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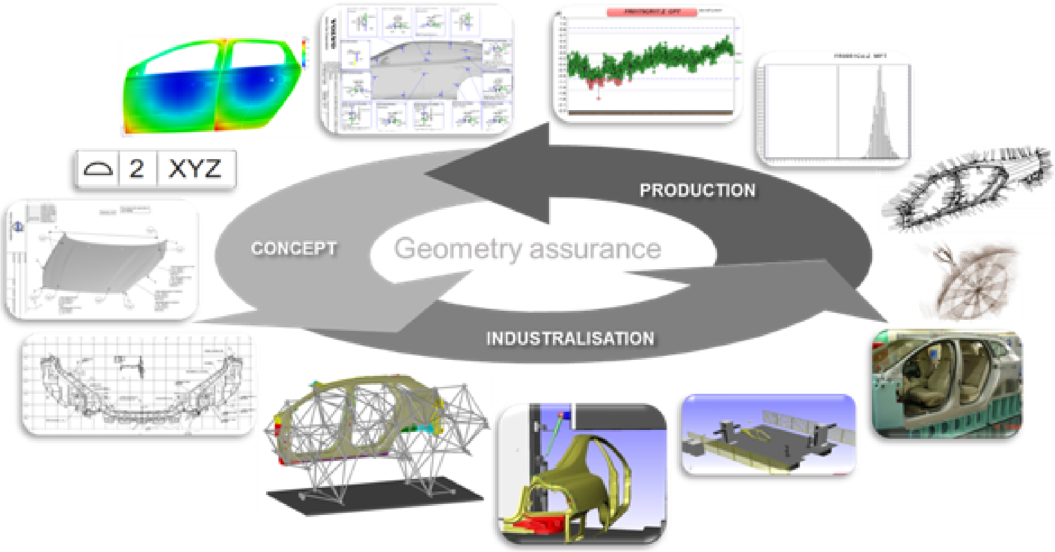

Usage of Volvo Cars Internal Management System: FLOW

Creating a Clear and Efficient Working and Documentation Procedure for the Geometry Organisation

Master's thesis in Product Development

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Department of Industrial and Materials Science
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2018

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Cover: Geometry Assurance Loop by Söderberg et al. (2016)

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Claudia Ardelean
Gothenburg, June 06, 2018

Abstract

Manufacturing premium cars requires sophisticated processes, tools and standards in place. A car is assembled by hundreds of components which are divided by so called split-lines. The final appearance of these split-lines will affect how the end customer perceives the total quality of the car and in order to limit the size and variation of these split-lines there are specific requirements defined, called aesthetical geometrical requirements, or final demand requirements within Volvo Cars. These requirements are part of something called the geometry assurance process which helps minimising variation and create a robust design. There are more than thousand final demand requirements defined in relation to the development of one specific car model. Implicitly, the fulfilment and management of these requirements requires sophisticated processes, tools and standards in place.

There are four different departments involved in the geometry assurance process which all have different responsibilities in relation to final demand requirements; defining, performing theoretical calculations, physically verifying and maintaining the status of the requirements. This research investigates the possibilities to develop a new working procedure, supported by the internal issue management system FLOW, in terms of managing and documenting activities and deliveries in relation to the work performed by these departments. By systematically analysing interview results, a generic process map has been created, describing activities and deliveries in relation to each involved department as well as milestones and gateways in Volvo's internal product development system VPDS.

A new working procedure has been developed which will aid the process of handling final demand requirements in terms of being more effective, efficient, transparent, intuitive, among other things. The previous strict handovers between departments has been blurred and focus has shifted from seeing it as a strict handover to a more cross functional way of working. In addition, a lot of waste administration work has been eliminated with this new working procedure. However, there are some elements that need to be investigated further, first, the suggested working procedure is based on the assumption that the outcome from another simultaneous project will be in a certain way. This simultaneous project concerns how the software System Weaver will be used as a base for all requirements whereas the developed working procedure suggest a connection between the two systems – System Weaver and FLOW, which also is dependent on a plug-in currently under development.

Keywords: Geometry Assurance, Robust Design, Aesthetical Geometrical Requirements, Issue Management, Requirement Management, Documentation, Geometry Loop, Working Procedure, Product Development

Abbreviations

AL	Attribute Leader
BMS	Business Management System
CAT	Computer Aided Tolerancing
DRM	Design Research Methodology
DSM	Digital Shape Model
FD	Final Demand
FDJ	Final Data Judgement
FDR	Final Demand Requirements
FSR	Final Status Report
GA	Geometry Assurance Department (Running Production)
GE	Geometry Engineer
GAE	Geometry Assurance Engineer
GAP	Geometry Assurance Program Department (Program Phase)
GSU	Geometry System Developer (former name of the role RDE)
MP	Measurement Point
MP (1,2)	Mass Production
PC	Program Confirmation
PP	Pilot Production
PS	Program Start
PSF	Program Strategy Finalised
PQ	Perceived Quality Department
RD&T	Robust Design & Tolerancing Department
RD&T	Robust Design & Tolerancing Software
RDE	Robust Design Engineer
SW	System Weaver (Functions and Requirements System)
TPC	Trim Part Coordination
TT	Tooling Trial
VP	Verification Prototype
VPDS	Volvo Product Development System

Contents

1
Introduction

Volvo Cars (further mentioned as 'Volvo') is a global automotive company manufacturing cars in the premium segment. Implicitly, this requires the company to have a strong focus on quality, in particular perceived quality which is a term used to described the customer perception of a product and included aspects based on the '...feeling of good quality of a product' (Chalmers University of Technology, 2014). Perceived quality can furthermore be divided into different areas, for instance, material and geometrical quality. This thesis will focus on geometrical quality which is assured by the involvement of several different departments included in a so called geometry loop, see fig. 1.1. There are several activities performed within this loop to secure the geometrical quality of the car, these activities are part of a well established process – geometry assurance.

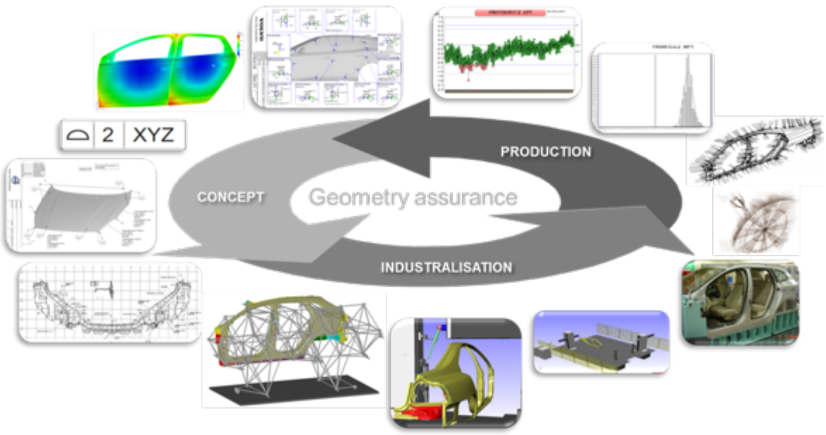


Figure 1.1: Volvo Cars Geometry Assurance Loop.

One particular part of this process is the definition and fulfilment of a specific type of requirements – final demand requirements (FDR), in theory also called aesthetical geometrical requirements. The use of FDR is a way to define and quantify the accepted and desired relation between two components, in terms of perceived quality. Today, there are four different departments involved in the process of defining, predicting and verifying these requirements. Along this process, it is crucial to monitor the evolution of the requirement and document issues and deviations that might occur. Today's working procedure for the management and evolution documentation and related issues is not ideal and sometimes even not existing, therefore, there is a need to investigate how this could be done in the future.

Volvo has recently introduced a new internal issue management system called FLOW, which is intended to facilitate the management of product related issues with one common working method and one common tool. Previously, several applications and software were used to manage issues depending on the different departments and stages in the product development process. Using several applications in this way hinders effective cross functional communication and management due to the complexity of both the product and the working process. Therefore, the need for a new system arose and FLOW was developed and introduced.

With the introduction of this issue management system possibilities of handling and documenting FD deviations supported by this system arose. This is where this master's thesis will play an important role. This chapter will first present a brief background of the company, followed by research questions, deliverables and delimitations.

1.1 Company Background

Volvo was founded by Assar Gabrielsson and Gustav Larson in 1927. The founders recognised a gap between the cars offered on the market and the need for the Swedish environment, there were simply no cars strong or safe enough for the Swedish roads (Volvo Cars, n.d). In 2010 the Chinese based company Zhejiang Geely Holding acquired Volvo (Zhejiang Geely Holding Group, n.d). Today, Volvo is a true international company with 38000 employees and manufacturing plants in Sweden, Belgium, China and the United States. Ever since the foundation of the company, there has been a strong philosophy and focus around safety, people and quality, and these are still today's core values. Håkan Samuelsson, President and CEO, describes it as: 'Our purpose is to provide safe, sustainable and convenient mobility, making a positive contribution to society' (Volvo Cars, n.d).

Volvo's mission is to '... be the world's most progressive and desired premium car company and to make people's life less complicated.' (Volvo Cars, 2017). However, Volvo is not as any premium brand, everything starts with people which is why they are the core of everything they do.

There are big changes in today's environment, with new emerging technologies, digitisation, increasing automation and a different mindset from consumers (Gao et al., 2016). These changes are of course of great importance for Volvo and bring some interesting challenges. The first step towards addressing the changes is already taken; by 2019 all new Volvo's will be electrified and by 2020 and beyond autonomous cars can be expected to be introduced on the market (Volvo Cars, 2017).

1.1.1 Research Questions

The purpose of this thesis is to suggest a working procedure for handling FDR across the departments included in the geometry loop. This should facilitate easier communication between the different departments and help being more effective and efficient. To assist in achieving this goal, three research questions have been formulated, see list below.

1. In relation to each involved department in the geometry loop: how are deviations managed and documented today?
2. Supported by FLOW, how can the process of handling final demand requirements be improved and simplify a cross functional way of working?
3. How can a new way of working be communicated to users in order to achieve awareness and acceptance?

1.1.2 Deliverables

The expected outcome of the project is to carry out a thorough investigation of the current situation of today, to experiment and test different setups with the application FLOW and consider how to best implement and carry out a potential change in order to avoid complications and resistance among users. This will generate the following deliverables:

- Theoretical description of today's working and documentation procedure within each step of the geometry-loop.
- One proposed setup of how to manage final demands throughout all steps in the geometry-loop.
- Recommendations of what is required in order to successfully implement a new working procedure.

1.1.3 Delimitations

In order to achieve and deliver qualitative results within the time frame given – 20 working weeks – it is necessary to make some limitations to the project. These limitations are made due to the extensive possibilities FLOW brings since it can simply handle all kinds of issues related to the product, independent of department or phase in the development process. The following delimitations have been made:

- No other issues than geometrical, will be considered.
- No other departments apart from the ones involved in the geometry loop will be included.
- The research will only be made on final demand requirements.
- Potential development needs of FLOW will only be left as a recommendation.

2

Theoretical Framework

The purpose of the Theoretical Framework is to provide relevant theory and a summary of existing research, relevant for this thesis. This will help create an overall understanding about the topic and support further reading and understanding regarding results and analysis of the thesis, presented in chapter 4.

2.1 Geometry Assurance

...involves all the processes aimed at creating geometrically robust and well-defined products that are close to perfection in their geometrical design...

PE Geometry

Manufacturing a car requires a manufacturing process that supports the assembly of hundreds of components. Geometry assurance or geometrical part quality assurance or dimensional management, all aiming to describe the set of activities aiming to minimise the effect of geometrical variation in the final product (Söderberg et al., 2016) or as described by PE Geometry (n.d.) "...involves all the processes aimed at creating geometrically robust and well-defined products that are close to perfection in their geometrical design...". Geometrical variation may have an impact on the customer's perception of the overall quality, in terms of aesthetics and functional impact, and even though it in theory might appear simple to manufacture products that are perfect, that is not what the reality looks like (Wagersten, 2013). Ajiduah (2010) argues that it is evident and impossible to manufacture a part or product without variations in terms of deformations, vibrations and thermal changes.

As for what is seen in industry today, there are still many companies not applying and using geometry assurance in a widespread way and several authors claim that this is the missing link, especially between research, development, design and final product (Ajiduah, 2010). Further, Söderberg et al. (2016) claim that the consequences of bad managing in terms of geometrical part assurance will lead to decreased added value and trying to solve this late in the process will only be costly. Even though there might be high costs involved in introducing geometrical metrology and a geometry assurance process, it needs to be seen as an investment and in the light of the long term benefits, i.e. saving both time and money since part quality can be controlled, monitored and assured in early phases (Lindqvist et al., 2016).

In order to avoid re-designing when deviations are discovered in late phases and instead enable corrections, Lindqvist et al. (2016) claim that geometrical part assurance should be carried out through all phases in the product realisation process and Ajiduah (2010) agrees it should be carried out in early design and development phases. This is especially important because the longer it takes to discover major deviations the more expensive it will be to change the design or the tools used for manufacturing, see fig. 2.1 by Sullivan (1986).

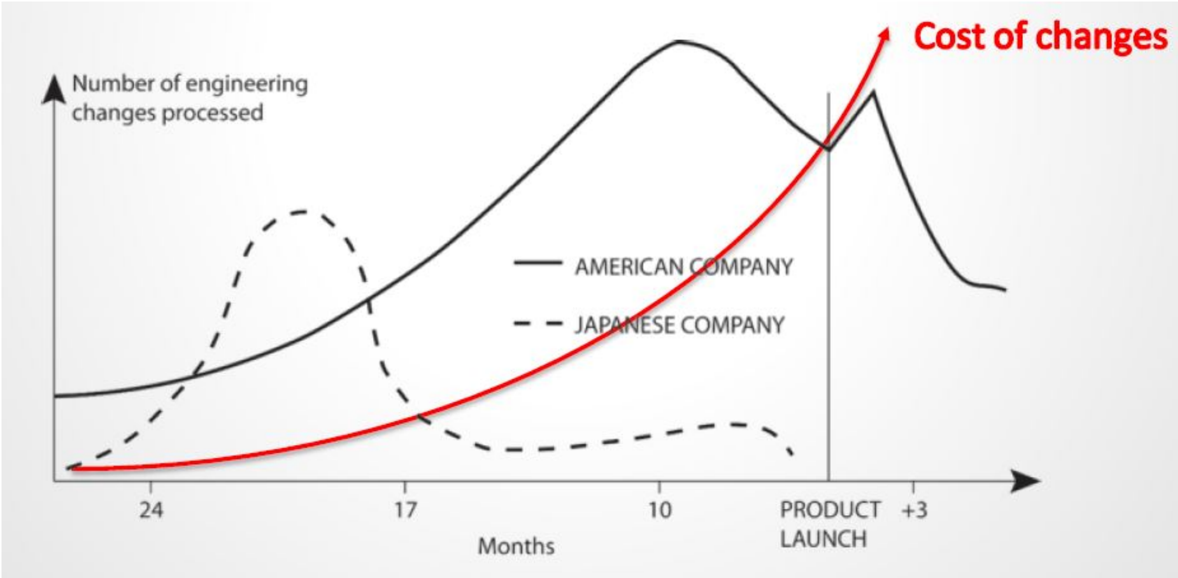


Figure 2.1: Demonstration of the increasing cost when getting closer to launching the product (Sullivan, 1986)

2.1.1 Robust Design

The outcome and purpose of performing geometry assurance activities is to secure that the produced products are designed in a robust way. In simple terms, a robust design is defined as a design insensitive to variation (Söderberg et al., 2016) and to improve the product quality by minimising the effect from the cause of variation (Phadke, 1999). It is self-evident that a manufacturing process producing parts without any variation will be very expensive since it requires extremely tight tolerances, as Wagersten (2013) states, decreased tolerances means increased manufacturing cost and there is usually a trade-off between cost and quality in these cases. An option to decreasing tolerances and to avoid expensive manufacturing processes is to in early phases make sure that the product design is as robust as possible, which can be controlled by the locating scheme which defines the fixing points for a component in the assembly. In fact, 60 % of late changes are due to sensitive or unclear concepts and tolerances (Söderberg et al., 2016) and as shown in fig. 2.1 the cost increases the later in the process this is discovered and taken care of, which is why robust design and geometry assurance activities need to be considered throughout all phases in the development process.

2.1.2 Aesthetical Geometrical Requirements

As previously mentioned, a car is assembled by hundreds of components. Wagersten (2013) states that the division of these components is defined by so-called split-lines, as shown in fig. 2.2. The final appearance of these split-lines will affect how the customer perceives the total quality of the car, therefore, specific requirements are defined to limit the variation and size of the split-lines. These requirements are called aesthetical geometrical requirements (final demand requirements at Volvo) and limit the gap, flush and parallelism (Wagersten, 2013). These requirements form a solid base supporting the geometry assurance process by being numerically measurable. The outcome, if they are within specification or outside specification, can be seen as a validation of if the design is robust or not, see section 2.1.1.

Figure 2.2: Visualisation of split-lines between components, (Volvo Car Corporation, n.d.)

The quality of these requirements are dependent on several factors, described by Wickman and Söderberg (2010) and presented in fig. 2.3, where we can see that geometrical variation is dependent of the robustness and variation in the manufacturing processes which is why geometry assurance is such an important aspect when designing products.

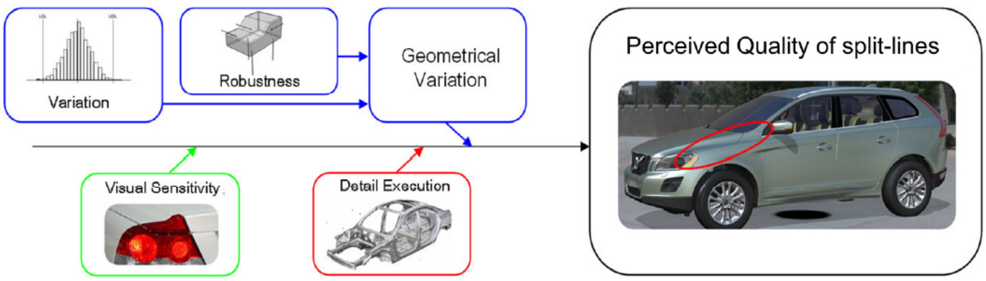


Figure 2.3: Factors contributing to the perceived quality of splitlines

2.1.3 Phases within Geometry Assurance

Geometry assurance can be a complex process within a company and involve many different people. In theory, a geometry loop divided by three different phases has been defined according to fig. 1.1 and the following phases:

- Concept phase
- Verification (pre-production) phase
- Production phase

Summarised by Söderberg et al. (2016), the **concept phase** can be defined as the phase where product and production concepts are developed. Different methods and tools can be used to support this process, but the CAT-tool RD&T is commonly used in several industries and also at Volvo. The following activities are generally performed during this phase:

1. Definition of split-lines, where the components meet and divide the product into different parts
2. Definition of top level requirements, i.e. product tolerances
3. Define locating schemes to optimise geometrical robustness
4. Tolerance allocation, i.e. define part tolerances to meet top level requirement.

Verification (pre-production) phase also called 'Industrialisation Phase' internally within Volvo, aims at preparing for full production which includes physical testing and verification where the objective is to find and correct deviations or errors that occur. One important activity used to support this stage is the creation of inspection preparation material, for instance, measurement point drawings (MP-drawings), which define measurement points to be used in order to control the quality of the product. In order to keep the verification phase on a reasonable level it is important to find the minimum number of inspection points that can act as verification points and be used to find deviations that need to be corrected (Söderberg et al., 2016).

The **production phase** defines when the product is in full scale production. At this point, the majority of all issues and deviations shall be solved. However, the remaining issues or new arising issues need to be taken care of which is why adjustments on production processes are common during this phase. The focus is therefore put on inspection data, e.g. result from measurement points, and used to control production and detect and correct errors (Söderberg et al., 2016).

What is important here is also the feedback back to the first phase where lessons learned need to be documented and taken into account into the next development process. This is the reason for being a closed loop always iterating back to improve between projects.

Departments, Roles and Responsibilities

The phases described above are also used at Volvo. Furthermore, each phase is managed and 'taken care of' by different departments and roles, where all are responsible for different activities assuring the geometry and robustness of a design. An overall definition is shown in table 2.1. As this thesis will focus/be limited to aesthetical geometrical requirements the responsibility for each department only defines activities and responsibility areas regarding aesthetical geometrical requirements.

Table 2.1: Outline of departments, roles and responsibilities within the geometry-loop

Phase Geometry-loop	Department	Role	Responsibility/Activity
Concept	Perceived Quality (PQ)	Attribute Leader (AL)	Define
	Robust Design & Tolerancing	Robust Design Engineer (RDE)	Calculate/Predict
Industrialisation	Geometry Assurance Program	Geometry Assurance Engineer (GAE)	Analyse and verify
Production	Geometry Assurance	Geometry Engineer (GE)	Maintain

Perceived Quality and the Attribute Leader is responsible for the definition and creation of the requirements and operates mainly during the concept phase. Robust Design & Tolerancing and the Robust Design Engineer operates during the concept- and industrialisation phase with the responsibility to perform theoretical calculations on the requirements defined by Perceived Quality, this is done by using the software RD&T, which is a commonly used tool in geometry assurance activities. Furthermore, the next step is to verify the requirements in physical builds, during the industrialisation phase, this is done by the department Geometry Assurance Program and the role called Geometry Assurance Engineer. Finally, the responsibility is handed over to the department Geometry Assurance and the role Geometry Engineer in the production phase. Activities performed in this phase aims at assuring requirements maintain fulfilled even in production. Even though this strict responsibility division can be made, it is important to note that all departments acts as a supporting function during other phases.

As concluding remarks to section 2.1, the following savings stated by Söderberg et al. (2016) have been identified as the effect of applying the specified geometry assurance process with its toolbox (results from one specific Swedish car manufacturer), which play an important role and contributes positively to an organisation in large and show why geometry assurance is as important as it is.

- 80 % time saved in documentation of gap and flush requirements
- 30 % time saved for definition of locators and requirements breakdown
- 80 % time saved compared to making the drawings in CAD
- Drastically reduced cost related to the launch and less adjustments in production

2.2 Product Development Process

A product development process can be defined in several different ways depending on authors, companies, situations to mention a few reasons. However, some elements or phases can generally be recognised regardless of the definition. Ulrich and Eppinger (2012) define the product development process according to fig. 2.4

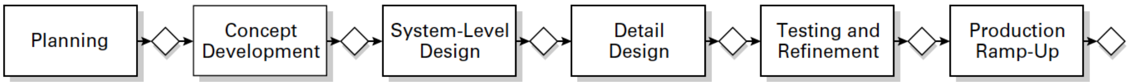


Figure 2.4: The Product Development Process presented by Ulrich and Eppinger (2012)

2.2.1 VPDS - Volvo Product Development System

Volvo has developed its own product development process to fit their specific needs and time frame. This process is called Volvo Product Development System (VPDS) where milestones, gateways and other events are defined over a 3,5 year time line. Figure 2.5 presents an outline of the process, starting from ‘Concept Phase’ to ‘Industrialisation Phase’. To keep it as simple as possible, the inapplicable milestones, gateways and other activities has been excluded from this picture in order to keep a close connection to the relevant parts in relation to this thesis. Note that these phases correlate with the ones in the geometry loop presented in fig. 1.1, however, the ‘Engineering Phase’ in VPDS is merged into the ‘Concept Phase’ in the geometry loop and the ‘Production Phase’ in the geometry-loop is not included in VPDS. Furthermore, the phrase ‘Program Phase’ is used occasionally, this implies all activities prior to FSR.

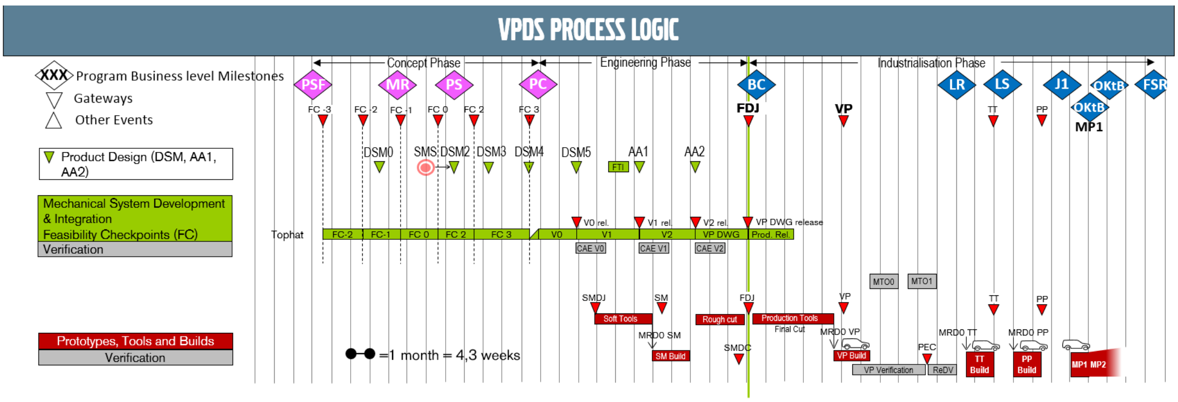


Figure 2.5: Outline of Volvo Product Development System

2.3 Issue Management System FLOW

This section presents one of the most important parts of this thesis, Volvo’s internal issue management system FLOW. First, some background of why there was a need for this kind of system is presented, along with a brief presentation of previously used systems, which today are replaced by FLOW. Further, an outline of the basics is presented, i.e. how the system is used and what is required by users.

2.3.1 Background

Volvo has around 8500 employed white collar workers only in Gothenburg, and implicitly, this requires a sophisticated organisation with many processes, tools and standards in place. Usually, this is something that evolves over time, new processes, tools and standards can be created, others can be scrapped and some can be changed.

In 2014, Volvo started the development of a new software supporting the management of issues related to a car program, where one program is equal to one specific car model. The need for this development arose mainly due to the number of different issue management systems in place at that time. The usage of several different systems led to it being difficult to get a good overview of issues related to a program since it required an employee or manager to be familiar and have access to several different systems, and it quickly got very complex. This led to the introduction of the new issue management system – FLOW, which was introduced October 2016.

Previously, there was one system called VQDC, that handled 'hardware'-related product issues, there was one called Software Issues, which simply handled issues related to the car's software. The intention with FLOW was to replace these two systems but the benefits of the system spread quickly across the company which motivated more users and departments to look over their existing processes and systems. Consequently, three more systems have been replaced by FLOW today.

2.3.2 The System

FLOW is a web based application based on Atlassian's JIRA software (Atlassian, n.d.) and intends to manage product related quality issues during the lifecycle of the product. To help with this, various different issue-types are used, the issue types used in relation to geometrical issues are presented with a short description in fig. 2.6. Additional issue types are available, for instance 'Defect' and 'Change Request'. These will not be considered in this thesis since they are used to software related issues.

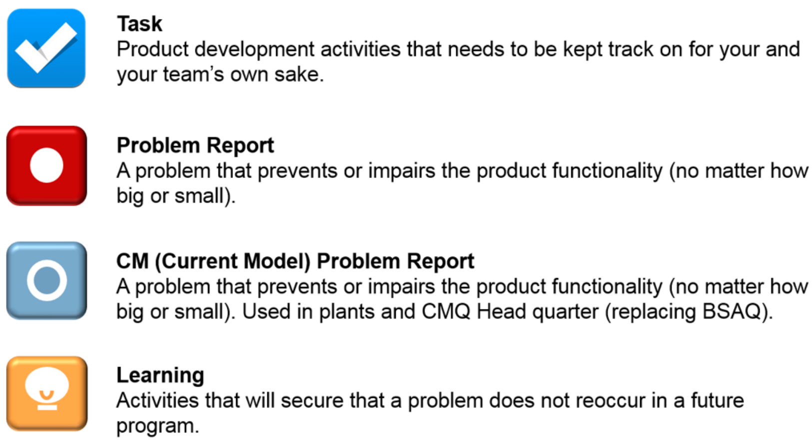


Figure 2.6: Different issue types available in FLOW

In addition to these issues there are different user-roles defined in relation to an issue type. These can define who is responsible, who is currently working to solve the issue to mention a few, for a full summary see table 2.2.

Table 2.2: Different types of user-roles available in FLOW

FLOW User-role	Definition
Reporter	• The person that finds an issue and reports it in the system. • Responsible to handshake (agreement) the Problem Report with an Owner.
Owner	• Responsible for performing a root cause analysis. • Responsible for securing that a technical solution is developed to solve the issue.
Assignee	• Indicates who is responsible to take action in an issue (several people can be involved).
Watcher	• The watcher wants to follow the progress of the issue and will get notifications when the issue is updated.

Issue type and user-role are the most important and basic parts in FLOW. However, there are a lot of possibilities within the system that can help visualise and present relevant issues depending on the interest of a specific user or viewer. To mention a few possibilities, a issue can be labelled, similar to using hashtags in social media, users can create filters including just the issues they might be interested in and it is also possible to create visual dashboards containing all kinds of charts, all issues assigned to one specific user, favourite filters, due date charts and much more. There are simply unlimited possibilities, for an extract of these possibilities and how it visually looks in FLOW, see fig. 2.7, fig. 2.8 and fig. 2.9.

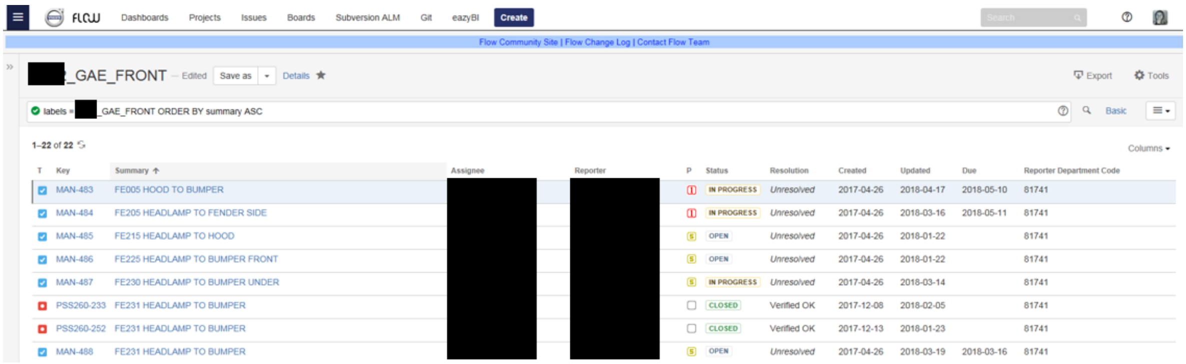


Figure 2.7: Extract of a filter created in FLOW

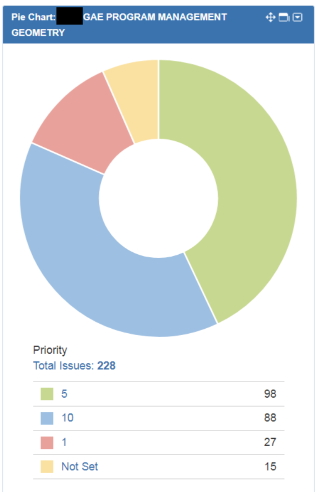


Figure 2.8: Pie chart in dashboard

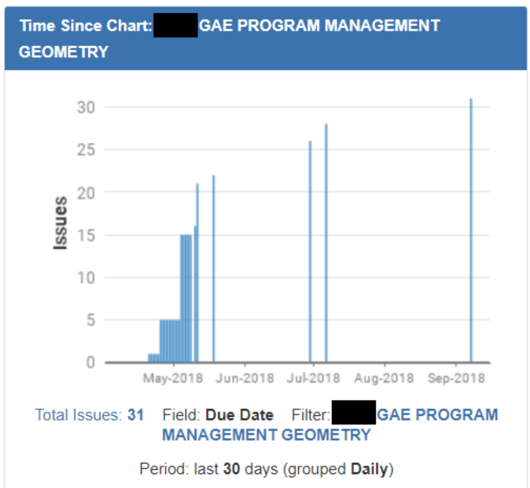


Figure 2.9: Due date chart in dashboard

The system is already today used by the GAE's and their department. The process for this will be presented in chapter 4, section 4.3.3.

3

Methodology

This thesis covers several departments within Volvo, as well as several different processes and people, all dependent on a well defined interplay between them in order to be able to deliver premium cars to the market. In order to approach the research in a systematic way, usage of a clear methodology and different research methods is required, these are presented in the following chapter along with an explanation of why these were chosen and how they helped answering the research questions.

3.1 Design Research Methodology

Several authors, Finger and Dixon (1989) and Cross and Roozenburg (1991) among others, argue that a clear work practice or a design research methodology is needed in order to achieve validity in the results. Blessing and Chakrabarti (2009) have defined a design research methodology as:

...an approach and a set of supporting methods and guidelines to be used as a framework for doing design research.

Blessing and Chakrabarti (2009)

They have developed their own design research methodology, see fig. 3.1, which is a collection of several different research methods. They place a specific focus on the understanding as well as the usage of this understanding to find suitable alternatives to an existing situation and to implement them. The methodology is divided into four different stages which all have defined basic means as well as main outcomes. Each stage is presented with a short description below, together with an estimation (XX%) of the time division between these step.

- *Research Clarification* aims at finding indications that support the researcher's assumptions which can be the initial desired state, i.e. the thesis goals. It should also include a definition of measurable criteria that can be used to validate the success of the research (20%)
- *Descriptive Study I* focuses on existing design process where an objective analysis is made to understand existing situation and find improvement areas (50%)
- *Prescriptive Study* aims at finding a solution to support the *Research Clarification* by changing the existing situation (25%)
- *Descriptive Study II* is the final step which aims at evaluating the solution implemented in previous step by applying observations and analyses (5%)

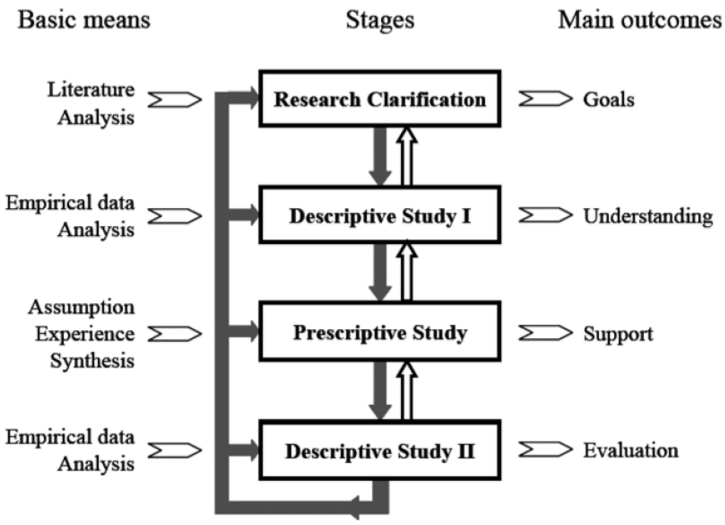


Figure 3.1: DRM framework by (Blessing and Chakrabarti, 2009)

Due to the time frame of this thesis it was decided to focus on the first three elements of the framework, i.e. to leave 'descriptive study II' for further research. This was decided based on two aspects, first, due to the fact that the working procedure needs to be implemented and used for several months before an evaluation can be done. Secondly, due to the complexity in creating relevant measuring criteria, based on that the working procedure aims at being implemented across four different departments, where all have different objectives and presumably different measuring criteria with conflicting interests which requires a sophisticated evaluation method that was deemed too extensive to fit the time frame.

3.2 Research Clarification

At the starting time of this thesis the issue management system FLOW was in the middle of its start-up phase with several different departments starting to implement the system and slowly phase out the old system VQDC. It quickly became evident that this also was needed within the geometry organisation which partly is why this thesis was formulated and initiated. Project definition, research questions, deliverables and delimitations (see chapter 1) were defined during this early stage of the project. The methods used to support the formulation of these parts are presented below.

3.2.1 Literature Studies

Literature studies was carried out in order to find the relevant theory related to the thesis. The core of the literature study was to find information about the geometry assurance process, to understand its importance and to find out how it is managed across different industries and if there is a best practice used. Studies related to the creation of working procedures were done in addition to this. Here, the focus was to find out what is important when designing and implementing a new working procedure and what the challenges could be when doing this in a complex product development process.

3.2.2 Internal Material

In addition to the literature review described in the previous section, a review of internal material was made. Due to the nature of this thesis, aiming to create a working procedure suitable for four different departments with the application FLOW as a base, there was a need to scrutinise internal material thoroughly. For instance, to understand why it was decided to implement FLOW from start and what already was done by the geometry organisation in relation to FLOW as well as understanding the VPDS process on a detailed level. Through discussions within involved departments, the need for developing a new working procedure became evident due to its undefined nature and sometimes ambiguous boundaries.

As previously mentioned, these reviews, section 3.2.1 and section 3.2.2 laid the foundation for the whole thesis and helped formulate project description, research questions, deliverables and delimitations.

3.3 Descriptive Study 1

To avoid unnecessary work and avoid reinventing the wheel again it was important to put a lot of emphasis on this stage to analyse the existing situation. This stage was extremely important and helpful in creating the basic understanding for existing processes and tools used in the geometry assurance process, especially since the process is quite complex covering four different departments. This stage was done in several steps which are described in the following sections.

3.3.1 Department and Role Analysis

As previously mentioned, there are several departments and roles that can be defined as the core in securing the geometry of the car, more specifically, the departments and roles defined in table 2.1. Volvo has something called Business Management System (BMS) where role descriptions, responsibilities, working procedures are documented. A description for each department and role involved in this thesis was extracted from BMS and systematically analysed early in the project in order to support the work in later stages. The systematic analysis was made by highlighting and summarising relevant points and sentences in each description.

3.3.2 Interviews

With the theoretical descriptions of the involved departments and roles as a base, interviews were conducted in order to validate theory (descriptions found in BSM). With the aim to understand the existing situation and processes it was decided to use a mix of semi-structured and unstructured in-depth interviews. This approach was considered to be suitable and generate the best results and is in line with the conclusion made by Boyce and Neale's (2006); qualitative methods will generate the best result when the aim is to create a deep understanding with enough details about the current situation. Furthermore, Van Teijlingen (2014) states qualitative data is preferred when answering the question 'why' as well as explore purpose, context or meaning. The mix of semi-structured and unstructured was chosen due to the possibility to ask both generic questions and more open-ended questions where the interviewees got the opportunity to express opinions or issues regarding the current situation. Structured interviews was deemed inappropriate due to the formal nature and risk for limiting the output and hindering dynamism in this case.

In total, twelve interviews was held with representatives from each involved department, managers and representatives from the FLOW team. Appendix A shows a detailed outline of the interviewees and their expertise field, note that their names are left out due to privacy regulations. This sample was chosen to ensure relevant information and viewpoints were gathered from each department, i.e. from users as well as managers and to cover a wide range of employees in terms of demographics as well as the amount of years within the company. Due to this sample three different interview guides were created. An extract of posed questions is shown in table 3.1 and a full outline of each interview guide can be found in appendix B.

Table 3.1: Extract of posed interview questions

Type	Question
Generic	• How would you define final demands and their importance?
	• How is your department divided in terms of responsibility areas?
	• Which software and systems are you using to support your work?
Open-ended	• Can you describe the existing working procedure in your department, related to the handling of final demands?
	• Can you tell me about the recurring routines/activities you follow?
	• In your opinion, what is of great importance in a close collaboration with other departments?
	• What reactions have you received during the implementation?

The overall objective with the interviews was to collect information about current situation, in terms of how FDs are managed and monitored today, what issues there are as well as discover future possibilities for a more efficient working procedure. All interviews were sound-recorded with permission from the interviewees.

Transcription

The transcription of data is a procedure at the core of analysis... The transcript is seen as a 'representation' of the data...

Hutchby and Wooffitt (1998)

To be able to perform an objective analysis of the collected data it was decided to transcribe all interviews. Pomerantz and Fehr (1997) argue that one shall use both a tape and a transcript when analysing data since there is a risk of losing information when working with a transcript only as well as it is hard to extract relevant information only working with a tape. The decision to transcribe was based on the the complexity of getting a good overview and create an understanding of the working procedures covering four different departments, even though transcribing can be a time consuming process. This also allowed time for reflection since the data was processed and viewed several times, i.e. at the interview occasion, the transcription phase and later in the analysis, see next section, section 3.3.2. The benefits of performing the transcription were simply deemed more valuable than potentially saving some time.

KJ-analysis

A systematic analysis of the collected data was made by using a so called KJ-analysis, also referred to as – Organise the Needs into a Hierarchy – in Ulrich and Eppinger (2012, p.83-86) where they describe one step in how to identify customer needs. Compared to a traditional KJ-analysis where the categorisation usually leads to the formulation of weighted customer needs it was decided to modify the analysis in order for it to fit the purpose in this particular case. The expected outcome from this analysis was set to be a detailed process map over today's working procedure including its deliveries and connection to the VPDS process, more specifically mapping how FD deviations are managed today. It was also important to highlight issues with today's working procedure as well as capturing potential improvement areas and opinions regarding what is important from a user perspective. Important statements from each interview were extracted from the transcripts and grouped into different categories according to fig. 3.2, where the core focus was on the categories within the rectangle, i.e. the departments and their handovers. These were later divided into more detailed subcategories according to the bullet point list below.

- Physical deliveries/responsibilities
- System and tools used to support deliveries
- Outspoken improvement areas
- Scorecard between AL and RDE - documentation area for the status of each FD requirement
- FLOW System
- Definition of FD requirements
- Baseline judgements - decision made when the initial requirement value is changed

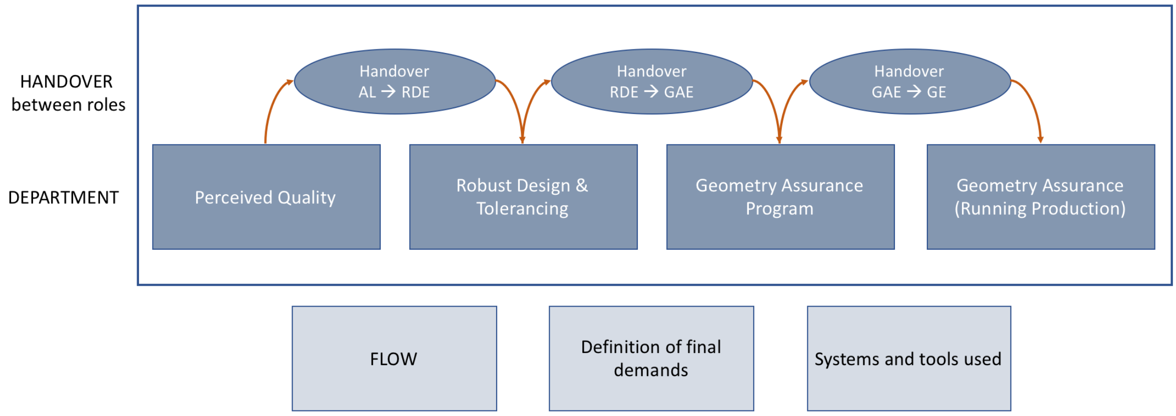


Figure 3.2: Overall categorisation as a result of the KJ-analysis. Core focus within the rectangle.

This detailed division was deemed necessary to help structure the collected data and because each subcategory play an important role in the daily work of handling FDs. For instance, 'Scorecard between AL and RDE', this is one of the most essential tools used to document the status of each requirement. Same goes for 'Baseline judgements', a decision made when the initial requirement value needs to be changed, which is important to document and keep track of. Additionally, there are two different types of judgements that can be made, which is why it was important to make the distinction and gather the related data into one category.

3.4 Prescriptive Study

According to the DRM framework, this step aims at finding a solution to the Research Clarification by changing the existing situation (Blessing and Chakrabarti, 2009). By using the extensive analysis and mapping described in previous section – section 3.3 – as a solid base, the development of a new solution could take place. However, it is important to point out that ideas for a potential solution were considered throughout the complete project but this section will present specific methods used to facilitate the development.

Apart from the methods described in this section, a great amount of effort has been dedicated to continuous discussions and spontaneous brainstorming together with people that will be more or less affected by a potential change of working procedure. This approach highlighted plenty of important aspects that got investigated further and considered through the development of the solution.

3.4.1 Requirement Formulation

Formulating requirements by interpreting collected data is a common method used as a preparation for future development. One definition of this is given by Ulrich and Eppinger (2012, p.81-83) where one step in identifying customer needs is defined as – Interpret Raw Data in Terms of Customer Needs. The customer is in this case represented by the people involved in managing FDR.

A light version of this method was considered appropriate for this thesis where only a few key aspects were extracted as requirements for the continuing development. Since the interviews mainly focused on the existing process it was necessary to interpret and extract requirements based on aspects that were mentioned as problematic. It is important to note that it is difficult for the customer to directly express their needs due to them not always knowing what they want or need until they see it. Therefore, additional requirements were added apart from the ones related to outspoken problems, these were based on intentions defined by FLOW and Volvo, i.e. desired mindset in cross functional working procedures. The importance of formulated requirements was partly based on intentions from the organisation but also the frequency and emphasis each interviewee placed on each aspect.

3.4.2 Continuous Idea Generation

Due to the nature of this thesis, focusing on improving existing situation and developing procedures for activities that might not exist, it was substantial to apply an iterative process, especially in terms of idea generation, whereas, this was made continuously. As soon as a problem or specific topic was brought up potential solutions were discussed by using a brainstorming approach. Massachusetts Institute of Technology (n.d.) defines brainstorming as a process where ideas are generated in a short period of time without any limitations or restrictions. However, even though this method was applied continuously it had its peak after the data collection and analysis and before the focus group, described in next section, took place.

To support the idea generation process the FLOW training environment was used. This is an area where one can experiment and create an infinite number of issues without it affecting existing operations and ongoing projects. This was very useful since it directly could give an indication of a potential solution or idea was realisable with FLOW.

3.4.3 Focus Group

In order to support the generation process, a two hour focus group was held. Usually, focus groups are used as a complement to interviews in order to capture people's ideas and opinions regarding a specific topic and allow them to interact since it can capture more spontaneous expressions and building upon others ideas (Freitas et al., 1998).

However, to fit this particular project, it was decided to use the focus group more as an aid to support and receive feedback regarding the development of a new working procedure. At this point, a proposal of a new working procedure was created and used as discussion material during the focus group.

All interviewees was invited to participate in the focus group which was deemed appropriate due to their already existing involvement in the project as well as their interest in contributing to the development of a new working procedure. These participants formed a solid base of representatives from each department which was considered important in order to capture all viewpoints, regardless of department affiliation. Nine out of twelve interviewees attended the event, these are highlighted in turquoise in appendix A. The focus group structure was designed as follows:

1. Short presentation of thesis scope
2. Presentation of findings from interviews
3. Presentation of proposed solution
4. Discussions based on four questions

The questions posed as an introduction to the discussions are presented in table 3.2.

Table 3.2: Questions used to initiate discussions during the focus group

Area	Question
Solution in general	• What possibilities and/or difficulties do you see with this solution?
	• What is required by your own department and by the ”neighbour” department, in order to be able to embrace this kind of working procedure?
Lean way of working	• How can we ensure we focus on the ”right” activities? (No work duplication) • Internally within our department • Cross functionally over department boundaries
Updated information	• How can we ensure we have the latest information? And where should it be stored? • Current requirements • Decisions made to deviate from original requirement (baselines etc.)
	• Where should it be stored and documented?
	• Who and how do we update this information?
History and lessons learned	• How do we manage history? • Feedback from physical builds • Who to update? • When to update? • How to update?
	• How will this be evaluated and weighted into next programme?

3.5 Descriptive Study 2

As previously mentioned, this step in the DRM framework was decided to be left out from this thesis, mainly due to the time frame given. The solution has, however, been partially evaluated through feedback given by the company and user representatives, i.e. the stakeholders. Buur (1990) suggest a method called ‘Verification by acceptance’ which is also suggested and used by Blessing and Chakrabarti (2009) in relation to the DRM framework. For a design to be deemed as ‘verified by acceptance’ it should fulfil the following critera:

- The theory is accepted by a relevant scientific community - in this case: the management team within the geometry organisation
- Models and methods derived from the theory are acceptable to experience designers - in this case: users and representatives from each role presented in table 2.1

For future evaluation it would be appropriate to apply the method of usability testing. Note that this has not been done in this thesis but is suggested as an appropriate method for the future. This method refers to a product or service evaluation method where representative users are invited to test a specific product or service. Usually, this is done by a test where the participants are asked to complete a specific task while they get observed (U.S. Department of Health & Human Services, n.d.). This method is deemed appropriate due to it enabling direct feedback from the users which will use this application in their daily work, not to mention that their expertise is required to evaluate it in the first place. It is suggested to perform this method by using the same representatives as in the interviews and focus group.

U.S. Department of Health & Human Services (n.d.) states the following benefits as a result of usability testing:

- Learn if participants are able to complete specified tasks successfully
- Identify how long it takes to complete specified tasks
- Find out how satisfied participants are with the system/product
- Identify changes required to improve user performance and satisfaction
- Analyse the performance to see if it meets usability objectives

Moreover, the test also allows evaluation of the formulated requirements presented in section 4.5.3 and will form a solid base for measuring the success in terms of improving existing situation.

4

Current State

This chapter will describe the current situation in detail, which is objectively based on the collected data, gathered through interviews, internal material and additional discussions within the respective departments, see table 2.1. In the case of including quotes from interviewees no names will be published due to integrity restrictions. For a detailed description of the methods used to generate this result, see section 3.3.

Section 4.3 and section 4.4 will present today's process of handling FDR. First, this will be done by a detailed, department specific, description including activities and deliveries related to the management of FDR, this will be done along with a description of the handover between each department. Furthermore, a generic overview of the complete process will be presented, i.e. covering the complete geometry loop. This result is solely based on interviews and material collected during interviews.

4.1 Definition of Final Demand Requirements

Based on the interview question; 'How would you define final demands and their importance?', posed to all interviewees, this section will present a summary of the answers gathered. The interviewees are not named due to integrity restrictions but as described in section 3.3.2, the interviewees represent a sample from the four involved departments.

According to theory, a FD is set to limit the variation and size of a split-line which in turn will affect the customers perception of the total quality of the car (Wagersten, 2013). A majority of the interviewees used this definition in their answer but also mentioned elements as:

''If two neighbours buy the same car [model], we want them [the cars] to be close to identical. They should not be able to see a difference in the tailgate position and its split-lines to adjacent components''

''There should be harmony between all surfaces in terms of flush and gap, even though the customer might not really understand why the car looks attractive''

''A visible requirement that the customer notices. The totality gives an impression of the quality but it can be difficult to state if something is too big or too small''

Consequently, the requirements play an important role in limiting the variation between cars and to ensure it is perceived enchanting by the customer. This will in turn make the customer get a feeling of good quality.

To conclude the definition of a FD and why they are extremely important the following quote was also mentioned in addition to the ones above:

> *‘’It is similar to when you assemble an IKEA cabinet, when you attach the doors you want it to look pleasing for the eye, will you not?‘’*

4.2 VPDS Milestones and Gateways

In section 2.2.1, a scaled-down version of the VPDS system was shown, this section will present the process in an even more scaled-down fashion but with a detailed presentation of the relevant milestones and gateways in relation to the result, see fig. 4.1. To be classified as a relevant milestone or gateway, it should play an important role in relation to the activities and deliveries connected to geometry assurance and FD handling. Their relevance has been based on the result from the interviews. Note that a ‘program’ is equal to one development project of a specific car model.

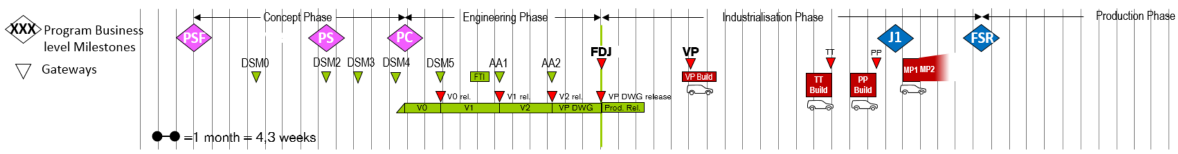


Figure 4.1: Outline of Volvo Product Development System - connected to the management of FDs

Each milestone and gateway will be presented with its full name and its high level purpose. In table 4.1 the milestones are described followed by table 4.2, where the gateways are described. In addition to the milestones and gateways, other important events are presented in table 4.3.

Table 4.1: Description of the relevant milestones in VPDS

Milestone	Name	High level purpose
PSF	Program Strategy Finalised	To describe and get approval for the Program Strategy.
PS	Program Start	Start the program and set prerequisites, mission, targets and program finance ant to get program funding approval up to PC.
PC	Program Confirmation	Program gets its final approval according to the authorization rules for programs. Secure that all chosen function & system solutions are confirmed and compatible with each other (balanced targets).
J1	Job #1	Confirm that all prerequisites are read for production and that vehicles for external customers can be produced and confirm that the markets are ready to receive and sell the vehicles.
FSR	Final Status Report	Document lessons learned and carry them back as changes in guidelines, routines, cycle-plan and VPDS process. Program closes.

Table 4.2: Description of the relevant gateways in VPDS

Gateway	Name	High level purpose
DSM0,2,3,4,5	Digital Surface Model (0,2,3,4,5)	DSM0 is first official release from Design. Each DSM-release imply there is a new or refined design. Changes in DSM5 relative to DSM4 to be judged and implemented to FTI.
AA1,2	Appearance Approval (1,2)	AA1 - Final Design Intention. All technical input included. Release for design quality verification. AA2 – Final design verified and quality assured.
V0,1,2 rel	Verification (0,1,2)	V0 – secure that all systems/components design and mechanical solutions are in place to reach requirements. V1 – secure the compatibility and that requirements are fulfilled. V2 – secure a 100% compatibility and be ready to order components.
FDJ	Final Data Judgement	All development should be as ready to order production tools. Cross functional confirmation that designs satisfy all business requirements.
VP	Verification Prototype	Secure that VP series can be used to verify Production Intent for the complete vehicle.
TT	Tooling Trial	Secure that the TT-build met the targets for the program.
PP	Pilot Production	Secure that the PP-build met the targets for the program.

Table 4.3: Description of additional events in VPDS

Other event	Name	High level purpose
FTI	Final Technical Input	All technical input shall be received and considered into AA1, AA2.
VP Build	Verification Prototype Build	Physical building activity performed to verify the complete vehicle level for all systems and processes. All components are assembled together with the same processes as planned in full production.
TT Build	Tooling Trial Build	Physical building activity performed to verify capability of production tools, equipment, facilities, systems and processes.
PP Build	Pilot Production Build	Physical building activity performed to confirm product quality, process plan, final quality & function equipment. Close to J1 conditions.
MP1, MP2	Mass Production (1,2)	Mass production starts and volumes are increasing.

4.3 Managing FDR - Department Specific

Due to the complexity in managing FDR it was decided to analyse the collected data in a systematic way, see ‘Transcription’ and ‘KJ-analysis’ in section 3.3.2. This section will, in detail, present the processes, tools and methods used by each specific department in relation to VPDS, corresponding to the core focus in the analysis, shown in fig. 3.2. This outline will include crucial input elements, activities and finally, the deliveries or outputs generated from each activity. Furthermore, the handover from one department to another will be discussed and presented.

4.3.1 Perceived Quality

Perceived Quality or PQ, is the first department in the chain of handling FDR. As previously mentioned, the role involved in this process is the Attribute Leader (AL). Their main responsibility is to define all FDR where they perform activities mainly between PSF to FDJ but with continued support throughout the complete program. In order to systematically define these requirements there is a distinction between something called ‘sections’ and ‘requirements’, where one section can contain several requirements, more specifically different types of requirements, see list below.

- Gap width
- Flush
- Variation
- Parallelism
- Left/Right
- Radius
- Alignment
- Ball corner

This is further illustrated in fig. 4.2 and fig. 4.3. Starting with the section, the picture to the left, this is basically a cut through a split line between two components, see number 1 in the picture. Further, this section can be divided into several requirements which are summarised in the box, see number 2. In fig. 4.3 these requirement are highlighted depending on their type. As a generic guideline, there are about 450-500 sections per program and 1500 requirements, all to be defined, verified and hopefully fulfilled.

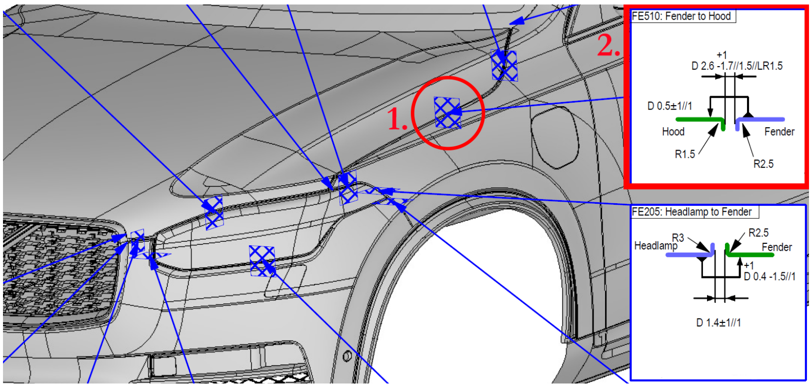


Figure 4.2: Illustration of a FD Section

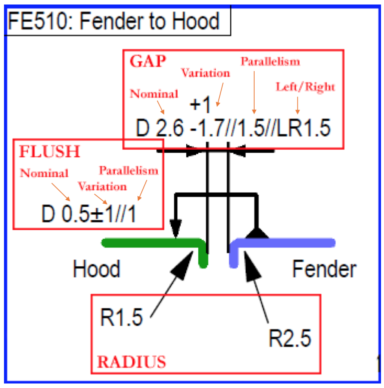


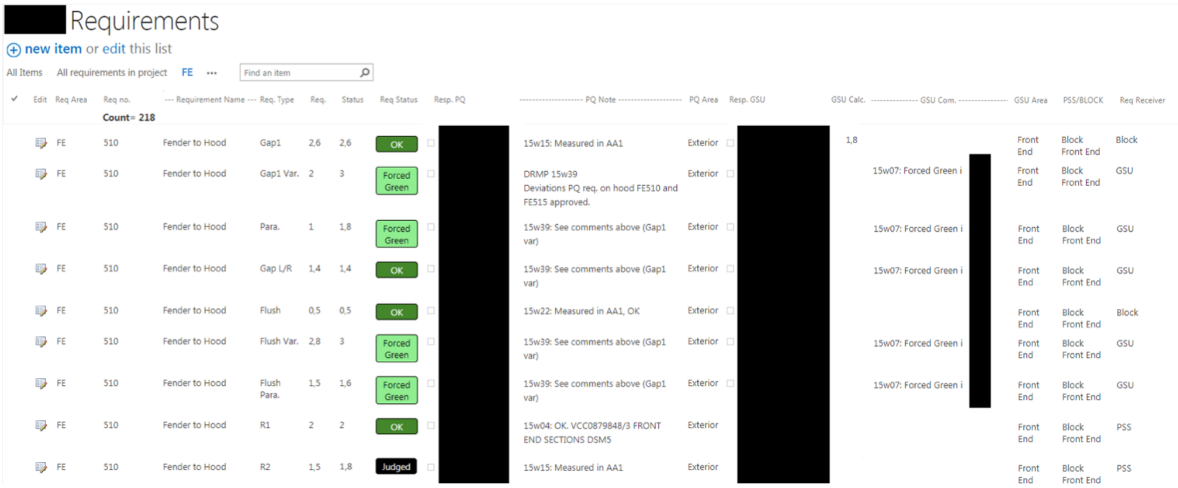
Figure 4.3: FDR types

The first step in the process of defining FDR is where PQ receives strategic input from the department Product Definition, responsible for strategically defining the position and prerequisites for all new car programs introduced. Among other things, they define the target customer for each program but most importantly in relation to this thesis, the definition of the aesthetical quality of the car, i.e. guidelines for the level of perceived quality attributes in comparison to competitors. Based on this input, PQ performs a benchmark where a thorough analysis of relevant competitor cars is made which gives an indication on the level of quality that needs to be achieved to fulfil the strategy objectives. This is done between PSF and PS.

Between these milestones – PSF and PS – the first DSM model is also released. This is the first input from design which indicates that the AL can start defining FDR. Further, there are four additional DSM releases which implies changes on the design, it is a maturity process which also reflects on the creation of a FDR. This can result in sections and requirements being changed, added or removed which is why defining FDR is a highly iterative process.

To support this process the AL uses several systems. First, the CAT-tool RD&T is used, this facilitates the positioning of the sections and generates clear visual material to show this in an understandable manner. This software also helps creating the official document where all requirements are summarised, i.e. requirements on complete car. This document is called – PQ document – see fig. 4.2. As soon as there are any changes to a requirement this document is updated. The first release of the document is made at DSM2 but iterates up until FDJ, when the final document shall be released, meaning there will not be any more changes to the requirements, apart from unique situations where it is necessary to modify them, this will be described in section 4.4.1.

Apart from the PQ document, a SharePoint site is used to keep track of the requirement status and assign them to the relevant requirement recipients, this site is called – The Geometry Scorecard. The site contains all requirements, divided by area, where each requirement (note! not section) is listed with its nominal value, tolerances, status, comments, GSU calculation (GSU is the former name of the role RDE), responsible persons and more, see fig. 4.4. This Scorecard is used to support the creation of the PQ document described previously and contains more information than the PQ document as it is seen as the working area which is used on a daily basis. Beside this Scorecard there is a Masterlist which accumulates all, ever used, requirements in one single list, this is to facilitate re-use between programs where the same relation exists.


[redacted] Requirements

new item or edit this list

All Items | All requirements in project | FE | ••• | Find an item

Count= 218

Req Area	Req no.	Requirement Name	Req. Type	Req.	Status	Req Status	Resp. PQ	PQ Note	PQ Area	Resp. GSU	GSU Calc.	GSU Com.	GSU Area	PSS/BLOCK	Req Receiver
FE	510	Fender to Hood	Gap1	2,6	2,6	OK	[redacted]	15w15: Measured in AA1	Exterior	[redacted]	1,8		Front End	Block Front End	Block
FE	510	Fender to Hood	Gap1 Var.	2	3	Forced Green	[redacted]	DRMP 15w39 Deviations PQ req. on hood FE510 and FE515 approved.	Exterior	[redacted]		15w07: Forced Green i [redacted]	Front End	Block Front End	GSU
FE	510	Fender to Hood	Para.	1	1,8	Forced Green	[redacted]	15w39: See comments above (Gap1 var)	Exterior	[redacted]		15w07: Forced Green i [redacted]	Front End	Block Front End	GSU
FE	510	Fender to Hood	Gap L/R	1,4	1,4	OK	[redacted]	15w39: See comments above (Gap1 var)	Exterior	[redacted]		15w07: Forced Green i [redacted]	Front End	Block Front End	GSU
FE	510	Fender to Hood	Flush	0,5	0,5	OK	[redacted]	15w22: Measured in AA1, OK	Exterior	[redacted]		[redacted]	Front End	Block Front End	Block
FE	510	Fender to Hood	Flush Var.	2,8	3	Forced Green	[redacted]	15w39: See comments above (Gap1 var)	Exterior	[redacted]		15w07: Forced Green i [redacted]	Front End	Block Front End	GSU
FE	510	Fender to Hood	Flush Para.	1,5	1,6	Forced Green	[redacted]	15w39: See comments above (Gap1 var)	Exterior	[redacted]		15w07: Forced Green i [redacted]	Front End	Block Front End	GSU
FE	510	Fender to Hood	R1	2	2	OK	[redacted]	15w04: OK. VCC0879848/3 FRONT END SECTIONS DSM5	Exterior	[redacted]			Front End	Block Front End	PSS
FE	510	Fender to Hood	R2	1,5	1,8	Judged	[redacted]	15w15: Measured in AA1	Exterior	[redacted]			Front End	Block Front End	PSS

Figure 4.4: Excerpt of the Geometry Scorecard including all different columns

There is a clear flowchart, see appendix C, describing different scenarios of signing off a requirement to the right recipient and what comes next, e.g. who is responsible for making the next move or make a decision based on the input from the previous step. This is indicated by different status modes presented with a description in fig. 4.5. The three first status modes are used when PQ needs input from another instance, i.e. a requirement receiver, and the four last status modes are used to show the actual status of the requirement.

4.3.2 Robust Design & Tolerancing

The department Robust Design & Tolerancing or RD&T is working in the same phases – concept and engineering, see fig. 4.1 – as PQ and their activities are somewhat overlapping. Here, the role Robust Design Engineer is active. In late concept phase they are working together with PQ and Design to find 'forgiving design solutions', meaning a design that allows for some variation without it being perceived poorly by the customer. The next step is the creation of system descriptions, which is their main responsibility

FINAL DEMANDS STATUS DESCRIPTION
IN PQ SCORECARD

GSU to Calc.	**GSU to Calc.** Status to be calculated by GSU.
PSS/Block to Report	**PSS/Block to Report** Block to report status on nominal relations. PSS to report nominal relations and variation.
PQ to Decide	**PQ to Decide** Calculation performed, Req. status to be decided by PQ.
NOK	**Not OK** Calculated variation or prediction exceeds final demand. Changes required to be able to fulfill final demand.
OK	**OK** Calculated variation and prediction corresponds to final demand level.
Forced Green	**Prediced Green (i.e. Forced Green)** Calculated variation exceeds final demand. However requirement is accepted by GAE based on experience or measured outcome in earlier programmes. Cannot be used if there are effects on nominal setup.
Judged	**Judged** Requirement deviation decided at DRM-P

Figure 4.5: Geometry Scorecard status with description

and delivery. This starts at PC and is an iterative process ongoing up until FDJ. A system description describes the referencing system which gives the prerequisites for a robust design. A rough estimation shows 80% of the RDE's work is dedicated to system descriptions and only 20% is dedicated directly to the calculation of FDR. However, the systems used will directly affect the outcome of the FDR. If there is no robust design it will be difficult to fulfil the requirements given by PQ.

Right after PC, the RDE can start their main activity in relation to this thesis – the prediction and calculation of an assigned FDR. When the AL sets the status 'GSU to Calc' in the Geometry Scorecard the RDE is responsible for verifying the requirement on a theoretical level. This status means PQ requires input from the RDE in terms of a theoretical calculation of the possibilities to fulfil the original requirement value. This is done with the CAT-tool software RD&T where simulations and calculations can be made. To quote an interviewee, the calculations are done by:

> *''Positioning the car exactly as we would have in reality. We add requirements, tolerances, processes. Further, we perform a calculation that shows the outcome of the FDR in terms of gap and flush.''*

When a calculation is made a contribution analysis can be generated, this shows the original requirement, the nominal calculation as well as the calculated variation with a list of the positioning points that contribute to the variation the most, for an excerpt see appendix D. The calculated value is added into the Geometry Scorecard along with the RDE changing the status to 'PQ to Decide' whereas they decide the status of the requirement, i.e. if it is OK, NOK or needs further action to be deemed as Forced Green or Judged.

As previously mentioned, this is an iterative process due to new design releases. This implies potential re-calculations to fit the new design. Finally, around FDJ, there is a workshop held by the RDE which among other things reports the status of all systems and FDR. This is part of a handover and will be described further in section 4.3.5.

4.3.3 Geometry Assurance Program (Program Phase)

The next instance in the chain is Geometry Assurance Program or GAP, who is responsible for the fulfilment of FDR, on physical car. This responsibility extends over the industrialisation phase (between FDJ and FSR) where the active role is called Geometry Assurance Engineer (GAE). The main focus is the verification of requirements, where certain activities are performed with the aim to confirm the fulfilment of FDR or discover specific issues or problem areas where these requirements are outside specification (spec) and highlight these issues to the relevant department.

Even though the main responsibility stretches from FDJ to FSR the GAE's work begins around three months before FDJ where the first activity – measurement preparation – takes place. This is done to support the process of verifying requirements or find issues by actively measuring points on physical car. Measurement preparation includes the creation of measurement point drawings and measuring routines, i.e. the measuring sequence followed. MP-drawings are used to control a single component while measuring routines are used to define measuring points on complete car, i.e. fully assembled. Measuring routines define each measuring point and show the original FD section and requirement, what tool to be used to verify the value and where it is positioned. An excerpt of an MP-drawing is shown in appendix E and appendix F shows an excerpt from FD-web where routines are stored. Note that the GAE's responsibility is to prepare and create these, not to perform the actual measuring activity. However, the measuring result is later used by the GAE when performing analyses or confirming the fulfilment of a requirement.

The physical verification is done during physical builds, VP, TT, PP and all the way up until mass production starts. All builds, apart from the VP-build, are built in the actual manufacturing plant whereas regular production processes/routines start to take place. VP is built in a Pilot Plant which is as indicated, a pilot. However, independent of a specific build the GAE performs an activity called Trim Part Coordination (TPC) where they assemble the car in something called nominal buck. Nominal buck is a nominal, close to perfect 'car' where components are assembled with the objective to identify how components fit together and if they deviate or not. Deviations are found based on measuring FDR and checked against the original requirement. The result from assembling components on nominal buck is summarised at something called sum-up, where all problem areas are highlighted to the program management. To summarise the deviations found in TPC, a document called 'Onepagers' is used, see fig. 4.6. This document summarises one issue per one PowerPoint slide including fields for defining the problem and a visual picture, root cause analysis, if there is a solution incoming or in place (ICA or PCA) and additional notes. The TPC is part of an iterative process where refinement and requirement fulfilment is expected to increase further into the process and VPDS time line.

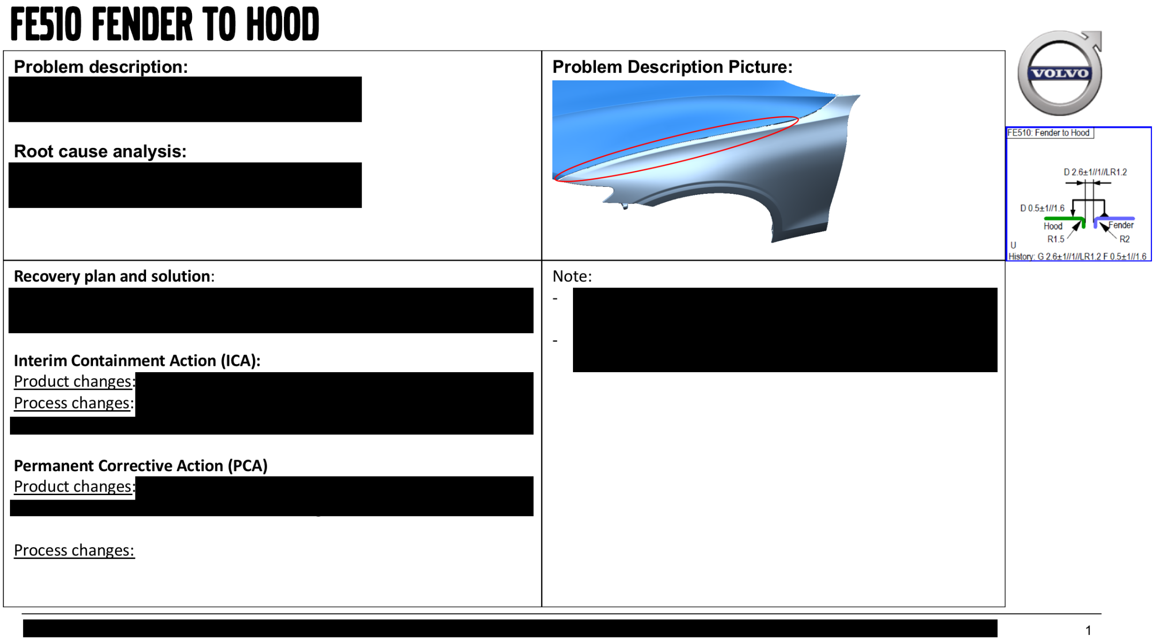


Figure 4.6: Illustration of a completed Onepager document

Existing Working Procedure - FLOW

To support the TPC activity there is a need for documenting any issues found and highlighted during sum-ups. There is already today a working procedure in place to aid this, which is through the system FLOW. First, one FLOW Task is created corresponding to each PQ section. In fact, this is done around V2 rel, i.e. long before the TPC activity which is why the created structure includes one Task for each section, even though there is no issue found yet. This also assists in understanding the status on complete car, i.e. the relation of fulfilled or not fulfilled requirements in different stages. This structure is created separately for each program due to the uniqueness of issues between programs. The working procedure is set-up as follows and supported by fig. 4.7.

1. Creation of FLOW Tasks - one for each PQ section
2. Naming the Task according to standard - defining PQ section and program
3. Labelling the Task according to standard - defining program, plant and GAE area
4. Assigning to the responsible GAE
5. Linking a Onepager template into the corresponding Task - one for each PQ section and Task
6. Usage of a priority scale to internally indicate the status of the specific requirement

7. Usage of the Workflow statuses to indicate if the Task is currently under work
8. Add watchers - individuals that might be interested of the information added to the Task (they will receive an email as soon as there is an update)
9. Create Problem Report when an issue is found and assign it to a responsible person, e.g. design leader or manufacturing engineer
10. Link Problem Report to corresponding Task
11. Use attachments to include important documents/pictures that might be needed
12. Use comment field to communicate with affected parties

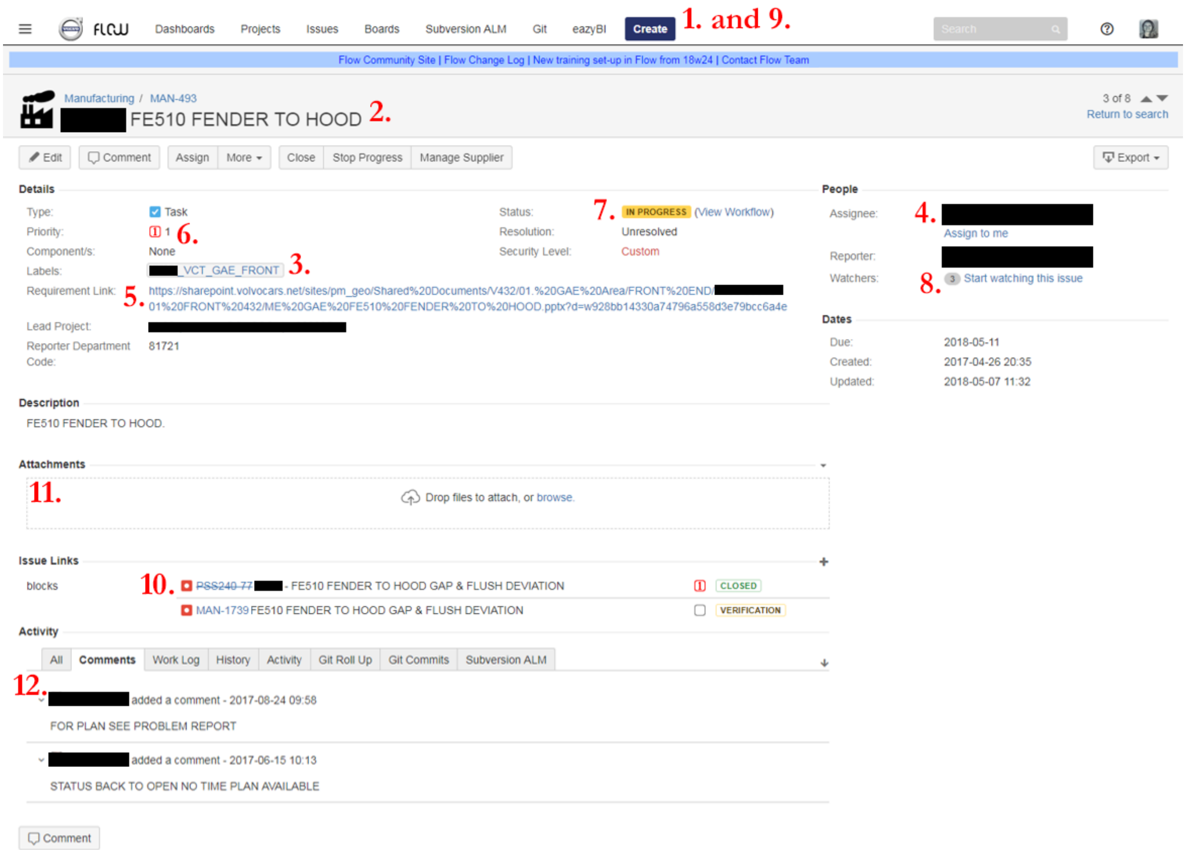


Figure 4.7: Visual presentation of the different steps performed in relation to the presented working procedure

As there are around 200 Task created per program it is important to sort between the different areas easily, this is done by creating filters in FLOW which are based on the label added in step 3. The filters are named identical to the label name. These filters, see fig. 4.8, help the responsible GAE to get a good overview and natural working area for their specific Tasks since all Tasks with the respective label are shown as a list when entering the filter, see fig. 4.9 for an example.

This working procedure allows the responsible GAE's to work with their specific Tasks, one by one, in a structured way. The process for stating the priority and workflow status level is shown in appendix G and appendix H. However, to enter each Task is not an intuitive and accessible way of working for the program manager, since they are interested in the status on complete car. Therefore, a more general overview is needed.

Figure 4.8: The different filters used to sort between GAE areas

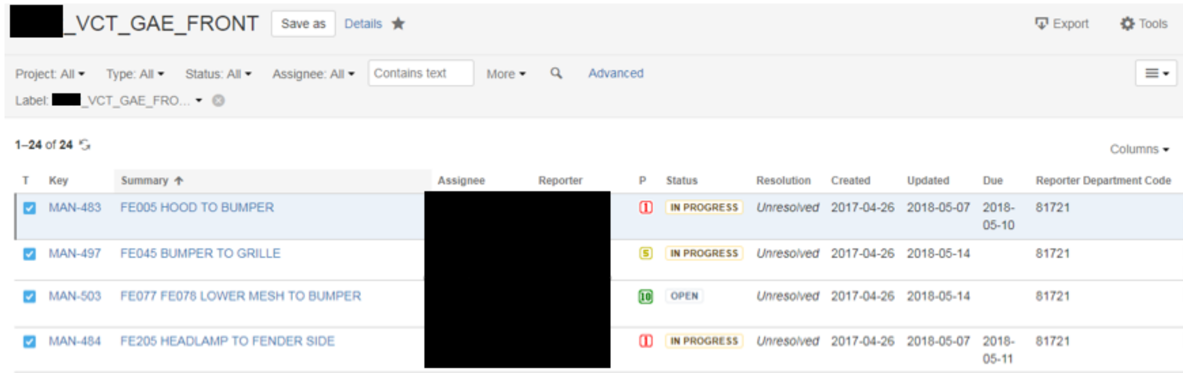


Figure 4.9: Example view of an opened filter

This is created through the usage of a FLOW Dashboard and pie charts, see fig. 2.8 and fig. 2.9. This allows the program manager to view the number of Tasks with a specific priority level, the status of Tasks or Problem Reports as well as the assignee's organisation, see fig. 4.10.

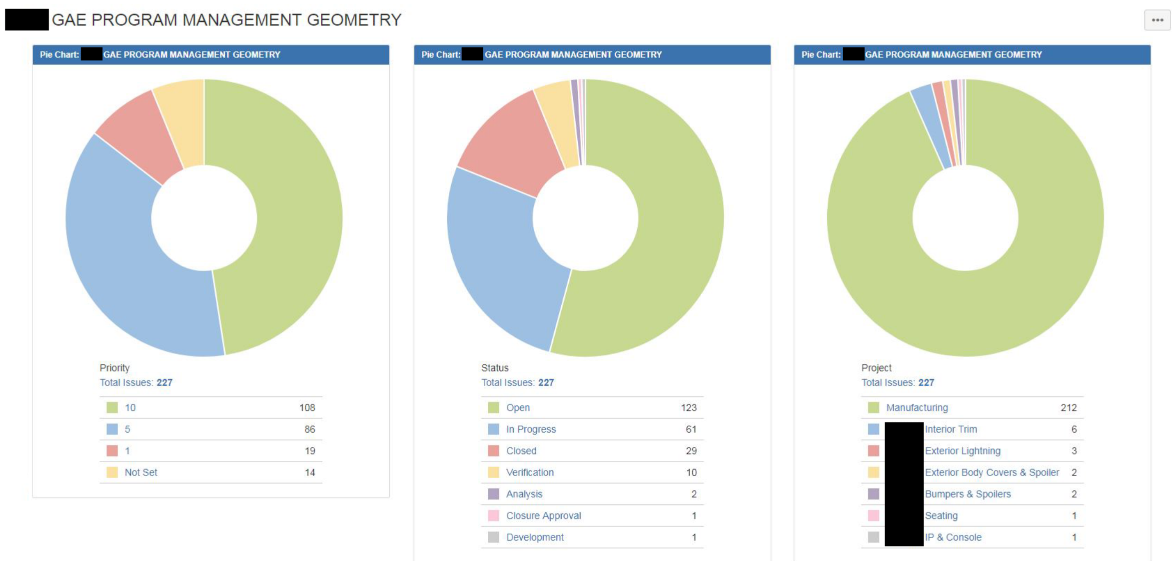


Figure 4.10: Illustration of a dashboard used by the geometry program manager

To conclude this section, the existing working procedure followed by the GAP department was the driving force for conducting this master's thesis. When the possibilities and benefits were visualised for the department they realised it could be extended across the complete geometry loop in terms of managing FDR. However, the research has investigated this further to see how this could be done in practice as well as if there were any improvement areas on existing working procedure.

4.3.4 Geometry Assurance (Running Production)

The last instance in this chain of managing FDR is – Geometry Assurance (GA) in Running Production. Their responsibility is to make sure the requirements are fulfilled throughout the life cycle of the car. The program phase focuses on developing and solving potential issues in the design in terms of FD's while the GA department needs to maintain the requirement status and deliver stability.

The official closing of a program is when FSR is reached and this is where the responsibility is completely shifted to the Geometry Engineer (GE). However, in order to be well prepared and aware of issues found in project phase they need to start their involvement earlier, which is around TT. As previously mentioned, TT is the first physical build that takes place in the manufacturing plant where the car will be build when mass production starts. Therefore, the GE's can start getting involved, i.e. gradually from TT up until FSR where they have the complete responsibility to follow-up and control the fulfilment of FDR.

As for all the physical builds, the manufactured cars are measured in order to detect requirements that are out of spec. The measurement result lays the foundation for something called PIST-values. This is a value that indicates the percentage of FDR that are within spec, also referred to as 'green', and the further in the process, the higher the target PIST-value is expected to be. When cars are measured and a measuring point appears to be out of spec they are logged in a summarised alarm list. This list defines the quantity and which exact point that is out of spec. With this list as a base, the GE needs to act by performing an analysis, plan a corrective action and finally verify it when a solution has been implemented.

In addition to the summarised list described above, there is another instance at Volvo, called Global Product Audit, who performs audit reviews which basically means they are inspecting the car with the eyes of the customer. They inspect the complete car and log any remarks they find, these corresponds to what they subjectively believe the customer also will remark on. As soon as there is an audit remark this is highlighted to the affected parties. Audit remarks related to fitting are generally highlighted to the geometry organisation and can implicate that there is a FD out of spec.

The main activity performed by the GE is based on the alarm list or audit remarks assigned to the geometry organisation. As soon as there is a deviation the GE starts looking into the problem and is responsible for delivering an definition, root cause analysis and action plan related to the specific issue. The analysis is done by scrutinising measurement data to see if incoming material is within spec (usually supplier material) or if they can find deviations caused by the process. Further, it is investigated if the deviation is unique or a trend. Based on this information an action plan is created where corrective solutions are proposed. When the solution is implemented by the responsible instance the GE is responsible for verifying it and confirm the fulfilment of the FDR.

To support the GE's working process they use two main documents – Onepagers and Action Plan Lists. The Onepager is identical to the one used by the GAE, see fig. 4.6. The Action Plan List follows the DMAIC methodology, commonly used in statistical process control (Qui, 2014). See appendix I for a template of an Action Plan List.

4.3.5 Handover Between Departments

In the sections above a detailed outline of the activities and responsibilities for each department have been presented. To get the complete picture it is also important to specify how the handover between the departments is made. Intuitively, there should be a handover between each step, according to fig. 4.11, i.e. from AL to RDE, RDE to GAE and GAE to GE. However, there is no physical handover between AL and RDE since their work is overlapping in terms of the AL assigning requirements to the RDE successively over a longer period of time. Due to this, the following paragraphs has been divided according to the scheme in fig. 4.12.

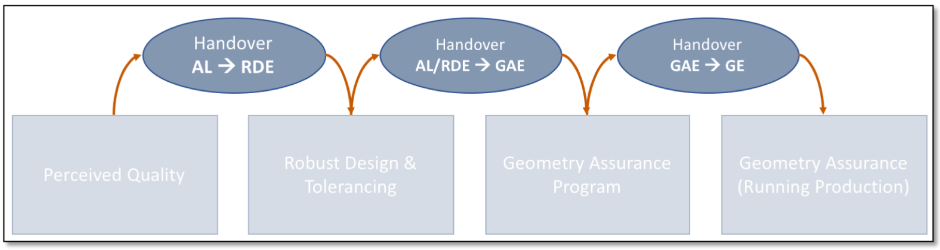


Figure 4.11: Intuitive handover scheme

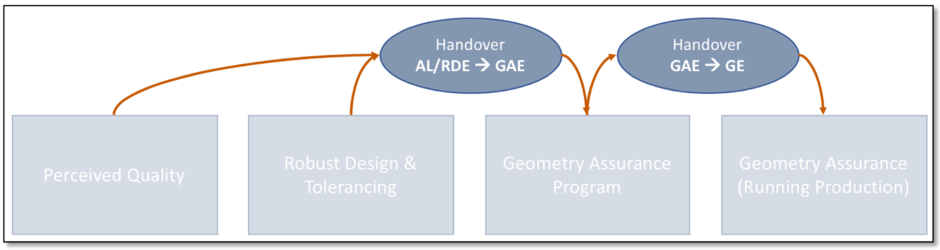


Figure 4.12: Actual handover scheme

AL/RDE —> GAE

Based on the interviews both the AL and the RDE implied that they are responsible for the handover to GAE. However, their input appeared to be slightly contradicting and ambiguous whereas this was investigated a bit further.

Eventually, it became evident that the tangible handover is held by the RDE in a workshop format but since PQ are requirement owners throughout the complete program they have the ultimate responsibility for the handover. PQ and in particular the AL is therefore, responsible for handing over the final document but for the GAE to understand what has been done previously in terms of deciding systems and predicting FDR fulfilment it is naturally more intuitive that the RDE arranges a workshop where the GAE is present. This allows the GAE to discuss potential issues that has been found which is more straightforward and beneficial than only relying on a document. During the workshop the selected systems are discussed in terms of why they were selected, if there has been any particular deviations, among other things. Further, the status for each PQ demand is discussed and presented in terms of the number of green, forced green and judged requirements. This creates a deeper understanding for the GAE. However, it also became evident that the GAE's presence is somewhat sporadic due to limited time.

For a successful handover it is important that all requirements are either green, forced green or judged, otherwise the GAE might refuse to accept and take over the requirements.

GAE —> GE

As previously mentioned, the GE takes over the complete responsibility at FSR. However, they should start getting involved as soon as the physical builds start in the manufacturing plant, i.e. TT build. This is also when the GA department has two representatives starting to measure all produced cars from the physical build, which continues during all builds up until the last car rolls of the production line several years after. Since cars start being manufactured before the official handover at FSR, the handover process needs to occur successively, starting earlier than FSR. As described by a GE during the interview:

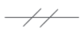
''It is like a constant handover between the GAE and the GE. But the final handover shall be completed at FSR.''

The official process for handover between GAE and GE is set to start at the PP milestone. During the handover each FD is reviewed and discussed in terms of PIST value, issues and actions to correct issues. For the GE to accept and take over a FDR, stability in the measuring output needs to be shown, meaning several cars have been measured with similar output. Further, positive PIST values need to be shown, alternatively, a corrective action needs to be in place for the GE to accept a take over. This successive process is documented through an Excel-list where the respective FDR are presented along with; their PIST values, if there are any audit remarks, a comment and finally, a transfer status field, i.e. if the FD is transferred or not. However, this process appeared to differ depending on the responsible Program Manager, GAE and GE. Even if the content is approximately the same, different formats of this Excel-list have been used over the past where at least four different list has been highlighted and found as a result from the interviews, see appendix J for an excerpt of this type of list. If the PIST value is within target it returns a green value, otherwise it will become red.

4.4 Managing FDR - Generic Process

The previous sections have described the process of managing FDR, department by department. To summarise this a generic process map will be presented, including the main activities, their inputs and outputs resulting in deliveries. To present this in a visual way it has been done in relation to the VPDS process and by using specific icons for the respective type, e.g. activity or delivery, see table 4.4.

Table 4.4: Description of each icon used in the process map

#	Icon	Description
1		Performed activity – "what and how"
2		Performed sub-activity – to support the main activity
3		Delivery – objective and result of activity – "why and what"
4		Delivery spread over time – objective and result of activity – "why and what"
5		Flow line connecting items together
6		Line connecting sub-activities together
7		Looping – indicates that the item is part of an iterative process

There are two special icons that require a separate explanation. Number 4: this refers to a delivery that evolves over time, where the final delivery is where the icon has been placed. To give an example, the PQ document, as previously mentioned there are several releases of this document over a longer time period, but it is an iterative process with an specified end. This is why the specific icon has been used instead of adding several icons in the process map. Number 6: this indicates that the connected activities in fact are sub-activities that occur simultaneously as part of the main activity they belong to, i.e. simultaneously over the complete time span.

Important to highlight is the fact that this overview never before has been documented in this way by the company themselves, which is why it was deemed extremely important to be able to fully understand the process to facilitate further development of a new working procedure affecting all involved departments. It is also important to highlight that the process only includes activities that are related to the management of FDR and relevant to this thesis. The generic process map is presented in fig. 4.13 and in larger format in appendix K.

To summarise shortly: PQ are requirement owner during the complete program and responsible for defining the requirements. When the requirements are defined the responsibility shifts to RD&T who are responsible for the theoretical verification in terms of predicting and calculating each requirement in a virtual environment and determining if it is possible to achieve the defined requirement. Further, the GAP department gets involved to perform the physical verification to evaluate what the value became in reality. Finally, the GA department takes over with the responsibility to maintain the level of each requirement. To get a feeling for the number of sections and requirements that evolve through the complete process, see table 4.5. The fact that not all requirements follow the complete chain is due to two reasons:

1. A supplier can be responsible for verifying their own components and is therefore, not handled internally by Volvo
2. A few requirements are impossible to physically verify due to them being inaccessible in terms of their position and the available tools

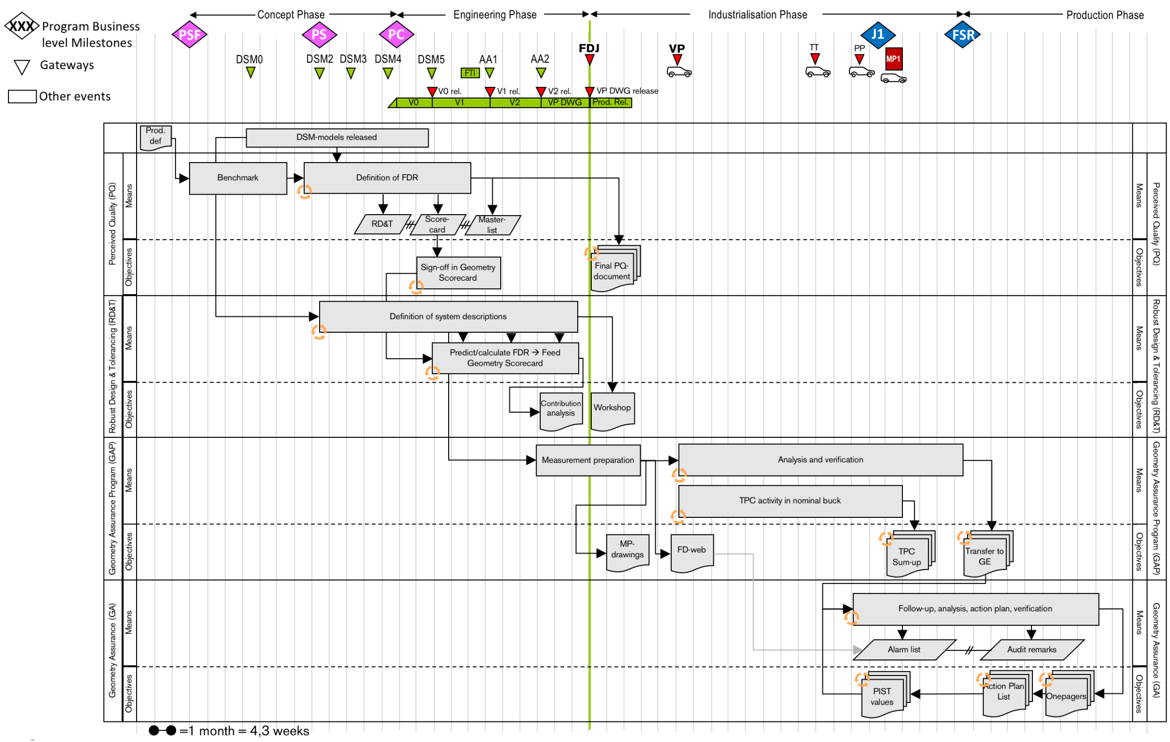


Figure 4.13: Generic process map of managing final demand requirements

Table 4.5: Illustration of the number of sections and requirements that evolve throughout the complete process

	PQ	RD&T	GAP	GA
Sections	471	380	194	194
Requirements	1480	983	-	-

To conclude this section, it is important to highlight that this is a generic process that has its exceptions and that all roles have other responsibilities beyond what is shown in the process map. Every department and individual also play an important role supporting the others even when not being mainly responsible. Further, from the fact that there are programs running simultaneously but in different stages it is evident that this working process is a never ending loop.

4.4.1 Modification of Original Requirement

As described in section 2.1 it is impossible to manufacture a part or a product without variations (Ajiduah, 2010) and therefore it is close to impossible to achieve 100% fulfilled FDR. This brings the need for adjustments in the original requirements. This section will therefore, present different types of decisions made when the original requirement needs to be adjusted due to various reasons. The difference between the decisions are typically in the type of forum and who is responsible and present during the decision.

Baseline Judgements

A baseline judgement or baseline judgement for life, is a decision that can be made on two levels, depending on the circumstances – in program phase or in running production. What also differs between the two is the people involved. In many situations, there is an audit remark involved in these decisions but there are exceptions as usual.

Starting with the program phase and the forum called DRM-meeting. Here, the program management is present to support in decisions where involved parties might not agree or are unable to decide due to other reasons. Depending on where in the project a judgement needs to be made there could be different reasons for this need. To give an example, in early project phase, a decision can be made when PQ and RD&T do not agree in terms of that the calculated value is higher than the original specification and PQ argue that it should be reachable. In late project phase, a baseline judgement can be made due to the high cost of changing a design, whereas it is decided to change the requirement instead. The decisions made in this forum will be valid during the complete life cycle of the car.

Further, there is the second forum which is during running production. Important to note is that there will not be any design changes during running production, only minor changes to the process, where it is possible. The forum used for decisions during this phase is a meeting called Judgement For Life, where the GA manager summarises issues that are obviously outside spec and there are no solutions to be implemented without major investments. These decisions will also be valid throughout the complete life cycle.

Temporary Baseline Judgements

As described above, a baseline judgement will be valid throughout the complete life cycle but there is one additional type – temporary baseline judgements. These can be made when there is an incoming solution that will fix an audit remark or requirements out of spec. This decision is made together with audit and always include an end date indicating when the requirement will revert to its original value.

Balancing

The last type of modification can be made when there is no audit remark. Here, it is possible for the GAE and AL to alone decide to change the original requirement, this is called balancing. However, this requires the AL to accept the change, if they believe it is achievable or consider balancing will lead to a poor perceived quality they can decide that it should be brought up on a DRM-meeting instead, see section 4.4.1.

4.5 Identified Improvement Areas and Preconditions

Based on extracted statements and the result from question 15-19 found in appendix B, a few improvement areas and preconditions for future work have been identified. These will be presented in section 4.5.1. Apart from outspoken needs there were also some interpreted improvement areas identified based on the description of today's working procedure and by interpreting statements during the interviews, see section 4.5.2. Apart from viewing this as improvement areas for the future work of this thesis, these can also be seen as future recommendations to the company.

4.5.1 Outspoken Improvement Areas

To create a clear structure over potential improvement areas these have been divided into four categories. These are summarised based on the collected data and will be supported by a few interviewee quotes.

Geometry Scorecard

The Scorecard format is occasionally considered cumbersome due to substantial scrolling both vertically and horizontally due to the vast amount of rows and columns. Figure 4.4 showed an excerpt of this Scorecard, but irrelevant columns were eliminated from the figure to fit this thesis, however, this still means the users need to scroll past the irrelevant fields. This is stated both by the AL and the RDE. For the AL it is a bottleneck due to the amount of time it takes to update each row.

The Masterlist briefly mentioned previously, includes pictures to show where the requirement is positioned. However, when working in the actual Scorecard related to a specific program there are no pictures connected to the specific requirement.

> *''It an be difficult to understand the position of a requirement only by reading the requirement name. It would be great if it was possible to click the requirement and see a picture.''*

It is not to be neglected that there are plenty of benefits with the Scorecard as well, it is a very well structured document where relevant information is relatively easy to access, e.g. original requirement, 'GSU calc' and important comments related to each requirement. However, there is another disadvantage, when the RDE refers back to an earlier program and if that program in turn refers back again, this can make it inaccessible and difficult to find the essential information.

Finally, the usage of the status 'Forced Green' has been defined differently by the interviewees which indicates it should be discussed or made clear how this should be used. However, this is easily solved by reminding users about the definitions presented in fig. 4.5.

Requirement Evolution

> *''...to see the requirement history from the beginning to the end. I want to see the evolution of a requirement, in relation to VPDS.''*

The quote above is only one of many mentioning the need to be able to see the history and evolution of a requirement, throughout a complete program. It is evident that this is not easy to access with today's working procedure partly due to the many different systems in use for documenting and following the performed work by the involved departments.

> *''Partly what the original requirement was set to be, the calculated prediction and what the accepted level was set to at the end.''*

It is clear that the eligible history requested is connected to the involved departments and the result from each phase. Connected to this a particular request has been raised regarding the documentation of baseline judgements and balanced requirements. Providing a more accessible evolution also enables easier and more natural lessons learned between programs, and therefore, closing the loop.

To conclude this section one last quote needs to be brought to light, which again shows the importance in enabling easy access to the requirement history.

> *''We can sometimes be perceived as harsh. For instance, when we say no to balancing a requirements despite the fact that we have already changed the requirement from 1 mm to 2.4 mm. But due to incremental changes of 0.2 mm this is not noticed.''*

Handovers

The third category identified as an improvement area is the handover between departments. Starting with the handover between AL/RDE —> GAE; it was discovered that the GAE's participation on the FDJ Workshop was somewhat sporadic due to limited time availability. However, the RDE see a clear trend in terms of success and easier understanding when the GAE has been able to be present in early phase as well as the workshop. It is not to be neglected that this trend also is confirmed by the GAE and that it mainly is a matter of setting aside time.

As previously mentioned, the ownership of the handover has also been discussed and it might be good to clearly state who has the ultimate responsibility for the handover and who shall be present during workshops for instance. During the focus group it was also discussed that the communication and cooperation between involved departments were slightly better in the past. There are probably many reasons for this, but a clear working procedure is one step on the way of restoring status-quo.

As for the handover between GAE and GE, the handover-timing was something primarily discussed. It was not clear when the handover was supposed to take place according to today's working procedure, nor regarding the timing of a future vision communicated from the management team. It was also mentioned that the prerequisites for a potential earlier handover are not in place, in terms of knowledge but also time. Due to these two departments belonging to the same organisation – Manufacturing Engineering – and regular communication it was also mentioned that the handover mindset sometimes were regarded as informal. This can of course be considered positive but it can also result in a fuzzy handover where there are no clear boundaries.

Miscellaneous

Apart from the identified improvement areas (or prerequisites) described above there are some additional ones found that did not fit into an overall category, these are presented here.

First, a prerequisite that was mentioned from PQ was stressed several times. Already today, they are experiencing an extremely tough situation regarding the large amount of requirements that bring a lot of admin work in terms of updating different systems. When an requirement is created or changed there is a need for managing the requirement in the software RD&T, updating the Geometry Scorecard as well as the Masterlist. This implies that a new working procedure needs to facilitate their working situation rather than adding more admin work.

Further, the fact that there are updates in several systems and lists also implies that there might be some difficulties in terms of finding the latest information. As an RDE employee expressed:

''It can probably be a good idea to define where the latest information can be found and when.''

To conclude this section, one last topic was discussed regarding today's working procedure in FLOW. At this point, FLOW has been used in one program and it is time to review the success of this working procedure. Part of this included a discussion and development regarding the information shown in the dashboards shown in fig. 4.10.

4.5.2 Interpreted Improvement Areas

Apart from the outspoken and discussed topics mentioned in previous section there were also some minor improvement areas interpreted and identified by the author of this thesis.

Onepagers

As described in section 4.3.3 as step 5 in the list of today's working procedure, there is a Onepager linked to each Task. This Onepager is linked from a SharePoint site which firstly is somewhat unreliable in terms of documents disappearing. Further, these also creates a lot of admin work since one Onepager is created for each Task (around 200 for each program), each Onepager needs manual linking to appear in FLOW. On top of this a rough estimation shows only 20% of these are filled with information during the program which indicates a lot of waste admin work.

Bulk Cloning in FLOW

Creating 200 Tasks in FLOW for each program requires a lot of manual admin work. But as around 80% of the exterior sections are generic between programs there is a possibility to once create a list of Tasks in FLOW (similar to the Masterlist used by PQ). By doing this it would be possible to use that list to easily mark and copy the relevant Tasks at the beginning of a program to create a new FLOW structure. However, this requires a new functionality in FLOW – Bulk Cloning – enabling several Tasks to be copied or cloned by 'one click', this is not possible today. Therefore, this has been discussed and brought up with the FLOW support team.

Contribution Analysis

Making the contribution analysis more accessible for the involved parties could create a deeper understanding for chosen systems and performed calculations which facilitates the work with each individual FDR, not only for the GAE but also the GE. This was extracted from the need for closer collaboration between involved departments and the RDE's comment regarding increased participation from the GAE's.

Action Plan List

Minimising the different systems and lists used is an important prerequisite and an obvious document to eliminate is the action plan list used by the GE, see appendix I. This document could easily be incorporated in the FLOW system and will be described further in chapter 5.

4.5.3 Extracted Requirements

Based on collected data and identified improvement areas described in section 4.5 several prerequisites or requirements have been extracted, see list below. These are moderately organised in a hierarchy of importance. Compared to general requirement formulation these are relatively subjective and have therefore, been used more as important **keywords** in the development of a new working procedure rather than measurable metrics. However, as described in section 3.5 these can be used when evaluating the working procedure in the future, through usability testing.

1. Eliminate waste admin
2. Monitor history
3. Manage complexity
4. Manage lessons learned
5. Hold important information
6. Be effective
7. Be efficient
8. Minimise number of systems/lists
9. Be intuitive
10. Be transparent
11. Be communicative
12. Trust

4.6 Major Findings

The final section of this chapter will present two major findings that played an important role for future development in relation to the thesis' scope. These are in fact not related to today's current situation in terms of being related to the existing working procedure, but are important due to them being introduced in a near future. The first finding was shortly mentioned in the beginning of the thesis but its relational importance was not discovered until a few months passed. The importance of these findings was due to the initial intention of finding a common working procedure by using FLOW as a support. These findings highlighted that there were other aspects which had to be taken into account in the development of a new working procedure.

4.6.1 System Weaver - Requirement Management System

Alongside the introduction of FLOW another system called System Weaver also started its official introduction simultaneously. This is a software which shall manage all functions and requirements connected to the product. As for FLOW, the usage of this software was a central decision made by top management team and is therefore, to be implemented throughout the whole company. System Weaver is replacing another software previously used for function and requirement management. Figure 4.14 shows an illustration of a regular interface when an function or requirement is opened.

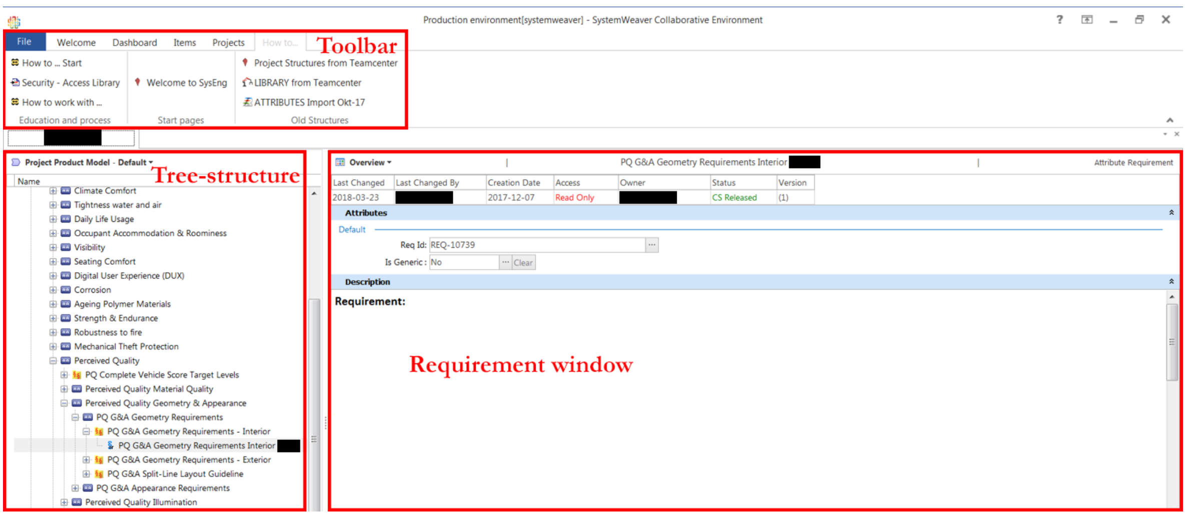


Figure 4.14: Illustration of a function or requirement interface in System Weaver

Since PQ is responsible for the attribute Geometry & Appearance Quality, they are also responsible to store their requirements in System Weaver. Partly, this has been done since the introduction of the software but only to some extent. Currently, they define two requirements in System Weaver which in turn refer to another system and their PQ document. Therefore, PQ is looking into the possibilities of extending their use of System Weaver and to include each and every requirement instead of referring to a second system.

An initial proposed structure has been developed by PQ, where all FD sections will be listed as a requirement and grouped according to the respective area, see bullet list in section 4.3.1. Each requirement will then contain the different requirement types shown in fig. 4.3. An interface of this proposal is shown in fig. 4.15. This is basically the same structure used in the Geometry Scorecard today which also implies that the functionality of the Scorecard will be moved to System Weaver instead.

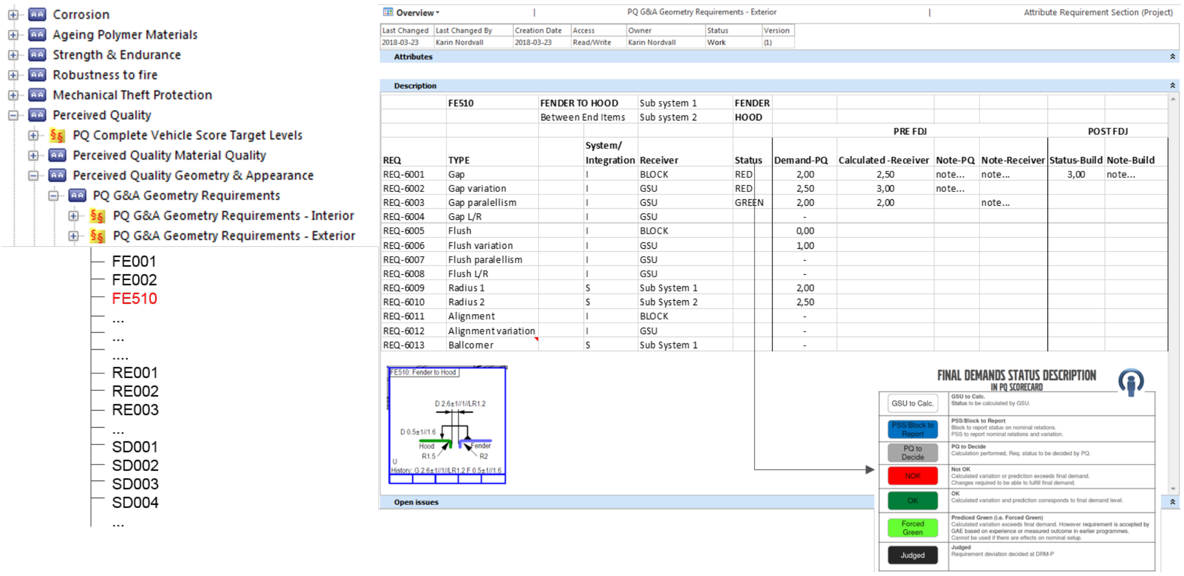


Figure 4.15: Illustration of proposed System Weaver structure from PQ

Due to this simultaneous project, held by PQ, it implies that the usage and extension of the FLOW working procedure will not be an alternative since it will lead to massive duplication work for the AL, managing the requirements in yet another software.

At this stage, it was evident that a new working procedure would require an integration between the usage of both systems; one requirement management system – System Weaver, and one issue management system – FLOW. It is undeniable that requirements and issues are interrelated and therefore, need to be integrated.

4.6.2 Plug-in - System Weaver and FLOW

As a result of further research it was brought to light that there was another department which recognised the need for an integration between the two systems. This lead to the finding of a plug-in which allowed linking between functions and requirements in System Weaver with issues in FLOW. This plug-in is currently under development and there is no decision to officially implement it yet. Before it can be officially implemented, further investigation is needed where the next step is to perform a proof of concept and see how different users would benefit from this plug-in. However, this finding definitely opened up doors for finding a favourable solution related to this thesis and the management of FDR.

The scenario of linking a System Weaver requirement to a FLOW issue can be done in two ways. These are both described below. Note that ‘Jira’ is equal to FLOW in this case since FLOW is build on the Jira database.

Scenario 1

1. Open System Weaver
2. Click the ‘Jira’ button in the top toolbar - the plug-in opens
3. Select a requirement in the right tree-structure
4. Click ‘Create issue’ in the plug-in window - Jira opens and a new issue can be created which will automatically be linked to the selected requirement

Scenario 2

1. Open up System Weaver
2. Click the ‘Jira’ button in the top toolbar - the plug-in opens
3. Select an Jira issue (FLOW issues) which you want to connect to one or several requirements
4. Select the respective requirement/s in the right tree-structure to link them to the specified Jira issue - they are now linked
5. Open the Jira issue - the linked requirements will now appear under ‘Activity’/‘SW Items’

Figure 4.16 and fig. 4.17 shows the initial developed interface of this plug-in with views from both System Weaver and FLOW. To support understanding of the linking scenario the different steps has been marked in the respective picture according to the list above, common steps are marked in red, ‘Scenario 1’ unique steps are marked in blue, ‘Scenario 2’ unique steps are marked in green.

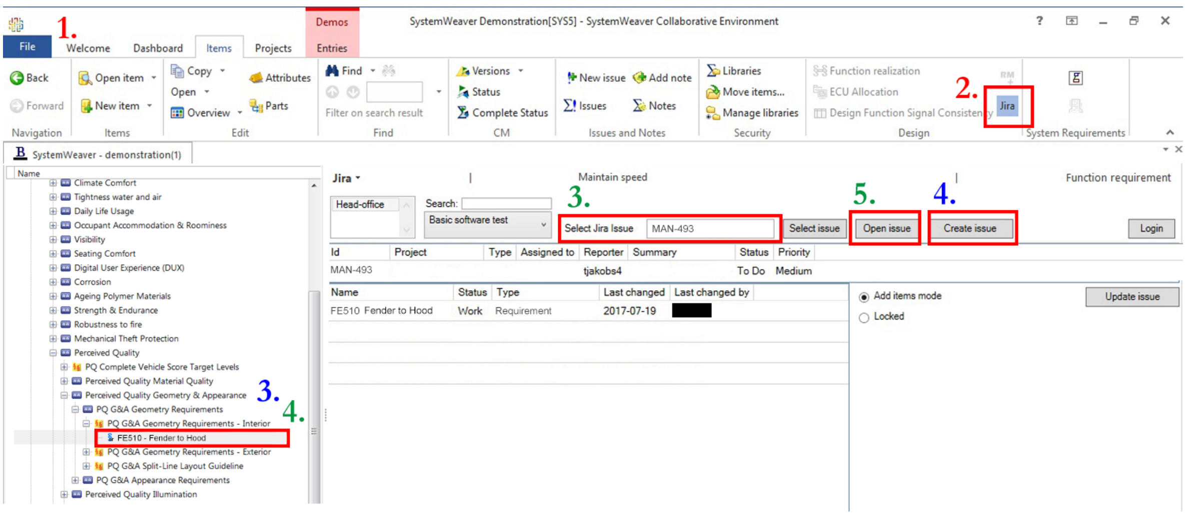


Figure 4.16: Plug-in interface in System Weaver

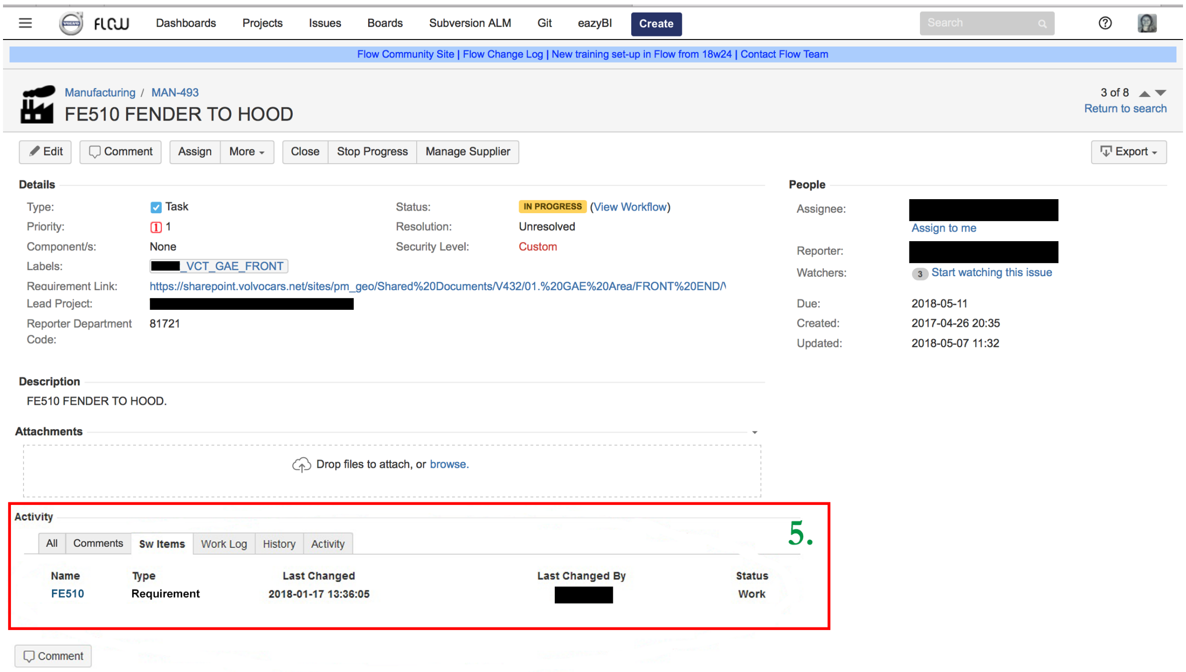


Figure 4.17: Plug-in interface in Jira/FLOW

The 'FE510'-name shown in the box in fig. 4.17 is an active link which redirects the user to System Weaver and opens the specific requirement.

To conclude this section, there is an additional functionality in the plug-in that allows the user to show which Jira/FLOW issues that are connected to a specific requirement. Unfortunately, this can not be shown due to limited access to the plug-in. However, this functionality has not been the focus in the development of the plug-in and might be developed further. A discussed solution is to create an interface which shows the connected issues in the specific requirement window, see mock-up picture in fig. 4.18. Similar to the link in Jira/FLOW, this could also be an active link that redirects the user to Jira/FLOW. This will allow a two way communication between the systems and enable users to easily access information from both systems independent of the origin system.

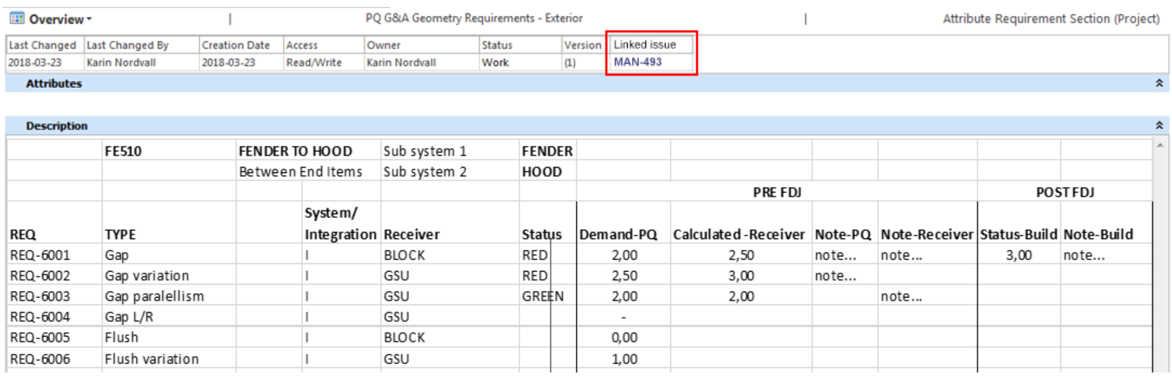


Figure 4.18: Mock-up plug-in interface in System Weaver

5

Desired State

Based on the result described in chapter 4 it became evident that there were a few improvement areas and gaps to fill in terms of the existing working and documentation procedure for handling FDR. This chapter will present a proposal for a new working and documentation procedure involving all four departments previously concerned. The methodology used to develop this working procedure is presented in section 3.4.

Due to the early stage of PQ's System Weaver project mentioned in section 4.6.1 and the plug-in under investigation described in section 4.6.2 the proposed solution is based on a few assumptions:

1. Assumption 1 - PQ will use the structure where one System Weaver requirement is equal to one PQ demand section.
2. Assumption 2 - the plug-in between System Weaver and FLOW will be introduced and have the functionality as presented in section 4.6.2.
3. Assumption 3 - the plug-in will be able to show linked items from both systems, i.e. independent of the system the user originates from

In order for the suggested working and documentation procedure to be implemented successfully these assumptions need to exist together.

5.1 Proposed Working and Documentation Procedure

This section will present the proposed working and documentation procedure (further mentioned as 'process', 'solution' or 'procedure') with the respective department's responsibility in relation to each step. The generic procedure contains the following 16 steps. A more detailed description is presented under each subsection below.

1. The AL generates a structure in System Weaver. Content: all requirements connected to a specific program
2. The AL assigns requirements to the RDE
3. The AL documents baseline decisions in the FLOW Task

4. The RDE creates one FLOW Task for each requirement assigned to him/her
5. The RDE performs calculations for each assigned requirement and documents the result value in System Weaver
6. The RDE documents all additional information in the FLOW Task by using at-

tachments and comments, e.g. contribution analysis and other relevant information

7. The RDE invites to a mini-workshop - lessons learned nr 1
8. The RDE transfers main responsibility to the GAE by re-assigning all Tasks in FLOW

9. The GAE reviews all Tasks and closes the ones that are not physically verifiable
10. The GAE continue working according to existing working procedure described in section 4.3.3 with one exception: Onepager format
11. The GAE invites to a mini-workshop - lessons learned nr 2
12. The GAE transfers main responsibility to the GE by re-assigning all Tasks in FLOW

13. The GE re-opens a Task when an issue is found in running production
14. The GE uses the Task to follow up ongoing issues, i.e. action plan list is incorporated into FLOW by the new 'Onepager' format
15. The GE documents his/hers work and important information by using attachments and comments
16. The GE invites to a mini-workshop - lessons learned nr 3

The original requirement will always be accessible through the linking between the specific System Weaver requirement and the FLOW Task. All departments will have access to System Weaver and be able to view the requirement.

5.1.1 Attribute Leader

As soon as the AL receives input from the DMS-releases the creation of requirements can start in System Weaver, see tree structure in fig. 4.15 for an outline of the created requirement structure. When it is time, the AL can start signing off requirements of which the RDE shall perform calculations. This sign off is done directly in System Weaver and will appear as a list directed to the RD&T department.

In section 4.4.1 different types of requirement modifications were presented. Depending on the modification type it is the requirement owner, i.e. the AL, who is responsible for documenting the new requirement value, when and in what forum the decision was taken. This responsibility applies to baseline judgements and balancing. Temporary baseline judgements are handled by the GAE or the GE.

As mentioned in section 4.6.1 the geometry scorecard will be moved to System Weaver instead. However, compared to existing working procedure it is suggested to document potential requirement changes in the linked FLOW Task instead. The Scorecard in System Weaver shall only include specific requirement values and no comments. Comments shall be stored in the FLOW Task.

5.1.2 Robust Design Engineer

All requirements assigned by the AL will appear in a summarised list from which the RDE can start working. By clicking one requirement and applying 'Scenario 1' described in section 4.6.2 the RDE starts the creation of a FLOW Task. This will automatically create a link between the created FLOW Task and the original requirement in System Weaver which makes it accessible from both system. The Task shall be named identical to the standard used by the GAE and labelled similar to the standard used by the GAE but with a difference in the defined role, see fig. 5.1.

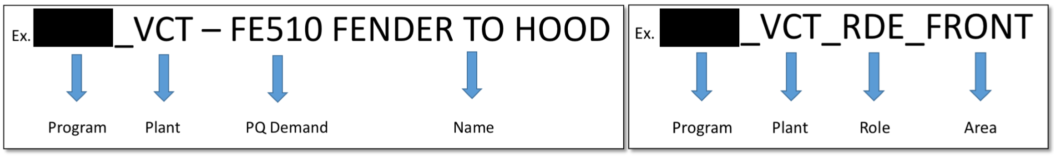


Figure 5.1: Standard of naming and labelling FLOW Task

When the calculation has been performed by the RDE the calculated value shall be added into the System Weaver requirement, see fig. 5.2. If a calculation does not correlate with the original specification it is up to the AL to decide if the requirement shall be balanced or brought up on a DRM-meeting which follows the workflow in appendix C. As described in section 5.1.1 the outcome of this shall be documented in the FLOW Task by the AL. Further, the RDE adds the contribution analysis, appendix D, into the attachment field in the FLOW Task. Additional relevant information can be added by using the comment field, this facilitates and makes the relevant information more accessible for the interested parties. Additional information can be a comment on requirements that are calculated by the RDE but not fulfilled according to the PQ specification, but which could be fulfilled on physical car if trimmed into position. To summarise; all calculated values shall be documented in System Weaver and all additional information shall be documented in the FLOW Task.

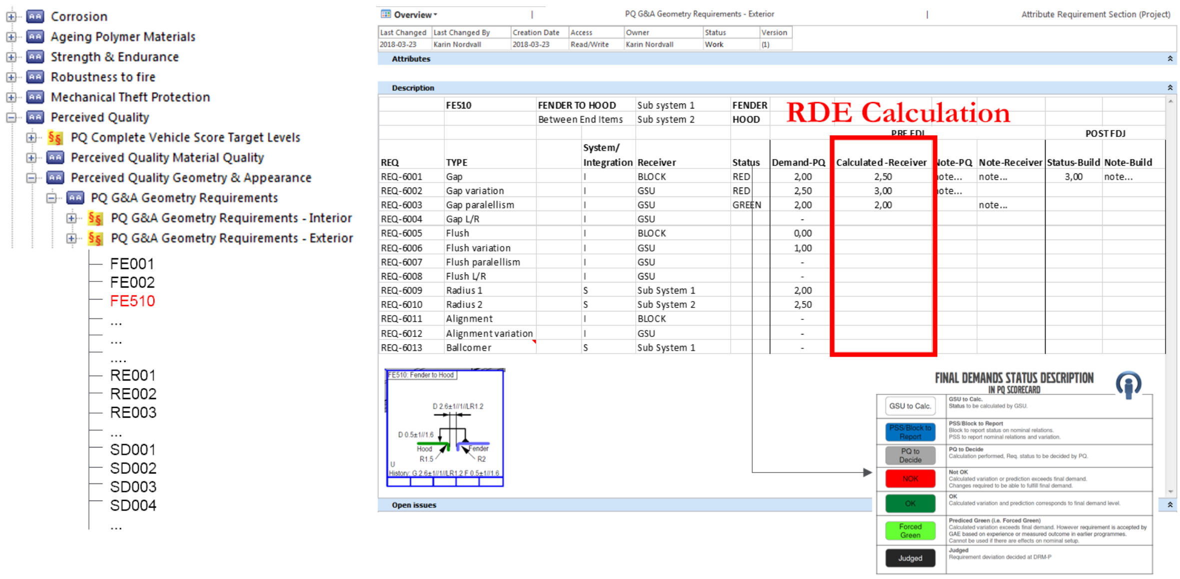


Figure 5.2: Field in System Weaver where the RDE documents the calculated value

Mini-workshop - Lessons Learned 1

When the majority of all calculations are performed, around FDJ, the RDE will invite all involved departments to a mini-workshop where the status of system descriptions and requirements are reviewed and reflected upon. Among other things, this is an excellent opportunity to review if the requirements are physically verifiable and discuss the requirements that were not calculated 'green' in relation to the original specification. To prepare for transfer, all requirements that will not be verifiable needs to be tagged with a comment stating why. The RD&T department is divided according to the same areas as the GAE, see fig. 4.8. This suggests a natural division where there will be one mini-workshop for each area. In comparison to previous workshop described in section 4.3.5 the idea is that the AL, RDE and GAE shall participate all together. At this stage it is not essential to have the GE present. However, they are more than welcome if preferred. This workshop facilitates transparent communication and opens up for a natural forum where issues can be found early by knowledge sharing between the different roles. Further, this will support the geometry assurance process and increase chances of affecting engineering changes early in the process and avoiding increased cost due to timing, related to Sullivan's (1986) model shown in fig. 2.1.

When the mini-workshop is completed it is time to start handing over to next instance. Due to the generic structure used in FLOW it is easy to transfer responsibility through FLOW directly. This is done by changing the assignee, reporter and label on all Tasks, see fig. 5.3. The label shall only be changed in terms of the 'Role' where 'GAE' shall be stated instead of 'RDE', this means the Task will appear in the filter of the GAE and be removed from the filter of the RDE. Note that the existing assignee and reporter are hidden due to integrity restrictions, however, these fields state the responsible individual.

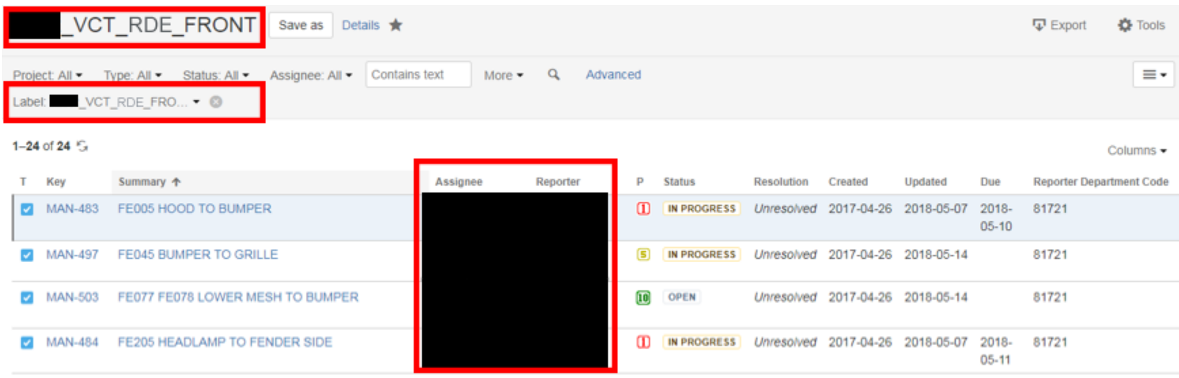


Figure 5.3: Fields to change when transferring to next instance

For the GAE to accept a transfer of a Task, the FDR must be calculated green according to the PQ specification or be balanced or judged before it can be transferred. Naturally, there will be Tasks and FDR that are calculated green without any problems, these could theoretically be transferred as soon as possible, not necessarily as late as FDJ.

5.1.3 Geometry Assurance Engineer

When the transfer is made the GAE will first review each Task and change the status to 'Closed' on the FDR that are not verifiable, this will be made based on the discussions and comments made during the mini-workshop held by the RDE. Apart from two modifications, the GAE will continue working according to today's existing working procedure described in section 4.3.3. These are presented in the next paragraphs.

Onepager

Today, one Onepager is created in correlation to each Task. This requires a lot of administration from the GAE which unfortunately result in only 20% of value adding work since that is the estimated relation of used Onepagers. The rest are only connected to the Task without being used. To address this issue, three solutions were developed and reviewed by the management team and the GAE team. The options presented were following:

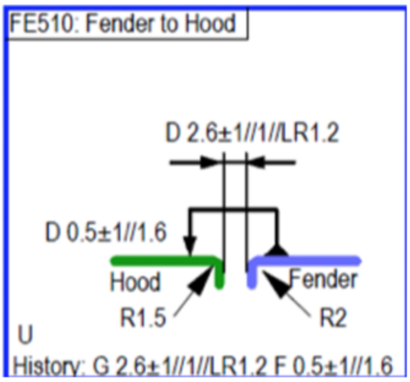
1. Include Onepager information into the FLOW Task ('Description' field) and feed with information when issue arises
2. Create Onepager only when issue arises and link these into the FLOW Task
3. Continue as today, i.e. create one Onepager corresponding to each FLOW Task and link into the FLOW Task

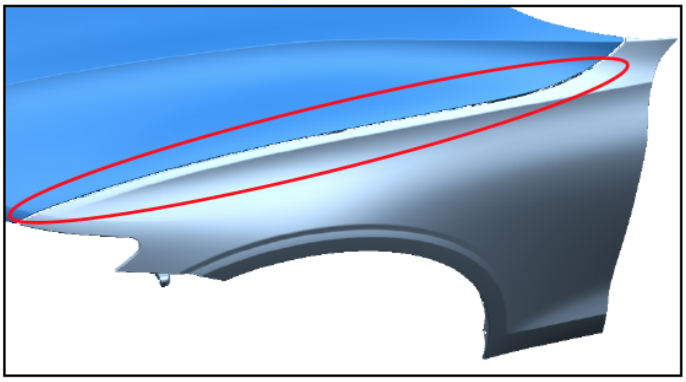
Due to the different number of systems used in the daily work the suggested alternative was number 1 since it eliminates irrelevant administration work as well as concentrates the work to one system – FLOW only. Alternative number 1 was also supported as the obvious alternative by the users and the management team. With this support the layout presented in fig. 5.4 was developed and decided upon. This new layout does not differ in terms of content, all existing fields in the previous Onepager, fig. 4.6, are now represented in the description field in the FLOW Task. In addition, one field is added into the Description field, the target PIST values, this summarises the TPC activity performed in relation to each physical build and facilitates in the transfer to the GE. To summarise, this solution allows for a more effective and efficient working procedure where focus is on the right things – documenting current issues – rather than creating a solid structure with one Onepager linked to each Task which is considered waste administration work.

Mini-workshop - Lessons Learned 2

Similar to the mini-workshop held by the RDE the GAE will also invite to a workshop after the TPC activity in PP build, at this point it is natural to summarise all issues found during the different TPC activities in the physical builds VP, TT and PP. This workshop coincides with the existing transfer to the GE. The difference is the additional participation from the AL and the RDE. Here, the scope will be focused on the status of fulfilled requirements on physical car. All instances benefit from this workshop since issues are reviewed and discussed and the AL and RDE can document lessons learned to prepare for the next program as well as the GE can prepare for coming production.

Description





Problem Description:

[redacted]

Root Cause Analysis:

[redacted]

ICA:

Product:

Process:

PCA:

Product:

Process:

Notes:

[redacted]

PIST-values:

VP Target XX%	TT Target XX%	PP Target XX%	MP1 Target XX%	FSR Target XX%
> XX%	> XX%	< XX%	> XX%	> XX%

Figure 5.4: Layout of new Onepager

Transferring to GE

As the GAE performs their work and verifies the FDR in the physical builds there will be requirements that are verified and fulfilled directly. These will in FLOW be marked with 'Priority 10' according to the scale in appendix H as well as in status 'Closed' according to appendix H. When a Task is closed by the GAE it can be transferred to the GE already after TT. The transfer shall progressively increase according to fig. 5.5. The GE will accept transfers of Tasks that are in status 'Closed' OR 'In progress' with 'Priority 5' **if** there is a solution incoming that will solve the problem.

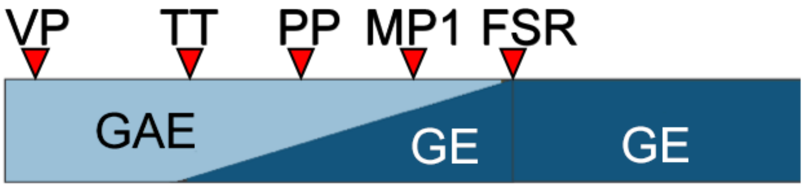


Figure 5.5: Progressive transferring from GAE to GE in relation to gateways and milestones

The transfer is done identically to the transfer described in section 5.1.2, by re-assigning the Task to the responsible GE which is made by changing assignee, reporter and label. This time the role shall be changed to 'GE'. This system contributes to a natural handover between the departments where FLOW manages most of the admin work automatically, i.e. a Task is automatically moved from one filter to another by changing label and the Task appears in the right 'Personal Dashboard' in terms of the stated assignee.

Due to this transferring procedure and the fact that the PIST-values are stated and summarised in the bottom of the Description field this enables elimination of the Transfer list used today, see appendix J. This was also discussed during one interview where an interviewee expressed:

> *''There is an official transfer list but it would be more than great if it could be implemented in FLOW.''*

The working procedure will not differ as much for the GAE as for the other roles, apart from where the summarised information from each sum-up is stored, i.e. in the FLOW Task instead of the Onepager stored in the local SharePoint. The transfer process will be slightly changed in terms of eliminating the existing transfer lists and incorporating it into FLOW instead. This working procedure will be more intuitive since relevant information from previous work is documented in the FLOW Task as well as all the work is concentrated to one system.

5.1.4 Geometry Engineer

As described above, all Tasks shall be in status 'Closed' or 'In progress' when the GE receives them. In a perfect world this basically means that the GE role is not necessary due to all requirements being green or soon to be green. However, this is not the reality of course, due to manufacturing variation there will be requirements that run out of spec from time to time which is why the GE is responsible during production phase. Their responsibility is to maintain the status of the requirement, therefore, they should use the Task according to the following process:

1. Re-open Task when measuring point and FD is alarmed out of spec
2. Use priority scale to indicate the type of issue, see appendix G
3. Document issue, root cause and corrective action in the Description field, i.e. in the new 'Onepager'
4. State verification date
5. Change priority and status according to verification result, for status definition see appendix H

Re-opening a Task allows the GE to access all previous information documented in relation to the specific requirement. This will facilitate in terms of understanding the occurring issues during program phase which might re-occur in running production and in this might in turn help solving the issues without re-inventing the wheel again. By accessing the contribution analysis added by the RDE the GE will also understand how reference points affect the process outcome. This enables the GE to perform changes in the process where it is needed, i.e. in the points affecting the variation the most.

By using the new 'Onepager' solution now incorporated in the Desription field the GE can replace their Action Plan List, see appendix I, and use the Task as their working and documenting area.

Mini-workshop - Lessons Learned 3

The final step in this new desired state is the last mini-workshop, held by the GE. At this stage, the process shall be more or less stabilised which is around FSR. This workshop shall be used as the last official meeting between the involved departments, i.e. the geometry loop. All instances are interested in the final result, i.e. to review where there still might be issues in terms of FDR fulfilment.

5.1.5 Lessons Learned

To comment on the prevailing mini-workshops and their existence, they will be beneficial in terms of incrementally transfer responsibility between departments. They will act as a natural forum where all departments meet to discuss current issues and use their common knowledge to solve them. Through the workshop, issues can be brought back

back to the own team in order to learn and perform corrections either to the next program or to modify current program if still possible. It also facilitates in being more transparent and effective in communicating and deliver a high quality car to the end customer, which is the common goal independent on the department.

To avoid issues disappearing in the hectic environment, as the development of a car is, it is crucial to document critical issues as a 'Learning' in FLOW, this helps in securing that an issues does not reoccur in a future program. A learning is yet another issue type used in FLOW, see definition in fig. 2.6. By labelling the learning with a suitable label the Learning will be easy to access when needed, this can be done by creating filters used to sort between different labels.

To conclude, this new working procedure will help in managing FDR covering the complete geometry loop. It will support in managing the complexity in terms of using a common working procedure, manage lessons learned and overall be more effective, efficient, transparent and intuitive in terms of mainly using one common system which everyone have access to. The plug-in will enable a connection between the requirement in System Weaver and FLOW which provides easy access to the original requirement or all related documentation only one click away.

5.2 Dashboards in FLOW

In addition to the developed working procedure presented in previous section, a minor modification has been proposed and performed in terms of the dashboards used in FLOW.

The existing working procedure presented in section 4.3.3 had at the time been up and running for almost one program which implied a revision was in place. Through discussions with the Geometry Program Managers it became evident that the dashboard content could be made more clear for them to be able to extract the most relevant information. Among others, the pie charts used in today's dashboard are presented in fig. 4.10. By reviewing the content in the pie charts it was suggested and discussed to develop a new structure since the current ones include both Tasks and Problem Reports. To fully get an overview and understand the current status in terms of fulfilled requirements and current issues, it was deemed necessary to be able to see the following pie charts:

Tasks

- The priority level of all Tasks

Problem Reports - Assigned to a design leader or manufacturing engineer

- The status level of all directed Problem Reports
- Which design department the Problem Reports are directed to
- Which area the Problem Report is internally related to

Problem Reports - Assigned to the GAE in terms of an audit remark

- The status level of all received Problem Reports
- Which area the Problem Report is internally directed to

To conclude this chapter, it is important to state that this is a desired and suggested state based on the authors findings generated through interviews and analysis of the current state. In addition to this, the new working procedure is based on three assumptions presented at the beginning of this chapter, these prerequisites will be discussed further in chapter 6.

6
Discussion

As one interviewee expressed it:

> *''For my own sake documentation might not be as important, but it surely is for the rest of the development organisation. It assists in creating an understanding and provides a natural forum where important decisions can be documented and are accessible by everyone''*

Some individuals might consider it unnecessary to document everything in a system because they are confident that they are in control of their work and so forth. But there are other benefits in being thorough when documenting performed work and potential issues found, for instance, to be transparent and communicative, to be able to rely on documented data in terms of a dispute or disagreements. And what if an employee decides to quit, by documenting the most crucial knowledge is stored and accessible by a new employee.

6.1 Benefits New Working Procedure

The suggested working procedure presented in chapter 5 is expected to aid the process of handing FDR. Among other things it will provide a more transparent working process since FLOW is accessible by all Volvo employees. By using the generic structure with one requirement and Task for each PQ section it is very clear where to access information regarding the original specification as well as information regarding current development or running production. System Weaver shall only hold information regarding the original requirement whereas FLOW shall hold additional information and decisions made along the way. This helps monitoring the evolution of each requirement as well as being an intuitive and communicative process, which all was extracted as keywords in the development. The suggested procedure enables revision of the requirement history, even though it might require some scrolling in the comment field to find a specific value.

As the common goal is to deliver a high quality car to the end customer it is essential to work together. The current working procedure is somewhat ambiguous where responsibilities not always are clear, handovers are seen as a strict handover where one responsibility abruptly ends and another begins. These strict handovers are contradicting the cross functional working procedure that is needed to achieve the common goal of delivering a high quality car to the end customer. Therefore, this new working procedure shall assist in blurring the boundaries between involved departments. The handover shall not be viewed as a strict line in time where responsibility is shifted, even though the main responsibility must be assigned to a specific person. The idea is to blur boundaries by being proactive and attending mini-workshops continuously, at different stages of the development. The importance is in sharing knowledge throughout the complete process and supporting each other when issues arises.

If the working procedure is successfully implemented there are a few long term benefits that might play an important role for the geometry assurance process and the organisation as a whole. By successfully applying and using the procedure as intended it might lead to issues being found and solved earlier in the development process compared to today. In the long run, this will lead to savings in terms of cost, according to fig. 2.1 but also in terms of time since the changes can be made at the right stage when resources are available and dedicated to the specific task.

6.2 Barriers New Working Procedure

Implementing this new working procedure is first and foremost expected to be beneficial, but of course there are some barriers for a successful implementation as well. These barriers will be described in the following sections and are divided by technical- and human barriers.

6.2.1 Technical Barriers

As described in previous chapter there are a number of elements that needs to be cleared out before this working procedure could be implemented and further developed. First, the uncertainty in how PQ decides to use System Weaver will play an extremely important role. The most crucial prerequisite is that they choose to set up all requirements according to the generic structure used in FLOW today, i.e. by defining one requirement for each FD section and not as it is done in the Geometry Scorecard today (one row for each requirement type, see fig. 4.3). If their decision results in a different structure the working procedure must be reviewed on a basic level since the connection between System Weaver and FLOW is the key for a successful improved working procedure.

Interrelated to the previous prerequisite, a decision to introduce the plug-in between System Weaver and FLOW needs to be made on a global level. First, it is essential that the plug-in is developed further to enable access between the two systems showing linked items independent of the system the user originates from. If the plug-in is rejected for some reason, there is in fact another solution for linking issues. The solution is based on extracting an URL-link from the System Weaver requirement which can be pasted into the 'Requirement Link' field in FLOW (where the Onepager is linked today). This can also be done the opposite direction, copying an URL-link from FLOW and paste it into the System Weaver requirement. However, this procedure is far from as successful as the plug-in would be. From an objective point of view this would not facilitate the handling of FDR in terms of all the manual administration work it would require, which also was a crucial requirement raised from PQ. It would all again be a matter of duplication work to a large extent. In addition to duplication work, it would also be a huge compromise and risk in linking the wrong requirements to the wrong Task which can be avoided by creating the Task directly through the plug-in.

The final prerequisite relevant for this working procedure to be implemented is the RDE's consent in terms of accepting to be the creator of all Tasks. As described in section 4.5.2 there are around 200 Tasks created for each program which as expected will require some administration. As the GAE's already today creates Tasks covering the majority of the ones that would be used by the RDE there is a possibility in them rejecting to create the Tasks from scratch due to the added admin and arguing that it should be created by the GAE. This would of course be a possibility, however, there are a few issues in relation to the GAE creating the Tasks which then shall be used by the RDE, GAE and the GE, these are listed below.

- The timing in creating the Task – today, the GAE creates it around V2 rel but it would be necessary to start creating them around V0 rel to fit the RDE
- The GAE does not create all Tasks which will be necessary for the RDE – this is due to the RDE performing calculations on more requirements than the GAE and GE can physically verify
- If the GAE shall create all Tasks the bulk cloning is a necessity – the RDE can create the Task by using the plug-in according to Scenario 1, the GAE will create all Tasks at once which would be facilitated by the bulk cloning functionality

These issues need to be addressed and discussed by the involved departments since it play an important role in terms of timing in the creation of Tasks, either the GAE needs to create the Task in advance (compared to today) or the RDE needs to take on more admin work. Logically, the RDE should create the Task based on two reasons. First, because they are the first instance to perform work in relation to the verification of a FDR. Secondly, due to them having the possibility to create the Task directly through System Weaver which also is more logical and natural in terms of it being done incrementally as the requirements are assigned to the RDE.

In addition to the three above mentioned prerequisites, it is also important to stress the need for all users being offered the support that is needed when starting to use the FLOW system and work according to the new procedure. To make sure this is done correctly it is important to offer relevant education and to make sure education and guideline material is available and easily accessible. Apart from being accessible it is also important to assure the material is intuitive and concise in order for the users to consider the material usable and value adding.

6.2.2 Human Barriers

Apart from the technical barriers described in previous section there are also a few human barriers that might occur when implementing the new working procedure. First – the willingness to accept a change – there will always be a few individuals that are restrictive to changing the existing situation. This requires all involved departments to understand and acknowledge the need for a new working procedure and a more effective and interactive communication style. The risks in viewing the previously described handovers as means for blurring out boundaries can be viewed as yet even more ambiguous responsibility areas, which is why communication and documentation is the key for success here.

When the working procedure is up and running there is also a risk in different users using the system differently and deviate from the standard way of working which can create confusion and added work for correction. This could for instance be different kind of information added into the Task or using different names and labels. Due to this, it is even more crucial to assure the right education and material is offered which can help in assuring users performing their work according to a given standard.

Finally, as Volvo is a global company this working procedure needs to be implemented across the whole organisation. Even thought the developing core is located in Gothenburg it is crucial to start implementation across the other plants as soon as possible. However, cultural differences and long geographical distance can be a human barrier in terms of acceptance from the receiver and difficulties in communicating a new working procedure in an effective way.

6.3 Improved Onepager Solution

The new Onepager solution is by most involved users deemed to be a very good improvement. First, it is considered to eliminate a lot of administration work from linking the Onepager from SharePoint to FLOW. This linking process is first and foremost time consuming since it is done one by one for each Task. Secondly, the SharePoint site has also been somewhat unreliable with Onepagers disappearing. Finally, it is also regarded more intuitive to only use one system and document relevant information in the FLOW Task which is already used. However, it came to light that the GE department uses the Onepager more extensively where they print it and brings a physical copy to certain meetings. This is used as a well known tool across several instances in running production. However, the whole developing organisation is affected by the transformation with FLOW which is why it is considered necessary to replace the existing Onepager and incorporate it into the FLOW Task instead. In a near future FLOW will be spread across a larger part of the organisation and it is important to be in the forefront and adapt to coming changes. However, the new solution does not hinder anyone from creating a Onepager according to the old way of working if necessary. Therefore, the management team and the users decided to apply the new solution and allow creation of ‘physical’ Onepagers by extracting the information from FLOW and using it during one particular meeting. After the meeting it is important to discard the physical copy and refer back to the FLOW Task where the latest information always will be found.

One element that was discussed in relation to the new improved solution was the desire to be able to extract the information from the FLOW Description field directly to a PDF, preferably in landscape orientation. This is something that could be elaborated more and discussed with the FLOW support team.

To conclude the discussion chapter, it is relevant to mention that the creation of a working procedure which shall cover four different departments, is extremely complex. First, it is a complex process in terms of understanding all the different responsibilities and activities performed in relation to each department and the management of FDR. There are also a multitude of exceptions which is hard to cover when trying to create a generic working procedure. Secondly, the departments are responsible for more than managing FDR which makes the process even more complex due to them requiring a working procedure suitable for more processes, requirements, you name it. However, even though the suggested working process is developed to fit the management of FDR it is considered relatively generic in terms of including elements that are applicable for other purposes. Within the development organisation everything is about problem solving and incremental development where issues arise and need to be addressed, whereas FLOW is the right tool to use due to it being a issue management system.

7

Conclusion and Recommendations

The purpose of this thesis was to find a common working procedure used to manage and document FRD requirements which should facilitate easier communication between involved departments and help in being more effective and efficient. Developing a common working procedure applicable and convenient to use for all involved departments and users is not an obvious and straight forward process. There are a lot of viewpoints to take into consideration. Intentionally, it was speculated if the existing working procedure used by the GAE's could be implemented across the complete geometry loop. As a result of RQ1 a systematic description of the existing processes used were presented, this in relation to each involved department and the VPDS process. This also resulted in finding that there were other systems to be used in relation to requirements, in particular System Weaver. System Weaver is a requirement management system whereas FLOW is a issue management system. Therefore, it was quickly understood that applying the existing working procedure used by the GAE's was not an option due to the PQ department being requirement owner and enforced to use System Weaver. However, it also became evident that a plug-in was developed and tested across the organisation. This plug-in would enable a connection between a System Weaver requirement and a FLOW issue. These two findings play an important role for future possibilities. Along with this, some improvement areas were found, for instance, eliminating administration work, being able to follow the evolution of a requirement and clarifying handovers between departments.

Even though it became evident that FLOW could not be used across the complete geometry organisation, a new desired state was developed which to a great extent is supported by FLOW. Answering RQ2, the new suggested working procedure is developed as follows:

1. The AL creates a generic structure of all requirement in System Weaver and assigns to the responsible RDE
2. The RDE creates one Task for each assigned requirement which is linked to the original requirement in System Weaver
3. The Task will then follow the whole chain; RDE —> GAE —> GE by transferring the Task at a specific time
4. During this process three mini-workshops are held to increase communication and understanding for the work made in relation to each FDR

This new working procedure enables all involved departments to easily access all relevant information in relation to a specific requirement, whether it is the original requirement defined by PQ or the theoretically or physically verified value. By a subjective assessment the new working procedure also meet the majority of the extracted requirements. The new Onepager solution is more intuitive and eliminates waste administration as well as minimising the number of systems used which also the overall working procedure does. Allowing all information to be gathered in one place and connected to the original requirement also enables the user to follow the evolution of a requirement without the need to search in several systems. Finally, it provides a more effective and efficient working procedure where communication and transparency is he key for success and to extract lessons learned along the way.

To answer RQ3, the most important part noticed along the way, is that awareness and acceptance is achieved by constantly involve and communicate with the users. This was early initiated by conducting interviews with all involved parties followed by a workshop where all met together and got the opportunity to discuss current situation as well as improvements. This is also something that was incorporated into the suggested working procedure, in terms of the mini-workshops, if all get the opportunity to meed during development and learn from mistakes as early as possible. Further, it is important to be transparent and open for feedback when developing a new working procedure and finally, to find a procedure that facilitates the daily work for involved parties.

The next step is to evaluate and follow up the progress of PQ's System Weaver project and the potential plug-in. The developer of the plug-in will soon perform a Proof Of Concept (POC) which is important to be part of in terms of highlighting what is needed to support the suggested working procedure. To improve the suggested working procedure there are some elements that could be researched further:

- Is it possible to automatically create a FLOW Task as soon as the AL assigns a requirement to the RDE? Which automatically extracts the section name, e.g. FE510 Fender to Hood, and labels the Task with a particular label.
- Look into the possibilities of creating a Onepager template in landscape orientation, more similar to the old layout but still incorporated in FLOW. If there is a demand from a larger part of the organisation this might be something beneficial for several departments.
- Investigate the possibilities to include a time line in FLOW, where all requirement values are presented in terms of original requirement, RDE calculation, physically verified and baseline judgements for life made along the way.

Finally, it is important to validate the working procedure to see if it serves its purpose and improve it where necessary. It is rarely a perfect procedure right from start, it is crucial to test and evaluate early to make improvements. This could be done by using the suggested methodology in section 3.5.

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Appendices

A Interviewees

Interviewee #	Department affiliation	Expertise Area/Role
1	Operational Development	FLOW Business Application Manager
2	Forward Quality	FLOW Superuser and Administrator
3	Perceived Quality	Manager Perceived Quality
4	Perceived Quality	Attribute Leader
5	Perceived Quality	Attribute Leader
6	Robust Design & Tolerancing	Robust Design Engineer
7	Robust Design & Tolerancing	Robust Design Engineer
8	Geometry Assurance Program	Program Manager Geometry
9	Geometry Assurance Program	Geometry Assurance Engineer
10	Geometry Assurance Program	Geometry Assurance Engineer
11	Geometry Assurance (Running Production)	Manager Geometry Assurance
12	Geometry Assurance (Running Production)	Geometry Engineer

* Numbers in **turquoise** are highlighted due to the interviewees participation during the focus group

B Interview Guides

Interview Guide FLOW

INTERVIEW GUIDE

FLOW Business Application Manager and FLOW Admin Manufacturing

Background questions

1. What is your current role and for how long have you had it?
2. What is the overall/core responsibility for your role?
3. When did you start working with FLOW? Have you been involved since the development started?
4. Can you tell me about the projects you've been involved with, in relation to FLOW?

Background and implementation

5. Can you describe how the development of FLOW started, why it was initiated etc?
6. What benefits would you say the system brings to the company?
7. How is the implementation going? According to plan, better or worse?
    a. Where is it implemented?
        i. Globally?
        ii. Department wise?
8. What reactions have you received during the implementation?
9. Since it's a new system, there is a need for a natural forum where queries could be brought up, is there somethings like this? Can you tell me more about the structure of it and what kind of questions are brought up?
10. Can you tell me about the future challenges and visions with FLOW?
11. What possibilities do we have to perform adaptations on the system according to our needs? What is required in order to get this kind of requests approved?
12. Do you have something you would like to add to this interview, that we haven't covered yet?

INTERVIEW GUIDE

Engineers working with geometry assurance

Background questions

1. What is your current role and for how long have you had it?
2. What is the overall/core responsibility for your role?
3. Have you had other roles related to geometry earlier?
4. How would you define final demands and their importance?
5. How is you department divided in terms of responsibility areas?

Existing situation – working procedure

6. How would you describe the management of final demands from a wider perspective? Where does it “start” and “end”?
7. Can you describe the existing working procedure in your department, related to the handling of final demands?
    a. Please explain this in relation to the VPDS (Volvo Product Development System).
    b. What input is required for you to have before you can start working and how is this input received?
    c. Tell me how you collaborate with other departments?
8. Would you say there are any differences in how you work within the department, even though you have the same role?
9. Can you tell me about the recurring routines/activities you follow? Are there some documents I can see related to these routines?
10. Which software and systems are you using to support your work?
11. How is the work documented and where?
12. How do you follow-up the work and document potential lessons learned?
13. Can you describe how you collaborate with other departments and how the handover (if there is one) is done?
    a. In your opinion, is there something that can be improved in relation to the handover and what works well today?
14. How is knowledge and results reused from previous car programs?
15. In your opinion, what do you consider is exceptionally good with today’s working procedure?
16. Do you see any general issues with today’s working procedures and can you describe these?
17. Do you see any potential solution to solve these issues and can you describe it?
18. In your opinion, what is of great importance in a close collaboration with other departments?
19. Do you have something you would like to add to this interview, that we haven’t covered yet?

Interview Guide Managers

INTERVIEW GUIDE

Manager within each department

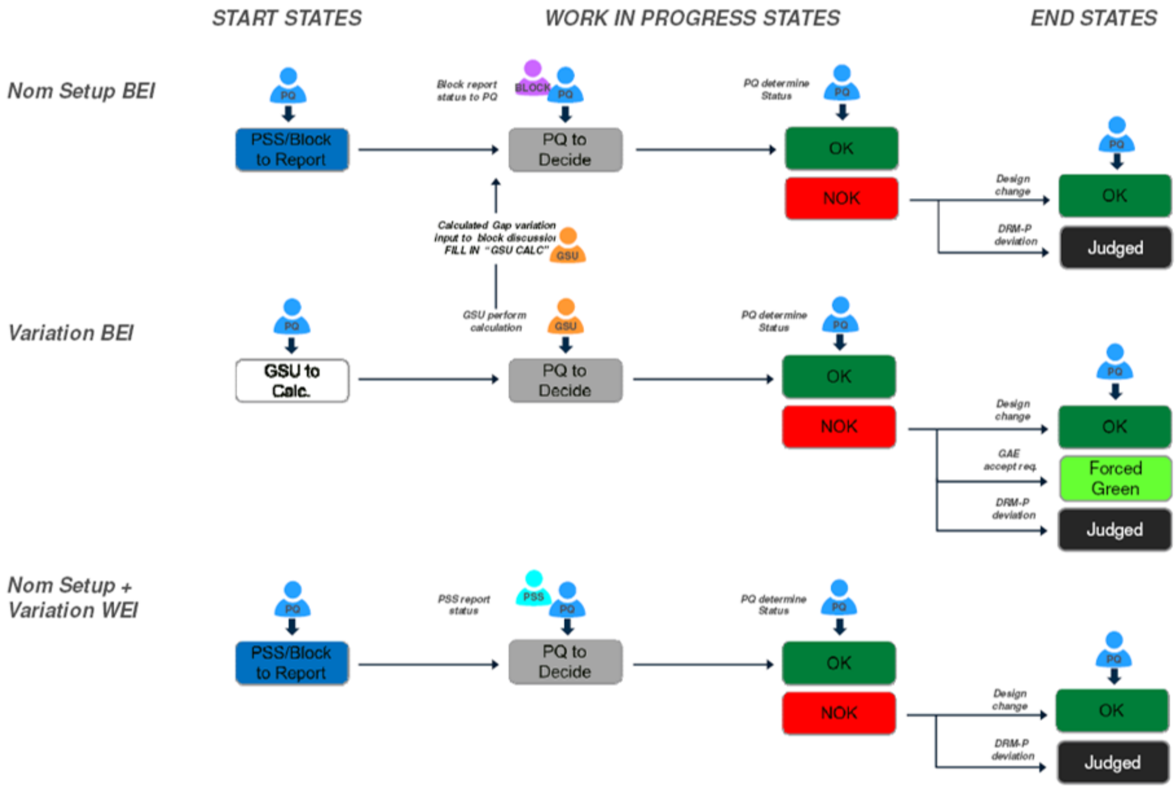
Background questions

1. What is your current role and for how long have you had it?
2. What is the overall/core responsibility for your role?
3. Have you had other roles related to geometry earlier?

Existing situation – reporting and information needed

4. Can you describe you responsibilities and activities connected to geometry status/final demand status?
    a. What are your specific deliveries?
    b. How do you report the geometry status to higher level management team?
    c. What information do you need in order to do this?
    d. Do you need any specific information from your employees?
5. Can you tell me about the collaboration between you and your employee? (provided that you need specific information from them)
    a. Do you receive the information you need? On time? Why/why not?
    b. Do you need to process that information in order to be able to use it for reporting?
6. In your opinion, what do you consider is exceptionally good with today's working procedure?
7. Do you see any general issues with today's working procedures and can you describe these?
8. Do you see any potential solution to solve these issues and can you describe it?
9. Do you have something you would like to add to this interview, that we haven't covered yet?

C Geometry Scorecard Workflow



D Contribution Analysis

Volvo Car Corporation	Document Type		Document Release Status	
	Document No	Revision	Volume No	Page No 24(50)
Document Name				

RE265: Rear Lamp to Rear closure : Gap				
Static Variation	Tolerance Name	Comments	Contr. %	Tol.
1	BIW, Hole pos, 015SS lower X LHS		23.6%	1.00
2	Rearlamp LHS, Edge, RE265 Gap		17.3%	2.00
3	BIW, Hole pos, 015SS lower X LHS		17.0%	1.00
4	Rearlamp LHS, Edge, RE265 Gap		6.8%	1.00
5	BIW, Hole pos, 015SS Y LHS		5.0%	2.50
6	BIW, Hole pos, 015SS Y RHS		4.9%	2.50
7	Process Tolerance, Tailgate		4.6%	1.00
8	Tailgate, Edge, RE265 Gap LHS		4.4%	2.00
9	BIW, Surface, Hinge surface ss005		4.1%	1.00
10	Tailgate, Edge, RE265 Gap LHS		3.5%	1.50
11	BIW, Hole pos, 015SS Y RHS		2.3%	1.00
12	BIW, Surface, Hinge surface ss005		2.0%	2.00
13	BIW, Hole pos, 015SS Y LHS		1.3%	1.00
14	BIW, Hole pos, 015SS lower X LHS		1.2%	2.50
15	ASSEMBLY FIXTURE TAILGATE, Surface, Process Tolerance		0.9%	1.00
		RD&T SIMULATION (8 sigma)	3.3	(0.01% Out)

Dynamic Variation		0
		0
Thermal Shrink/Exp.		0
		0
Paint/Material Thickness		0
		0
Predicted Meanshift		0
		0
Predicted Variation		0
		0

The demand is calculated to
Expected variation (8s): 3.5 ± 1.6 mm
Variation over time (6s): 3.5 ± 1.2
Tolerance zone (10s): 3.5 ± 2.0

The demand is predicted to 3.5 ± 1.6

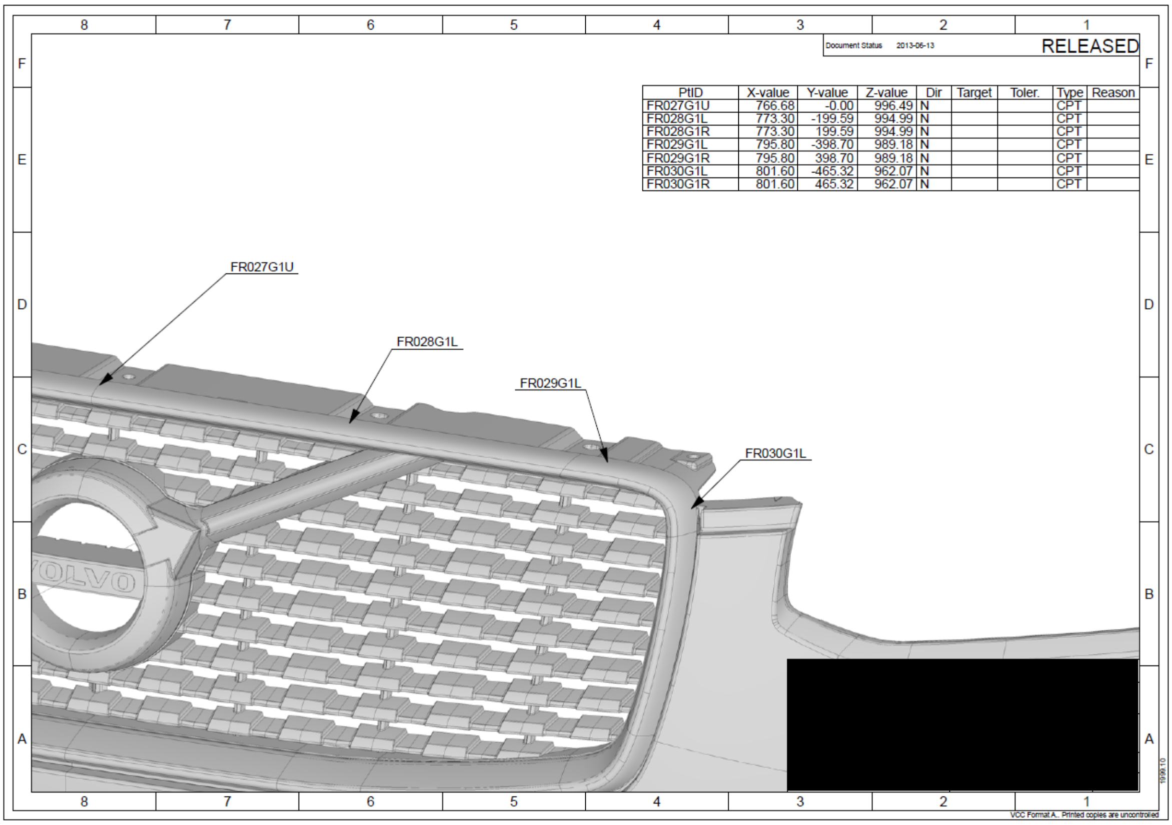
This system solution demands a gap of min 2.0 mm

NUFO cubing model (DSM) 2.0 mm

RE265: Rear Lamp to Rear closure

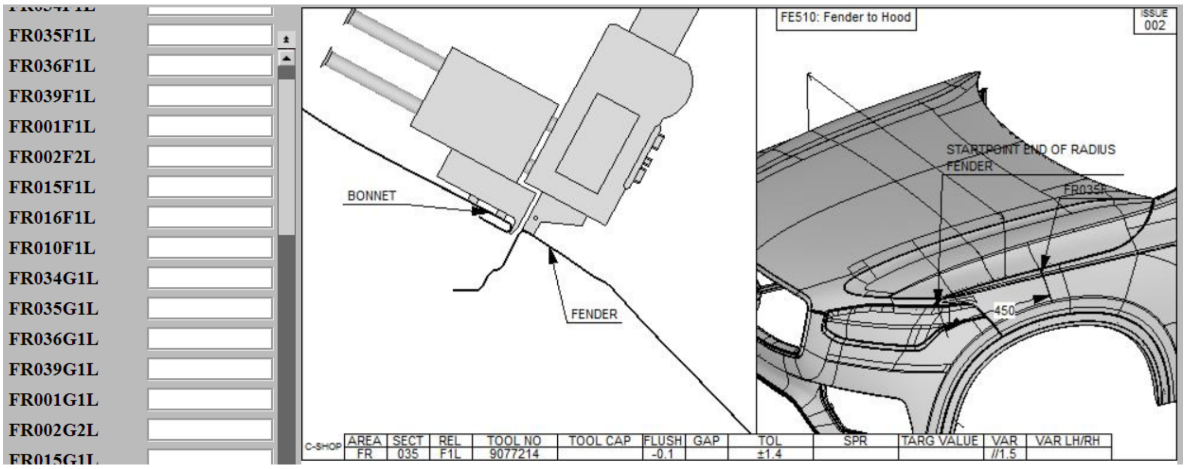
Demand	Proposal	Agreed
Gap	Base Demand: 2.5±1.9	
3.5±1.6//1//LR2.2		
Flush	Base Demand: 2±2.1	
2±1.6		
Ref Proj	**Demand**	**Prod**
Gap		
Flush		
	Competitor	**Prod**
Gap		
Flush		

E MP-Drawing



PtID	X-value	Y-value	Z-value	Dir	Target	Toler.	Type	Reason
FR027G1U	766.68	-0.00	996.49	N			CPT	
FR028G1L	773.30	-199.59	994.99	N			CPT	
FR028G1R	773.30	199.59	994.99	N			CPT	
FR029G1L	795.80	-398.70	989.18	N			CPT	
FR029G1R	795.80	398.70	989.18	N			CPT	
FR030G1L	801.60	-465.32	962.07	N			CPT	
FR030G1R	801.60	465.32	962.07	N			CPT	

F PKI Final Demand Web



G Priority Level Scale in FLOW

Used by GAE

1 **Level 1:** Escalated tasks.
Attention to program management. Final Demand deviation. No solution available. Create problem report.

5 **Level 5:** Final Demand deviation. Work ongoing, solution exists.

10 **Level 10:** Final Demands OK.

Used by GE

1 **Level 1:** Escalated tasks.
Attention to current model management. Final Demand deviation. No solution available. Create current model problem report.

5 **Level 5:** Final Demand deviation. Work ongoing performed by the GE, solution incoming or existing.

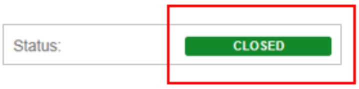
10 **Level 10:** Final Demand OK.

H Workflow Status Level in FLOW

Used by GAE

Open: Tasks will automatically be in status ”OPEN” when they are created.

In progress:
When work has started change status to ”IN PROGRESS”.
For example when you change priority to level 5 or level 1.

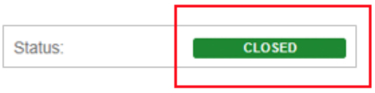


Closed: Close the Task when the PQ Requirement is fulfilled and ”green” and ALL Problem Reports connected to the Task are solved and in status ”CLOSED”.

Used by GE

Open: Not to be used by the GE. Status either ”IN PROGRESS” or ”CLOSED”.

In progress: Final demand out of spec, work ongoing. Priority level 1 or 5.



Closed: Final demand within spec, all Current Model Problem Reports in status “CLOSED”.

I GE Action Plan List

QUALITY CONFIRMATION MAPPING Year VCT Front

Week	Program	Responsible	D Define	M Measure	A Analyze	I Implement	C Control	Follow-up (wXXdy)	Source: External	Source: Audit	Source: Production	Source: In-Line	Source: Off-Line	Source: VRT / BSAQ	Source: Supplier	PRIO

J Transfer list GAE —> GE

Final Demands C-shop

Routine	PQ demands	VP Target XX% Result	TT Target XX% Result	PP Target XX% Result	MP1 Target XX% Result	FSR Target XX% Result	Transfer	Baseline for life	Changed PQ-specification
SIDE DOOR	GH505 QUATER GLASS TO CANTRAIL	> XX%	< XX%	< XX%	> XX%	> XX%	YES		
	SD105 DOOR TO FENDER	> XX%	> XX%	> XX%	< XX%	> XX%	YES		
	SD130 FRONT TO REAR CAPPING	< XX%	< XX%	< XX%	< XX%	< XX%			
	SD135 FRONT DOOR TO REAR DOOR	> XX%	> XX%	> XX%	> XX%	> XX%	YES		
	SD205 GRS TO ROOF	> XX%	> XX%	< XX%	< XX%	< XX%			
	SD215 C-CAPPING TO Q-GLASS								
	SD225 REAR DOOR TO UNISIDE								
	SD325 OUTER TRIM FD TO RD								
	SD340 OUTER TRIM RD TO QG IN Z								
	SD342 OUTER TRIM RD TO QG								
	SD365 OUTER TRIM QG TO UNISIDE								
	SD390 BELT LIST RD TO TRIM QG IN Z								
	SD392 BELT LIST RD TO TRIM QG								
	SD410 BELT LIST FD TO RD IN Z								
	SD412 FD BELT LIST TO RD BELT LIST								
	SD475 FD CAPPING TO OUTER TRIM								
	SD480 RD CAPPING TO GRS								
	SD036 CHEATER PANEL TO GRS								
	SD120 GRS TO A-PILLAR ROOF								
	SD327 OUTER TRIM FD TO OUTER TRIM RD								
	SD570 DIVIDETBAR TO GRS								
	SD510 RD REAR CAPPING TO GRS								

Note that this is an illustration of the transfer list format. Green values means PIST target is achieved, red means under target. When target is reached, FDR can be transferred to the GE.

K Generic Process for Managing FDR