occur on current application at the market. A QJ could be opened based either on problem reported by the market or problems found internally. The process is based on the 8D framework, but it is optional to use the 8D methodology and milestones within a QJ project. The QJ has to follow a defined process and go through their QJ milestones, which are:

DRAFT: An identified quality issue is documented in Argus, but has not yet been identified and qualified as a QJ

NEW: New is the status the QJ get when it has been qualified as a quality problem.

KOFF: Kick off is when the first meeting is held with the QJ team and the investigate phase starts with identification and verification of the root cause.

DEC: Corrective action decision is based on result from previous steps and is the gate when the change proposal is approved and status plan is frozen. Completion of the proposed solution can start.

REL: The final development is released and Design Change Notices (DCNs) are documented for both production and aftermarket.

SUP: Is when the supplies are ready to deliver the necessary parts needed for the change.

SPS: When the serial production start and when the breakpoint numbers has to be released.

MP: Market is prepared and ready to implement the change, the parts have to be available in warehouses and the deliverables has to be updated with instructions and guided diagnostics.

MR: Market Ready is when the solution is implemented in production and aftermarket. The documentation also has to be fulfilled according to standard.

END: The QJ is completed and archived.

CLO: The QJ is closed with no further action, just due to a proper reason.

2.4.1 Identify New QJ

2.4.1.1 Open Draft QJ

When a Case Manager (CM) has indentified a potential quality issue, he or she should check if the problem could be connected to any existing QJ. If an issue cannot be connected to an existing QJ, the next question is, if the issue is applicable for the QJ process, since there are other processes used to solve quality problems. If the issue is not severe or urgent enough, the issue should not be solved within the QJ-process. During this phase a ‘draft QJ’ should be registered in the QJ tracking system Argus under ‘Describe Problem phase’.

2.4.1.2 Initial Analysis

Initial information concerning the quality issue should be collected in order to get a better understanding what the problem is about. In initial analysis contact should be held with both supplier, manufacturing and responsible engineer, to make a prediction of the fault frequency and damages already made. The information should be used to decide if the QJ should be opened or not. In order for the quality issue to be a suitable QJ problem, there are some criteria’s, which need to be fulfilled.

2.4.2 Open New QJ

2.4.2.1 Open QJ Decision

After the initial analysis has been done, it should be decided if the quality issue should be opened as a QJ or put on hold to get more information about the issue. The decision to open a QJ should come from a Case Manager who has informed the Global CM Meeting (GCMM) about the problem, so that all affected platforms and business areas could be identified. The GCMM should come up with a proposal for leading site and guidelines for which sites that should only monitor the results of the QJ, since they also are affected of the quality issue. The sites monitoring the QJ, opens a so called following QJ.

If the CM decides that the quality problem is not qualified as a QJ, then the problem should be put on hold in order to get more data available or be solved within one of the other processes; Protus, QPMR or QSP that Volvo uses.

2.4.2.2 Prepare QJ-Kickoff

When the CM has decided to open the QJ, contact with CPM Maintenance has to be established in order to finish the QJ Checklist. People connected to the problem should be put together to create a QJ-team, with should be cross-functional and still have the right competences. To get the right people involved in the QJ-team is one of the most important factors to be successful. The team should also include PMQJs from the following QJs if there is any.

Purchasing should as soon as possible contact affected suppliers to ensure that they reserve time and knowledge about the affected part to help the QJ-team to make needed tests and verifications.

2.4.2.3 QJ-Kickoff

The PMQJ or CM is responsible to invite the QJ-team members and others stakeholders that needs to follow the progress of the QJ. At the Kick off, both the QJ-team and others that should be involved in the QJ, should be invited. The topics that should be presented at the Kickoff are; the case in general and the results from pre-investigation, claims, statistics and warranty cost, to better understand the scope of the problem.

It should be discussed if there are any possible containment actions, and if any campaigns should be launched in order lower the worst of the problems consequences. It is also time to inform the customer, as in the brand using Volvo Powertrain’s technology. In the kick off, how to perform further steps should also be

considered, such as how the root-cause analysis should be performed and what to do with the outcome it.

2.4.3 Containment actions

A containment action is an action that if implemented can solve the customers problems on a short time perspective while waiting for a long time solution. The containment action could be of a more expensive character than a long-term solution and focus to remove the symptom or just please the customers affected. To make the containment actions more effective and easy to implement, it is of importance to have a well-established connections with the production where it often is implemented.

2.4.4 Investigate QJ

2.4.4.1 Investigate Root Cause(s)

Investigating and understanding the root-cause(s) is one of the most important steps in order to get an effective solution. The PMQJ is responsible for making the root-cause analysis (RCA), but can also get a lot of support from the Quality department that is experts in making RCAs. The RCA should be started within 5 working days after the kickoff. The analysis should generate a list of possible root-causes for further investigation together with an action plan to follow-up the potential root-causes. The root-causes are often generated through a brainstorming session with the support of quality tools. The QJ checklist advocates using specific tools in order to make the investigation more effective, the suggested tools are; fishbone, Fault Tree Analysis and 5 Why.

2.4.4.2 Verify Root Cause(s)

To get a better understanding of the quality issue and the possible root-causes, a more thorough analyze has to be performed. In the analysis, verification tests are performed together with other ways to ensure that the possible causes are one of the root causes or not. It is also important to get the understanding of which root cause or root-causes that contributes the most to the problem, when there is more than one which it often is. The RCA has to be granted according to Volvos document in order to ensure a certain level of quality.

2.4.4.3 Investigate Solution(s)

To have the right understanding from previous steps are crucial to be able to develop a solution that can solve the issue. Since the lead-time of the project is crucial, this phase is often run in parallel to the verification of the root-causes to find a solution that is good enough as fast as possible.

When a potential solution(s) has been indentified a Product Change Request (PCR) should be performed. A review of the technical specifications for the problem areas is also made.

2.4.4.4 Prepare Corrective Action Decision

After possible solution(s) are found the focus should be to prepare the corrective action decision, which is the process where production and aftermarket solutions are developed. These solutions are evaluated through a Business Case to see if it is profitable or not. If multiple solutions exist, they can be compared through the Business Cases to see, which of them that are most profitable.

They should also test how the chosen solution fits in the production, check the assembly instruction and invest in tools needed to make the assembly. Other decisions, which has to be taken is, what should be done with old parts that are in the production and at the suppliers. Depending on the nature of the problem the existing parts could be used before changing to the new solution. If it is possible the parts could be reworked to the new solution, but in some cases the only possible solution might be to scrap them.

When the implementation time for a new solution is believed to be long, since new tools have to be made, temporary solutions could be implemented first. In some cases temporary solutions are implemented until the next generation of products, it might not be profitable to make large changes when a product generation is already on the market. To come up with a long-term solution for the next generation of products is then handed over to CPM maintenance, within continuous improvement.

To be able to go to the next gate all criteria within Market ready has to be fulfilled.

2.4.4.5 Corrective Action Decision

When all document and necessary decisions have been worked through a Corrective Action Decision meeting should be held by the PMQJ. It is up to the CM to accept the solution and the implementation of it, in the cases when it is not accepted they have to work through the solution again and then try to pass the corrective action decision in a new meeting.

2.4.4.6 Develop Campaign Decision Material

If it is recommended to launch any internal or external campaigns, the CM is responsible to prepare the campaign material. If there are any following QJs, campaign material for these should also be prepared, but to do this is up to the following QJ responsible.

2.4.5 Develop Solution

During this phase the final corrective actions are developed into the detailed aftermarket solution, where every uncertainty should be solved. All changes should be announced by a design change notice in order to give all the involved parties information concerning the changes and implementation.

2.4.5.1 Develop production solution

In this phase the new solution should be tested in the production, in order to discover how the solution is applicable in it. It is tested to see if changes have to be made to either the solution or the production. It is of importance to get both purchasing and production people involved, to avoid problems at a later stage, when starting the production.

2.4.5.2 Develop Aftermarket solution

It is up to the Aftermarket Responsible to make sure that the decided aftermarket solution is initiated to the aftermarket. Developing the aftermarket solution is done in close contact with the Parts Responsible Design-engineer and sometimes together with the concerned customer, when they are available. This step should also take care of when the solution is a part of a kit in order to update the mounting instruction and necessary tools for this kit.

2.4.5.3 DCN Governance (Design Change Notice)

It is necessary to have an approved Product Change Request from the DCN Governance to be able to release the Design Change Notice. The Product Change Request should be approved at the Corrective Action Decision or prior to this step. The focus of this step is to spread the Design Changes to everyone affected by it.

2.4.6 Implement Solution

2.4.6.1 Prepare Production

The aim with the preparation of production is to make sure that all supplies are able to deliver to the date that are set and that production have planned to make the change in production at the given time.

2.4.6.2 Implement Production

The implementation of production is when the actual change is implemented and it is important that the production responsible report the break point. The breakpoint is important in order to know which product that has the new and old solution.

2.4.6.3 Prepare Aftermarket

This phase is to prepare the aftermarket and ensure that there are spare parts available at the dealers, so that they can replace the affected part when it is needed.

2.4.6.4 Implement Aftermarket

The new solution cannot just be sent out on the aftermarket, it has to be prepared with new tools, instructions, and in some cases it is needed to educate the dealer to make the implementation less problematic.

2.4.6.5 Market Ready

When all the activities in Market Ready-criteria are fulfilled and implemented, the responsible CM could make the decision that the QJ is solved in a proper way. The QJ is then in the Market Ready phase.

2.4.7 Follow-up

At the Corrective Action meeting, a date should be set when the END phase should be verified by following up the effectiveness of the introduced solution. To be able to pass the follow-up phase and move into the next phase, the END Decision, the effectiveness has to be checked and the plan for doing this should be documented in the Argus system. It is the CM that is responsible for this phase.

2.4.7.1 Check effectiveness

The effectiveness is recommended to check six and twelve months after the Market ready decision. If the targets stated in the Corrective Action Decision not are reached, the CM should contact the customer to decide what further actions that is needed.

2.4.7.2 Inform concerned Process Manager

To prevent the problem from re-occurring the CM should identify which processes that caused the problem, document it in the system that handles problem areas, and inform the concerned Process Managers. The Process Managers should then define the root cause(s) that caused the issue, to be able to use the knowledge to later projects.

2.4.7.3 Check implementation of changes in process

To ensure that the Process manager(s) has considered the deviations reported by the CM, a QJ Auditor should together with the process manager review what measures that have been taken, to prevent the recurrence of the quality problem.

3 Methodology

In order to make a thorough analysis, different methods were used in this investigation. The different methods and why they were chosen will be explained in this section as well as the path of the investigation.

3.1 Path of investigation

The DMAIC framework is a well-documented theory based on best practice. To compare a theory against employee's perception of a process would not be fair. Employees tend to bring up negative aspects of a process rather than positive is one reason why this is not fair. In order to make the comparison between the QJ-process and the DMAIC framework fair, the DMAIC framework is first compared against the QJ-process at a steady state, as the QJ-process is defined. The comparison between them with the QJ-process at a steady state is in this report called *comparative analysis*. In order to detect areas of improvement and discover best practice within the QJ-process it is also important to investigate how the process really works, which is done in the *current state analysis* at a later stage. The findings from those two analyses are afterwards both included in a *SWOT-analysis*, which is the basis for the improvement suggestions and recommendations.

3.2 Pre-study

In order to understand the process and perform a good investigation a pre-study was performed. This pre-study was done by contacting and asking for information from both the owner of the process and persons aware of Volvo Powertrain's internal systems. In Volvo Powertrain's internal system, information about the different stages in the QJ process could be found, as well as information about tools, methods, standards and templates.

The QJ process is built on the 8D framework, which is why literature and research on 8D and Six Sigma also were studied to get a better picture of what the differences between them were. VPT's QJ-process was compared with the original idea in order to find out how their perception of 8D was different from the original.

3.3 Comparing the QJ-process with DMAIC

In the first part of the comparative analysis the 8D methodology is compared to the QJ-process to understand how much the QJ-process differs from the methodology it is originally based on.

In the rest of the comparative analysis where the QJ-process is compared to the DMAIC framework, the findings found through the interviews are not taken into consideration. The QJ-process is instead compared at a steady state, as it is defined, based on information from Volvo Powertrain's management system. In the management system, information concerning all the existing sub-processes and activities, which the process consists of, can be found. There are also in the management system instructions on how to perform steps in the process, checklists and templates that are used when performing certain tasks, and further recommendations concerning what tools to use and when. The information found through the pre-study was compiled and compared to the DMAIC framework.

To be noted here is that the DMAIC framework is a broader theory, which in some areas still makes this comparison unfair. The comparison made is because of this more in order to identify main differences and similarities that can't be used as facts, but rather areas of interest.

3.4 Current state analysis on the QJ-process

3.4.1 Interview method

After the pre-investigation had been made, a further investigation to understand how the QJ process work in practice was performed. Qualitative interviews were chosen as a method in order to gather more information, this to get a depth in the investigation. In order to get the most out of the interviews as possible different interview methods were evaluated. According to Bryman, A., Bell, E. (2007) the open questions is better, in order to get a depth of the investigation.

Open and closed questions were discussed and in order to get a depth in the analysis open questions were preferred and chosen, but with a structure to ensure that all areas were brought up.

3.4.1.1 Question generation and structure

In order to create questions that would bring as much information as possible, semi-structured interviews were designed in order to cover interesting topics from both Six Sigma and 8D (Bryman, A., Bell, E., 2007). This structure was based on; the main research questions, the Six Sigma framework and the QJ-process. The Six Sigma framework contains a lot of useful tools. These tools have different purposes, which reflect the underlying ideas of the different phases in the problem solving process. This is why many quality tools were brought together and structured according to the different purposes of them. The different groups of tools were then arranged subsequently based on the relevance to each phase in the DMAIC and QJ-process.

This in order to then be able to ask questions that answered if they perform certain procedures, how they do it and if they used a specific tool. The QJ process could use methods and tools that are unique for VPT but serve the same purpose as other well-known tools. To not ask direct questions about specific tools in the first place serves two purposes, one being not giving them an answer and the other finding out if they have well-established methods and tools of their own.

As an example, in the beginning of an investigation of a problem a good thing is to generate potential causes to the problem. This can be done in a good way by performing a structured brainstorming session, examples of tools or methods to use can be; Affinity diagram, KJ-Shiba method, Fishbone diagram (Ishikawa diagram) etc.

In order to not give them an answer directly by asking:

> "Do you perform a brainstorming activity with a use of a fishbone or other similar methods?"

The question could instead be put as an open question:

> "In the beginning of a project how do you generate ideas of what the cause could be?"

Depending on the answer to the previous question, proceed with the question:

> "Do you use a specific method or tool for this cause generation?"

There were also questions regarding in what ways they are working, communication, knowledge and responsibilities. More specific questions regarding the QJ process and Six Sigma were also asked.

3.4.1.2 Pilot tests

In order to test the interview structure and questions pilot tests were performed, both with persons that were familiar with the topic and persons that were not. This resulted in some minor changes.

3.4.1.3 Population and sample

In order to ensure a good outcome of the interviews and create an as objective picture of the process as possible a wide range of employees connected to the QJ process were selected. Together with the process owner and the master thesis supervisor

interviewee subjects were selected, the sample chosen represents about 85 percent of the population.

The sample chosen was:

- Four Case Managers
- Three Project Manager QJ
- Three Design Engineers
- Three Project Manager Engineers
- Two Quality and Reliability Engineers

3.4.1.4 Performing (conducting) the interviews

Before each interview an explanation of the purpose were sent out together with the meeting invitation. In the beginning of the interview each interviewee were given a more thorough explanation again. Two persons were always performing the interviews, one asking the questions and the other one recording the answers on a computer. The interviewees were interviewed separately to not affect each other.

3.4.2 Analyzing the material

After all interviews had been conducted they were read through and during this, notes were taken down on post-its, one note per post-it. After all interviews had been read all the post-its were brought together those post-its that had a connection were grouped together. When a structure was beginning to take form the groups were mapped according to the 8D process and other more general areas, such as communication, roles etc.

The interviewees were then read again and complementary notes were added. This map represented a good picture of the current state of the QJ-process, which areas that were of most importance and also created a good indication on areas of improvement. The map were then compiled and explained in a document and presentation, which were presented to the process owner and the investigation initiator.

3.5 SWOT-analysis on the QJ-process

In order to get a better overview of the QJ-process and discover areas of improvement a SWOT-analysis was made. Key areas and findings from the comparative analysis and the current state analysis were in this analysis identified as strengths, weaknesses, opportunities and threats of the QJ-process.

3.6 Delimit our further investigation

A lot of areas were found interesting during the investigation and all of them could not possibly be addressed. In order to use the information found through the analyses in a good way a discussion was held on how to continue the investigation. After this two issues were chosen as the most critical and the further investigation was prioritized to these areas in particular. The two areas chosen were; Root-cause analysis and how to make the project and process more traceable and transparent. Apart from the prioritized areas, further recommendations were also made to other interesting areas found through the SWOT-analysis.

3.6.1 Further research in main areas of interest

Together with a team established at Volvo Powertrain ideas about the main areas were shared and discussed. Based on the information gathered by these meetings an improvement suggestion was made. The improvement suggestion was how to improve the traceability and transparency of the projects and process, and also improve the root-cause analysis process.

4 Analysis and results

In this part the results from the comparative analysis, the current state analysis and the SWOT-analysis will be presented. The comparative analysis will first give a clearer picture over how the QJ-process is supposed to work. The QJ-process will also be compared to the DMAIC framework and the 8D framework. Secondly the current state analysis is presenting the results of the interviews that were made, which gives a clearer picture over how the process works in reality. Findings from the two analyses were then brought together in a SWOT-analysis, where the strengths, weaknesses, opportunities and risks of the QJ-process were identified.

4.1 Comparative analysis, QJ-process vs. DMAIC

The comparative analysis is made in order to distinguish similarities and differences between Six Sigma's DMAIC process and Volvo Powertrain's QJ-process. The comparison will not comprehend insights gained through the interviews. The QJ-process is instead compared at a steady state, as it is defined, based on information found through the pre-study. The Current state analysis together with this comparative analysis will later be summarized in a following SWOT-analysis, where all factors and comparisons are included. The QJ-process is to a large extent built on the 8D framework, which is why the differences between them will be briefly explained first in this analysis.

4.1.1 Differences between the QJ-process and 8D

The QJ-process is rather similar to the 8 Disciplines. The largest difference between them is in the end of the process, where the QJ-Process is not really going through the last step, the 8^{th} D, as it is written in the original 8 disciplines. In the 8^{th} D the team is supposed to be congratulated once the problem is successfully resolved and the collective efforts recognized. (Whitfield, R. C., Kwok, K. –M., 1996) In the QJ process congratulating the team is not mentioned in the process at all, even though the 8^{th} D is shown in the end of the timeline of the process.

Another thing that differ the QJ-process from the 8D framework is that even though all the process steps are there, the instructions to the process states that the QJs do not have to be performed according to the 8D framework. This is however a little bit contradictory because the process steps exist, follows the 8D structure, and most of the steps have to be completed in sequence in order to complete and close a QJ project.

The QJ-process has connected the disciplines from the 8D framework to VPT's other processes, such as handling design changes etc. The connections to other VPT processes create sub-tasks within the process that are not mentioned in the 8D framework, but serves the purposes of the different disciplines. That companies decide in what way to work with the 8D framework and adopts the framework differently is a common approach according to (Behrens, B. –A., Wilde, I. and Hoffmann, M., 2007).

One major part of the 8D methodology is how the team should work in order to get a good result, maybe not which methods, but what mindset the team members should have and what key ingredients that is required in order to perform good as a team (Connolly, C., 1992). This is not specified as clearly in the different steps of the QJ-process.

4.1.2 Comparison between the QJ-process and the DMAIC framework

The QJ-process will in this analysis be compared with the DMAIC structure at different levels, this in order to get a depth of the analysis and make the similarities and differences clearer.

The first level of comparison is made on principles. The principles concerns what the main goals are with the framework and what the underlying methodology of it, is. It also concerns, which important factors that distinguishes a well-performed project according to the different frameworks.

The second level of comparison is on practices, where the frameworks are compared on how the work is structured in order to reach the goals. It concerns what different phases there are and how these are different from each other, also what the deliveries are from each phase.

The third level of comparison is Tools. That is concerning what tools that are used in each of the phases and what similarities and differences there are in how they are used in the different frameworks.

The fourth level of comparison is concerning what knowledge and competence that is emphasizes as important when working with the different frameworks. It is also about in what way knowledge is supposed to be retained and handled within each framework.

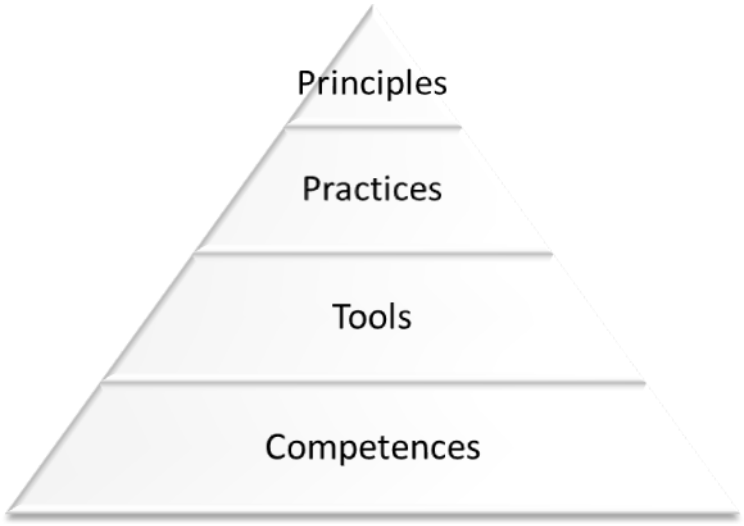

Figure 5: Principle, Practices. Tools and Competences

4.1.2.1 Principles

Six Sigma's DMAIC framework mainly focus on identifying critical-to-quality characteristics that are in need of improvement, and then improve them by the use of statistical methods and tools. The main goal is to improve the process output so that there are only 3.4 Defects per Million Opportunity (DPMO). This is not often manageable, but the goal is to eliminate or reduce input factor's bad influence on the output, so that the deviation from the target is as little as possible. To be able to come even close to that goal the process needs to be stable and the output measurable. If the process is not stable or if the measurement system cannot be trusted, the statistical data might implicate problem areas, but is not reliable. Important factors in order to be able to fully utilize the framework and methods of the DMAIC structure are, that the examined improvement target is a process-output, which is measurable and rather stable. The DMAIC framework is best used in process improvement, targeting critical-to-quality characteristics.

In order for the DMAIC framework to be really successful, the environment of the process, which is the target of the project should, according to Bergman, et al. (2003) be; transparent, developed and structured. Four criterions are specifically mentioned:

- The ownership and goal of the process should be clearly defined
- The process should be mapped to a level of detail, appropriate to the process
- The critical-to-quality-characteristics (CTQs) should be clearly defined
- The CTQs should already be measured and monitored continuously.

(Bergman, B., Korslid, D. and Magnusson, K., 2003)

The main goal of the QJ process is to solve problems related to safety issues or high fault frequency. Most of the problems are due to the criterions of opening a QJ of an urgent nature, the QJ-process solves because of this the problem in steps. The first and temporary solution is to "contain the problem" by a implementing a containment action. The second step is to implement a long-term solution, which should prevent the re-occurrence of the problem. The QJ-process is more applicable on a sudden change in fault frequency than the DMAIC, which rather focus on improvement projects than on problems that appear ad hoc. The DMAIC structure does not have the same step as the QJ-process for implementing preliminary solutions.

The QJ-process has criterions, which have to be fulfilled in order to open a new project. These criterions are basically that the project has to be urgent, either for safety issues or due to high fault-frequency, which implicates high warranty costs.

The QJ projects are because of this urgency also very dependent on short lead-time, in order to not get too high warranty costs. The management focus is due to the urgency often more on the lead-time of the project than on the quality of the solution. The lead-time is direct feedback, but the quality of the solution cannot be seen until much later. The focus of a DMAIC project is often on improving the quality and more than on the lead-time of the project, this is also something that differs between the two frameworks.

As mentioned in the theoretical framework both the DMAIC framework and QJ-process built on 8D are Vertical systems, but 8D use more knowledge-based information than the DMAIC framework, which rely more on data obtained from horizontal systems. To use information from horizontal systems is off course an advantage in the 8D framework as well, but due to the fact that DMAIC is based on the use of statistics, data is a prerequisite in order to work. In order for DMAIC projects to be as successful as possible they should be supported by horizontal systems and also generate new ones and support the already existing ones. The 8D framework should off course also have, as an objective, to result in the generation of new horizontal systems (Bajaria, H. J., 1998). One main difference between the two frameworks is that the DMAIC framework is more dependent on existing horizontal systems in order to be successful, due to the statistical methods used. The QJ-process on the other hand is applicable even though specific horizontal systems do not exist, due to the knowledge-based cross-functional team approach. Horizontal systems do although make knowledge-based problem solving more efficient, if they can provide projects with necessary data for problems that arise ad hoc.

There are several approaches on how to use Six Sigma in an organization. To use Six Sigma with only the DMAIC framework as a project based approach is one way. In order to get the best result from an implementation of Six Sigma it is emphasized by Banuelas, et al. (2006) among others that the implementation should be throughout the organization, to create and foster a Six Sigma culture in the company. That is focusing not only on process improvement projects but also on continuously improving the whole organization. To create a cultural change requires although a large effort in order to succeed. (Coronado, R. B. and Antony, J., 2002)

4.1.2.2 Practices

The structure of the QJ-process is similar to the structure of the DMAIC framework on several points. In this section a comparison of the different phases will be presented and the similarities and differences are also visualized in *Table 1*.

Project selection and generation

Both of the frameworks have a pre-phase in which the projects are generated and selected. The pre-phases are of a similar character, in the QJ-process they are mostly generated from tendencies or facts gained through claims and warranty data, and do not have any criterions regarding what type of problem it is as long as it is severe. The DMAIC framework on the other hand has criterions, which a problem has to fulfill in order to fit the DMAIC problem solving methods, one of them is that the problem should measurable. The QJ-projects are in almost all cases urgent matters, the DMAIC framework on the other hand is also for projects that are not urgent, but are expected to generate large savings.

Understanding the problem

Once a project is selected both frameworks gather information about the problem in order to map it and understand what areas that are affected by it. In a DMAIC project the process output, which should be improved is identified. This is done in a QJ project as well, but it is often not an output in the same sense as in the DMAIC framework, it is more of a problem formulation based on defects and warranty claims. The expected outcome of the project is in both frameworks also estimated. In the DMAIC framework it is important to calculate expected savings etc.

Establish team

In both frameworks a project-team is assigned. In a QJ-project it is really important that the team is cross-functional and that key expertise from all areas of the problem are included. Cross-functionality is important in a DMAIC project as well, but it is more emphasized in the QJ-project. When selecting the team in a DMAIC project the statistical competence is more vital. The project should have one Six Sigma

Blackbelt, supported by Greenbelts and other key competences, which should have statistical knowledge. The Blackbelt should also have prior expertise in the area of the problem.

Containing the problem
This is what differ the QJ-process most from the DMAIC framework. In this phase preliminary measures should be taken in order to prevent the problem from expanding and keep the customers satisfied while the team is searching for a long-term solution. This step is not included at all in the DMAIC framework.

Investigating root-cause(s)
The goals with the investigate- and verify- root cause are similar to, but somewhat overlapping, the measure and analyze phase in DMAIC see *Table 1*.

Both the DMIAC framework and the QJ-process are performing a root-cause analysis. In the QJ-process it is not specified exactly how to perform a root-cause analysis, but in the DMAIC framework there are various methods in order to perform one.

After generating possible causes, the methods on how to perform measurements, what to look for and which methods to apply are well specified within the DMAIC framework, but not as explicitly described in the QJ-process. One big difference from the DMAIC framework is that the measurements and analyses in a QJ often are performed by expertise not necessarily from the QJ-team. In the DMAIC framework the project manager (Blackbelt) often has more analytical and statistical knowledge and is participating more in the measurements and analyses.

In DMAIC projects the measurement data gathered are often of a better quality than in QJ projects, this is possibly due to the prerequisites that the DMAIC projects have to fulfill in order to be started. QJ problems can be harder to measure.

Verify root-cause(s)
In the QJ-process the verification of the root-causes is often done in parallel to the root-cause investigation and the investigate solution phase in order to save time. In the DMAIC process this is not desirable.

Both the frameworks are building their analysis on logical reasoning. After this the difference is that the DMAIC framework has to prove them to a high level of significance with stability-, capability-analysis and analysis of variance etc. These analyses are not always possible to do in QJ projects due to that the problems often only generate discrete data, which leads to that big samples are needed in order to

prove something to a high enough level of significance. The tools and methods used in a DMAIC project are thus not applicable in all QJ projects.

Investigate solutions

The DMAIC projects are often targeting rather stable processes, the improvement solutions generated are therefore often optimizations in order to lower the deviation of it. In QJ projects the solutions are often generated in parallel with verification phase in order to save time. In order to verify the root-cause the most desirable method in the QJ-process is to be able to turn the problem on and off, this is because of the problems discrete nature. The solution does not have to solve the root-cause as long as it is lowering the fault-frequency to an acceptable level.

In the QJ multiple solutions are seldom generated, but if multiple solutions exist they are often compared on various categories such as cost, complexity, difficulty to implement etc.

The following phases in the QJ-process are adapted to Volvo Powertrain to a large extent and are because of this much more in detail compared to the DMAIC framework. The 8D framework is applicable to all kind of problems and is therefore often adapted to fit into organizations processes to a great extent. If looking at the original steps from the 8D methodology, the remaining steps are quite similar.

Corrective action

In the QJ-process there are so called business cases, which contain information about the solution regarding cost calculations. The business case is brought to management and the possible solution is evaluated and gets approved or declined. The cost/benefit analysis found in the DMAIC framework is very similar to this one.

Develop solution and Implement solution

If the solution is approved it is developed and implemented with respect to the aftermarket and the production. In the DMAIC framework these steps are not described with the same detail, but that is due to that the QJ-process is adapted to the other processes within the company.

Follow up

The QJ-process' Follow up phase is very similar to the DMAIC's Control phase. In the DMAIC framework there is although a more rigorous description over how to continuously monitor the improved output. Then again the DMAIC framework is adapted to fit measurable problems. The QJ-process has only a requirement to follow up the fault frequency on a 6 and 12 months basis.

Table 1: QJ-process vs. DMAIC

QJ-Process			Six Sigma's - DMAIC
Identify New QJ	**1D – 2D**	DEFINE	**Define**
Open Draft QJ			*1. Generate projects to be improved and prioritize between them*
Initial Analysis			*2. Develop project and team character*
			3. Identify the outcome (y) to be improved
			4. Determine performance/map process
Open New QJ			
Open QJ Decision			
Prepare QJ-Kickoff			
QJ-Kickoff			
Containment actions	**3D**		
Investigate QJ	**4D**	MEASURE	**Measure**
Investigate Root Cause(s)			*5. For each output, indentify input signals*
			6. Develop measurement plan
			7. Data collection of input- and output-signals
		ANALYZE	**Analyze**
Verify Root Cause(s)			*8. Get to know the output based on the new data*
			9. Identify input signals that influence the output signal
			10. Establish improvement targets
		IMPROVE	**Improve**
Investigate Solution(s)			*11. Design solution(s)*
Prepare Corrective Action Decision			*12. Cost/benefit analysis*
Corrective Action Decision			
Develop Campaign Decision Material			
Develop Solution	**5D**		
Develop production solution			
Develop Aftermarket solution			
DCN (Design Change Notice) Governance			
Design Changes are officially approved and released			
Implement Solution	**6D**		*13. Implement best solution*
Prepare Production			
Implement Production			
Prepare Aftermarket			
Implement Aftermarket			
Market Ready			
Follow-up	**7D – (8D)**	CONTROL	**Control**
Check effectiveness			*14. Verify the planned improvements in the output*
			15. Estimate the cost saving
			16. Institutionalize and document
Inform concerned Process Manager			*17. Communicate and visualize*
Check implementation of changes in process			

4.1.2.3 Tools

In the beginning of a project where the project is defined and when the possible root-causes are generated the tools and methods are of a similar character in the DMAIC framework and the QJ-process. Both of the frameworks suggest that the problem should be mapped at first in order to create a better understanding of questions such as where, when, how, what etc.. Both the QJ-process instructions suggest using a brainstorming approach with the support of tools such as fishbone, 5-Why and Fault tree analysis when generating possible causes. In the analysis of the possible root-causes, the DMAIC framework is although more rigorous about the tools used. The QJ-process mentions to use FMEA, as the DMAIC framework also does, but in the QJ process they are lacking several tools that the DMAIC framework suggests, such as; VMEA, Correlation analysis, Regression analysis, Factorial experiment, Variation mode effect analysis (VMEA), Analysis of means (ANOM) and analysis of variance (ANOVA). The DMAIC framework is more specifically used for measurable problems, which reflects their methods used. These tools are not all applicable to problems that are of a discrete nature, when large samples do not exist. The QJ-process is more of contacting the customers and understanding the problem in order to try to solve it before it is shown in large samples, which is good.

Table 2: Tools used

Phase in process	***QJ-process***	***DMAIC***
Generate root-causes	*Brainstorming* *Fishbone, 5-Why, FTA*	*Brainstorming* *Fishbone, Ishikawa, 5-Why, FTA*
Investigate and verify root-causes	*FMEA,* *They are of course using other tools as well, but they are not explained thoroughly in the QJ-process*	*FMEA, VMEA, ANOM, ANOVA, Correlation analysis, Regression analysis, Factorial experiment, DOE, etc…*

There is at Volvo Powertrain great competence in analyzing data with statistical methods and tools, that knowledge is although not always utilized in the QJs. The main focus in the QJs is not to measure variance or stability in a process with the help of statistical tools, but more to solve a problem.

Overall is the team structure more important than what tools to apply in the QJ projects, while the tools in the DMAIC framework is emphasized as very important and is a large part of the framework.

4.1.2.4 Knowledge and competence

One major difference between the QJ-process and the DMAIC framework is the knowledge needed in the different frameworks. In the QJ-process, bringing knowledge from different departments, working in a cross-functional team constellation is emphasized as important. The DMAIC framework mentions the same thing, but the emphasis lies more on the need for high statistical knowledge. In order to use statistics in the right way a deep statistical knowledge and understanding is needed, otherwise wrong conclusions could be taken.

The DMAIC framework improves processes and base the decisions on information gathered from the processes and the success of them is built more on statistical knowledge and the ability to measure the right things than in the QJ projects. In order for the organization to learn from improvement projects, either 8D- or DMAIC-projects, it is important that an organization's management systems are well established, to handle information gained through them. This is even more important in the more knowledge based QJ-process. The QJ-process is because of its knowledge-based approach very dependent on the existing knowledge among the company employees, this makes it very sensitive to high employee turnover.

All project-based problem solving initiatives are able to contribute to organizational learning and continuous product and process improvement, if the knowledge from the projects are documented and taken care of in the right way, through the use of systems to transfer the knowledge. (Punnakitikashem, P., Somsuk, N., McLean, M. W. and Laosirihongthong, T., 2010).

4.2 Current state analysis – QJ-process

In the current state analysis the result of the interviews is presented. The interviews were built up in order to find out how Six Sigma's DMAIC and the QJ process differed from each other. The answers of each interview were summarized and structured according to the phases of the QJ process and other key areas of interest. In this section, the most interesting areas are those were most contradictions and troubles were found. Key aspects that could be related to the Six Sigma framework were also of importance.

An overall reflection is that the interviewees had troubles with identifying areas where they thought that they were successful. They had easier finding flaws and improvement areas.

4.2.1 1D, 2D – Identification of new QJ/Pre investigation

Prior to the QJ there is a pre-investigation done by the case managers (CMs), who investigate and evaluate the nature of the problem. If a problem re-occurs many times or if it could jeopardize safety a QJ should be opened for that problem. The pre-investigation is according to the case managers a rather undefined process and every CM can more or less choose how to work and what problems that shall be further investigated. Today when a QJ is going to be started it needs to be approved at the Global Case Manager Meeting (GCMM) in order to have more global control over which QJs that is started. This ensures that several QJs on the same problem cannot be started from different countries, which previously has happened. Another reason for these meetings is to ensure that all the QJs started really is of importance. According to many of the interviewees there has during the last years been a devaluation of the QJ's importance, which is dangerous because problems of that magnitude have to be prioritized. If small problems were to be brought up as QJs it would take away the importance of a QJ and also demand too large resources. The QJ still has authority to get the resources they need, but they need to obtain their high level of priority.

The CM is collecting information from different sources in order to discover potential problem areas. If they react on fault frequency it is already too late in many cases. In order to get an earlier indication of possible problem areas they request information and order material from the service centers, called Market Quality Reports (MQRs), to get a better look at the component. A large part of the CMs' job is to find as early indications as possible, but at the same time make sure that there is a real problem, this in order to solve the worst problems before they get too expensive. One of the interviewees compared being a CM to being a goalkeeper. To be able to catch the ball

you sometimes must act before the ball is shot and if you then miss it you will get a reprimand but if you catch it, you are just doing your job. It was emphasized by some interviewees that it is important that the cases are based on facts and not only on gut feeling. This is although a tough task because time is really important and if the case managers wait for facts, they might react too late.

In the pre-investigation a lot is about looking at tendencies depending on MQRs. One problem with this is that the MQRs might be misleading. They can point in the direction of a hardware breakdown, when it really is software that is the issue, since it looked like that at the first glance by a mechanic at the repair shop. This can lead to going in the wrong direction and cost both time and money. The problem with misleading MQRs has been mentioned by every CM. The interviewees also said that they have a lot of information, but finding the right information is hard. In order to get the right information it is sometimes necessary to travel to the customer in order to look at the problem.

An issue that has lead to an increase of the number of QJs is the customer impact. Customers emphasize the weight of their specific problems, which has increased the number of QJs especially in the US.

A large discussion has been about what criteria's a QJ should be opened. There are criteria's today, but in order to be sure that they are fulfilled a deeper investigation is often needed. There are definitely cases where the problem in the end turns out to fall out of these criteria because of the lack of time and the potential risks seen at an early stage. According to some of the interviewees some QJs are started on the wrong criteria by purpose just to mitigate the customer's complaints.

If a problem is important enough a QJ is to be opened and the responsibility of the problem is handed over to the Project Manager QJ (PMQJ). This handover is handled differently depending on the person responsible for the pre investigation. In some cases the PMQJ is involved before the case is opened and is able to gain insight into the nature of the problem. The most common scenario is that the PMQJ knows of the case right before the QJ is opened. To be involved in the problem before opening a QJ has advantages, but when asking the PMQJ about an earlier involvement in the issues they say that today there is no available time for them. They have between 10 and 13 QJs per person ongoing. The idea of being more updated in the case prior to the QJ opening is liked by some, but in that case they emphasize that their current workload and number of QJs can't stay the same.

Once the PMQJ has been briefed about the issue and the QJ is going to be opened a cross-functional team is put together in order to solve the problem. This is done in collaboration between the PMQJ and the CM, but there is according to the interviews room for changes in the team constellation if complementary competence is needed. The team is called to a kick-off meeting were all the knowledge gathered about the issue is presented. The CM is more familiar with the material concerning the problem and is because of this often responsible for the kick off.

It is sometimes held by the PMQJ but a reflection from the interviewees was that it would be better if the CM always held the meeting.

4.2.2 3D – Containment action

In order to make the effects of a problem less severe there should be a containment action made as soon as possible. The interviewees had a diverse opinion when it comes to containment actions. Depending on the nature of the problem it can be hard to contain the problem in an early stage. There are examples of containment actions leading to even bigger problems than the original problem, but there are also examples of efficient containment actions. This makes it hard to come up with guiding principles when it comes to containing the problem. If the problem is of a costly but simpler character, a containment action could be a good thing. In complex situations, on the other hand, it can do more harm than good.

It seemed like some of the interviewees had a rather narrow perception of what a containment action is. If one looks at it from a customer perspective a containment action could be to take measures to save the brand from being harmed, but does not have to solve the problem. The interviewees were sometimes missing guidelines for making containment actions and for when it is suitable and in what situations.

4.2.3 4D – Root-cause Analysis

When a problem arises the only thing that is really confirmed is the symptom. In order to solve the problems it is important to understand the root-cause of them. Depending on how complex or straightforward the problem seems to be, the root-cause investigation is done more or less thoroughly. In some cases where the problem is of a simpler character, a large investigation might not be necessary. There has however been QJs were the root cause seemed to be clear from the beginning, but was proven to be more complex in the end.

The interviewees were asked how they work in order to find the root cause and what methods and tools they are using. In those QJs where the problem was of a more simple matter the root cause analysis has not been as thoroughly made as in the more

complex problems. A reflection from the interviewees was although that the problem can look easy from the beginning, but in the end prove to be really complex. This makes the decision whether to make a more systematic root cause investigation or not hard.

In those cases were the QJ team felt that there was need for a more thorough investigation, external expertise in conducting root-cause analysis were brought in. Those experts often had a systematic way of digging further into the problem with the help of brainstorming sessions and visual tools like the fishbone diagram. The experts emphasized that it was really important to have the right people present at the brainstorming sessions in order to get a good result. They said that the result of a brainstorming session is often depending on a combination of method and people, which does not always go hand in hand. Persons are different, some need more freedom than others in their work, while other persons work best in a well-structured environment. This is why it is important to be able to adapt the brainstorming session method so it does not constrain the creativity.

The opinion goes apart whether the root-cause analysis should be done by the PMQJ at PD, or if external help from the Quality and Reliability Department should be used. The PMQJ sees advantages with doing it themselves, because they gain more knowledge about each problem, although they might not be able to ask the right questions during the sessions. Many of the interviewees see another advantage with taking in external expertise in the RCA, which is that they look at the problem from an outside perspective and with an open mind. One problem with root cause analysis has been that people tend to be more focused on finding a solution rather than finding the cause of a problem. To prevent this it might be good to have a more structured brainstorming session. *Due to these reasons it might be good that the one holding a RCA is from the outside looking in, but at the same time are able to speak the language of the participants.*

Doing a good root-cause analysis is also of importance because of as one of the interviewees pointed out, “it is very expensive to test for testing’s sake”. The tests made should be evaluated and performed for the right reasons. Another thing emphasized by some interviewees is that the testing method is often more important than the technique when measuring, which is not corresponding to the focus today.

When analyzing data some interviewees think that more knowledge is needed within the department in supporting software’s such as Minitab and Excel, this in order to work more efficient and be better at seeing correlations and analyze the effect off variance. This is also connected to the verification stage in the process.

When the root-cause(s) is going to be verified a common opinion was that the claimed cause is not questioned enough. This is good in one way because it is a sign that management rely on that the analyst's decisions are taken and based on a good basis. On the other hand it might be good to have someone questioning the results, because things that might have been overlooked is being brought to light. The interviewees also saw another positive aspect with being questioned, which is that they might get better at documenting and gathering proof of their ideas. One said: "if no one is going to read what you are writing, then what is the point of documenting?" If the management question the result it is not always about controlling it is also about showing interest in the work of the QJ team. One interviewee said that if you for instance are uncertain in a matter and mark a checkbox anyway you do not get questions. If you instead skip to mark the checkbox a lot of questions are asked. The validation is of a similar kind so if you have a solution it is not questioned, but if you do not have a solution you get a lot of questions.

To document what has been done in a QJ is also very important to be able to go back if the case is brought up again. To base the decisions on more facts is also something that some of the interviewees request.

4.2.4 5D – The solution

The interviewees were asked how they usually come up with their solutions and how they usually evaluate them. If they have a way to compare them with each other, in order to implement the best one.

They said that solutions often are generated in parallel with finding and verifying the root-cause(s). There is also a mindset that getting rid of the problem is more important than the solution. When asked which criteria that are of most importance, one interviewee said that they often go for the solution that is the easiest to implement and costs. One interviewee emphasized that they are pushing the limits in these products, so the "root-causes" cannot be adjusted at all times due to performance requirements, which leads to that the changes in the product are not big, they only just ease the symptoms in most cases.

According to one of the interviewees they seldom miss a good solution, but they do not have standard tools for evaluating the solutions. There were those who thought that an evaluation matrix and standard tools for evaluations could save a lot of time. Today it is possible to carry out a solution if you want to with a good argumentation, according to some interviewees.

Today they believe that they are doing a rather good job but they do not have a standard process to evaluate the solutions, which could be an improvement of their current procedure and also make sure that the right solution is chosen. Today they mostly evaluate the economic aspects of each solution. The evaluation is done through a business case, which has to be made before the implementation.

The interviewees did not think that the guidelines for how the business case should be done was clear enough, what expenses that should be included and how these should be calculated. The business case is mostly done by estimating the different parameters and expenses and can always be adjusted to a positive business case because. There was a common opinion that the guidelines of the business case are vague and that there should be a better standard. It was also not clear who should evaluate the business case, should the CM evaluate it or are they supposed to evaluate their own work?

4.2.5 6D – Implementation

The interviewees were asked how the implementation work from Design Decision to market ready and what they thought of it. The general view is that the process itself and the steps within the phase are quite straightforward, but since no case is similar to the other, "small" tasks can take a lot of time due to logistical problems, which often add costs to projects.

One of the phases discussed was when making new tools for production, which often results in much longer lead-time for the QJ. They did not think that it was fair that a QJ in need of a tool redesign was compared with a QJ that only was in need of minor changes and had other prerequisites. To order new tools had bureaucratic problems as well. Ordering a new tool often needs up to 35 signatures, which takes a lot of time and effort. Most of the signatures needed are from persons whose involvement in the matter is small, which allows one to question whether they are really necessary.

Another problem concerning communication is when the different customers are contacted regarding a change in their production. Today it is hard to find the right person to contact at each site in order to implement a solution. In reality there might be four or five persons to contact and discuss the issues with in order to get things done. Wishes are to assign main contacts at each customer, it would make this part of the implementation more effective and less persons has to be briefed.

According to the interviewees, the focus on lead-time results in that the proposed solution is not often challenged and questioned enough. The time spent and effort put on validating the solution will be limited due to lead-time focus. In practice the

solution is validated in parallel to the implementation and/or after a new tool is ordered. To not validate and verify the solution in a proper way might affect the outcome of it.

Another area in the implementation that was brought up was when the solution is market ready. Market ready is when a solution is approved by the customers and in production, but is it when all material are available at each customer (brand using VPTs products) or is it when it is shipped to the customer. A common desire was that they would like to get a better definition of when a solution can be defined as market ready. In some cases were the solution has to be implemented worldwide they can get an extension of their lead-time targets. The only problem is that this bonus time did not even cover the extra transportation time needed to ship the components to the right destination. One thought was that market ready should be when the solution is ready to go into production, since it also is up to the customers to take it into production.

4.2.6 7D – Evaluation

Questions were asked about how they follow up their work and who is responsible for it. The white books were discussed in most interviews and some of the interviewees had used them, but in most cases they said that there are no time to even consider writing them. The interviewees believed that it is important to evaluate the work, but there is no time reserved for it today, new project takes up all the time. One of them had just heard of the book and was interested in how it should be done in order to be able to write it in the future. In some cases they thought that someone else did them.

The discussion of the white book often ended up in the question of traceability and how to make the evaluation more useful. The interviewees said that one problem with the white book is that it is written after the project is completed and they do not really see the purpose of it since they are rarely used later.

To make the evaluation of each project more useful, the structure and the solving procedure of the project has to be better and more traceable. A searchable system was asked for by some of the interviewees, because to track old problems are very hard today. If it was possible to search in the system on what previously had been done in a specific area it would be of great advantage.

4.2.6.1 Follow up

The interviewees were asked how they and the organization follow up their result. An uncertainty of who was responsible for following up the result were amongst some of the interviewees, whereas some thought that the CM was responsible for it, which did

it 3 respectively 12 months after the implementation. Few of the interviewees had although seen the result of this follow-up. It was according to some of them better before when they had more direct contact with the customers of Volvo Powertrain.

One type of follow-up was according to the interviewees whether the QJ was opened again or not. If it was not opened again the result of the implementation was assumed to be quite successful, but if it was opened again the result was bad. The general attitude towards following up the result was that it was hard to gain useful information from the QJs as it looks today, but they thought that it would be good if there was a way so that it would bring something to the table.

4.2.7 8D – Bonus connected to KPI

In the 8D phase it is all about feedback and how the interviewees give or receive feedback. The feedback they get is often connected to the KPI lead-time, since the other KPI failure frequency is not measurable until long time after the QJ is closed. They even have a bonus system connected to the KPIs, because of this many of the interviewees say that the system itself prioritize lead-time before the outcome and that the quality often is forgotten. Feedback connected to quality is rarely received from management, but they continuously receive feedback connected to lead-time.

4.2.8 Organization

4.2.8.1 Site differences

The interviewees were asked questions in order to understand if there are any differences between sites. Many of the interviewees had opinions about the other sites and had collaborated with them a lot. There were even persons who had been employed by a site abroad and experienced differences. The general and quite similar view was that; the site in Japan work in a much more structured and standardized way. In Lyon they also have more structure than the site in Gothenburg. The site in Hagerstown (HAG) has a much more top-down management structure, which affects their way of working. When it comes to opening QJs, HAG tend to open more of them due to customer complaints, in order to please their customers.

One issue with the globalization that concerned some of the interviewees was the growing number of participants in each QJ teams. The increase of members in the global QJs has become too large in order to maintain the effectiveness according to some of the interviewees. Several interviewees see advantages with having the team at one site, which owns the QJ, and instead become better with communicating the result to the other stakeholders. Many of them believe that the communication will get

better once the newly introduced Global Case Manager Meetings (GCMMs) are more established.

4.2.8.2 Roles

Questions were asked in order to understand the relationship between the different roles and responsibilities, also in order to see the knowledge connected to each of them. One key phase in the QJ process often brought up by the interviewees was the root-cause analysis (RCA). This is according to all interviewees an important step in the QJ process, which brought up diverse opinions regarding the leading role. They also said that the RCA is not done properly in all QJ today, which is dangerous according many of them.

The members of the QJ team often appreciate all help they get from the RCA experts, which they consult in order to investigate possible root-causes. The interviewees had although different opinions about when and how much these experts should be involved, some also questioned why external experts should perform the root-cause analysis. Advantages with having an external resource performing or at least starting the RCA is that they often have a more open mind about the issue and are able to question the issue more. In order to question the issue in a more profound way the RCA experts also says that the RCA moderator often need to possess good technical knowledge to be able to ask the right questions. The question that some of the interviewees then asked was whether or not the PMQJ in some cases need to possess more knowledge in order to perform a good RCA and if it might be necessary that an outside expert performs it. There are also many advantages if the PMQJ performs the RCA, with the main being that they get more involved in the problem.

In order to better understand what responsibilities that each of the roles had in a QJ team some questions regarding that where asked. These questions were also used to detect ambiguities regarding their responsibilities.

Two roles within the QJ team have rather recently been changed due to organizational turnover, when asked about their responsibilities there were still uncertainties regarding some of their tasks. Before the organizational change there were one role called PMQJ, which managed the QJ from 2D to 6D. The role of the PMQJ has now been divided into two roles, PMQJ and PME. The responsibilities of these roles today are connected their different departments, were PME is at product development and PMQJ is at the department of Quality and Customer satisfaction. Understanding what responsibilities that are connected to each department is not clear in all situations. The interviewees did not see this as a big problem today because all of them have the same prior experience working as PMQJs, but they think that it could become a

problem when new persons are employed to either of the positions. The interviewees could although see benefits with this role structure when looking at it from a global perspective.

PMQJ

PMQJ was the role most of the interviewee had thoughts about and they themselves say that they have a too high workload with around 10 QJs all the time. This have led to that they do not have any time to be involved in the RCA as much as they want to and that they have evolved to become more of a "spider in the web" or according to some of the interviewees a more administrative role. The PMQJs are not involved in the pre QJ phase, they get all material handed over from the CM once the QJ is started up, this makes the start up time longer according to some of the interviewees. The PMQJs say that a prerequisite in order to be more involved before the QJ is started, is that the number of QJs per PMQJ has to be decreased, otherwise they will not manage the workload.

There were contradictive answers concerning how involved the PMQJ should be in the RCA. The PMQJs themselves would prefer if someone else performed the RCA, but they could see benefits with doing it themselves. This while most of the others thought that the PMQJs should be able to lead the RCA themselves, but that they might need more knowledge in that area. The PMQJ is not always participating in the RCA due to a high workload and because they do not feel that it is necessary at all times. Some of the interviewees stress the importance of the PMQJs participation in the RCA, even if they are not leading it, because they get a deeper understanding of the problem and how to perform a RCA by taking part of it.

4.2.8.3 Business Package team

In the part of the interview were they were asked to come up with improvements two of them started to discuss the Business Package team and their involvement in the QJ process, they thought that they should be included in the QJ team. They thought that the Business Package team has lost their purpose in last years of re-organization and that the QJs could gain a lot if resources like them were used properly.

4.2.8.4 Visualization

The interviewees were asked how they communicate their work both internally in the team and to other stakeholders. If they used any methods or tools in order to visualize their work and what methods that they thought were good. They said that the communication work quite well within the team but many of them thought that it could be good with a standard report structure. The reports they have to deliver to different parties today are different, which leads to that unnecessary work is being

done. It would be good and more effective according to several of the interviewees, especially those working at product development, if they could come to an agreement of a structure that could be used to all stakeholders. Another benefit mentioned with having a standard report structure is also that you are able to more easily follow-up the results.

The PMQJs mentioned that they now in VPT Gothenburg use the same template for the action-plan, which always is included in the meeting invitations. This was according to them good so that it is familiar to everyone. They mentioned that a fishbone diagram is good in order to visualize, structure and create a common picture of a problem. In order to visualize their progress to other stakeholders they use so called one-sliders, updated ones a week, they also had shop-floor meetings in order to get an overview of the work being done. There are although too many unnecessary meetings according to some of the interviewees.

4.2.8.5 Prioritizations

The interviewees were asked about important areas that should be considered in the QJ process, both improvement suggestions and things to prioritize. The interviewees thoughts when asked about this is expressed in this part.

The QJ process is parallel in reality

The QJ process consists of sub processes and activities that are subsequently following each other. In reality some of these processes are run in parallel in order to save time and this was necessary in order to meet the lead-time requirements according to the interviewees. The developing and verifying phase are often run in parallel.

The interviewees thoughts about the lead-time, firefighting and finding the root-cause

- The QJ teams' task is to put out fires
- Short QJ lead-time contributes to even more firefighting
- The focus is to solve problems according to some of the interviewees.
- The focus should be more on finding the root-cause instead of costs
- The focus is to find the root-cause but with the short lead-time it is a problem
- PMQJ wants to reduce the lead-time not find a good solution
- With today's focus on lead-time we cannot work proactively
- Lead-time focus has led to the wrong priorities

Different requirements and deliveries, which were emphasized by the interviewees

- Having a time plan is important – Should have that as a requirement
- FMEA should maybe be a requirement
- Reduce the administrative work in the QJs
- To follow-up the result should be more prioritized
- In a longer perspective it is good with performing a root-cause analysis when following up the result
- To have a standardized way of working in certain steps of the process could be a good idea, some suitable steps are; Kick-off, design decision and release
- The PMQJs have started to use the same action-plan template in order to get more standardized and get a better way of working

Other areas that were emphasized by the interviewees

- We should have more customer focus
- The knowledge level has declined
- The symptom and the root-cause is not the same thing, this needs to be understood by everyone
- A lot of QJ at the same time for each PMQJ, 12 per person

4.2.8.6 8D contra Six Sigma

At the end of the interview, the participants were asked about 8D and Six Sigma, both what they knew about each framework and also how they were different from each other. Most of the interviewees had heard of 8D and knew that the process was built on the theory. It was although only a few of them who knew more about the theory behind it. The knowledge of the Six Sigma framework were better amongst the interviewees, some of the interviewees had good knowledge in the area and the rest of the interviewees, knew a little. One who knew enough to be able to compare them thought that 8D is more synoptically and liked the "containment action". Another difference is according to the same person that 8D is more applicable when you have sudden change and Six Sigma for continuous improvement. Another person said that:

> "*Six Sigma is better but more time consuming and the process that we have today has more focus on time than accuracy."*

4.2.9 Knowledge

In most of the topics the interviewees were questioned about knowledge and the level of knowledge needed for specific tasks. The interviewees had different opinions concerning this area, which make most of the findings personal.

The knowledge level has declined during the past years on how to perform a root-cause analysis, according to some of the interviewees, education in that area is requested.

The ones that had quite good knowledge of RCA asked for more technical competences within the team, since they believed that the combination of good analytical knowledge and technical competences would be very useful in solving problem. A lot of discussions were also about the value of transferring knowledge from the QJs and how the knowledge gained from QJs could be useful in the development of new products.

The individual knowledge level is quite good according to some of the interviewees and the component owners are often included in the QJ team, which connects the problem to product development in a good way. The knowledge is although always carried between the departments and projects of individuals and cannot easily be found in a system. The solution is often presented in Argus but how the team got there is not always explained in a good way, which in the long term perspective does not improve the organizational knowledge according to one interviewee. The same interview said that the knowledge transfer and feedback is not so good at QJ level, but that they have better or at least some within each department.

Another interviewee said that they continuously document what they have done, but that they do not give and receive enough feedback. The information written down is rarely used in a proper way afterwards.

The interviewees were asked whether or not they thought there should be a more standardized way of working and documenting and if they preferred working with standards. Most of the interviewees asked for better standard to keep a certain quality but there were people that thought that having a standard just created problems. In general the interviewees, who had worked with a system for a longer period of time, did not like standards since they preferred to do it in their own way. There were also interviewees, which thought that having a standardized way of working could help new employees and they thought that they could have been better introduced when they started working. One interviewee said that they have a low employee-turnover today so the knowledge is retained.

4.2.10 Systems

4.2.10.1 Argus

Argus is a work platform for storing and working with QJs. It was one of the areas in the interview were most interviewees had thoughts and negative complaints. There were those who thought that Argus was sufficient, but most of them did not think that it was. There were also some persons that did not work with Argus, but instead choose to work at a team-place.

Interviewees said that they have little education in how to use Argus and there were some that had not gotten an introduction to the system. Most of the interviewees were uncertain in how to fill in information in Argus correctly and asked for examples of what it could include. A few of them argued that Argus has to be completed in order to be traceable later.

The interface of Argus

There were allot of complaints about the interface of Argus and that it make Argus hard to use. Most of the complaints on the interface were about the structure with all the files in just one box and that the old system QJS had allot of advantages in compared with Argus.

Improvement suggestions made by the interviewees

- Make the data in Argus possible to analyze
- Not applicable could be useful as a checkbox in some cases
- Make it more user friendly by adding descriptions of what information to add in the Argus system
- It is not possible to add customers after Design Decision

Store information in Argus

The interviewees have different views of how to store information while the QJ is ongoing. Most of them think that it is hard to work with Argus and keep it updated and some have started to store all documents at team places during the QJ and then transfer it over to Argus when the QJ is closed. The reason for using a team place is according to the interviewees due to that Argus structure and interface is hard to work with and that the customers, that sometimes is involved, do not have access to Argus.

To use a team-place instead also has disadvantages according to some of the interviewees. One is that when information is stored at two places it often create misunderstandings and you tend to forget to put everything into Argus in the end. At a team-place it is also hard to backtrack and see what has been done. The lack of file and information structure in Argus leads to that all of the documents just pile up in one folder without any structure at all, according to some of the interviewees.

4.2.10.2 The Protus system

The protus system handles problems that were not taken care of before the launch of the truck. The interviewees see that some protus reports tend to become QJs later on and they discuss that it would be much more cost effective to solve them properly from the beginning. If the problems arise again it would be really useful if better investigations were made in the protus system and if the information was easy to find. They think that the protus system have been improved a lot since they now have requirements to perform a root-cause analysis in each protus. The protus system would be even better to use if it was made to be more traceable, facilitating the use of existing information that concerns a problem.

4.2.11 KPI

In order for management and other stakeholders in the QJ process to see how well the QJ-teams are performing there is a key performance index (KPI) that should summarize this. In the QJ process they have two KPIs; QJ lead-time and Failure frequency. These KPIs have been discussed with the interviewees. The interviewees had a lot of comments especially regarding the first of these two, QJ lead-time. The answers about QJ lead-time were sometimes contradictive, in general the opinion was that it was not a fair measure and that it advocates speed and not the outcome of the QJ. The KPI has to measure everything from time, performance, implementation to the outcome in order to be fair, which is hard according to some of them.

The way the KPI is constructed today is intimidating to some of the interviewees, since it is differing between sites and because some large QJs clearly need more time than 130 days in order to be successful. There were also interviewees that thought the KPI was quite good since time is really important and easy to grasp, while the quality of a solution is hard to measure initially.

4.2.12 Time

In order to better understand the process the interviewees were asked about which of the phases that required much and time resources. The investigate phase required the most man-hours according to most of the interviewees, but the implementation phase could also take a lot of time, but mostly because it is a heavy process and a lot of time is spent waiting and getting in touch with the right people.

Therefore some think that it is very important to have a realistic time plan and update it continuously. One problem with this is that the managers often then say that it is possible to do it in half of the time. As one interviewee said, “it is not accepted to have a realistic time plan that takes long time, but it is accepted to not keep to an unrealistic short time plan and get more time later.” To keep up with the short lead-time most of the interviewees emphasize that it is necessary to work in parallel in most of the cases to be able to shorten the lead-time. There are also QJs were the lead-time target is realistic, software issues are an example of where they thing that it is.

4.3 SWOT analysis on the QJ-process

In this analysis, characteristics and factors found through the current state analysis and the comparative analysis are being categorized into strengths, weaknesses opportunities and threats of the QJ-process. When conducting the interviews the interviewees had easier finding negative aspects of their work than positive things.

4.3.1 Strengths

- The case managers are often capable of finding problems at an early stage, before the signs of the problems are shown in the statistics.

- The containment action is good because it enables solving the problem in steps; first implementing a preliminary solution followed by a long-term corrective action into both production and aftermarket.

- The 8D framework, which the QJ-process is built on, is an appropriate for the problems that the QJs are intended for, it is applicable for most problems even those that arise ad hoc.

- Volvo Powertrain has a high level of competence and profound knowledge within their area of expertise, which makes them good at finding solutions to problems.

- They focus a lot on establishing the right team, gathering the right people to the problems and are continuously evaluating if other team members are needed to fill possible gaps.

- There are within the quality department experts in the use of quality tools and in how to perform a good root-cause analyze, to support the QJ-teams when needed.

- The newly introduced Global Case Manager Meeting is good in order to be able to work globally and keep better track over what problems that currently is under investigation.

- The QJs are still highly prioritized, which is good, so the resources needed for the projects are obtained.

4.3.2 Weaknesses

- The process does not have to be followed strictly in all the steps and the project team can decide how they want to perform a lot of activities. The result of a QJ project is because of this highly dependent on the individuals within the team.

- When verifying causes and solutions the burden of proof is not always that high, as some of the interviews said: “A lot of things can be carried through with discussion.”

- In the QJs there is sometimes weak documentation of how tasks have been performed, especially what has been done through the project. When looking at closed QJ cases it was hard to see the path of the investigation, understanding what actions and analyses that lead to the end result. The documentation regarding what knowledge that was important to the success of the project and key findings is often also missing.

- The QJ team is often consisting of people from product development, which tend to look for solutions instead of potential causes to the problem. It is important in the beginning of projects to disconnect the potential solutions from the problem to be able to go in the right direction.

- The QJ-team do not at all times use statistics to the extent that it is possible with the data available.

- Instructions and template for how a business cases should be done is not that well defined.

- The data and information acquired through MQRs and other systems are often giving a false picture of the problems and does not always represent the actual problem.

- The containment action, which is one of the advantages with the QJ-process, is not performed in all cases today. There seems to be a chattered image on what a containment action could be and in many cases containment actions are not implemented. It is important that a mutual image of what a containment action is and how to use it.

- The root-cause analysis is not that well defined in the process today and it is of differing quality. The quality of the root-cause analysis is very dependent on who is performing it.

- Today external expertise is in most cases brought in to perform root-cause analyses, this expertise should maybe exist within the QJ-team.

- A thorough performed RCA is not done in all QJs today there should maybe be more requirements regarding this.

- There is an uncertainty about who should be responsible for performing the root-cause analysis and also where the money and resources for this and tests should come from.

- A lot of knowledge exists within the company, it seems like the employees does not in all cases know where knowledge is located, this leads to that they do not at all times utilize the existing knowledge within the company.

- Feedback from performed projects are not usually given or received. If feedback is received people tend to improve more and also have an incentive to perform better.

A lot of the interviewees said that their current workload is too high. This probably affects the result in a negative way. The PMQJs has approximately 12 projects per person, which is not an optimal level in order to be productive. Studies have shown that two projects are optimal in order to be as productive as possible. (Wheelwright, S. C. and Clark, K. B., 1992) To have 2 projects might in this case not be productive at all, but to have 12 projects ongoing certainly will affect the quality of the result.

4.3.3 Opportunities

- Share knowledge more to identify best practice to even out the quality of the QJ projects and get the result of them less dependent of the individuals.
    - Standardize certain steps of the process
- Make the projects more transparent and traceable in order to after a project has been closed know what has been done and who was responsible for the different actions.

- Improve the quality of the warranty data such as MQRs, by setting more requirements on how they should be done.

- Become better at finding and especially take care of critical-to-quality characteristics acquired through projects, in order to improve; future projects systems, and develop more robust solutions.

- Several steps have been taken in order to work more globally, to continue working with global initiatives build a stronger organization.

- Develop the process to be more customer-oriented, not as it is today where the focus is mainly on Volvo Powertrain's costs and expenses.

- Becoming better at using the containment action and at an early stage, create more guidelines for the QJ-team to use.

4.3.4 Threats

- The QJ-process is because of its knowledge-based approach very dependent on the existing knowledge among the company employees and is because of this very sensitive to high employee turnover.

- If not the root-cause analysis are performed thoroughly the investigation might go in the wrong direction, the problems might reoccur and resources might be spent on the wrong things.

- That the result varies a lot depending on who is performing the QJ investigation can become an issue in the long-term perspective
- The lead-time focus can lead to poor quality of the QJs, which might lead to long-term problems

- There has been a tendency of opening QJs on issues that are not that urgent or important, this might lead to a devaluation of the QJ, which means that project might not get full attention and support needed from the rest of the organization, when it is really necessary.

- To have an organization that can operate and co-operate at a global level is important, the process needs to be well adapted to this purpose.

- The difference between the PMQJ's role and PME's role are not so strictly defined today, this needs to be better defined, especially in the future when new employees are hired to either of the positions.

- To keep the high focus on the lead-time of the QJs might lead to decreased quality of the solutions. There might be a need to have a complementary KPI to ensure that the focus lies on the quality of the result. Management needs to emphasize the importance of a high quality more than they do today.

- Ensure that the globalization do not create a too bureaucratic procedure, sometimes decisions have to be taken fast.

5 Discussion

The DMAIC structure is very suitable for improving processes that are in control but not optimized. The problems handled in the QJ-process are often of a different nature, they do often not fulfill the criteria, which characterize a suitable DMAIC project. The complexity of Volvo Powertrain's products often leads to that their problems are of a complex nature as well. The characteristics of the problems addressed at Volvo Powertrain are often not comparable to a stable process, and even if some could be considered as stable, it is often hard to perform measurements in order to prove it. Volvo is in many cases unable to rely on statistical data, the problem solving process at Volvo Powertrain is because of this very dependent on the existing knowledge and competence within the team. This was something that was expressed by several of the interviewees as well. One interviewee said,

"…the result of a project was very dependent on that the right people were involved."

Today, competence might not be a problem for Volvo, but the company cannot always rely on, that everyone stays within the company.

The QJ-process is well defined to a certain level and most of the activities are included that are needed to solve a problem, which makes it suitable for its intended purpose. How some of the steps in the QJ-process are performed, was however very dependent on the persons performing them. To have freedom when working is very important to a certain degree, in order to not inhibit the creativity of the employees. It is also of extra importance, to not be delimited by too much rules and restrictions, especially when solving urgent quality problems. One of the things found through the interviews was although that this freedom for some of the interviewees created some uncertainty, which can be a side effect by having little restrictions on how to perform certain tasks and activities.

One activity that was done differently depending on the employees involved was the root-cause analysis. The RCA were in some projects performed very thoroughly, these projects were often those, which the participants did not think were that straightforward. In other projects were the root-cause was initially more clear a thoroughly made RCA was not even performed. To not perform a RCA in some projects can lead to, and possibly have led to, that the wrong conclusions were taken and the wrong "problem" was attacked. The RCA is a very important step in the QJ-process, which many of the interviewees said was crucial to the success of the

projects. If the RCA is not performed thoroughly it can lead to that a lot of work is done for no good, when testing and implementing a wrong solution.

Another thing that many of the interviewees did differently was the documentation. To be able to afterwards evaluate a problem, documenting is very important. When looking into old, closed QJs, it was hard to follow the project from A to B. The problem definition and the implemented solution could be found in closed QJs, but not how they got from the problem to the solution. If a problem would re-occur, it can be hard in some cases to gain information about what the potential causes of the problem were, and what tests and analysis that were made the last time. If not the same persons are involved in the problem, if it would rise a second time, a lot of tests would have to be ran again. To document and use the information documented properly in the organization can lead to that more knowledge stays within the company. The QJ-problems are often concerning issues that could be solved in a better way in the next generation of products, it is because of this important to spread the information gained from the projects to the right departments. The information gathered through projects is to some extent carried on to the next generation of products today, but this could be done better and more often.

Today, the QJ is to a large extent valuated on their failure frequency and time. It is necessary to have time-constraints on a project, but at the same it is in credibly important to really solve the problems. In order to today be able to get actual figures concerning how well an introduced solution worked, almost a year has to pass before it can be seen on the failure rate. To evaluate the quality and performance of a recently closed QJ-project might require other means.

One thing could be, how well the root-causes are verified and to what extent the problem can be removed. To estimate how much of the problem a QJ solves is already done today, but the estimations made, are often just ruff estimations. Ideally, it would be good to be able to turn the problem on and off, but this is not always possible. It might be necessary to evaluate the quality of QJ-projects in other ways as well.

In order for managers to be able to evaluate and challenge a solution of a QJ-project, it is necessary to understand what has been done. To document what, who and why certain tasks have been performed in a QJ, and then what the results of them were. Simply presenting a solution without explaining how the project ended up with it, often becomes difficult to challenge.

One way for a QJ-project to be evaluated could be on the methods that were used to resolve the issue. That a structured method was used to generate causes of the problem and then probate or confirm the causes by measurements and tests. Especially being able to show the chain of events that led from the root-causes to the symptoms and why the solution is suitable. It is important that the QJ-projects are transparent and traceable in order for managers and other stakeholders to be able to evaluate and challenge the proposed solution.

The projects use statistics to some extent today in their projects, but benefits could be gained by using it more often in order to verify root-causes and look at correlations and tendencies. In order to use statistics in the QJ-process to solve and understand issues in a better way, the knowledge and training of the employees has to be sufficient in that area. The data used in statistical analysis also has to be of good quality otherwise the result can be misleading. The QJ-projects would be able to perform better analyses if the data from MQRs and other systems were of a better quality.

6 Improvement suggestions and recommendations

The result of the analyses and the SWOT-analysis has led to a proposal and some recommendations. The proposal that first is presented involves the importance of making a thorough root-cause analysis (RCA) and may also facilitate the evaluation of the projects due to a better transparence and traceability.

6.1 Improvement suggestion

The root-cause analysis was discussed with all the interviewees and everyone stressed the importance of performing one in the beginning of the projects, some more than others. The process that exists today is not that clear, the process steps defined are basically, "Identify root-cause(s)" followed by "Verify root-cause(s)", as can be seen in *section 2.4.4*. The instructions on how to perform a RCA were not entirely completed either.

Today, different methods are used in order to perform a root-cause analysis and some of the interviewees have made their own templates in order to perform and document the RCA. There is also an action-plan template that is used by some of them.

Together with a team at Volvo Powertrain all the existing material at VPT concerning the RCA were collected in order to get everyone's thoughts. With ideas from this material a suggestion was created. The suggestion comprehended an RCA-process, -checklist and -template, together with training/education material.

6.1.1 The RCA-process

The RCA-process should not only be applicable for QJ-projects, but also for other issues at VPT that is in need of an RCA. This makes some steps in the process similar to the already existing QJ-steps, such as "establishing the RCA-team" and "identify problem in need of an RCA".

The different symbols and objects in the process are defined accordingly:

The processes at VPT are made so that sub-processes exist within the main processes. In the RCA-process “Investigate root-cause” and “Verify most likely cause(s)” are sub-processes within the main process, see *Figure 6.* In the real process-system, the sub-processes can be clicked, in order to be expanded.

The process steps have descriptions attached to them, which explains the steps more thoroughly and also contains an RCA-checklist with instructions on how to perform certain tasks, which can be read in *Appendix B.*

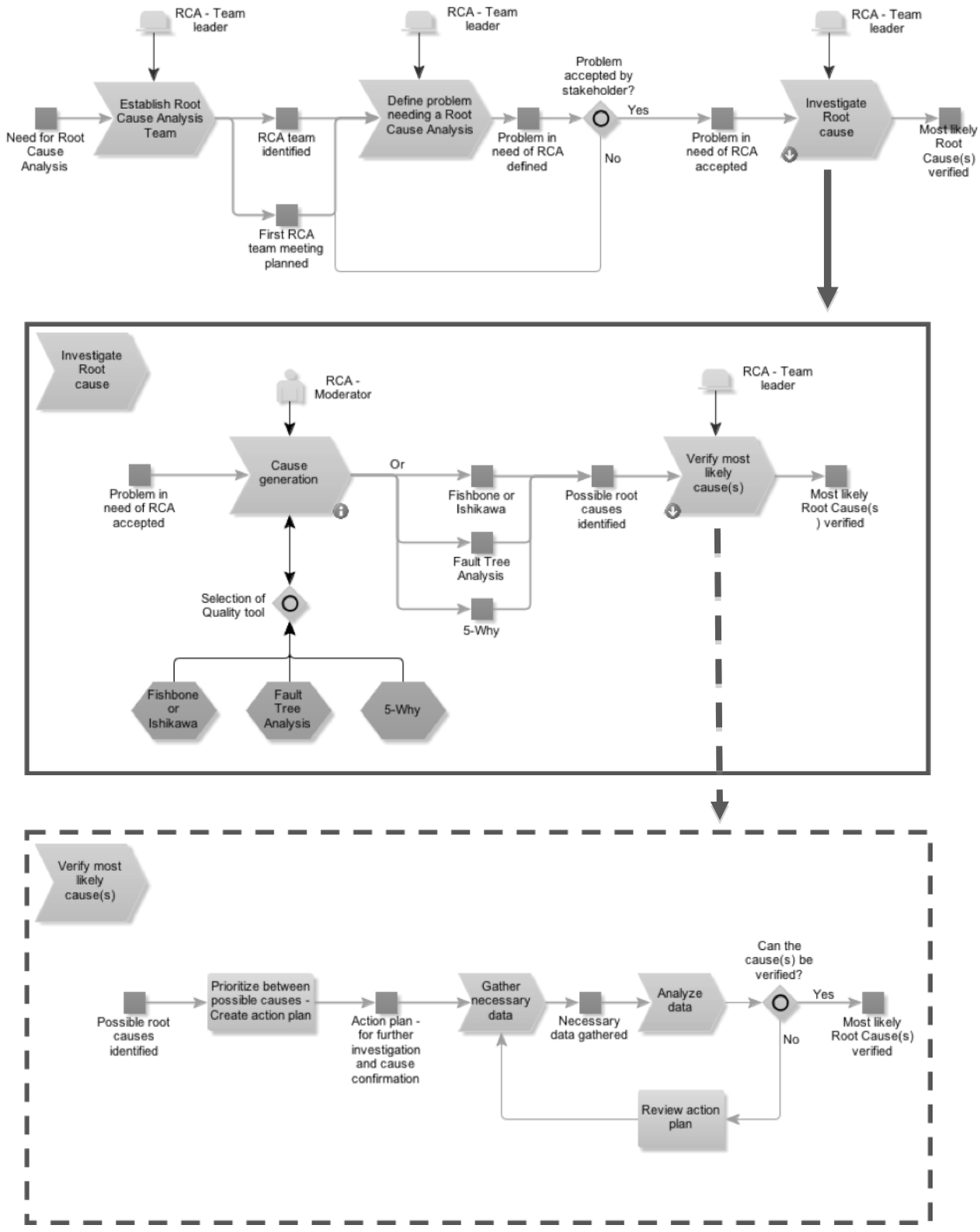

Figure 6: The recommended RCA process

6.1.2 The RCA-template

The root-cause analysis made today in the QJ-projects are really thoroughly performed in some cases and in other cases they are not performed at all, when the root-cause is believed to be known already. According to some of the interviewees, the assumed root-cause in the straightforward/easy cases has not at all time been correct. To gather the team in order to generate and discuss potential causes does not necessarily require that much time, especially if there are not a lot of potential root-causes. The time required for such a brainstorming session is however not that long if it is measured against the potential benefits.

As stated before there are some existing templates at VPT, in order to handle the potential root-causes generated at the initial brainstorming session. These were reviewed in order to gather thoughts and make the proposal as familiar to those as possible.

The template was also made as a working document to update continuously during the project, so that when the potential causes had been generated, it also works as an action-plan for further testing and verification of them. The template is due to that reason facilitating the traceability and the transparency of the QJ-project or any other issues that needs a root-cause investigation.

The template, *see Appendix A*, consists of four parts/sheets plus a fifth part/sheet with the instructions on how to use it. The first part/sheet is a summary of information concerning the problem and the current status is written there, this page could also serve as a template for presenting the issue in short for potential stakeholder to the problem, it consists of:

Top Event:	*The event, condition or state constituting the starting point. Preferably linked to customer/user and measurable*
RCA Owner:	*The one who owns the problem, issued by the RCA facilitator*
ID number:	*The id number connected to the RCA, this could be a QJ number, a protus number etc.*
Start date:	*The start date of the RCA*
End date:	*The end date of the RCA*
Last update:	*When the RCA-template was last updated*

Chain of events:	*Explore chain of top event until, a root-cause which is possible to correct/measure/evaluate is identified.*
Affected parts and products:	*Main system/component/process: Concerned system/component or process connected to the top event.*
Persons involved in the RCA:	*A list containing the roles, name, etc. of the participants in the RCA-team*
Methods used:	*A checklist containing the methods which were used in the RCA.*

One important part of the RCA is to perform a brainstorming session, this session is described more thoroughly within the RCA-checklist, *see Appendix B*. The next two parts/sheets of the checklist is where one of the results of that session should be posted as a fishbone diagram or Ishikawa diagram, to visualize the problem in a good way to all the participants and stakeholders.

The third part/sheet also includes a guide/instruction on how to make a fishbone diagram in Microsoft Visio, which is a software available at VPT. To make the fishbone in Visio serves multiple purposes. One is that the software is an easy to use program, which is suitable to make fishbone diagrams in. The second purpose is that the QJ-team could be located in different countries. With the use of Visio, a brainstorming session could be made jointly from different locations, still with the ability to maintain a common focus. The third reason is that the fishbone easily could be exported to an excel sheet and be used for further investigation. How to export the Visio file to excel is also explained within the instruction in the third part/sheet.

When the fishbone is finished, this should be exported the fourth part/sheet of the template, *see sheet four*, *Appendix A*, which contain the actions for further investigation connected to each potential root-cause. All the actions have complementary fields, which contain information about:

Main failure mode:	*TOP EVENT: In these columns shall all confirmed/likely root causes be stated.*
Level 1:	*Causes of failure level 1: The direct cause to the top event. Preferably measurable. Only one cause/row. There may be several causes to the top event.*
Level 2, 3, ...:	*Causes of failure level 2, 3, ..: The direct cause to Cause of failure level 1,2,... Preferably measurable. Only one cause/row. There may be several causes to each Cause of failure level.*
Action:	*Actions and Comments: State required actions to confirm/reject root cause and any comment.*
Responsible:	*Resp: Responsible person for Action.*
Measurement/Data:	*Write down shorter description of what measurements that have been done and the outcome of them.*
Clarifying notes:	*Could be used to state logic flow or reasoning.*
Possible root cause?	*Choose between: Yes/No*
Status:	*ACTION/STATUS: In these columns are actions to confirm/reject root cause, evaluate root cause, follow up timing and responsible to be stated.*

The document is made to serve as a document to use continuously, throughout the RCA. No performed actions should preferably be deleted in order to make the progress traceable. Every potential cause could have multiple actions connected to it, a row could easily be added below the previous one, see sheet 4, Appendix A. If one action is made that concerns multiple causes, these could be color-coded in order to make it visual.

The idea of this document is that it should be easy to use, help employees to in a structured way solve issues with a higher accuracy, and in order to make the progress of the RCA more visual and understandable for management and other stakeholders.

In order to use these documents properly a three-hour training session has also been made, in order to teach the employees the mindset needed, and important factors that characterize a good root-cause analysis. The education material is however not included in this thesis. It is important to also educate and train employees in doing a structured root-cause analysis.

6.2 Further recommendations

- Adopt more from the original 8D framework, such as containing the problem and the last two disciplines, which is about spreading knowledge and giving feedback.

- Improve the documentation of how tasks have been performed, especially what has been done through the projects. Deciding upon a standard how to name files in the Argus system or create a better file structure.

- The QJ-team do not at all times use statistics to the extent that it is possible with the data available.

- Instructions and template for how a business cases should be done is not that well defined.

- Become better at performing containment actions, make a clearer definition on what a containment action could be.

- Map where existing knowledge is located and become better at utilizing the existing knowledge within the company. Become better at updating and maintaining tools and methods, assigning owners (experts) to each tools. It is also important to take away methods/tools that are not used.

- The workload connected to certain roles has to be more synchronized to their responsibilities. The PMQJs has approximately 12 projects per person, which is not an optimal level in order to be productive and it probably affects the result in a negative way.

- Share knowledge more to identify best practice to even out the quality of the QJ projects and get the result of them less dependent of the individuals.
    - Standardize certain steps of the process

- Improve the quality of the warranty data such as MQRs, by setting more requirements on how they should be done.

- Become better at finding and especially take care of critical-to-quality characteristics acquired through projects, in order to improve; future projects systems, and develop more robust solutions.

- Becoming better at using the containment action and at an early stage, create more guidelines for the QJ-team to use.

7 Conclusions

The QJ-process is a process that fits its intended purpose to a great extent. The QJ-process is good in order to handle problems that appear ad hoc, the DMAIC structure on the other hand is more applicable when improving processes rather than solving urgent problems. Statistical methods should however be used more than they are today. The methods that are used in the DMAIC framework are suitable in some cases, which is why the statistical knowledge level should be increased. The QJ-process could also gain by adopting more from the original 8D framework and improve some of the process steps, such as containing the problem and the last two disciplines. In some areas the knowledge level should be increased and certain steps should be better defined in terms of, how things should be done and who is responsible to decrease the employees level of uncertainty. The projects and process should also be made more transparent and traceable, in order to be facilitating for the QJ-team, management and other stakeholders. The QJs could in a longer perspective then be better evaluated on the quality of the solution, instead of as it is today, mostly only on lead-time targets. The improvements of the QJ-process will support both to reduce lead-time of QJs as well as the quality of the solution.

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Appendix A, Root Cause Analysis template

Table 3: First sheet in RCA template, with easy information to grasp

Top event (Problem description)		**RCA Owner**		**ID number (QJ, Protus, etc.)**	**Method used**	
					Fishbone/ Ishikawa	
					KJ-method	
Root Cause		*Start*	*End*	*Last update*	FTA	
	Date				5 Why	
					Other	

Chain of events

Affected parts and products	**Persons involved in the RCA**		
	Role	**Name E-mail Function**	
	RCA Leader Product Development Manufacturing Purchasing Aftermarket Quality		

Table 4: Second sheet in RCA template, How to make a fishbone

Make a fishbone in Microsoft Visio

Instruction - How to make a Fishbone in Visio

Instruction - Fishbone from visio

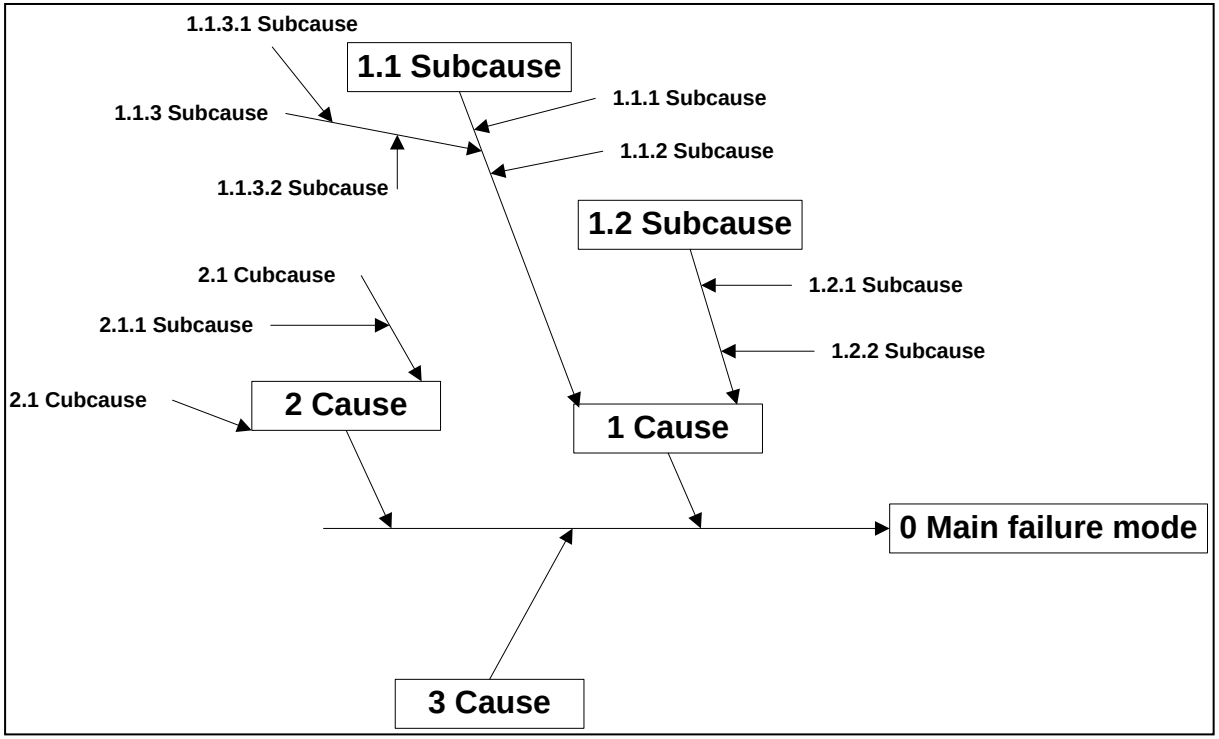

Table 5: Third sheet in the RCA template, how to make a small fishbone

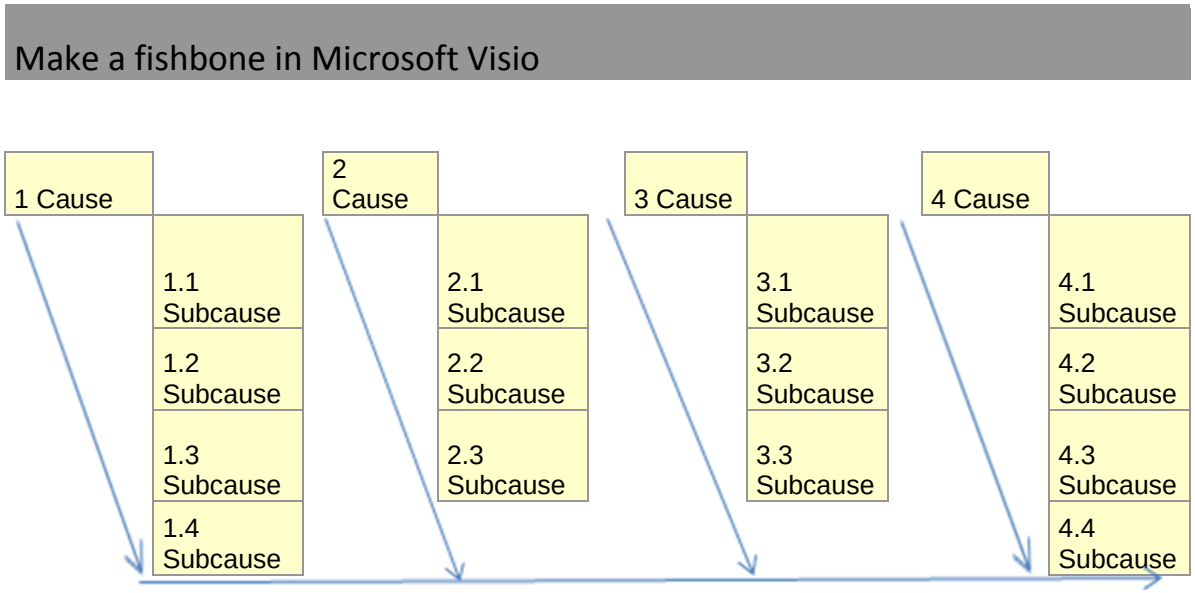

Table 6: Forth sheet in the RCA template, Work area with action plan

Order number	Cause structure and Action plan											
	Main Failure Mode	Level 1	Level 2	Level 3	Action	Responsible	Measurements /data	Clarifying notes	Deadline	Priority	Possible root cause	Status
1	0 Top event										Maybe	Completed
2		1 Cause									No	To be started
3			1.1 Subcause								Yes	Ongoing
4				1.1.1 Subcause								
5			1.2 Subcause									
6		2 Cause										
7			2.1 Subcause									
8			2.2 Subcause									
9				2.2.1 Subcause								
10				2.2.2 Subcause								
11		3 Cause										

Root Cause Analysis – Guideline and Template

When holding a Root Cause Analysis this Checklist could be good consider:

Scope

- Root Cause Analysis (RCA) is conducted whenever there is a perceived need to systematically investigate the root cause of a problem.
- RCA is a matter of initiating, mobilizing resources, clarifying the problem and finding the root cause.
- To secure that actions are implemented in relevant processes conclusions including decided corrective actions shall be documented.

Terminology

A root cause can be defined as:

- The causal or contributing factors that, if corrected, would prevent recurrence of the identified problem
- The "factor" that caused a problem or defect and should be permanently eliminated through product and/or process improvement.
- The factor that sets in motion the cause and effect chain that creates a problem.

Appendix B, RCA Checklist

10 Checklists for RCA

Step 1 – Establish team

- Appoint RCA leader

Identify needed competences – *Get the right people involved*

To get the best result from your root-cause analysis it is important to involve the right people. In rare cases a team from one department can be preferable, but more often the problem is concerning more than one department and in order to take all possible causes under consideration it might be better with a cross-functional team. It is recommended to have 3-6 people as members of the team.

Example of departments to support with necessary expertise:

- Product Planning
- Product Development
- Testing
- Purchasing
- Manufacturing
- Aftermarket
- Parts
- Quality
- Supplier
- Customer
- Dealer

The selection of needed competences might have to be looped. Remember to constantly evaluate if all that are needed competences are involved.

Valuable points that is good to think of:

- Make a time plan that are realistic and update it during the process
- Document who are responsible for what
- Have a Kick off to get a better start
- Secure resources that are needed for the project

Step 2 – Define the problem

Describe and surround the problem in order

- Distinguish affected areas with higher failure modes (especially for QJs and other problems at the aftermarket)
- Try to distinguish the occurrence of the problem i.e. by:
    - Geographical
    - Age
    - Application specification
    - Version and variants of parts and software
    - User type
        - Specific user applications
        - User combination
    - Producer and/or Supplier

History of the problem

- Check for re-occurrence
- Check if an RCA has been made previously on the same problem
- Could the problem be related to another recently fixed problem

Find all affected customers

Examples of areas where customers could be affected:

- Aftermarket
- Manufacturing
- Customer engineering
- Customers within the Volvo group
    - Volvo Trucks
    - Renault Trucks
    - Mack Trucks
    - Volvo Penta
    - Volvo Construction Equipment
- Etc.

Define the problem

- Is the problem definition weakness focused?
- Is it brief, succinct, avoiding jargon?
- Does it avoid stating the cause?
- Does it avoid assuming the solution?
- Has the problem definition been agreed with sponsor?

Step 3 – Investigate root-cause(s)

Step 3.1 – Gather possible causes and selection of quality tool

This is a suggestion on how to generate and gather ideas of possible causes in an organized way

- Gather the team for a meeting
- Present the top event (symptom) and the background information. Make sure that all understands the issue. Avoid stating the cause(s) or possible solutions.
- Let everybody independently write down their ideas of possible causes and remind them of that no idea is less worth than the other
- Assign someone to record all ideas
- Go around the table and let everybody express one idea each until all ideas have been brought up and fully understood. During this it is important that:
    - No one gives judgment to the ideas
    - No solutions or improvement suggestions should be brought up
- Try and group the causes together
- Proceed with further cause generation and determine what tool that will be appropriate to use. It is often appropriate to use a fishbone at first to get a breadth of the investigation and as a second step use 5-Why in order to dig deeper into the possible areas:
- *Pros and cons with each tool*:
    - **Fish bone, Ishikawa**
        - Pros
            - Avoid overlooking possible root causes
            - Visual representation of the causes
            - Potential to discover alternative opportunities
            - Enables focus on the “big picture”
            - Even after addressing the need has been addressed the fishbone diagram shows areas of weakness
        - Cons
            - It can be time consuming
            - It is hard for very complex and interrelated problems
            - If possible causes are missed it might lead into the wrong direction
    - **5-Why**
        - Pros
            - The method is easy to learn
            - The method can lead to that the root cause is found
            - It is easily adaptable for different kinds of problems
        - Cons
            - It has a tendency to stop at symptoms

                - Inability to go beyond the investigator's current knowledge
                - Results aren't always repeatable
                - Tendency to isolate a single root cause, forgetting other possible causes
        - **Fault tree analysis**
            - Pros
                - Visualizes the problem in a good way
                - Provides correlations between different causes
                - Identifies possible failure potentials which might have been overlooked
                - Determines where to place emphasis for further testing and analysis
                - It can handle complex problems and interactions
            - Cons
                - It is a deductive approach, which gives a rather black-and-white perspective
                - If making bad estimations on the correlations the end result could be invalid

- Break down the different possible causes and try to dig deeper with the help of the chosen method
    - Note that solution suggestions is not part of this section
- Prioritize the possible causes for further investigation.
    - It is good assign which of these possible causes that is of most importance to investigate them first. The possible causes can as an example be prioritized depending on:
        - Ability to fast strengthen the proof or reject the influence of the cause by performing tests and measurements.
        - Have strong believes that the influence of the cause is strong.
- Create a action plan from the result of the session

10.1.1.1 Explanatory text

Leave the solution behind and just focus to find the causes that could contribute to the top event. Use a structure since it is less change to miss the real root cause.

When the problem and background has been presented for the team the RCA moderator should collect ideas of possible causes of the problem from the team without a discussion at first. Preferably ask the team to write down their ideas of possible causes and then present them one at the time. All possible causes should be recorded, without judgment as to the validity of the idea. These ideas could preferably be good to group together in order to get a clearer picture over how they are

connected. If it is unclear which category that is appropriate, the problem owner decides which is best and records the idea in that section. Once a first cause generation has been made the moderator should decide upon which method that is applicable for further investigation and generation of causes. In order to successfully find the root-cause of a problem it is good to have a structured way of working. One tool that is preferable to use is a fishbone method but other tools could also be used, such as 5-Why or in very complex cases with a lot of interrelations the Fault Tree analysis. 5 Why is a method that is appropriate when digging deeper into one cause, but in order to get many dimensions of the problem it is best to combine with a structure i.e. fishbone. In the beginning of a root cause analysis it can be dangerous to go to deep into one area.

The team should collectively determine, preferably by trying to get consensus in the group, which of the ideas recorded is most likely to be a cause of the problem. They should be prioritized from most likely to least likely. As an alternative a voting system or other methods can be used by the group to establish the priority order of the most likely cause(s) of the problem. If this list contains more than a single cause, more information is needed to complete the analysis to end up with just one cause or a combination of causes that are identified as the root cause of the problem. When the causes are prioritized the list or map over possible causes could be made into an action plan and act as a good as a base for further investigation.

Step 3.2 – Verify cause

- Make a logic flow of how the problem has occurred
- Make it visible so it is easy for others to grasp
- Get as much supporting data as possible that indicate in the direction of the cause.
- Try to re-create the cause in a controlled situation

Step 4 – Communicate and archive the result from root cause analysis

A thoroughly made root cause analysis should have a way to easily follow the work as it is progressing. To have a living document throughout the project is a good way to keep track of the progress during and also follow up the result in the end of the RCA. After the project is finished it is also good to reflect upon the project and write down learning's from the project.

- Have a living document throughout the project
- Reflect over the project and write it down
- Make sure that the information spreads to all involved parties
- Give feedback to your colleagues