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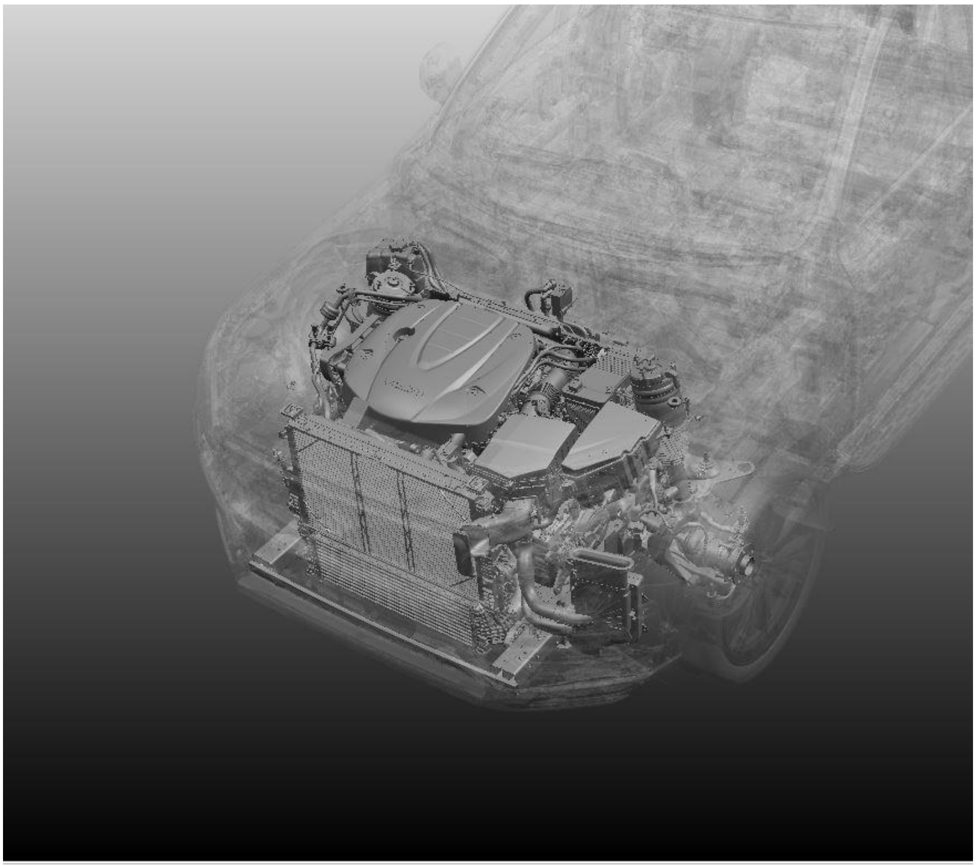

Feasibility study for Front Trunk Compartment Engineering Template in Engine Bay area

Master’s thesis in Product Development

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2020

MASTER'S THESIS 2020

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Cover: A visulization of the engine bay area in a Volvo XC90.

Abstract

At Volvo Cars Cooperation, the vision to develop cars at a rapid pace is of upmost importance in the current competitive environment that is the automotive industry. Through implementation of new and innovative ways of relaying information and requirements between the stakeholders of the car development, more robust processes can be built to account for design changes throughout the development process in an easier and more time effective way. One example of such implementations is Engineering Templates.

Through the use of an Engineering Template, requirements and demands from stakeholders can be communicated through a hierarchical information flow, were the information is shared through digital visualisation. This thesis has evaluated the possibility to create an Engineering Template for the Engine Bay area, with a focus of the possibility of using an Engineering Template when developing a front trunk compartment. The conclusion of this thesis is that it is possible to develop an Engineering Template for the purpose of sharing information and make development processes easier. By using an Engineering Template, especially in the upper area of the Engine Bay which is affected by tophat changes to a larger extent, the information flow and state of the revisions are clearer and better communicated.

Keywords: Engineering Template, Front storage compartment, Product development

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First of all, I want to express my gratitude to the Engine Bay block team members, to not only offer the possibility of the project, but all the support and guidance throughout the project. Also, all the people working at the department of Mechanical Architecture and Integration, especially my supervisor Erik Jarskär and Zara Thapper, supporting me with their immense knowledge of templates.

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Björn Persson, Gothenburg, April 2020

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Nomenclature

PSS = Product Structure System (old name of ARTs, Department in charge of particular part construction)
VCC = Volvo Cars Cooperation
TC = Teamcenter (PLM system at Volvo Cars)
MIE = Mechanical Architecture Engineer
ME = Manufacturing Engineering
ART = Agile Release Train, a concept within the Scaled Agile Framework (SAFe) that defines synchronization of scrum teams
CAD = Computer Aided Design
CM = Collector Mod

1 Introduction

In this chapter, the background of Volvo Cars Corporation and their development process is described. The background of the project, the purpose of the thesis and information regarding the thesis itself is included.

1.1 Volvo Cars Corporation

Volvo Cars Corporation is a luxury vehicle company situated in Torslanda, Sweden and is active on the global market. They specialize in developing, manufacturing and providing cars models such as SUVs (Sport Utility Vehicle,) sedans and station wagons and are known for safety and reliability. Evidence of the safety policies of the company are for example the Vision 2020, striving to increase the safety of the Volvo Cars car models through changes concerning speeding, intoxication and distraction while driving. As a result of the expanding market for semi- and fully electrical vehicles, Volvo Cars Corporation has stated that by 2025, 50% of their sales volume will be fully-electric vehicles and are committed to develop hybrid or full-electric powertrain for all car models, as a way to create a more sustainable and environmental automotive sector. Furthermore, commitment to high quality and ethical business and development is one of the core values of VCC (Volvo Cars Corporation, 2019).

1.2 Project Background

Developing a car is a complex matter of development. Individuals working at the Research and Development part of Volvo Cars Corporation are aware of this. Specifically, engineers working with Mechanical Architecture and Integration are continuously working with the component architecture of the car and the interaction and integration of the different components of the car. Their task is to make sure that the components fit in a correct and desirable way together and that there are no undesirable clashes between components. Since there are a multitude of departments involved in the engine bay of the car, changes in component design causes ripple effects onto the positioning of components which in turn can cause delays and issues with redesigns. This mainly due to the size of knowledge required to have a full understanding of the engine bay area and its' components. By using so called Engineering templates, the relations and requirements between components become more standardised and make the design more robust to design changes regarding the components. An Engineering template consists of the requirements set upon the design space and then in turn the CAD models in this design space need to follow the relations and requirements. This makes the communication between departments easier and for designers to work more efficiently, since they know the input and output of the Engineering Template. The Engineering Template itself creates a documented and graphical representation of the requirements and the input and output needed for the development process.

As of now, no there is no Engineering Template in use for the area called the ‘Engine Bay’, which signifies the area were the engine is situated in the frontal part of the car. The main cause for this is that the engine bay area is rarely affect significantly by new design changes. With the transition to electrical driven cars however, combustion engines are replaced by electrical ones and as a result, the components in the engine bay are changed to a substantial degree. One of these new components is the front storage compartment, which is more of a design-oriented component in comparison to most adjacent components. Therefore, to improve upon the designing in this area and for future iterations of cars to be developed faster, there is a desire to have such a template in place. Engineering templates are continuously improved over time and the template itself could be used as a supplement to the development in an efficient way.

1.3 Development process of a car

For the car to be developed in an efficient way, a certain order of processes needs to be followed. Not only is one single car in development, but a whole platform as well. The car development is divided into two parts: platform and the tophat area. Below in Figure 1, a description of the different sections or blocks of the cars is visible. The platform area consists of the Engine Bay and the Floor area, whilst the rest constitutes the tophat area. There are cases of cross-block development, but as of now, a simplified overview will be presented and looked upon.

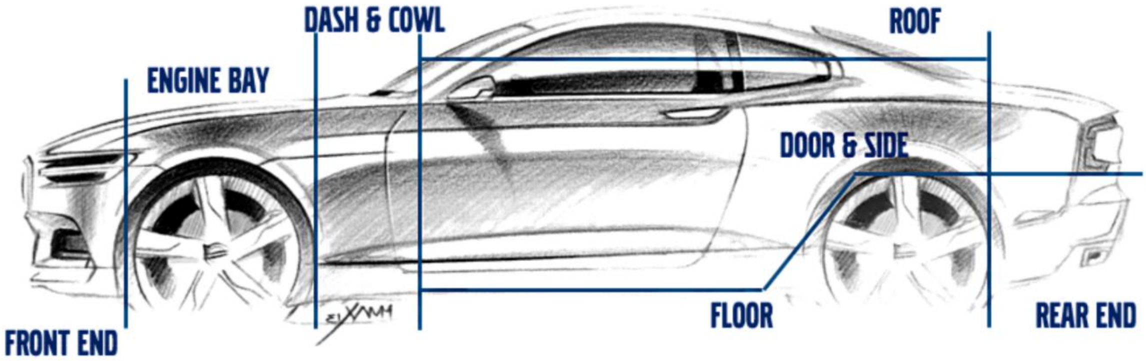

Figure 1 - Description of block areas of the car

The tophat area of the car is what distinguishes unique car models in the product platform. Compared to the less visibly exposed platform area, the tophat area is more design-oriented, since the purpose of the tophat is to create the distinguishability of a car model. The tophat is later in the development as well, even if it begins before that the platform is completely finished. This is a result of trying to decrease the lead development time and at the same time trying to counteract the eventual issues that might arise with the synchronisation of the platform and the tophat.

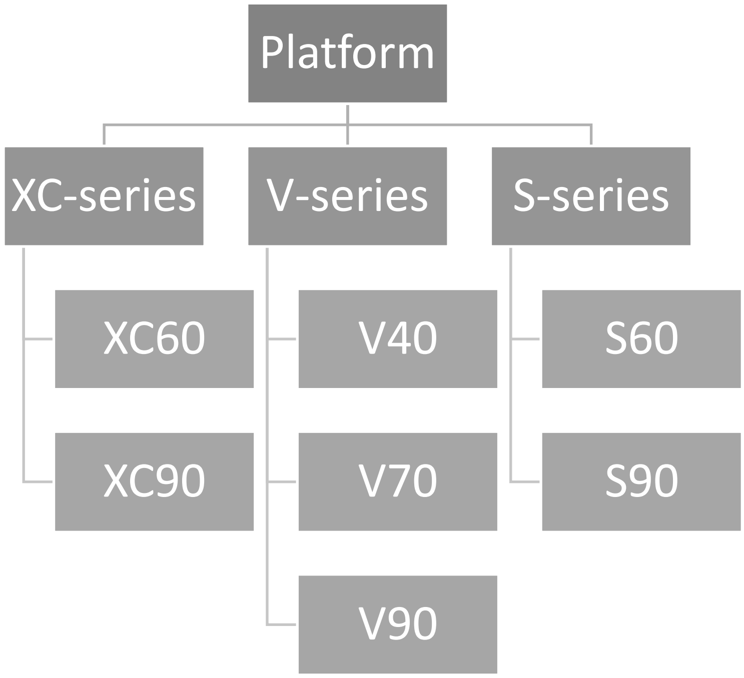

Figure 2 - Distinction between platform and tophat area

In Figure 2, the distinction between tophat and platform is made clearer. Whilst the tophat has variations, the platform needs to be developed in such a way that it is compatible to the greatest extent with all the variation in the product platform.

1.4 Organisational Structure

The stakeholders of the development in the Engine bay area can be divided into categories: design, block, PSS/ARTs. These interact in different areas of the development but are dependent on each other to make the development process function. Below in Figure 3, the role of an intermediator between stakeholders in the development process is described.

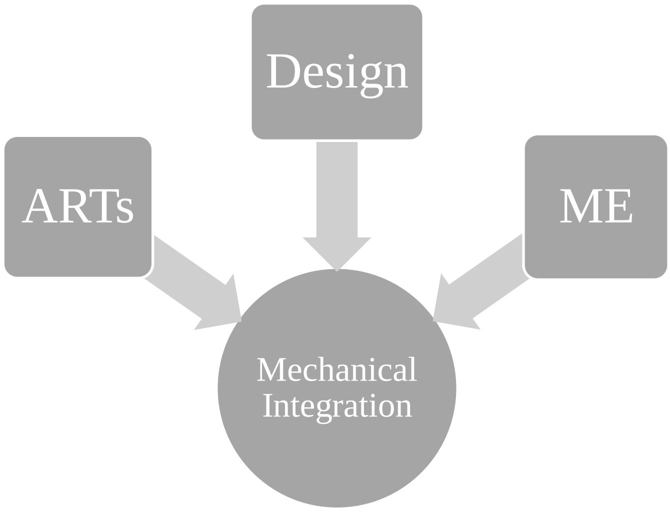

Figure 3 - Interactions between stakeholders in the Engine Bay

1.4.1 The Engine Bay block

The Engine bay block is responsible for the packaging of the components inside of engine bay and are in charge of the communication regarding different requirements and demands. Therefore, the block team is in charge of a lot of communication between the parties involved in the Engine Bay and need to be flexible with finding solutions for the issues regarding packaging. One of the major issues packaging works with is the issues of components clashing and the need for clearance between components with special needs. The area is visualised in Figure 4 below:

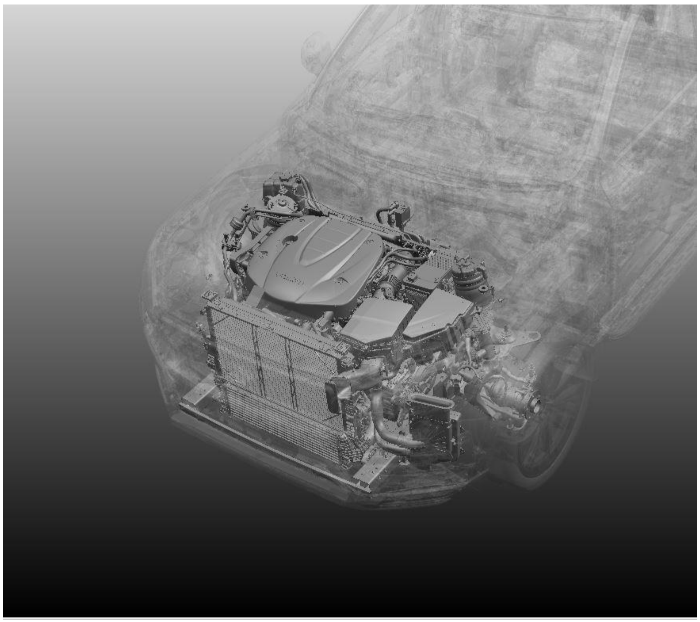

Figure 4 - Engine bay area in Volvo XC90

The components can be divided into two parts: the moving and the static components. Components that interacts with the engine would be under the influence of movement when the cars are operational. This creates two different clearances: the static and dynamic clearances. By running field testing and simulations the movement pattern of components can be observed and through that, a dynamic clearance can be created.

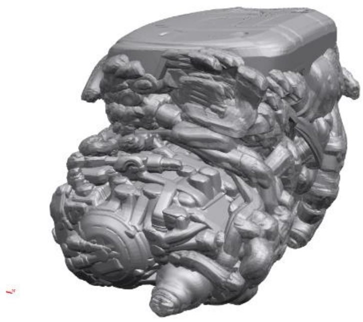

Figure 5 - Dynamic envelope of an engine

These processes of generating dynamic clearances among the assignments of the MIE, Mechanical Integrations Engineer. Such a dynamic envelope can be observed above in Figure 5. Clearance requirements are most often verified through virtual measurements in the TCVis Mock-up software.

The Design team

The design team is in charge of the design surfaces of the so called "tophat" part of the car, which is different depending on the car. The platform of the car is similar for different models in the Volvo Cars franchise. This in turn sets demands on the platform, because a mutual solution for the platform need to be achieved. The design team works with DSMs, or design releases, were a new design is released that other components need to consider.

The PSS/ARTs

There are various so-called PSS/ARTs, or departments at Volvo Cars Corporation. Examples of these would be PSS120, who's in charge of the Interior Trim of the car, and PSS240, who's in charge of the Front Systems components of the car. Since the Front Systems department is in charge of several components, Table 1 below describes the roles of some of the PSS/ARTs that could be affected by the development of the front trunk compartment.

Table 1 - The division of roles for the individual PSS/ARTs

PSS/ART	ROLE
PSS120 – Interior Trim	In charge of the development and components regarding the interior, such as the upholstery and the luggage compartments
PSS240 – Front Systems	Develops the front part of the cars, i.e. hood, grill, aero, cover panels
PSS270 – Lower Body Structure	Creates the lower parts of the body structure, with a heavy focus on structural durability
PSS90 – Repair Kit	In charge of the repair kit feature in the VCC cars.

In the case of the Engine Bay, the main component would be the engine itself, consisting of a multitude of components in a confined area. There are as well PSS/ARTs that are not component owners. These instead set requirements on the components, examples of such PSS/ARTs are described below in Table 2:

Table 2 - Roles of individual ARTs

PSS/ART	ROLE
Safety & Collision	Ensures that the development follows safety guidelines and verifies by simulation
Ergonomics	Ensures the ergonomic aspects of the usage of the car and reduce the amount of ergonomically taxing features of the car
ME (Manufacturing Engineering)	Ensures that manufacturing demands and requirements are taken into consideration during the development and confirms producibility

These set requirements and demands on both the block, design and PSS/ARTs. Examples of requirements could be reachability, functionality and safety assurance.

1.4.2 Engineering template description

An engineering template can be described as a working methodology and a way of sharing requirements and demands in a virtual environment. The most basic explanation is that an input in the form of design and founding parameters are inserted into the engineering template. An information flow then describes in the order the stakeholders will adhere to this input, as well as updating their own models inside of the CAD assembly. The release of new design surfaces and requirements create a waterfall effect on the flow and in turn create an output in the form of an output, which is usually a type of technical input.

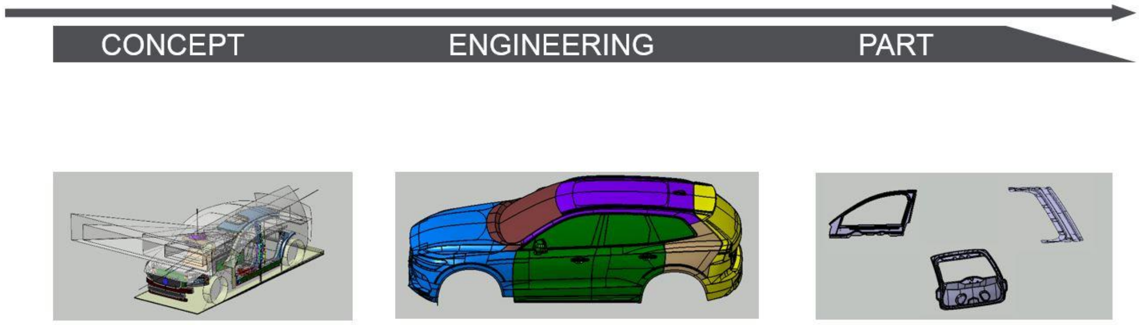

Figure 6 - Description of the Development flow when using template

Templates in general are widely used at VCC although there is quite some distinction between the variations of them.

The templates themselves interact in different parts of the development process. The concept template can be described as using the main requirements and size demands of the car to develop the concepts that will be in the car. As soon as the concepts are set, there is a transfer of the information to start working in the engineering template. The engineering template supports the synchronisation of the components as a whole and relays information for the part templates that are used for design of components.

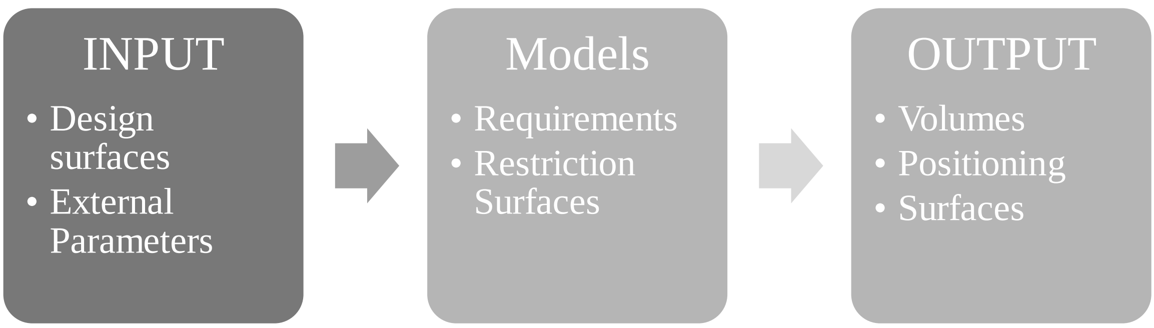

Figure 7 - Overall structure of the Engineering Template

In order to make sure that the information is shared in a correct way and the correct order, the Information flow describes what information is needed and in what order the information will “flow” down the development process. The stakeholders involved in the Engineering Template will form a team. In this team, a common goal or scope will be decided upon to make the most out of the development process. Then, the individual requirements of the components are translated into Catia V5 models. One of the main benefits with Engineering Templates is to communicate requirements and demands early in the developments process, as well verifying requirements on models corresponding to the components in question, instead of verification on the actual component. This in turn creates a development flow of templates visible in Figure 7, where the part development will be dependent on the technical input of the engineering template.

1.4.3 Front Trunk Compartment

With the transition from combustion engine to electrified drive, the architecture of the engine bay area has to be reconsidered. In the wake of this transition, a new feature has been added to increase the customer satisfaction, which is the front trunk compartment. A front trunk is not a new concept, since it is a common feature in cars which either the engine being placed in the back of the car or in electrified cars of today.

An example of an existing front trunk compartment is visible below in Figure 8, available in Tesla's Model S. In order to stay competitive in the car industry, understanding the customer needs is a must. Compared to other components in the engine bay area, the front trunk compartment has a more significant effect on the user when it comes to the design and visual appearance, since the engine bay is usually hidden beneath cover panels. This makes the product development process more design dependant compared to most components in the engine bay area.

Figure 8 - Front trunk compartment of a Tesla Model S (Mike, Anthony, Model S Front Trunk (Frunk), 2014, insideevs.com, 16 April 2020)

Since the introduction of the front trunk compartment into the VCC product platform, a more complex product development process has emerged. Previously, the interaction between the Engine Bay area and tophat development has not been substantial. By introducing the front trunk, a design area was both platform and tophat development play together and a component that are dependent on design changes, new ways of communicating requirements has to be developed.

1.5 Purpose

The purpose of the project is to improve on the existing methods of developing and updating product designs and to make the collaboration between the involved departments at Volvo Cars Cooperation easier. In this instance, the Engine Bay area of the car where different departments work with components that have requirements onto each other. By evaluating the feasibility of implementing an Engineering Template in the Engine Bay area with the introduction of the front trunk compartment, the possibility to improve upon the current development process will be evaluated.

1.6 Goal

The goal would therefore be to produce a proposed engineering template assembly structure in combination with the development of the front trunk compartment that can be implemented and used at Volvo Cars Cooperation. Feedback on how well the assembly structure explains how information and requirements are being shared between the involved parties of departments is important to prove the success of the project and the engineering template itself.

1.7 Limitations

These are the limitation for the thesis:

- Equivalent workload of 30 ETCS at Chalmers University of Technology
- The development process of the Engineering Template should follow Volvo Cars Corporation guidelines
- The CAD development will be conducted in the Catia V5 environment
- The Engineering Template will only focus on lower cars, referring to car models smaller than the XC-model series
- Secrecy regarding on-going development of cars
- Focus on developing an Engineering Template CAD assembly structure, not individual models in it

1.8 Research Questions

To evaluate the success of the project, these following questions will be answered at the end of the project:

- Can a well-working engineering template assembly structure be developed for this part of the car in combination with the front trunk compartment?
- Would the involved departments benefit from this template?
- What limitations of the engineering template are reasonable and is there a possibility to apply the template to a larger extent, mainly a functional Engineering Template for the whole platform?

2 Theoretical Background

This chapter describes the theoretical background and content needed to understand the development processes of product platforms, product varieties and how information and requirements are shared.

2.1 Product Platform and variation development

The platform area can be described as the foundation of the car, where the platform generally is set before the tophat area of the car, since the platform will create the foundation for the product-family of cars that are being developed. Robertson and Ulrich (1998) describes the benefits and challenges with using product platforms as an alternative to one-by-one development (Robertson and Ulrich, 1998). The fundamental aspects of product platforms are as follows:

- **Components** – This constitutes all the unique components that constitutes a product
- **Processes –** The processes by which the product is manufacturing and assembled, and all processes associated with production and supply-chain
- **Knowledge** – The information and experience needed to develop the product
- **People and relationships –** the people and stakeholders involved in the development and manufacturing of the product

By introducing product platforms successful, companies can reap rewards such as lower development time and cost, as well as create a more robust product portfolio in order to supply larger customer segments. Creating components with high commonality results in less complexity between distinctive car models. Also, by having so called 'carry-over' components that are applicable for the whole product platform, there is a lowered risk in both investment costs and the ability to service a multitude of car models (Robertson and Ulrich, 1998). As of now, VCC offers a wide arrange of car models to satisfy different customer segments' needs, which makes the benefits of product platforms desirable.

On the other hand, product platforms present mainly two challenges (Robertson and Ulrich, 1998):

- What markets segments are possible to deliver to whilst balancing commonality and distinctiveness for the product?
- What system architecture should be developed to both share components and production processes and at the same time offer distinctive products?

Facing these challenges are difficult, since the product platform needs to offer product that are distinctive enough to fulfil unique market segments and at the same keep the developments costs low (Robertson and Ulrich, 1998). This is especially difficult in the automotive industry, were development and manufacturing costs are high.

2.2 Knowledge sharing and management

According to (James Gao & Alain Bernard, 2017), knowledge sharing is among the most important issues in knowledge management. By sharing information, especially in regard to time to market in new product development, efficiency and quality, considerable improvement can be made. Also, considering the need to stay competitive, knowledge management is considered key in to improve and speed up the quality of the product development.

Since Volvo Cars compete on a global scale in a very competitive market, the need for well-developed process of sharing information and requirements to different parts of the company is very important.

2.3 Product Lifecycle Management

In order to share information regarding products through its lifecycle, managerial processes have to be implemented. One way of managing product lifecycles are PLM systems. CIMdata (as cited in Xu Xun, 2015 p.338-339) defines the usage of PLM systems as:

- Support the collaborative product development process in a virtual value chain with no time, distance or organizational boundaries
- Collaboratively create, manage, disseminate and use digital product definition information across the extended enterprise through the complete product lifecycle from the concept to the end of life of a product when it becomes obsolete

At VCC, the PLM system SIEMENS Teamcenter is in place to provide a platform to provided information needed for the development process.

2.4 Change Management

Change management is defined by C.S.V.Murphy (2007, p 22) as managing the process of implementing major changes in information technology, business processes, organisational structures and job assignments to reduce the risks and costs of change and optimise its benefits. The aim of change management is to understand:

- Why change happens?
- How change happens?
- What needs to be done to make change a more welcoming concept?

By understanding these factors, change in development and organisational processes can be used to optimise the benefits and reduce the risks. Furthermore, C.S.V. Murphy (2007, p.23) Describes the level of difficult and time to resolve technical change as low in comparison to change in regard to people. Being a competitor in the automotive industry, change through organisation and technology becomes a regular occurrence for VVC in order to stay competitive. Therefore, it is important for VCC to adapt to changes to technology and market demands.

2.5 Planning and Pre-study phase

In order to make the development process of the front trunk compartment, essential needs from stakeholders in the area need to be gathered. Ulrich and Eppinger (2012, p. 74) describe a method of collecting customer needs with the goal of (among others):

- Identify latent or hidden needs as well as explicit needs
- Ensure that no critical customer needs are missed or forgotten
- Develop a common understanding of customer needs among members of the development team

The method suggested is as follows:

Table 3 - Collecting and handling customer needs

1. Gather raw data from customers
2. Interpret the raw data in terms of customer needs
3. Organize the needs into a hierarchy of primary, secondary, and (if necessary) tertiary needs
4. Establish relative importance of the needs
5. Reflect on the results of the process

The first step of the process relates to gather raw data or information from customers to be translated in customer needs. Ulrich and Eppinger (2012, p. 76) suggest interviews as an option to retrieve raw data, with one or more development team member with a typical duration of one to two hours. It is also suggested to conduct somewhere between 10 and 50 interviews to gain an appropriate amount of data (Ulrich and Eppinger, 2012, p78). Edward & Holland (2013, p.90) suggests qualitative, semi-structured interviews as an alternative to conventional interview techniques. By using open-ended questions and creating more of a discussion during the interview, a more in-depth perspective can be from the interviewee in regard to their experience. This is especially important when the interviewee has no experience of the subject. Ulrich and Eppinger (2012, p.80) suggest methods of documenting the raw data through audio recording and notes, although the time-consuming nature of audio recording is discussable.

The second step of the process is to interpret the raw data in terms of customer needs. A customer data template (Ulrich and Eppinger, 2012 p. 82) describes two fundamental and critical guidelines for an effective translation:

Expressing the needs in terms of what needs to be done, not a suggestion on how to do it
Have the same specificity as the raw data

The third step is to organize the needs into a hierarchy. The hierarchy list suggested would involve the categories:

- Primary needs
- Secondary needs
- Tertiary needs

This process is suggested to be made on a wall or a large table to make the work less awkward and difficult, especially in regard to the subsequent development activities.

The fourth step is to establish the relative importance of the needs. It is suggested to use a numerical gradient to describe the importance of the customer needs. Two basic approaches are presented (Ulrich and Eppinger, 2012 p.86):

- Relying on the consensus of the team members
- Basing the importance assessment on further customer surveys.

The last step is to reflect on the results and the process. The reflection process is to evaluate if the four previous steps have been done consistently and what to improve upon in future research (Ulrich and Eppinger, 2012 p. 87).

Some questions to consider are:

Table 4 - Reflection questions for the customer needs

Are there areas of inquiry we should pursue in follow-up interviews or surveys?
What do we know now that we didn't know when we started? Are we surprised by any of the needs?
Did we involve everyone within our own organization who needs to deeply understand the customer needs?
How might we improve the process in future efforts?

2.6 Courses in CAD Advance & Engineering Templates

Volvo Cars Corporation offered courses in both CAD Advance and Engineering Templates to provide the necessary knowledge to understand and create the template and the models inside of it. This is also crucial in order to understand how component owners work with their components. As well as gaining the knowledge provided by the courses, the method team providing the courses will be a supportive force throughout the project.

2.6.1 Engineering Template Course

In this course, the fundamental concepts of templates at VCC was described, as well as an introduction on working in the Catia V5 environment with the Engineering Templates. The content of this course was as follows:

- Distinguishing between the assortment of templates existing at VCC
- How to create an Engineering Template assembly
- How to link components to each other in combination with Teamcenter and using correct naming conventions to create working models

The main learning of this course was the background of engineering templates and the purpose of them.

2.6.2 CAD Advance Course

The CAD Advance course consisted of the structured creation process of Catia V5 models at VCC. During this course, these aspects were the focus:

- Parameterization – How to build models using parameters and connect them through formulas to create a dependency between the parameters to make changes to the design easier.

- Building stable geometries – How to properly build Catia V5 models in a way to decrease the likelihood of models causing errors or fail and to be easily used when implemented into a Catia V5 assembly.

- Advanced CAD - In-depth creation of Catia V5 models using surface modelling and Boolean operations and proper naming conventions of the content of said models

The content for this course were not used during the project, mainly due to the fact that the aim was to create a CAD assembly structure and if there was time, individual models inside of the template. Therefore, this course is a suggestion for future template engineering team members of an engineering template to take part of.

3 Methodology

This chapter describes the methodology used in the project. The methodology used in this project has been in line with the processes used at VCC to create an Engineering Template.

3.1 Planning & Pre-study at VCC

Below in Figure 9, the process of identifying potential stakeholders and requirements is described. To successfully comprehend how an engineering template can be developed and what stakeholders to include, several steps had to be taken.

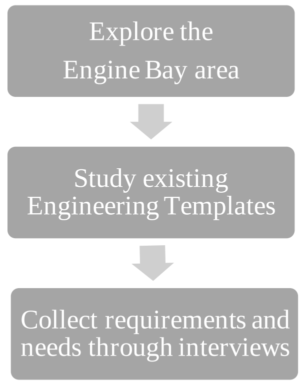

Figure 9 - Process of the Pre-study phase

3.1.1 Study of the Engine Bay area

The first part of the pre-study was to understand how components correlate in the engine bay area, especially in regard to the front trunk. By identifying the components, the potential stakeholders could be traced and later invited for interviews. Also, by observing the interfaces between components, some idea of the relation and dependence between them could be made. This be used as material for questions during the interviews. The questions asked during this part of the pre-study were:

- What components are present in the Engine bay either adjacent or in relation to the front trunk compartment?
- What PPS/ART is the owner of the components?

Below in Table 5, the components identified during this process is presented with their corresponding PSS/ART. Due to secrecy regarding on-going project, the majority of components cannot be disclosed. Instead, they are presented under the label "other surrounding components".

Table 5 - Components and corresponding PSS/ART

Component Name	**Corresponding PSS/ART**
Front trunk compartment	PSS120 Interior Trim
Front Crossmember	PSS240 Front Systems
Lower Crossmember	PSS270 Lower Body Structure
Cover Panels	PSS240 Front Systems
Latch Wire	PSS240 Front Systems
Hood	PSS240 Font Systems
Spring Towers	PSS270 Lower Body Structure
Sealings	PSS221 Sealing
Other surrounding components	PSS150 Climate PSS330 EDS (electronics) PSS050 Cooling

Additional stakeholders that were identified as well. These were identified through general conversations with MIE at the engine bay block. The PSS/ARTs are described below in Table 6.

Table 6 - Additional PSS/ARTs

Ergonomics
ME (Manufacturing Engineering)
Service
Safety and Collision

3.1.2 Previous attempts for Engineering Template in Engine bay area

In combination with the study of the Engine Bay area, earlier documented attempts at creating an Engineering Template existed at the Mechanical Architecture and Integration department. This information would be crucial in understanding previous struggles with the development process and what to consider when beginning the working processes. Below are examples of issues that were mentioned as a cause for failure:

- **Lack of knowledge** of how to develop an Engineering Template
- **Lack of trust** in the benefits of an Engineering Template and the developing time being worthwhile
- The **complexity** of the development of the Engine Bay area seemed to be a hindrance to create a well-working template
- The issue of **working less with design** and in a platform-oriented environment could pose a problem in creating an Engineering Template applicable for whole platforms

Also, a suggested information flow as well as content for the engineering template had been documented, but can cannot be disclosed.

Table 7 - Suggested content for Engineering Template

Hood interface – Lid/Sealing
Fixation Points Front trunk
Fixation points Cover Panels
Draft Angles – Tool direction front trunk
Draft Angles – Tool direction Cover Panels
Cross members
Material Thickness of front trunk
Hood hinges

The suggested content of the front trunk engineering template is visible in Table 7. What can be said about the suggestions is that there is variety to involved components and their features. Fixation points combined with the draft angles and requirements related to the manufacturing process is mention. Also, design features such as material thickness could be of interest for other stakeholders such as Safety & collision concerning durability requirements and component weight.

3.1.3 Existing Template structures

The second part was to get an understanding of the Engineering Templates, what they are and how they affect the way stakeholders work in their individual area. This was done through study of the Engineering Templates available in the SIEMENS Teamcenter software. Things to consider are:

- How is the level structure built and how many levels does the template contain?
- What is the content of each level? What are the number of models and what is their purpose?
- How are the models built? What can a model look like?

The differences of the Engineering Templates at the Mechanical Architecture and Integration vary quite much. Depending on the needs of the stakeholders, the input and output of the templates differ to a large extent, both in the intended purpose but also in the form of the models, such as restriction surfaces, volumes and positions. The knowledge gathered from this research would become fundamental in understanding how Engineering templates work, as well as what to ask the interviewees.

3.2 Interviews

To understand the requirements and needs of the stakeholders, interviews were decided to be conducted. From the information gathered in the previous pre-study phases, a list of interviewees was created. A variety of interviewees working in on-going, semi-finished or finished project were chosen to collect the experience from previous development processes as well as current ones. The interviewees can be divided into three categories:

- Engine Bay block MIEs
- Template MIEs at the Mechanical architecture and integration department
- PSS/ARTs

The questions asked during the interviews were different, to fulfil different purposes, although the common purpose was to create the raw data needed to understand the customer needs. An explanation of what the purpose of the questions are described in the following parts of the chapter. Worth of notice is that during this phase, attempts at reaching out to additional stakeholders were made,

Summarized descriptions of the interviews can be found in Appendix A.

3.2.1 Engine Bay Interviews

The purpose of interviewing the Engine Bay was to, on one hand understand how the development process and the work of the Mechanical Integration engineers look like presently, and secondly understanding what the potential scope and needs of an engineering template could look like. Since there is no existing Engineering Template in the Engine Bay block, the process of translating the needs to inputs and outputs of the template might be more difficult than at a block were a template already exists.

Therefore, the questions in the interviews were created in such a way that the answers could be more general in describing the issues that are prevalent in the current working process and how to improve it. One thing that became clear during the information gathering was that attempts had been done in trying to create a template before. Suggestions on content for an Engineer Template and a corresponding Information flow would therefore be the foundation for the creation process.

Due to the nature of the purpose of the mechanical integration engineers, the needs of the block were a combination of both up-to-date models to verify an acceptable clearance, but also needs expressed by other stakeholders. Since PSS/ARTs rely on the mechanical integration engineers to work as an intermediate for needs, the individual needs of the MIEs revolve around clearances.

3.2.2 Template engineers at Mechanical Architecture and Integration

Since the experience of working with Engineering Templates are limited at the Engine Bay block, the knowledge has to be gathered at other blocks were the knowledge and experience of Engineering Templates are wider. Also, the structure and Information Flow vary to a large extent between the different blocks, which could work as inspiration for the Engine Bay Engineering Template.

Some concerns were expressed for the likelihood of less design-affected packaging, which would create less of an impact from the design input. On the other hand, the models would have more of an individual impact.

Conclusions and recommendations from the template engineers are summarized below:

- Keep the level of simplicity of the Engineering Template as high as possible
- Produce quick results to make a more compelling argument towards sceptical stakeholders
- Create a robust Engineering Template to begin with, to ensure changes would cause critical failure to the functions of the template

Also, since the Front block uses an Engineering Template, inspiration and information from said template could be useful in some stages of the development of the Engine Bay Engineering Template.

3.2.3 Interior Trim PSS120

Since the PSS120 department is responsible for the front trunk compartment, their requirements are essential in how to develop an Engineering Template with the front trunk in the centre. The main focus of the interviews was to showcase problems with early projects and discover the needs and issues that could possibly be solved with an Engineering template. The result of the interviews with the Design Engineers involved in the development of front trunk were similar to the Engine Bay block interviews. The majority of the interviewees had no to little experience of the use of template, even though several parts of the Front Systems currently work within some Engineering Templates, mainly the Front block Engineering Templates.

Synchronisation between the developments of components seemed to be an issue for the front trunk, since it interacts with both the platform and the tophat area of the car development. This would in turn affect the actual design area that were possible to work within and cause frustration. Also, some concepts of components were introduced late in the development and in turn resulted in less optimal solutions to problems. The idea of involving these components in an Engineering Template to improve the communication were met by positive response.

Customer needs expressed during the interviews can be summarized as such:

- Fixation points shared by multiple stakeholders should be defined earlier
- The available design area should be easily available
- Communication with surrounding components should be better

Due to the lack of knowledge about Engineering Templates, suggestions on content for models owned by the Interior trim department were few.

3.2.4 PSS240 – Front Systems

The main PSS that was interviewed was PSS240, which is the Front Systems department. Since their area is the front area with the hood, cover panels and cross members, they are affected by both what happens in the Engine Bay as well as the design changes.

One thing that became apparent during the interviews with the PSS240 was that the lack of knowledge about Engineering Templates was shared with the Engine Bay block and Interior trim. Only the ones involved in other parts of the car (such as the Plenum or Front area) knew how a template was built and were aware of the potential benefits.

The attitude towards the implementation of an Engineering Template were mixed. Some could see the potential benefits of the template and gave suggestions on content that could be available in it, whilst others were sceptical towards the work needed to put such a template together. A clear issue towards the needed time in regard to other work tasks were one of the major concerns of the interviewees.

3.2.5 Other Stakeholders

The PSS/ARTs response towards an Engineering Template were mixed as well. Some saw their requirements as something rather project-specific and were concerned about how to translate their requirements into a CAD environment. Others had more important priorities and therefore had no time to be able to participate in interviews.

The Studio Engineers that that worked with other projects were interviewed as well. The purpose of the studio engineering is to be a mediator between design engineering of components and the actual designer of the surfaces that becomes the components. Since design is at play in the front trunk area, technical input (TI) from the block, PSS and ARTs have to be communicated in a proper way. By proper, it means that the stakeholders' demands and requirements are being communicated and translated into either a virtual model in Catia V5 or in any other way clearly, i.e. pictures clearly marking the issue.

During the interviews, difficulties between translating technical requirements and issues into design changes became one of the major problems in the existing development. Also, the crucial technical inputs needed to make these design changes were perceived as lacking.

3.3 SWOT-analysis of the Engine Bay block

The SWOT-analysis (Renault Val. ,2018) reflect the information gathered through the interviews with engine bay MIEs.

Table 8 - SWOT analysis of the Engine Bay interviewees

STRENGTHS	WEAKNESSES
• A wide knowledge and experience of the working area already exists • A limited area of the Engine Bay affected by design changes directly	• The general knowledge and experience with templates among the stakeholders are limited • A well-set working process is already being used • The area in question is generally different from other areas were Engineering templates has been implemented
OPPORTUNITIES	**THREATS**
• Since no engineering template exist at this moment, the possibility of having a "clean" slate • Thorough development processes or Engineering Templates on VCC and good knowledge on the department for overall support	• Lack of engagement from the stakeholders due to lack of knowledge about engineering templates might hinder the implementation of the template • Due to time constraints, only some parts of developing and implementation process might be done in time • Unique complexity to individual project could make a general Engineering Template difficult to create

What can be concluded from the SWOT-analysis in Table 8 is that the lack of time and engagement due to the time the development of an Engineering Template takes could become a problem. Also, the creation of a "Master Engineering Template" could be difficult to be implemented for several projects, which is one of the main benefits for Engineering Templates.

3.4 Customer needs of stakeholders

The customer needs of the potential stakeholders are presented below in Table 9. The customer needs were collected from the raw data of the interviews. An example of the translation from raw data to customer needs are the question asked to the engine bay MIE in regard to suggestions for content for the engineering template.

Table 9 – Stakeholders and their individual needs

Stakeholder	Customer Needs
Engine Bay Block	• Rough estimates of components in the form of volumes and surfaces could be useful • Early feedback from design to make the packaging process easier • Earlier feedback regarding safety for the integration • Better communication between design and platform • Better synchronisation between stakeholders
PSS120 Interior Trim	• Available carry-over solutions and volumes would be useful • Technical input with regards to fixation points
PSS240 Front Systems	• Fixation points and restriction surfaces could be useful • Front trunk volume to crossmember strength ratio • Early verifying of concept and component design suggestions • Earlier feedback for the surrounding components regarding the demands and requirements • Early suggestions on fixation points and easily available, up to date restrictions surfaces would be useful
Design team	• A collective TI from the parties involved to ensure the right revision is used • Restriction surfaces, envelopes or any guidelines would be a big improvement in regard to aid in the designing
Safety & Collision	• Run simulations earlier • Requirements in regard to stack-up has to be communicated and verified earlier
Ergonomics	• Volume demands • Reachability and entrapment demand • angles in combination with ME
Manufacturing Engineering & service	• Better assembling process • Requirements on angles in regard to assembling needs to be considered

3.5 Requirements list

The requirements list describes the demands that the PSS/ARTs and the block adhere to, which would be to some degree what the models inside of the template would represent.

Table 10 - Requirements list

Stakeholder	Requirements
Engine Bay Block	1. Safety & Crash Requirements 2. Ergonomic Requirements 3. Volume Requirements 4. Clearance Requirements 5. Sound and Vibration Requirements
PSS120 Interior Trim	1. Positioning of fixation points 2. Clearance from the pedestrian surface 3. Restrictions from surrounding components
PSS240 Front Systems	1. Positioning of fixation points 2. Clearance from the pedestrian surface 3. Radius demands regarding latch wire
Design team	1. Available design volume 2. Feasible Design Features

From the requirements list available in Table 10 above, fixation points seemed like a common requirement throughout the PSS/ARTs. Also, the Engine Bay block and the Design team share the volume requirement. In the sense of mechanical integration, this will be used to evaluate the clearances and possible packaging solutions. In the design regards, the available volume becomes the design area in which the front trunk can be developed. The level of detail of the requirements list is intentionally kept low, some of the requirements would suggest the existence of components in the engine bay that are kept secret.

3.6 Creation of Engineering template team

After the process of collecting demands and requirements and identifying potential stakeholders, the stakeholders were invited to a kick-off meeting according to the VCC engineering template guidelines. Since the stakeholders had little to no experience of engineering templates, experts in the field were invited to act as support. During this meeting, engineering templates were explained and showcased to give a better understanding on how it can be used. Also, the benefits an engineering template were described and how this is connected with the stakeholders' requirements and current issues in the development process.

When the stakeholders understood to what extent that a potential engineering template could be used, the requirements and information from the pre-study was discussed and the stakeholders expressing an interest in participating in the engineering template are as follows:

- Engine Bay Block MIE
- Design team Front trunk component Studio Engineer
- PSS240 Front Systems Design Engineers (including the individual parts of Front Crossmember, Cover Panels)
- PSS120 Interior Trim Front trunk component Design Engineer

The design engineering of the latch wire component later joined. These would form the engineering template.

When the formation of the engineering template team was completed, a scope regarding the engineering template were discussed. The scope of the engineering template was decided to provide the following requirements and needs:

- Technical input regarding the design volume of the front trunk compartment
- Output regarding positioning of fixation points for front trunk component
- Verification of latch wire radius requirements

3.6.1 Continuous Meetings

After the formation of the engineering template team were formed and a scope were agreed upon, continuous meetings were held to report on the progress of the information flow, the Catia V5 assembly structure and the included models. Meetings were intended to be held once per week, but due to the team members being unable to attend, the meetings were held less frequent. As an alternative, feedback regarding the development process were communicated through email.

3.6.2 Involvement of other ARTs

With respect to the suggestion from experienced template engineers regarding the simplicity of the engineering template, ARTs such as ergonomics, manufacturing engineering, service and safety and collision were chosen not to be included directly into the engineering template team. Instead their requirements were included through the engineering template team members and their models.

3.7 Creation of the Engineering template

The creation of the engineering template was in accordance with the pre-defined development process at VCC. The process of creating the engineering template relied on the requirements list and customer needs, with consideration to the conclusions made during the template MIEs. Therefore, both the suggested criteria needed to create a beneficial engineering template was considered. From the discussions with the engineering template team and taken into consideration the set scope of the engineering template, an information flow was created and continuously updated by presenting the current state of it for the engineering template team.

The creation of the models of the engineering template were to act as suggestions on how requirements can be formulated into Catia V5 models. Due to the time restriction of the project as well as the inexperience of the engineering template team in regard to engineer templates, they would act as suggestions of future models. During the process of creating the models, the purpose of them were discussed during the continuous meetings.

4 Results

The following chapter describes the results of the work process as well as the end results of the Master thesis. Here, the final Information Flow and the Engineering Template Catia Assembly Structure is described. Worth noting is the level of detail for the Information flow, Engineering template architecture and Models is decreased due to secrecy.

4.1 Information flow

The final proposal for the information flow can be observed below in Figure 10. Due to secrecy, hierarchy of the models cannot be disclosed.

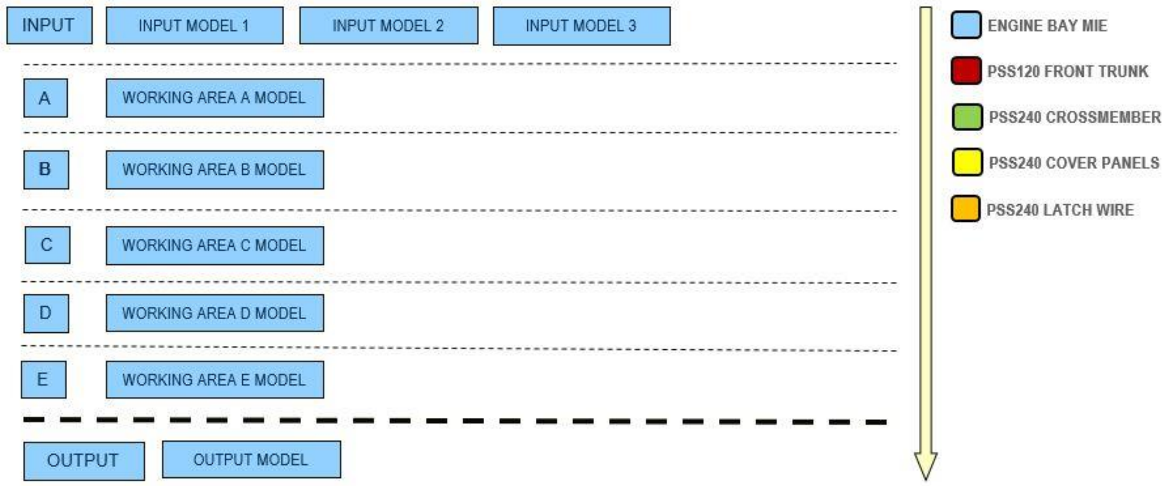

Figure 10 - Suggested Information Flow

4.2 Engineering template assembly structure

The Catia V5 assembly picture is presented in Figure 11 below. Since the information flow and at what level each corresponding model are at, the figure describes the general appearance of the information flow in the Catia V5 environment.

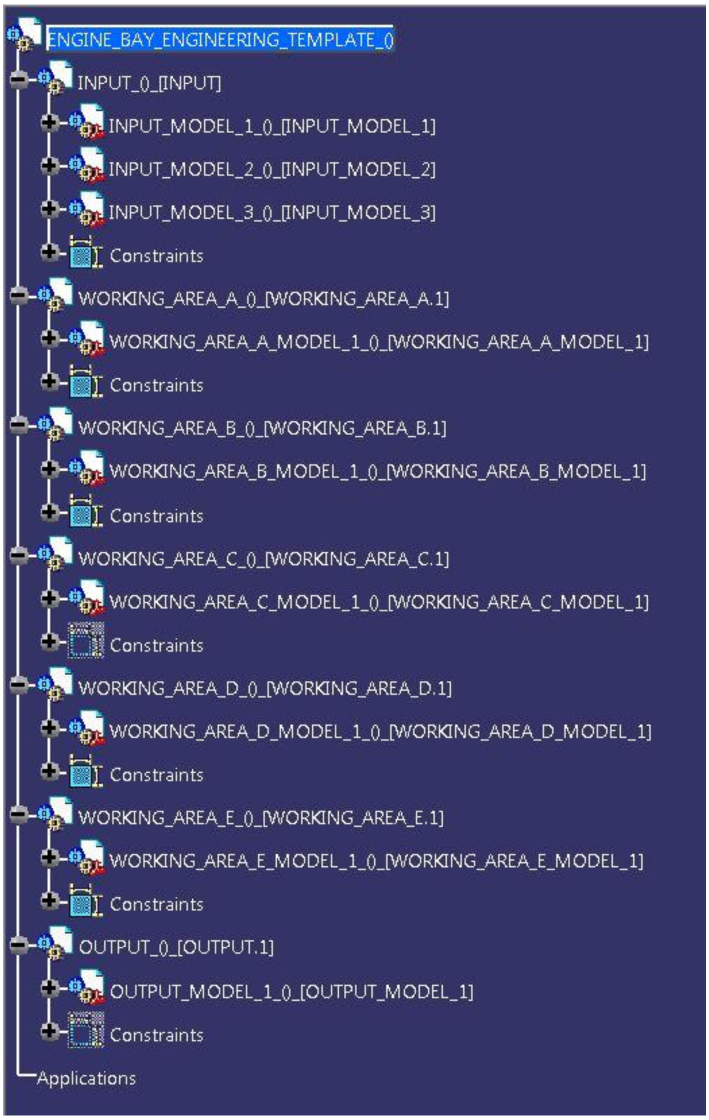

Figure 11 - Suggested Catia V5Assembly Structure

4.3 Models

Below the individual levels and their models are described, throughout the development process. Throughout the process, the template has been continuously improved, and the appropriate models and surfaces has been formed. The models come in no particular order.

4.3.1 Input

The input provides necessary information affecting the stakeholders and are the first of the level structure:

Design

These include the design surfaces involved in the design area. This is mainly the hood, since it sets a height restriction for the Engine Bay area. Something to consider is that the design area itself is a product of design. Therefore, a design input for that particular part would also be included in the input level. For this report, the hood surface of a XC90 car model represents the design surface. This surface is visible below in Figure 12.

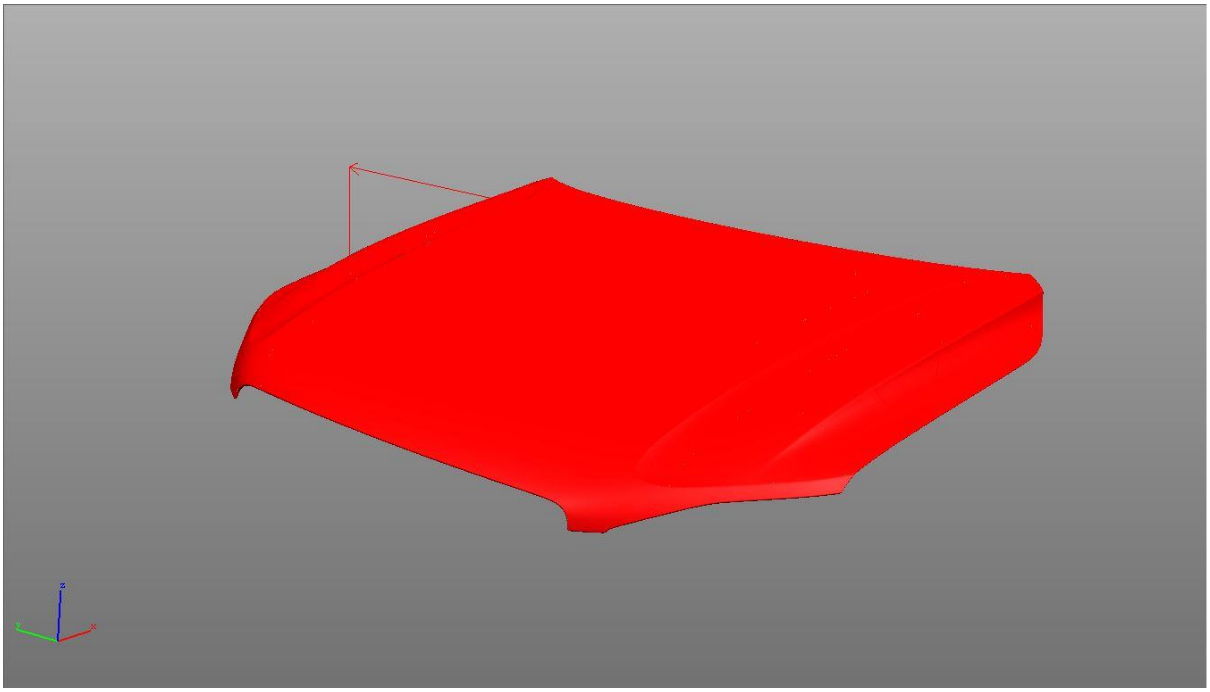

Figure 12 - Hood of the XC90

Car-specific requirements & Global Parameters

The Car specific requirements are foundational measurements and lengths that defines the car. In this regard, the Engine Bay design area is not directly affected by these parameters, but changes are more of a by-product depending on the area looked upon. Global Parameters on the other hand is parameters of components and lengths that affect the design area to a large extent.

Engine Envelopes

The Engine Envelopes create a lot of the restriction for the design area. The upper moving parts of the engine creates the limitations in the x-direction and somewhat in the negative z-direction. The purpose of involving the engine envelope, which is shown in Figure 13, in the Engineering Template is to have the most recent simulation run available to make sure there is an appropriate clearence to the engine bay components.

Figure 13 - Engine envelope of XC90 engine

4.3.2 CAVA, CM Front & Surrounding Components

The Cava model provides the pedestrian area defining the upper limits of the design area. Since the CAVA model collects data from the design of the hood area and then translates it to safety requirements, the CAVA model needs to be lower in the level than the Design model. Also, in the future some other appliances for the CAVA model might be useful.

The CM Front is an import from the Front-End Engineering Template. Some models or surfaces might be interesting to collaborate with. Also, this is for the purpose to have synched information in the template, so that not two different models which might look differently exist and are supposed to interact.

The surrounding components are components that has an adverse effect on the design area in question. There is a mixture of stakeholders in this part of the template which is visible in Table 11. On one hand, there is the front crossmember, were the stakeholder is a part of the engineering template team and has a living model. Some components are not disclosed in Table 11 due to secrecy.

Table 11 - Description of surrounding components

Surrounding Components	**Effect on the design area**
Front Crossmember (**PSS120)**	Constraints the area in the front of the trunk and the fixation points of the front trunk
Lower Crossmember (**PSS270**)	Constraints the lower design area as well as for lower fixation or load relief points
Stays and screws (**PSS270**)	The screws set the constraints for the lower fixation points and the stays have a significant impact on the geometrical possibilities of the design area
Battery (**PSS332**)	Creates constraints for the x-direction.

4.3.3 Engine Bay Design Volume

The Engine bay design area model is a main volume that becomes constrained by the surrounding components. These create the blue surface in Figure 14 that then in combination with the Catia V5 trim function trims the volume into the design volume of the front trunk.

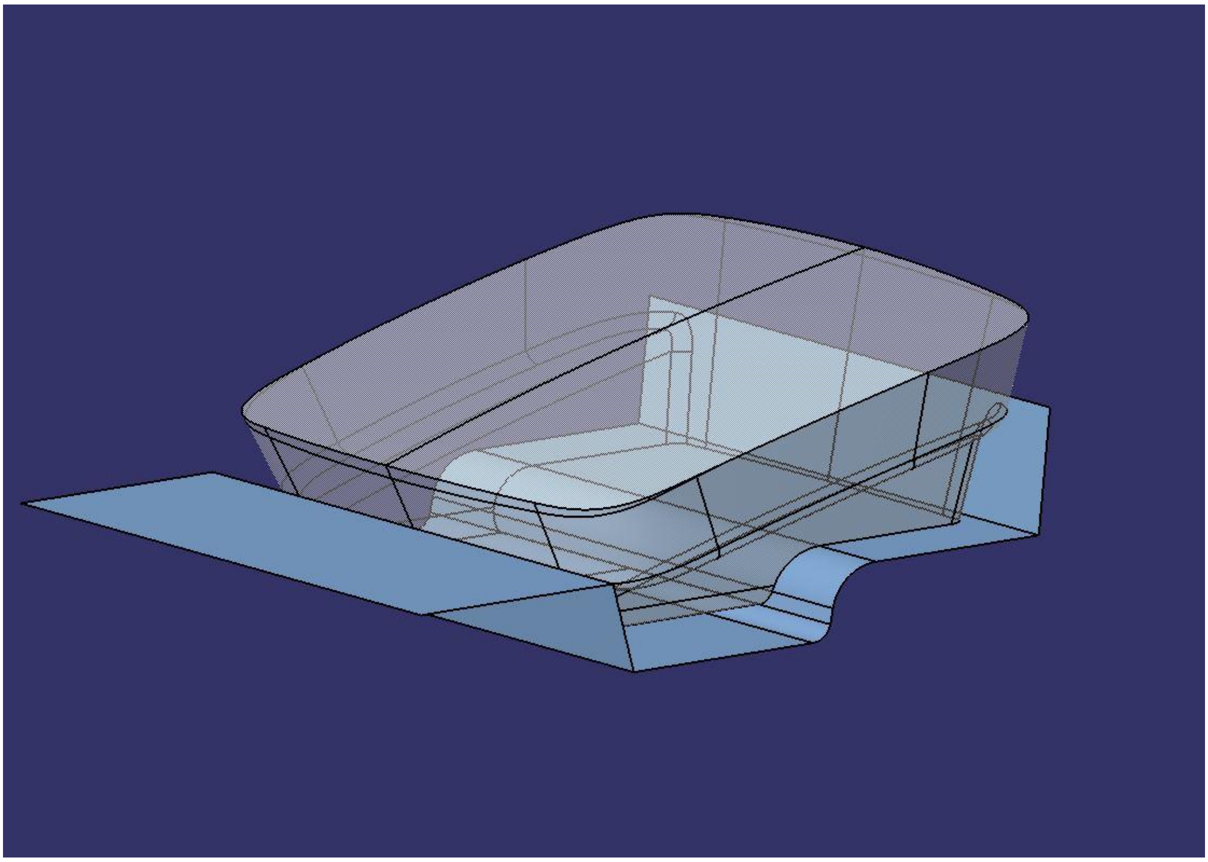

Figure 14 - Design volume constrained by surrounding components

4.3.4 PSS240 Crossmember

This models' purpose is mainly to create an outline for the possible area for fixation of the front trunk as well as for the cover panels. The area is an extraction of the middle, upper surface of the front crossmember implemented into the model. It would then be changed depending on the desired area for fixation. This is visible below in Figure 15.

4.3.5 Front trunk restrictions

The front trunk restrictions are the requirements that are put upon the front trunk from a number of stakeholders. Safety, Ergonomics and from the PSS itself. Inside of the model there are the wishes of the PSS, in this regard about the fixation points in the front crossmember. The main focus of the front trunk restriction model would be to create the suggestions for areas of the fixation points and to relay that information for the limitations of the radius of the hood wire as well as the cover panel fixation points. The blue cylinders in Figure 15 below represents these fixation points.

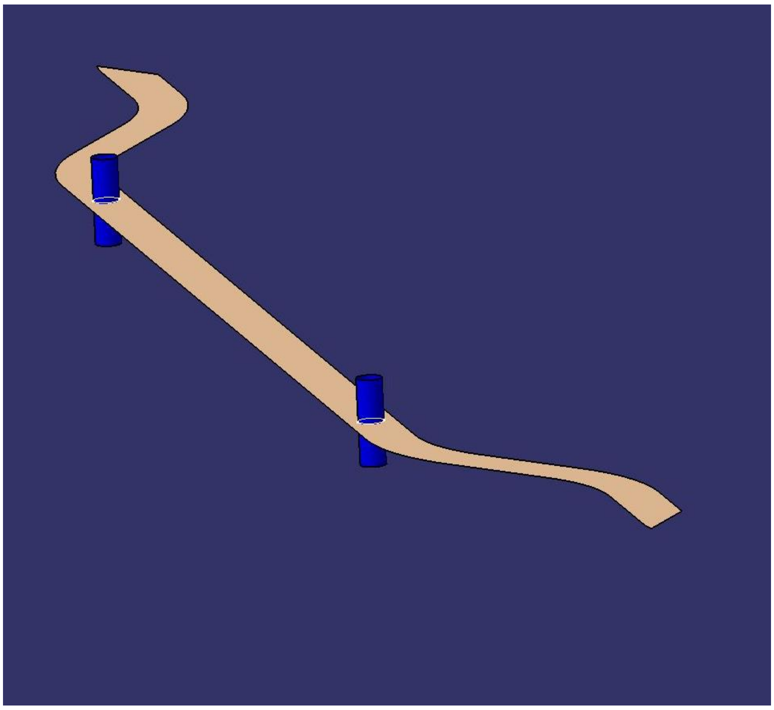

Figure 15 - Catia V5-model representing crossmember and fixation points

These in turn are affected by the possible fixation points on the crossmember. The restrictions of the front trunk in the positive x-direction is also affected by the geometrical limitations of the front crossmember. The surface represents the crossmember surface and the cylinders represent suggested positioning for the fixation points.

4.3.6 PSS240 Cover Panels, PSS240 Latch Wire

This working area of the assembly structure consists of the models of the Cover Panels and the Latch Wire. The Cover Panels would share the fixation points of the front trunk. Also, the fixation points for the design volume as well as for the front crossmember are crucial for the limitations of the latch wire and its' components.

The cover panels would share the fixation points of the front trunk. Therefore, the fixation points are mostly set by the front trunk limitations and therefore the cover panels will receive that information. The cover panels will also be constrained between the components from the Engine Bay from below, as well as the Pedestrian surface from above.

4.3.7 Output

The isolated Collector Model will be the "dead" surfaces that are cut from the Collector model. These will provide the technical input needed for the development of the components involved in the Engineering Template. The output can be summarised as follows:

- Trimmed design volume as technical input for design
- Fixation points for front trunk compartment, cover panels
- Clearances for latch wire radius

Below, the different outputs are displayed in Figure 16 & Figure 17.

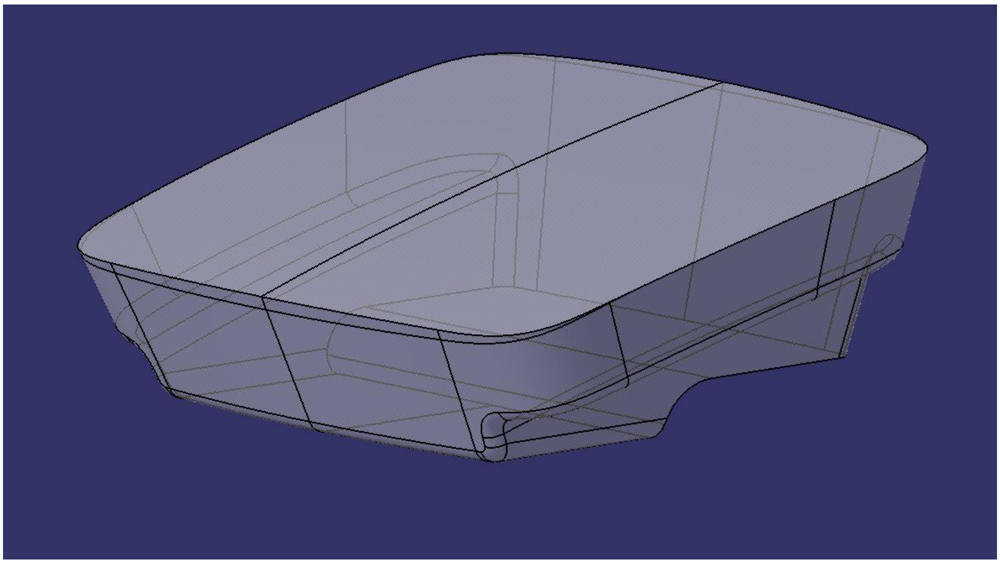

Figure 16 - Design volume output

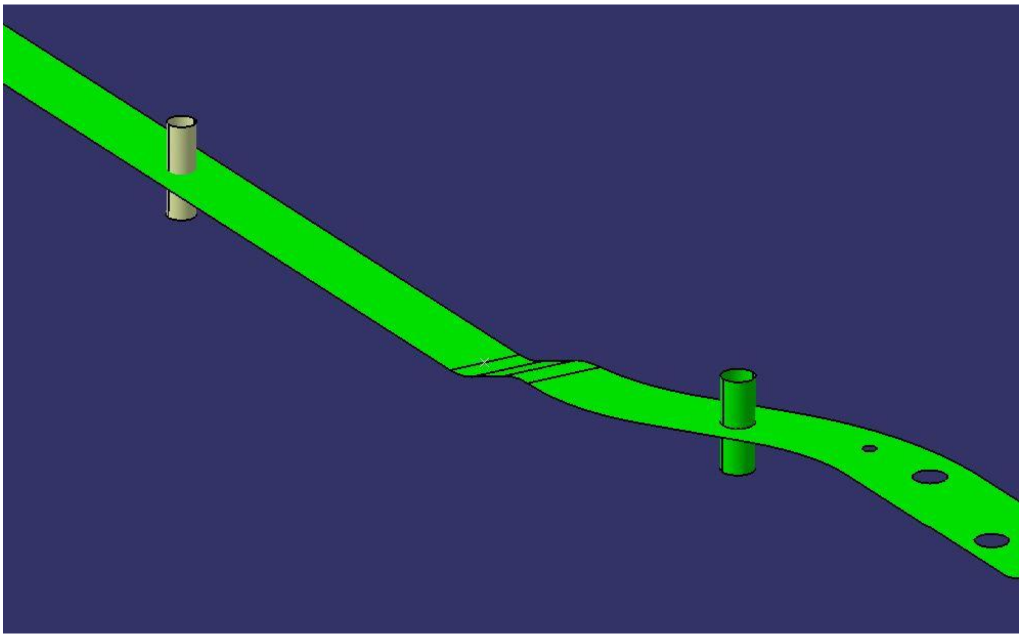

Figure 17 - Fixation points positioning output

In Figure 17, the green cylinder will act as the positioning for the latch wire radius demands' centre point.

5 Discussion

This chapter will discuss the outcome of the project as well as how well the methodology worked throughout the project and the result it resulted in. Alternative methods are discussed and how the results fulfil the aim of the project.

5.1 Pre-study & Interviews

The chosen method to first identify components and potential stakeholders by observing the engine bay area in previous and current project and then invite the stakeholders for interviews proved to be a sensible approach. This gave a better understand of the extent of how components are affected by the front trunk compartment and how interfaces interact with each other through clearance, fixation points and requirements.

The interview questions with the engine bay block and the PSS/ARTs had to be different in comparison with the questions of the interviews with MIE template engineers. The responses from the template MIEs would work as inspiration on how to create templates, how requirements can be translated into models and what to consider during the development process.

5.1.1 Collection of Customer needs

The process of collecting customer needs faced some challenges. One of them were the availability of the potential stakeholders for either an interview or being contacted at all. In the case of PSS270, which the other stakeholders share interfaces with and have requirements and needs towards, were not responsive. In the future, the customer needs and requirements have to be collected to ensure that critical information is being shared.

The chosen method of collecting customer needs was useful in this thesis, although some constraints to the steps included in the method were disregarded to improve upon the applicability. The study of the area in combination with the information from previous attempts at creating an engineering template and evaluating other engineering templates provided sufficient information for the list of potential stakeholders.

Since the first step of the process of collecting customer needs were to obtain raw data, interviews were chosen as the only source. Using qualitative semi-structured interviews were useful in collecting data that might only be achievable through one-on-one conversations, but the lack of numeric values for some questions decreased the level of detail of the responses and therefore made the raw data more open for interpretation. Using audio recording proved to be a time-consuming process, but provided an unfiltered raw data, not affected by the interviewers' own opinions or perception of the answers.
It is suggested that surveys can work as a complement to the interviews, but this was decided not to be used. In the case of potential stakeholders not responding to communication, the likelihood of their participation in a survey are low. This in turn could result in missing raw data crucial in the process of knowledge sharing between the stakeholders.

The second step to translate the raw data into customer needs relied heavily on how the respondent answered the question, which most likely was a result of the open-ended nature of most questions.

The third step to create a hierarchy for the customer needs were disregarded, with the reasoning that the customer needs would be discussed with the engineering template team instead in step four. Step four was to establish the relative importance of the customer needs, which was established through the engineering template team. With the experience of these template team members, finding common requirements that needed to be communicated proved to be a good method of evaluation. By discussing customer needs in a setting were the stakeholders themselves would be affected by it, they could reach an agreement on what customer needs to focus on to gain the most value from.

Since the last step of the method was to reflect on the results of the process, it can be said that changes could be done to. One of these would be to increase the responsiveness of the potential stakeholders, to get an extensive amount of raw data. Another one would be to add a numeric value as a gradient for some of the questions in addition to the open-ended questions that were used. In the process of defining the importance of the customer needs, there could have been a risk that some of the stakeholder's needs would be supressed by other stakeholders.

5.1.2 SWOT-analysis

The SWOT-analysis of the engine bay provided a clear way of communicating the issues with creating and implementing an engineering template for the block. The usage of the SWOT-analysis was mainly to communicate to the block the issues at hand, but also highlight the strengths and potential benefits of implementing an engineering template in the engine bay area.

5.1.3 Customer Needs & Requirements list

The customer needs list was useful in order to explain the needs of the stakeholders in more general terms. The requirements list was a good tool to use as foundation for finding potential content for the engineering template. By using the requirements as a discussion point during the kick-off meeting, the needs and requirements of each invited stakeholders, suggestions on what the initial scope of the engineering template could be found rather quickly.

5.2 Engineering template team and meetings

The scarcity and irregularity of meetings can be considered the most detrimental factor in regard to the progress of the development process for the Engineering Template, especially in regard to the models. This was mainly due to the team members having overlapping meetings were other meetings were prioritised. Changes in the common time scheduled for the Engineering Templates were made but did not have a significant effect on the absence. In addition to the overlapping meeting, other factors that caused absence were:

- The division between from which department the team members corresponded to
- Some team members having a central role in the development process of components at their corresponding department
- Lack of involvement due to the development process being too slow

On the other hand, the meetings provided a space were the requirements and needs could be discussed to create a suggested information flow and Catia V5 structure. It should be said that the meetings fulfilled their function to create the intended result of this thesis.

5.3 Selection & creation of Information flow

The final Information flow agreed upon seemed to be a sufficient start for the engineering template. As mentioned in the results of the interviews, making the process simple by involving only a few, key stakeholders and agreeing on a realistic scope were kept throughout the development process.

On the other hand, due to the lack of resources, availability and responses from other PSS/ARTs, the possibility to involve more stakeholders and at the same time maintaining a simplistic approach were not possible to evaluate.

A method that could have been used could have been Brainstorming (Barnett & E.Mendenhall, 2019) to ensure a creative idea environment and decrease the likelihood of ideas being disregarded. Though, the competence of the support from more experience template engineering and the fact that this template is in its' early stages should not be overlooked. Stated in the interviews, the start-up phase of an Engineering Template demands the "trial and error" method, since no prior examples of success or failure are available for a similar project.

Adding a screening or weighing tool to evaluate the suggested Information flows could have proven to be useful in a more objective assessment. The main input for the evaluation of the Information Flow were subjective opinions, which in turn could cause risks due to the inexperience of the Engineering Template team.

5.4 Development of the CAD assembly structure and models

Throughout the process of forming the Engineering Template team as well as the Information flow, the general process to start up Engineering Templates has been followed. By following the suggestions of the template MIEs, a simplistic approach was taken. This can be considered a good approach, when too many involved stakeholders would make the feedback loop of the development of the information flow and models even more complex. Also, the assembly structure and models will be an example for future engineering template developments.

Through this development process, the knowledge shared about requirements have increased the overall knowledge of the engineering template team. By participating in an engineering template, a better understand of how design changes in components can indirectly affect other components and requirements. This is especially effective in the engine bay, since the area includes both the platform and tophat, and therefore include platform- and tophat specific requirements.

5.5 Suggested Catia V5 Assembly structure and models

As stated in the limitations, the intent of this thesis was to evaluate the feasibility of creating a Catia V5 assembly structure and if time were available, develop some of the models. This in turn affected the maturity of the models, whom currently are at a very early stage. In their current stage, they would be considered to be more of a proposal of how future models would look like and how they would interact with each other. The main purpose of these models was to give the engineering template team a better understanding of how their requirements could be translated into CAD models.

Another aspect of the low maturity is the distribution of ownership of the models to the corresponding engineering template team members. For the development process to be improved, ownership would be provided additional incentive to make the models as efficient as possible, since the development would be relying on their effort.

In relation to the adaptability to changes in the input, the engineering template would provide several benefits. For one, the process of synchronising the models throughout the information flow would be faster than the current process. Compared to using the software SIEMENS TCVis Mock-up, Catia V5 models would be able to check the design change in regard to requirements quicker, since the models provide the output needed for the detail design of the components. This would be considered to be a better use of the PLM system SIEMENS Teamcenter in place at VCC, since the information in the engineering template would be the most up-to-date version and the knowledge would be known by all stakeholders involved.

5.6 Validation and Verification

The validation process for feasibility of the suggested engineering template was through the response of the engineering template team. When presenting the final revision of the information flow, assembly structure as well as the models, the engineering template team members expressed a positive response and a willingness to participate in the further development of it. In addition to the engineering template team, other employees at VCC who acted as support throughout the development expressed the potential of the engineering template and the further development of it.

On the other hand, the maturity of the Engineering Template was not sufficient enough to make objective testing of the effectiveness of it. The main causes of this was: the scope of the project was to develop an engineering template assembly structure; therefore, the focus was put on defining a well-working information flow and the Catia V5 assembly structure. The second was the lack of time from that the development process started.

5.7 Ethical, societal & environmental aspects

As described in the **Chapter 1**, Volvo Cars Corporation has taken steps to ensure a more environmental-friendly development process of their products. Through this thesis, evaluating an engineering templates' applicability to improve of the product development process can be considered to one step towards VCCs goals. Through implementing an engineering template, a more robust development process can be had to handle issues such as sudden changes in design and clearer deadlines. Since the purpose of an engineering template is to improve upon communication, miss-communication and unsynchronised development can be avoided and development lead time can be decreased.

Also, by implementing tools in order to improve the development process, the quality of the product itself is improved upon. This creates a product with higher competitiveness, which sets a standard in the automotive industry. As a result, competitors are forced to adapt to the level of quality and in turn, the general quality is increased on the market. This is a benefit to the user, since more pressure is put on companies in regard to quality aspects such as:

- Consideration to the impact the whole product lifecycle has on the environmental and on society as a whole
- The available features the product provides to fulfil the needs of the customer
- How the development and manufacturing process is handled through a ethical perspective, for example choosing suppliers and sources of resources

Since VCC has stated that progression towards electrification of their vehicles will happen in the near future, this will in turn add to the paradigm shift towards more sustainable ways of transportation. In the case of the engine bay, the electrification will pose challenges since the integral part of the engine bay, the engine, will change as well as the corresponding components. Therefore, the engineering template might be useful in this paradigm shift.

6 Conclusion

The conclusions drawn from this thesis can be related to the questions stated the Specification of issues under observation:

Can a well-working engineering template assembly structure be developed for this part of the car in combination with the front trunk compartment?

Yes, since there now exists a suggestion on an Information Flow and an Engineering Template structure, it is believable that a well-working engineering template assembly structure is possible to create, at least in the case of a component such as the front trunk compartment, were design has to be taken into account.

Would the involved departments benefit from this template?

Since the suggested Engineering Template is based on the requirements and demands of the stakeholders in the Engine Bay area in regard to a front trunk, there is no reason to believe that it would not be useful and beneficial. Positive feedback suggests that having one source of information requirements is needed to avoid miss-communication and decreases adaption time to design changes.

What limitations of the engineering template are reasonable and is there a possibility to apply the template to a larger extent, mainly a functional Engineering Template for the whole platform?

The main question at hand in regard to platform implementation of an Engineering Template is the question of an existing front trunk compartment. Since the front trunk is design oriented, there is much greater impact on the Engine Bay area when such a component exists from the Design changes connected to the tophat-development.

The conclusions of the thesis can be summarised that the Engine Bay area has much to gain from an Engineering Template. Since the Design and packaging of the Engine Bay have become more connected through the front storage compartment, there is a need to communicate the demands and requirements of the corresponding parts properly.

7 Recommendations

The focus of this thesis has been to find out the potential benefits of an Engineering Template and if it is possible to implement said engineering template in the Engine Bay area, especially in regard to the addition of a design-oriented front trunk compartment. Since potential benefits have been found, it is recommended to proceed with the development according to VVC engineering template development guidelines. Below are suggestions on how to proceed with the development:

- Implement more automatic functionality in regard to the trimming of the design volume
- Distribute ownership of models in the engineering template to the engineering template team members
- Greater involvement from other stakeholders of components adjacent to the front trunk compartment
- Evaluate how to include PSS/ARTs such as ergonomics, safety and manufacturing engineering into the template
- Further development of models with linking
- Increase the robustness of the engineering template to be applicable for other projects

In the case of using this template assembly structure in other projects, the question remains if there is an intention of having a front trunk in the Engine Bay area. In the case that there is no front trunk, the only obvious design input would be the hood and therefore a different framework and Information flow would have to be created. Therefore, the main benefit of this structure is in the case of a front trunk, but the usage of an automated system to update the most recent pedestrian area as well as envelopes could be an application in an Engine Bay Engineering Template.

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Appendix

A - Interviews with Engine Bay MIE

Interviews of the Engine Bay MIE						
Role at VCC	**Experience of Templates**	**View on Templates**	**Why hasn't there been an Engineering template at Engine Bay prior?**	**What needs to be improved in the Engine Bay area**	**What problems are being faced right now**	**Suggestions for content in an engineering template**
MIE	No experience	May slow progress when no changes are made, but can be useful when implemented correctly	Difficult to implement for whole platform, Engine Bay not that affected by Exterior design changes,	Better time plans, early feedback from design to make the packaging process easier	Uncertainties regarding limitations on the front trunk and lack of clear intentions	Hood restrictions, platform restrictions and clash detection would be useful, maybe make an early electric and cooling layout
MIE	Some experience	Difficult to work with but very useful, takes time and can be tedious to create CAD models in the template	High complexity, dynamic movements with engine and hoses creates problems, area prone for changes and variation	Earlier feedback regarding safety for the integration, dedicated CAD designers for projects and more co-location	Difficult with integration of new components in regard to safety, effects such as air flow and heat is difficult to predict before testing	A too complex template would not work well in Engine Bay, simpler surfaces and restrictions would be preferable

Interviews of the Engine Bay MIE						
Role at VCC	**Experience of Templates**	**View on Templates**	**Why hasn't there been an Engineering template at Engine Bay prior?**	**What needs to be improved in the Engine Bay area**	**What problems are being faced right now**	**Suggestions for content in an engineering template**
MIE	No experience	Might be useful in the areas its' already implemented, probably more useful in the upper Engine Bay area then the lower	Difficult to create a working template, Integration very dependent on unique project, most demands are at PSS/ARTs	Earlier, rough concepts to improve integration, earlier communication between concept and integration	Constant changes and compromising, down prioritization of projects, some PSS/ARTs late with resources	Rough estimates of components in the form of volumes and surfaces could be useful, template less useful in lower parts of the car
MIE	No experience	Not really sure what it is, good with a visual representation of requirements, but can be difficult to work with	No obvious usage for a template, could be time demanding without providing any result, requires a dedicated pioneer	Better holistic view and dedication from stakeholders, better communication between Design and Platform	Lack of commitment from stakeholders due to resources, more component and complexity in a smaller space	Simple requirements and models to begin with, make unknown or unclear requirements more visible and better synchronisation between stakeholders

B - Interviews with template MIE

Interviews with template MIE at Mechanical Architecture and Integration department						
Role at VCC	**Experience of Templates**	**View on Templates**	**What to think about when developing a new template**	**Most common problem with templates**	**Additional comments**	**Working area**
MIE ET Leader	Experienced, working in engineering template at the moment, worked with Plenum area before	Positive as long as the involved parties do their part, otherwise it can cause problems with synchronisation	Requires time and commitment, convincing stakeholders it's a good idea and involve them	Stakeholders set in their old ways in the beginning, time consuming, requires commitment from all parties	Important to work with the stakeholders to create trust, understanding to make it easier to involve others	D&C
MIE	Experienced, working in template at the moment	Continuous learning working with templates and Catia in general	Its' slow, iterative process, understand what the scope is and what the input and out is asked for	Not all stakeholders are involved in the template, lack of documentation cause confusion, difficult to know what	Important to make sure all stakeholders feel that they gain something from the template and are actively participati	D&C

				to include in the template	ng in making it better	
MIE Template Leader	Experience, previously worked with Rear End	Necessary in D&S, close ties with the PSS/ARTs and MIE, co-located on site	Take inspiration from other templates, find what would be applicable and use it, make the input and output of the template clear	Team member leaving creates issues when trying to replace the person, some parts of the template could be redone, but there is a lack of time and resources	Stay open about the content of the template and the scope, important to show the benefits to keep stakeholders motivated	D&S

Interviews with template MIE at Mechanical Architecture and Integration department						
Role at VCC	**Experience of Templates**	**View on Templates**	**What to think about when developing a new template**	**Most common problem with templates**	**Additional comments**	**Working area**
MIE	Experienced, part of developing a template and working with templates right now	Works well as a complement, should not take too much time and be practical	Important to document the purpose of the models, keep it simple, a good, stable templates ease the stress later on when changing it	What design models to emanate from, lack of synchronisation creates confusion and causes delays and re-dos	Make the input and output clear and the rest of the template will come naturally	Rear End
MIE	Experienced, have been part of developing a template from scratch	Good, templates become better by time and the stakeholders become more positive and knowledgeable regarding templates, the beginning of	Gain knowledge from other template and template engineers, discuss the scope and purpose thoroughly with the	Convincing people set in their ways to change, can be time-consuming, different departments work in different ways	Make sure to put demands on the stakeholders to ensure that there is progression in the template, then the	Rear End

		a template is the most difficult	stakeholders to decide input and output		process of express the benefits will be easier	
MIE	Limited Experience, currently working in template	Logically built, creates a clear line of work and communication and in turn decreases the risk of working with different revisions and requirements	Make sure every stakeholder is clear with what to gain, do not make it overcomplicated and take too much time to maintain and update	Gaining responsibility for an already existing template is difficult without good documentation, mixed commitment from PSSes	Try to minimize the work on the models, make it simple and easy to understand and well-documented for stakeholders to understand	Front

Interviews with template MIE at Mechanical Architecture and Integration department						
Role at VCC	**Experience of Templates**	**View on Templates**	**What to think about when developing a new template**	**Most common problem with templates**	**Additional comments**	**Working area**
MIE	Long Experience, started at D&S with templates	Great, an effective process to adapt to design and concept changes, the benefits for the stakeholders are great	Start simple, keep the momentum going and learn-by-doing, opened-minded people are easier to work with	Large conceptual changes are difficult to adapt to, especially when new, creating a template from scratch can be time-consuming	On-site stakeholders make communication easier, most important is to define input and output	Roof
CAD template Principle Engineer	Long Experience, before roof, now working with template time plans and supporting other templates	Great, dynamic way of working and continuously improving, but not a painless process	Be clear with intention of the template, something a small amount of content is better to decrease	Unclear intent in the beginning, low participation creates problems, not always easy to convince new parties	Do not have too big of a scope, create a smaller group to begin with and slowly involve others as	N/A

			miss-communication	that templates are beneficial	the scope grows	
Vehicle Concept Engineer	Long experience, has worked with D&S template previously	If it's done right, it works well, information can be obtained earlier, should be worth the time and effort put in	Keep a simple structure and geometries, a template can be almost anything that creates benefit for the development	Being too ambitious and adding to much content to the template, making the template robust enough for changes in the beginning	Main experience from concept templates, the transition from concept to engineering template is quite important	Tophat development

Interviews with template MIE at Mechanical Architecture and Integration department						
Role at VCC	**Experience of Templates**	**View on Templates**	**What to think about when developing a new template**	**Most common problem with templates**	**Additional comments**	**Working area**
MIE	No experience	Positive, when well-developed templates, makes parameterisation and scalability easier, clearer way of sharing and communicating information	All stakeholders need to be committed, clear scope and the right stakeholders and make the benefits clear	Creating a committed team for the template, not as design dependent as other blocks, knowing the input and output to make the process more effective	Would ensure that all the stakeholders are aware of decisions being made, want a simple template to fulfil the needs	Floor

C - Interviews with PSS/ARTs

Interviews of the PSS/ARTs					
Role at VCC	**View on Templates**	**What needs to be improved**	**What problems are being faced right now**	**Additional comments**	**Working area**
Design Engineer	Not very familiar with it	Set early volume constraints, safety verification and packaging suggestions	Difficult to take safety and crash into account, finding solutions to work for ME	Any technical input with regards to fixation points, carry-over solutions and volumes would be useful	PSS120 - Interior Trim
Design Engineer	Not really familiar with engineering templates	Component changes and revisions need to be communicated better,	Some changes or plans has not been communicated, resulting in components clashing	It has to be worthwhile to be involved in this template, in time and the benefits it brings	PSS120 – Interior Trim
Design Engineer	Not familiar with templates	Better communication between different PSS/ARTs, try and verify earlier	Issues with verification of the stability of the crossmember cause design changes, which in turn causes clashes	Fixation points and restriction surfaces could be useful, front trunk volume to crossmember strength ratio can be included in the template	PSS240 – Crossmember
Design Engineer	Not familiar with it, communication through block meetings	Early suggestions on fixation points and easily available, up to date restrictions surfaces would be useful	Issues with gap and flush for ME,	The earlier we know about the requirements of other PSS/ARTs and how their components look like, the better	PSS240 – Cover Panels

Interviews of the PSS/ARTs					
Role at VCC	**View on Templates**	**What needs to be improved**	**What problems are being faced right now**	**Additional comments**	**Working area**
Design Engineer	Not familiar with it	Earlier feedback for the surrounding components regarding the demands and requirements, being ‘more in the loop’ required	Design and implementation too late, created a lot of issues and made the process a lot more stressful	If an engineering template could have the requirements for surrounding components and early concepts, the work in the engineering template might be useful	PSS240 – Latch Wire
Ergonomics engineer	Familiar with it, but in other parts of the car	Clearer guidelines for the usage of the front trunk, make access and load demands more visible	What the areas in the front trunk can be used for, verification from safety are in the later part of the process	Volume demands, reachability and entrapment demands, angles in combination with ME could be useful to have as content in the engineering template	Ergonomics
Safety Engineer	Heard of it	Run simulations earlier, requirements in regard to stack-up has to be communicated and verified earlier	Time restraints an issue, issues in regard to clearance in regard to pedestrian area and stack-up problems	Translate our requirements into CAD-models could be useful, early project could be created and used as reference in other projects	Safety & Collision
Manufacturing Engineer	Somewhat familiar with it in the interior	Better assembling process, requirements on angles in regard to assembling needs to be considered	Non-ergonomic assembling positions can cause problems, late changes to components become costly and difficult to adapt to	General clearances, requirements on angles and demands on material thickness could be content for the template	ME

Interviews of the PSS/ARTs					
Role at VCC	**View on Templates**	**What needs to be improved**	**What problems are being faced right now**	**Additional comments**	**Working area**
Studio Engineer	Not very familiar with it	More clear scope on what needs to be achieved, balanced input, communication between design and engineering, better technical input	Not enough people and involvement, time-consuming process to iterate with design changes, difficult to align requirements from different parties	Engineering template could help to improve TI and the communication between design and engineering	Interior Design
Studio Engineer	Not very familiar with it	A collective TI from the parties involved to ensure the right revision is used	Difficulties with clearances, lack of involvement from crash/safety,	Restriction surfaces, envelopes or any guidelines would be a big improvement in regard to aid in the designing	Interior Design