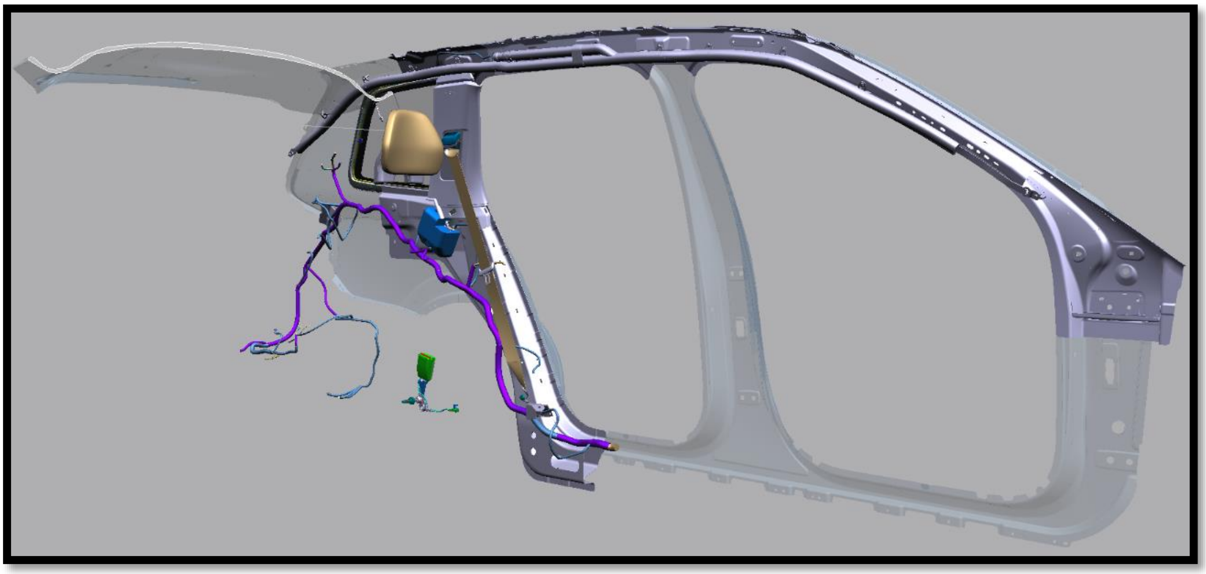

Engineering template development around the C-pillar at Volvo Car Corporation

Master's Thesis in Product Development

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2019

MASTER'S THESIS 2019

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Cover: Graphical representation of the C-pillar engineering template content, p. 32.

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Abstract

Volvo Car Corporation's department mechanical integration strives to implement engineering templates in their product development process. Engineering templates are CAD-assembly files that are continuously updated and contains content such as models, agreed positions, surfaces, requirements and similar design and packaging related aspects. These engineering templates are used in projects to simplify the development phase. Every engineering template is combined with an information flow, a logical flow of inputs that shows how the content relates to each other. One area of interest to create an engineering template around is the C-pillar. The area is exposed for a lot of uncertainties between different projects. This is because the design is based on the surroundings and not pre-defined.

The purpose was to investigate the actual need for a C-pillar engineering template and to create a proposal for how one could look like. To investigate the needs, a pre-study was made. Several interviews were conducted with relevant stakeholders. The answers resulted in internal customer needs, a requirements list and a SWOT-analysis. The interviews were complemented with an engineering template survey that focused on experiences with the tool. After the pre-study phase a development phase started. This consisted of meetings, to set a proper scope, as well as CAD-development in CATIA V5, to create inputs to the engineering template. The result became a proper proposal for how a C-pillar engineering template can look like. Proving that an engineering template can be created for the most uncertain areas in a car.

Keywords: engineering template, product development, knowledge management, change management, collaboration, C-pillar, cars, CAD.

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Abbreviations

R&D – Research and development.

ME – Manufacturing engineering.

PSS/ART – Product system structure/Agile release train.

CAE – Computer-aided engineering.

CAD – Computer-aided design.

PLM – Product lifecycle management.

KM – Knowledge management.

UUID – Universal Unique Identifier.

MIE – Mechanical integration engineering.

R – Requirement.

LR – Legal requirement.

NVH – Noise Vibration Harness.

AI – Artificial intelligence.

PQ – Perceived quality.

IC – Inflatable curtain.

FMH – Free motion headform.

BiW – Body in white.

SWOT – Strengths, weaknesses, opportunities, threats.

TI – Technical input.

1. Introduction

In this chapter the master's thesis will be introduced. The subject is presented as well as the scope of the project. It is intended to give a proper view of what the report is about and will deliver.

1.1. Background

In order to better understand the content in this thesis, information about the company, the department and the working tool that has been used is presented. In addition, the area of focus is introduced.

1.1.1. About Volvo Car Corporation

Volvo Cars is a respected premium car brand based in Gothenburg, Sweden, now owned by Zhejiang Geely Holding of China. The main office is in Gothenburg as well as a major part of the manufacturing. In addition, the company also have manufacturing facilities in the China, Belgium and the US as well as assembly facilities in India and Malaysia. Furthermore, Volvo have R&D in Sweden, the US and Denmark and design centres in Sweden, China and the US. The first Volvo car series was delivered back in 1927 in Gothenburg. Today, Volvo's cars are available for purchase in over 100 countries. The company has three core values that they work to achieve with their cars. These are safety, quality and sustainability. Volvo Cars focus on safety has been a main point of focus since the very start. The company has a goal called Vision 2020 which states that no one should die or get seriously injured in a car from Volvo from year 2020 and forward. The human is in absolute focus in all that the company does. As a consequence, the view on sustainability is not restricted to the corporation or cars but in society as a whole. Volvo wants to become the leader in electrification, safety technology and autonomous driving. By 2025 half of all sold cars are aimed to be completely electric driven and a third of the cars autonomous. Inspired by Scandinavia, Volvo Cars focuses on functionality and simplicity. The company combines these with world changing innovations to make life easier and safer for everyone (Volvo Car Corporation, 2019).

1.1.2. Mechanical integration engineering

At Volvo Car Corporation, some employees in the research and development department are working as mechanical integration engineers. These engineers are working with packaging and are divided into different blocks that represent certain areas of the car. Such as rear end, door and side, roof, floor and dash and compartment. The individual block is working as the central spot for other engineers across other departments in the corporation. The mechanical integration engineer's assignment is to work as the link between those departments that affect the respective blocks area of focus in one way or another. The working procedure is a typical example of how cross-functional teams work. Mechanical integration's connections to other departments and functions can be seen in figure 1.

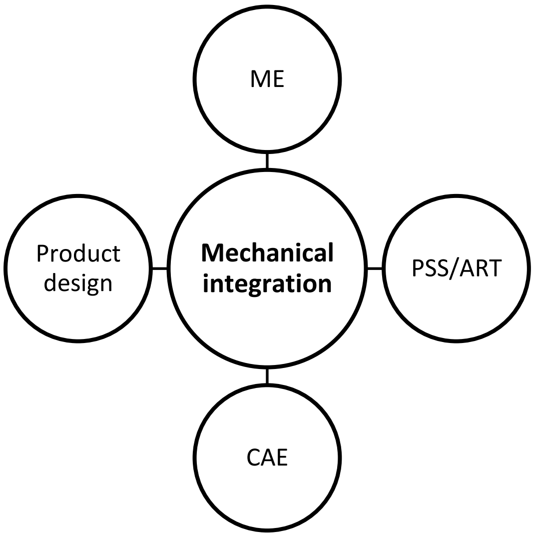

Figure 1. Mechanical integration's connection to related departments

For instance, engineers within several PSSes/ARTs are working with their particularly assigned parts and functions within their area of focus. PSS stands for product system structure and ART stands for agile release train. Both are names on groups of employees where the former is from an old department system and the latter is the new department system that is currently being implemented. Concurrently, the design department works with aesthetics in the same area. The goal of the mechanical integration engineer becomes to make sure that the interests of every stakeholder are met as much as possible while at the same time making sure that the solutions are feasible as well as fits in the car. Knowledge and information must be transferred in an efficient way, both from the specialists to the mechanical integration engineer and the other way around. The transferred information can for instance be legal and project specific requirements as well as about positioning of parts and assemblies in the car.

1.1.3. Engineering template

To make the working procedure as efficient as possible it is beneficial to have a standardized structure as a basis for new, incremental and ongoing projects. To achieve this at Volvo Car Corporation, the company has started to work with templates. At mechanical integration, the different blocks are currently working with engineering templates. These templates are made with a set of CATIA V5 models, which are designed and sorted in a logical order based on what parents and children the involved models have. Engineering templates are living files that are continuously updated and thereby contains agreed positions, surfaces, requirements and similar design and packaging related aspects. The combined models creates a final assembly structure that engineers can use in current and future projects. As a complement to the CATIA V5 models there is a logical flow of information that represents the models content in relation to each other. This is called an information flow. Together, these are thought to provide the necessary information to develop the car by improving communication and knowledge sharing. Thus potentially shorten lead-times and reduce the amount of needed resources. In other words, the goal with engineering template is to make it easier and more efficient to start and to work with development projects.

1.1.4. The C-pillar

As of today not all areas in the car have a dedicated engineering template. One of them is the area around the C-pillar. An example of the C-pillar and its position in the car is presented in figure 2.

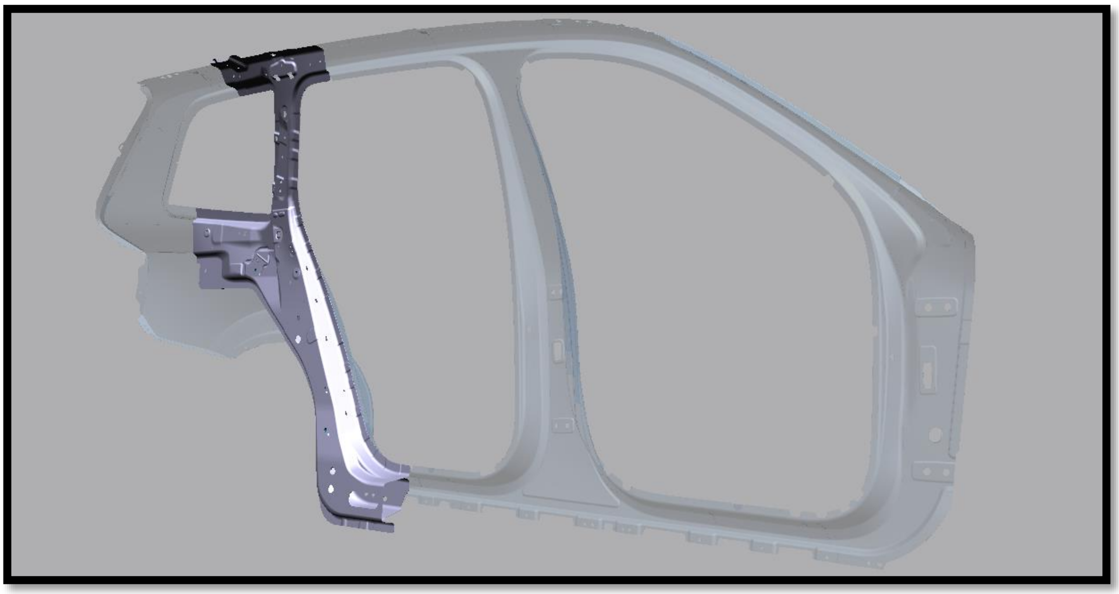

Figure 2. The C-pillar area

This area is located in between the engineering templates belonging to rear end, door and side, roof, floor and dash and compartment. The C-pillar area thus becomes an uncertain overlap to these engineering templates.

The appearance of the C-pillar is more or less dependent on what is happening around it rather than a pre-defined design. In other words, it looks different between every development project. It is largely influenced by modifications that vary from one project to another. This is related to the variable amount of mounted components nearby as well as their project specific dimensions. This brings a lot of uncertainties to every new project since the area always has to be remade or highly modified. It is also a tight packaging area due to it being affected by everything that happens around it. The addition of an engineering template is thought to bring a positive effect to the development of future cars. This by increasing knowledge sharing and awareness about the area during projects. However, prior to this master's thesis there has not been any research about possible implementation of an engineering template in this area.

1.2. Purpose

Since Volvo Car Corporation strives to further implement engineering templates the creation of an engineering template around the C-pillar is desired. If the template would be successful it is thought that it would ease the information and communication flow during projects. It is also thought to reduce the car development complexity from the start of new development projects. The implementation could in addition further improve Volvo's knowledge management, change management as well as the efficiency within the cross-functional adaptation in the corporation.

The purpose of this master's thesis is to investigate the need of a C-pillar engineering template and to create a preliminary proposal of how a C-pillar engineering template at Volvo Car Corporation can look like. This by investigating the needs of internal customers in the company and to utilize this information to create a proposal. The C-pillar engineering template proposal should contain a CATIA V5 assembly model as well as a related information flow.

1.3. Goal

The goal of the master's thesis is to deliver an engineering template for the C-pillar, based on input from a relevant project that can be applied in multiple projects in the future. It should include a CATIA V5 assembly model and an information flow.

1.4. Research questions

- What is important to consider when working with engineering templates?
- Is it suitable to work with an engineering template for the C-pillar area in development projects?
- What are the consequences of making the C-pillar engineering template due to it being an uncertain area caused by many changes?
- How can an engineering template in the C-pillar area look like?

1.5. Limitations

In order to structure the thesis within a clear scope some limitations are present. These are the following:

- The master's thesis shall have the equivalent workload of a 30 credit course at Chalmers University of Technology.
- The C-pillar engineering template development shall only focus on cars smaller than the XC line-up.
- The engineering template design should follow Volvo's general guidelines for template development.
- The C-pillar engineering template should be applicable on multiple projects.
- The CAD-model is limited to an assembly-structure, CAD modelling of individual parts are not included.
- The C-pillar engineering template shall be a preliminary proposal for future development, not completely finished.

2. Theory

This chapter contains necessary theory to enable an understanding for the subject of engineering templates. Common similarities to ordinary product development are presented. Furthermore, the theory behind the pre-study phase, regarding collecting customer needs, is shown. In addition, processes that are essential to understand in the engineering template development phase at Volvo Car Corporation are described.

2.1. Product development and engineering template

At Volvo Car Corporation, engineering template is an essential tool within the area of product development. The tool is mainly thought to gather knowledge, enhance communication, ease design of models in computer aided design, enable an easy process to deliver changes to models and to present the scope in a logical structure. These aspects can together enable better efficiency to the product development phase. Wheelwright and Clark (1992, p. 1) mentions the importance for companies to launch their products to the market more efficiently and sooner while matching target customers' expectations and needs. Thus, being able to do the product development as good as possible is a business advantage.

Wheelwright and Clark (1992, p. 3-5) discusses the automobile industry and states the need of variety and speed in product development due to changes regarding technology and the market. The authors further mentions the competitions meaning for the individual companies. First, it demands high level of product reliability while keeping control of product cost. Secondly, the importance of efficiency regarding bringing new products to market is mentioned. This must be combined with an ability regarding identifying opportunities. These aspects are enabled in engineering templates due to that they are continuously updated and used as a standard across the development departments at Volvo Car Corporation. Thereby providing a common working tool to discuss, build and change inputs of relevance within development projects. Thus, saving costs and increasing quality discussions.

Furthermore, Wheelwright and Clark (1992, p. 4-5) mention that since the amount of new products and process technologies have become more at the same time as product life cycles have shortened, companies have to take on more projects than before while using less resources per project. Engineering templates helps to stabilize this balance, due to reducing uncertainties, enhancing knowledge sharing and thereby saving time in projects.

Regarding uncertainty, Wheelwright and Clark (1992, p.8-9) mentions that the presence of it and the complexity of the project causes a hurdle to accomplish efficient and fast development of high quality standards. Naturally, the issues related to uncertainties are intensified by the level of complexity in the project. The authors' further states the essence of having an entire product created, integrated and done functioning during the development phase. All of these aspects are being handled in engineering templates since the work is done in CAD software.

2.2. Planning phase

Ulrich and Eppinger (2011, p. 74-75) presents the idea of identifying and collecting customer needs. The authors describe the process as being an integral part in the whole product development procedure. The basic thought is that those in charge and responsible for a product have to interact with customers in order to get experience from how it is to use the product. The authors present a five-step method regarding how to identify customer needs, which is represented in table 1.

Table 1. Five step process for identifying customer needs (Ulrich and Eppinger, 2011, p. 75)

Step 1	Collect customer data
Step 2	Translate the collected data into customer needs
Step 3	Create a hierarchy of the needs based on the data
Step 4	Set up the needs based on relative importance
Step 5	Make a reflection of the used process and the outcome

The first step can be made by several methods. Ulrich and Eppinger (2011, p.76) mentions interviews as one appropriate method. These are most often made during one to two hours in the customer's regular setting. Moreover, the authors mention that it is a good idea to collect the input from the users of the product in question. The documentation can be made by for instance audio recording and by taking written notes. The result of the data collection is raw data to use in identifying the needs (Ulrich and Eppinger (2011, p.78-81).

The second step is about translating the statements from the interviews into customer needs. Ulrich and Eppinger (2011, p.82) presents two crucial guidelines to use in order to translate effectively. These are represented in table 2 below.

Table 2. Guidelines for translating raw data into customer needs (Ulrich and Eppinger, 2011, p. 82)

Guideline 1	Write the needs based on what the product must do, not related to technological solutions.
Guideline 2	Write the needs on the same level of detail as the collected data.

Step number 3 is based on gathering the collected needs and put them into a hierarchical list. How to organize the needs is intuitive and do not need specific detailed instructions (Ulrich & Eppinger, 2011, p.84). One appropriate method to use in this process is the KJ-analysis. Chalmers University of Technology presents the method and describes it as a bottom-up method and, similar to Ulrich and Eppinger, mentions the method as being based on intuition and creativity rather than logical thinking. Chalmers University of Technology presents an example of the workflow as a seven step process which are represented in table 3.

Table 3. KJ-analysis (Chalmers University of Technology, p. 20)

Step 1	State facts on "Post-it" notes.
Step 2	Place all notes in the upper left side of a big sheet
Step 3	Choose a note and place in in the centre of the sheet
Step 4	Choose the next note. If related to any previous placed note these should be placed together
Step 5	Continue until the final note is placed on the sheet
Step 6	Group all notes in themed groups
Step 7	Write headings on the groups

The fourth step regarding how to collect customer needs is to establish a sense of how the needs relate relatively to each other by importance. Ulrich and Eppinger (2011, p.86) describes this step as important to be able to do appropriate trade-offs with respect to resource allocation when designing a product. The result is a weighting number that translates the relative importance of a subset of needs. The authors presents two main approaches to get the weighting numbers, which are represented shown in table 4.

Table 4. Approaches for weighting needs (Ulrich and Eppinger, 2011, p. 86)

Approach 1	Trusting team members view on the subject based on customer experience.
Approach 2	Conducting additional surveys to set the importance valuation.

The final step regarding identifying customer needs is to reflect on the process and the outcome. Ulrich and Eppinger (2011, p.87) states the importance of challenging the results in order to check if the outcomes are in line with the experience from interacting with the customers. This since the process of identifying customer needs, even though can be structured in an appropriate way, is not a precise science. The authors' presents a set of questions to reflect upon, represented in table 5.

Table 5. Reflective questions (Ulrich and Eppinger, 2011, p. 87-88)

Question 1	Have all important kinds of customers in the related target market been interacted with?
Question 2	Can the latent needs of the related target customers be collected while seeing past needs that are solely related to present products?
Question 3	Should certain areas of inquiry be followed in review surveys and/or interviews?
Question 4	Of the customers that were talked with, which could be appropriate participants in the current development attempts?
Question 5	Compared to the knowledge in the beginning, what has been learned? Have any of the gathered needs been unsuspected?
Question 6	Was every person inside the own organisation that must understand the gathered customer needs included?
Question 7	Looking at the used process, how can it be improved in upcoming attempts?

2.3. Template development essentials

In order to understand the concept and thoughts of template development at Volvo Car Corporation, there are some crucial terms to be aware of. These are presented below.

2.3.1. Product lifecycle management

Saaksvuori and Immonen (2008, p. 2) describes product lifecycle management, PLM, as a business model for managing a product through its lifecycle. This contains the items, bill of materials and documents for a product. Moreover, PLM also handles more information like results from analysis, test specifications, manufacturing information, and data related to the performance of a product. The authors further mentions that updated PLM software also involves program management, workflows and control features that helps with automation, standardization as well as enabling faster operations regarding product management. PLM also improves efficiency in terms of operations, this due to that everyone throughout the value chain retrieves the information, shares it electronically and reuses the input. This together with many other programmed capabilities. A company that uses PLM thus gets several benefits, including saving time and labour.

At Volvo Car Corporation, PLM is used as a tool to save, share and synchronise the CAD-models that belongs to a template. The used PLM software is Siemens Teamcenter.

2.3.1.1. Change management

One of the most important areas in a product lifecycle management system is change management. Saaksvuori and Immonen (2008, p. 16) describes change management as a means of where the most recent valid information regarding product or/and component changes are logged in items or documents and shared to related stakeholder when and where it is needed. Saaksvuori and Immonen (2008, p. 32) also mentions how change management enables tracing of the products process regarding changes in engineering that has been done to a products design in its past. In addition, the authors mention how change management enables substantial potential in a company working with development. Change management enables timed and controlled changes, a fast electronic working environment, control of conflicts between relations for present product information and information about finished and upcoming changes.

2.3.2. Knowledge management

North and Kumta (2018, p.11) presents the importance of common knowledge within an organisation. By having knowledge of what the entire company knows, relevant improvements would be possible to make earlier. Presented possible areas of improvement would be quicker reaction to changes on the market, improved productivity, earlier release of innovative products and to be able to better meet customer requirements. The authors continues by presenting four common issues related to knowledge in organisations. The first issue is related to employees not being able to find important information at the right time. The second issue is that previous lessons learned are not provided to the rest of the company, creating the risk that other employees repeat mistakes already discovered. Thirdly, due to lack of knowledge sharing organisations are not aware of what parts of the organisations knows at the time. Lastly, since knowledge is not shared and stored within the organisation it disappears with the employees that leave the company. Thus not contributing to possible areas of improvement.

North and Kumta (2018, p.12-13) mentions that knowledge management, KM, gradually has become a usual area of focus in business companies. The authors presents a definition which brings up how KM allows organisations, groups and individual people to share, produce and apply knowledge together through a system in order to acquire operational and strategic aims. Furthermore, the definition also states how KM add a growth to the effectiveness and efficiency for operations at the same time as creating a learning organisation. North and Kumta (2018, p. 245) describes how the operational activities, mentioned above, contributes with effective responses to internal or/and external customers as well as enabling an efficient value chain by taking, processing and spreading information quickly. The authors mention that this needs, for instance, an intranet that contributes with accessible and available information as well as process support.

These aspects are maintained by Volvo Car Corporation's template structure. This by having a way of using knowledge through creating CAD-models in CATIA V5 as well as sharing and storing these with the rest of the company through Teamcenter. This way, all related stakeholders can access, discuss and elaborate on new ideas and concepts while keeping the knowledge within the company through the CAD-files and added documentation.

2.3.3. CAD Advance

When working with CAD in CATIA V5 at Volvo Car Corporation, the designers are encouraged to design their models with the awareness of having to adapt it to potential future changes. To do this, they can follow the guidelines from the company's course CAD Advance. The course presents a philosophy that consists of flexible and predictable models that should be built with a stable design. Furthermore, the models should be well-structured and be named in a certain logical way.

2.3.3.1. Flexible modelling

Wolf and Hansson (2014) presents a definition for flexible modelling within the CAD Advance course at Volvo Car Corporation. It states that models that are made in a flexible and stable manner are ones that deliver predictable outcomes when updated. There are three common rules to obtain flexible models. The first rule is to design the models with a geometry that is as simple as possible. The second rule is to think through the models dependency chains so these make sense. The author mentions that short relation chains are beneficial in order to enable shorter updates, quicker troubleshooting as well as contributing to an even more logical structure. The final rule is to avoid building models around sub-elements when the models contain surfaces and wireframes.

2.3.3.2. Sub-elements

Wolf and Hansson (2014) presents some arguments why sub-elements should be avoided when working with surface models. The author states that sub-elements do not contain an UUID. UUID stands for Universal Unique Identifier and assures that elements in CATIA V5 are unique. In contrast, sub-elements are only named in the program after sequential numbers. For instance, a sub-element can have the name "Edge.1". This can result in a consequence that the sub-elements can be removed or alter sequence number at the time of geometry update, which can cause issues with relations in the model. Non-sub-elements are the elements that can be found in the tree-structure. By using design parameters that are not sub-elements, unexpected problems can be avoided. Some examples are self-defined points, planes and extremum elements.

2.3.3.3. Parameterisation

An additional aspect to consider when working with CAD-models is the use of parameters. In order to control attributes in a CAD-model, design objects can be connected to parameters. Wolf and Hansson (2014) states that formulas and parameters can control several features at the same time. Furthermore, parameters should be used when making dimensional restrictions. Depending on the content and its relations, which should be connected to a specific type of parameter, the content should be organized logically at the matching place in the tree-structure.

3. Method

In this chapter the methods used will be presented. The chapter is divided into the pre-study phase, where needs were collected, and the following engineering template development phase.

3.1. Pre-study

The pre-study phase was made in order to gather information and knowledge about the C-pillar area, engineering templates and the current interests of a C-pillar engineering template. This was to be able to plan based on relevant customer needs and to set a good foundation for the development phase.

3.1.1. Template experience interviews

A general interview template was made in the beginning of the thesis towards employees at mechanical integration, regarding experiences with templates. The purpose with these interviews was to get an initial understanding of the origin of template development at Volvo Car Corporation. Furthermore, how the employees experienced the tool in their daily work were of additional interest. The interview template consisted of ten questions. In total four interviews were made whereas two were made in pairs and two with only one interviewee. The complete interview template can be seen in appendix A.

The collected answers set the base knowledge to enable understanding of the tool. However, the answers cannot be shown in this thesis due to secrecy.

3.1.2. C-pillar engineering template interviews

After the initial template experience interview had been done, two versions of in-depth interviews with the focus on a C-pillar engineering template were made. The first was to employees at PSSes/ARTs with the purpose to collect internal customer needs regarding engineering templates in the C-pillar area. The interview template consisted of fifteen questions including general questions what the interviewee thought of when hearing engineering templates and experiences with it. Furthermore, the interview covered more detailed questions related to strengths and weaknesses as well as related parts that affect the C-pillar within the PSS/ART. The complete interview template can be found in appendix B.

The second interview version was aimed towards employees at related mechanical integration blocks with the focus to define the C-pillar. It consisted of ten questions ranging from how engineering templates contributed with value in the daily work to which parts that connects to the C-pillar within the respective block. The complete interview template can be found in appendix C.

In total, ten interviews were made where half were toward mechanical integration and half towards PSSes/ARTs. The interviews were scheduled between 60 to 90 minutes depending on the number of interviewees per session. Seven interviews were made with one interviewee and the rest with two interviewees due to time resource related circumstances. Before each interview the involved had to choose if they allowed the conversation to be sound recorded. This to enable detailed transcription after the interviews had taken place in order to get as much out of the answers as possible for later analysis. The recordings were deleted after transcription had been made in Microsoft OneNote. The outcome of these interviews were used as data to the customer needs study.

3.1.3. Surveys regarding engineering template

In parallel to the in-depth interviews regarding the C-pillar engineering template, two surveys regarding engineering templates were made. These surveys were sent to employees at Volvo Car Corporation that work frequently with engineering templates. This was to get an overview on how the employees at PSS/ART and mechanical integration perceived engineering templates at the company. Both surveys contained the same questions with the main difference of providing the specific PSS or MIE block for investigation purposes. The responders' answers were left anonymous. Questions were made with the intention to collect experiences and thoughts on how engineering templates were currently working. The purpose of the surveys were two folded. Firstly, it was made to complement the detailed interviews about the C-pillar. This by providing general information about how the internal customers at PSSes/ARTs and the mechanical integration department viewed the engineering template adaptation. The answers were thought to contribute with information about areas where the engineering templates were well thought of and were it had improvement areas. It could also show a potential contrast between the departments. Secondly, the surveys were interesting for Volvo Car Corporation in order to improve their working method. This by focusing on the possible areas of improvement. An overview of the results can be found in the chapter results while secrecy controlled survey outcomes can be found in appendix D.

3.1.4. Requirements list

With the answers from the C-pillar engineering template interviews, a requirements list was created. The answers were gathered and sorted in groups related to design, geometry, manufacturing, attributes, legal demands and CATIA/template development. Since an engineering template is not supposed to represent parts and components in precise detail, the requirements gathered were high level requirements. This means that the requirements are on an overview level rather than being very detailed. As everything mentioned within this subject were critical as a part of the development of a car, none were listed as wishes. Instead each requirement was listed as either a requirement, R, or a legal requirement, LR. A column regarding which PSS/ART or mechanical integration block that mentioned the requirement was included as well. The requirements in the requirements list would not only show what seemed crucial to fulfil, it also provided an overview and a good reminder of what to keep in mind while developing the engineering template. For instance space requirements between parts. The complete requirements list can be seen in the results chapter.

3.1.5. Customer needs lists

When the in-depth interviews had been transcribed, two lists of customer needs were made in Excel. The first list was related to the template model needs, in which the components and interfaces that were mentioned to affect the C-pillar were listed. The purpose of this needs list was to collect every physical component, and its interactions, that was mentioned to affect the C-pillar in the interviews. The second list included statements related to internal work needs, combining engineering templates in general with specific engineering template needs in the C-pillar area. When the lists had been created a KJ-analysis was made in order to categorise the needs and give them appropriate names that expressed the internal customers' statements. Finally a rating related to the perceived importance was given. Both needs lists can be seen in the results chapter.

3.1.5.1. KJ-analysis

During the KJ-analysis the template model needs and the internal customer work needs were sorted and rated. Both rating processes were individually adapted based on the related circumstances. Each need was given a rating point in order to get an indication of the importance of it. Since many statements had been made in both needs lists, it was more efficient to do the analysis in Excel rather than on regular post-it notes.

Regarding the template model needs, the list was based on the answers from the internal customers from mechanical integrations perspective, the PSSes/ARTs. The component could be mentioned in maximum five different interviews. Building on this, a rating system was created which can be seen below in table 6.

Table 6. Template model needs rating criteria

Score	Meaning	Recurrence
1	Barely mentioned	Mentioned in one respect during one interview
2	Mentioned	Mentioned at least in two respects during one interview
3	Common	Mentioned during two interviews
4	Often mentioned	Mentioned in more than 2 respects in 2 interviews
5	Crucial	Mentioned during three or more interviews

The purpose for rating these components was to get an idea of the importance of each component prior to the start of the development phase. This to get a sense of which component to focus on initially and to create a discussion topic with the development team. This regarding if the component needs should be different and why that would be the case. The KJ-analysis for the template model needs resulted in a sorted list with rating points. It can be seen under the results.

When the internal customer work needs list had been made there were many statements that had to be considered. In total 115 different needs statements were found in the interviews. These needs had been highlighted from the interview statements in Microsoft OneNote and then put into the Excel sheet. Critical key words were highlighted as bold in order to keep track of the specific type of need that each statement covered. For instance, these keywords could be speed, efficiency and time. The highlights were put there to make it easier to get an overview of the main importance of each need and to ease upcoming analysis.

The process was made by colour coding the statements, where each colour matched a specific need. For instance was statements related to speed highlighted with orange colour, knowledge with yellow and so on. In total, 22 main categories of needs were covered.

The needs were sorted in a list based on the perceived importance. This was based on how many times the related aspects were mentioned and the number of interviews the aspects were mentioned in. Mentioned means that the need was either mentioned or strongly related to the statement from the interviews. For used criteria, see table 7. As seen in the table, the number of interviews the needs were mentioned in weighs heavier than the total amount of mentions.

Table 7 – Internal work needs rating criteria

Rating	Recurrence
1	Mentioned in only one interview
2	Mentioned in two interviews and less than five mentions
3	Mentioned within the gap of two interviews and more than five mentions and four interviews and five mentions
4	Mentioned in four interviews and more than five mentions
5	Mentioned in all five interviews

The analysis resulted in that the internal customer needs were sorted in importance order. A final internal customer needs list was then finalized. The related KJ-analysis can be found in appendix E.

3.1.6. SWOT-analysis

As a complement to the internal customer needs, a SWOT-analysis was made. Rouse (2019) describes it as a model that can be used to find and analyse factors externally and internally that possibly can affect a product, individual, project or place. SWOT stands for the strengths, weaknesses, opportunities and threats that relates to, for instance, the investigated project.

The analysis was built on answers from both the PSS/ART interviews as well as the mechanical integration interviews. Since both departments work daily with engineering templates it was important to make sure that both sides were taken into consideration regarding how a C-pillar engineering template was perceived. The answers were thought to contribute to an understanding of how the template was considered and what to think of in the development in terms of the SWOT related aspects.

3.2. Template development

After the pre-study was done a foundation had been created to move forward with the thesis. The next step was to begin with the template development. Since the thesis was conducted on Volvo Car Corporation, this part of the thesis generally followed the company's standard approach regarding how the company works with new engineering templates.

3.2.1. Engineering template development meetings

During the development phase a total of 16 development meetings were executed. The majority of the meetings were made with a development team. This team consisted of representatives from PSSes/ARTs, both from the interviews and from added scope during the development. The new representatives were added after having an individual meeting regarding possible new input to the template. Prior to every meeting a PowerPoint presentation was made in order to have a structured agenda. Depending on the purpose of the meeting the agendas were made differently. During the meetings the involved stakeholders were allowed to discuss with each other rather freely under the predefined agenda. This way the meetings allowed for open communication of needs and knowledge sharing between the employees. Topics during the meetings included to define and update the scope, update the information flow and how to manage CATIA V5 input in the engineering template. Notations from the meeting were written down in Microsoft OneNote. Meeting requests and summaries were sent to all stakeholders in the development team by e-mail though Microsoft Outlook.

3.2.1.1. Development kick-off

In order to start the development phase of the C-pillar engineering template a kick-off meeting was made. The attendances were either the same persons that attended the interviews, employees that the recently interviewed persons sent or employees that work with template development at Volvo Car Corporation. The agenda was based on letting all employees meet and present themselves as well as discuss their view on a C-pillar engineering template. The outcome of the pre-study was presented and discussed. Ratings on the importance of the components and interfaces in the template model needs list were discussed and compared with the values that had been set based on the interviews. The ratings were discussed since it was interesting to note the actual component needs as it was brought up and discussed among all parties. This set the initial basis regarding the focus and scope of the template.

3.2.1.2. Setting information flow

During the development an information flow was created and continuously updated. An example of a possible information flow at Volvo Car Corporation is presented in figure 3.

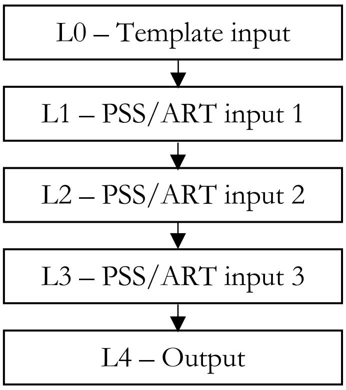

Figure 3. Example of information flow

The information flow was based on a waterfall level structure. Geisler (2015) mentions how the waterfall model has phases where each one has deliverables and review processes. The author states that these phases works with and finishes on its own, thus the phases does not work against each other in parallel.

The top level, level 0, consisted of basic input information related to the template, the middle levels consisted of input from different PSSes/ARTs and the last level allowed for an output that interested stakeholders could use. This system allowed engineers to be confident that input that exists in one level had to come from a level above and not from below.

3.2.2. Catia V5 development

Based on the continuously updated information flow, the engineering template was made in CATIA V5. The CAD-model was built as an assembly model where the tree-structure represented the level structure of the information flow. The template owner had responsibility regarding input to level 0 as well as maintaining and organizing the engineering template. The related PSSes/ARTs had responsibility to deliver input to their respective level, or levels, of focus.

3.2.2.1. Product lifecycle management – Teamcenter

The content of the engineering template was saved, stored and accessed through the PLM software Teamcenter. Thus, CATIA V5 and Teamcenter were connected to enable updates. The content had specific ownership depending on who was creating the model and thus was responsible for it. However, the complete engineering template was owned by the project owner. By having a synced library of files, Teamcenter ensured that all files were accessible and updated to the latest status.

3.2.2.2. Integration support

The role as an integration engineer included the task to support the PSSes/ARTs with knowledge and management of the area. When the need for new or changed input to the engineering template arose, an investigation of the subject between the integration engineers and an expert in the related area occurred. Furthermore, when the development of the C-pillar engineering template faced obstacles or uncertainties the main task was to unlock the issues. This was initially done by controlling the CATIA-model, come up with a suggestion and then create opportunities for knowledge sharing and cross-functional communication through meetings.

4. Results

In this chapter the results of the C-pillar engineering template development are presented. The chapter is divided into the pre-study and the template development phases.

4.1. Pre-study

In this sub-chapter the results from the pre-study phase will be presented. This considers results from the surveys as well as results from the interviews which are the requirements list, needs lists and SWOT-analysis.

4.1.1. Engineering template surveys

Below, a summary of the results from the interviews “Template survey for employees at mechanical integration” and “Template survey for employees at PSS/ART within an engineering template team” are presented. It contains statistical data as well as brief comments from written responses, answering what is important to consider when working with engineering templates. Complete secrecy controlled survey results are shown in appendix D.

Question 1:

What do you think of Volvo Car Corporation’s engineering templates with respect to:

A) Technical productivity

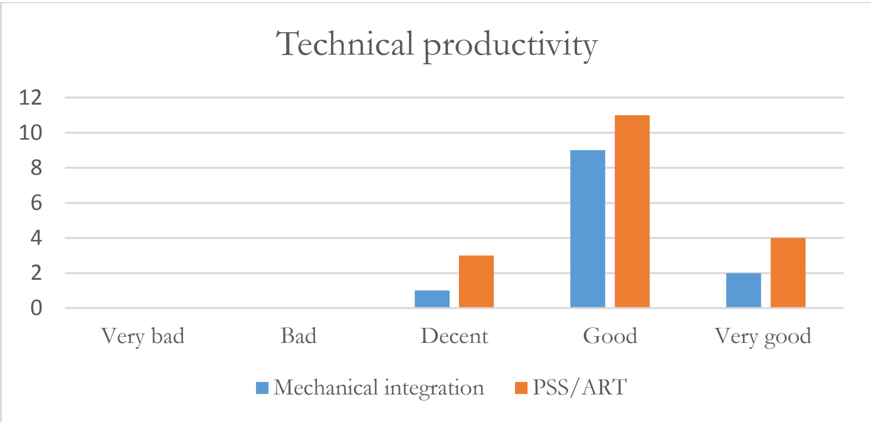

Figure 4. Survey result regarding technical productivity

Overall, both employees at mechanical integration and the PSSes/ARTs are satisfied with the technical productivity in engineering templates. It improves process time, speed, knowledge capturing and packaging work. Possible areas of improvement are to apply it in more areas and to keep track on necessary information to include in the engineering template. Detailed comments can be seen in appendix D.

B) Feasibility

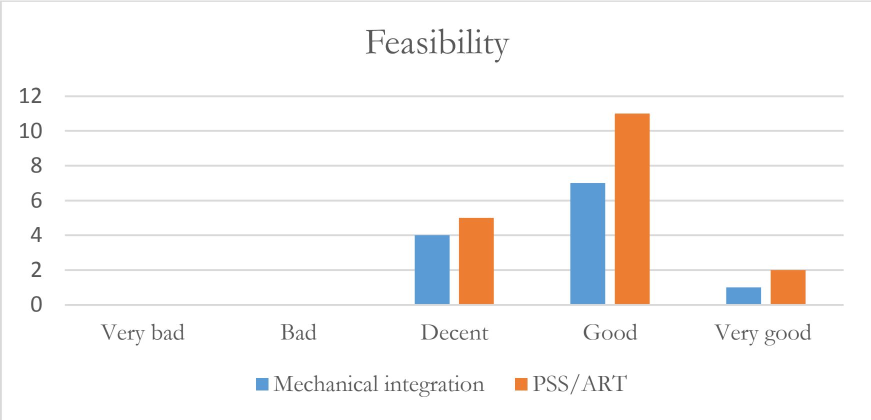

Figure 5. Survey result regarding feasibility

Overall, most employees at mechanical integration and the PSSes/ARTs thinks the feasibility in engineering templates are at least good. Though, some think there are room for improvement. Risks can be found and visualised early. However, templates can be difficult and time consuming to implement. It also demands advanced CAD skills and experience can be required in some models. Detailed comments can be seen in appendix D.

C) Efficiency

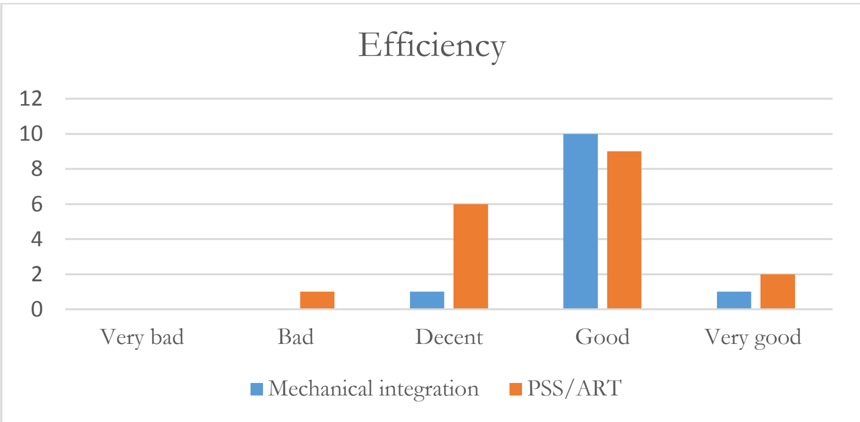

Figure 6. Survey result regarding efficiency

Regarding efficiency, the view is divided. One employee at the PSSes/ARTs considers it bad. Mechanical integration is overall more pleased than the PSSes/ARTs. The engineering template contributes with faster variable checks, iterations and inputs. However, it is highly dependent on individual availability and the sync processes can take time. Detailed comments can be seen in appendix D.

D) Ease of use

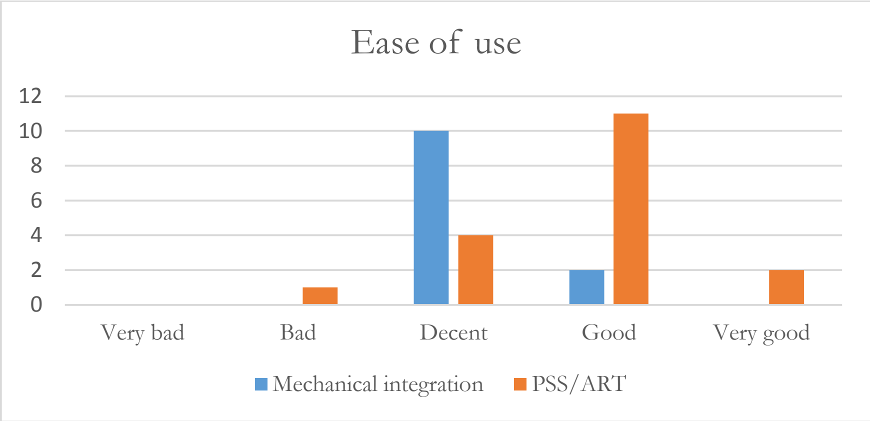

Figure 7. Survey result regarding ease of use

In terms of ease of use, the view is also divided. One employee at the PSSes/ARTs considers it bad. However, overall the PSSes/ARTs are more satisfied than mechanical integration. At mechanical integration, only two employees thought it was at least good. The engineering template is rather easy to work with and easy to use, understand and apply. However, it can be complicated and requires maintenance. Detailed comments can be seen in appendix D.

E) Communication

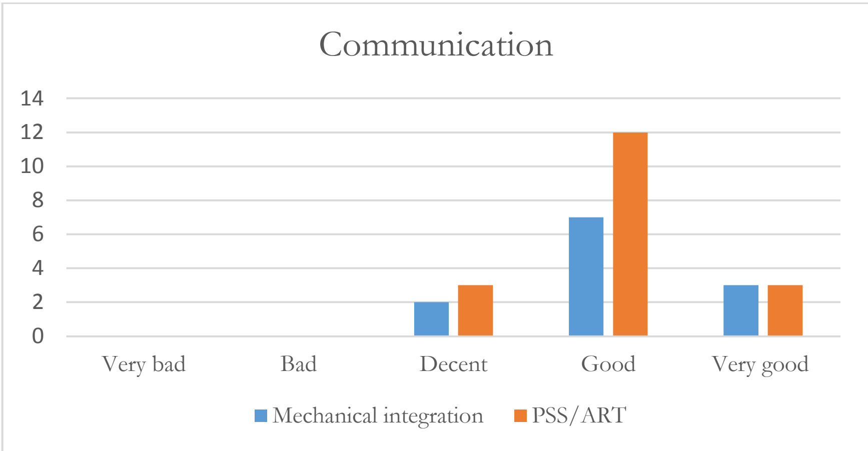

Figure 8. Survey result regarding communication

With respect to communication, it is overall positive feedback. Five employees think that it is decent, while the rest thinks it is good or very good. In general there are positive comments regarding communication in engineering templates. It is mentioned that it is an excellent source of discussion and the single source of information. On the other hand, the communication quality depends on the template leader and sometimes there are too many meetings. Detailed comments can be seen in appendix D.

Question 2:

Approximately, how much time do you spend on engineering template related activities every week?

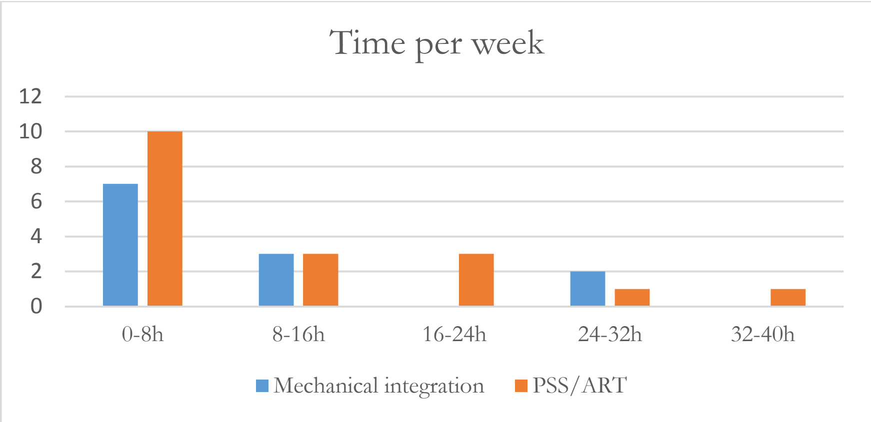

Figure 9. Survey result regarding time per week

The majority at both departments spends approximately one day per week with engineering templates. Some spend up to five full days. Two common activities on both departments are meetings and engineering template updates. Detailed comments can be seen in appendix D.

Question 3:

Mention the one most common activity you spend your time on regarding engineering templates.

<u>Mechanical integration:</u>

Meetings.

<u>PSS/ART:</u>

Updates.

Question 4:

Pick the one alternative where you think engineering templates contributes the most with.

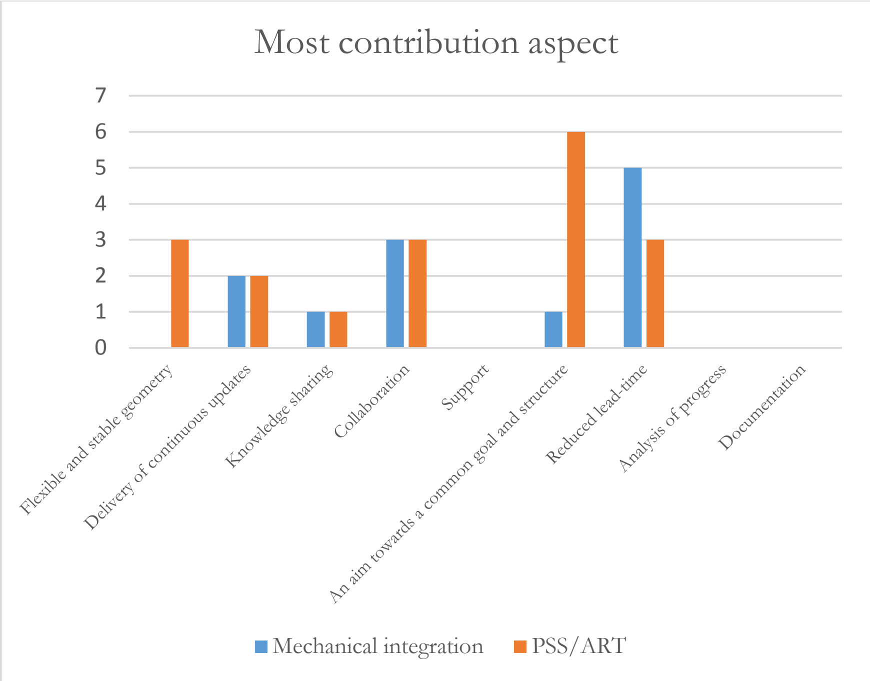

Figure 10. Survey result regarding most contribution aspect

Regarding most contribution aspect the focus areas support, analysis of progress and documentation get no votes. Employees at PSSes/ARTs votes most for an aim towards a common goal and structure while the mechanical integration votes most for reduced lead-time. Detailed comments can be seen in appendix D.

Question 5

Pick the one alternative where you think engineering templates can benefit the most from improvement.

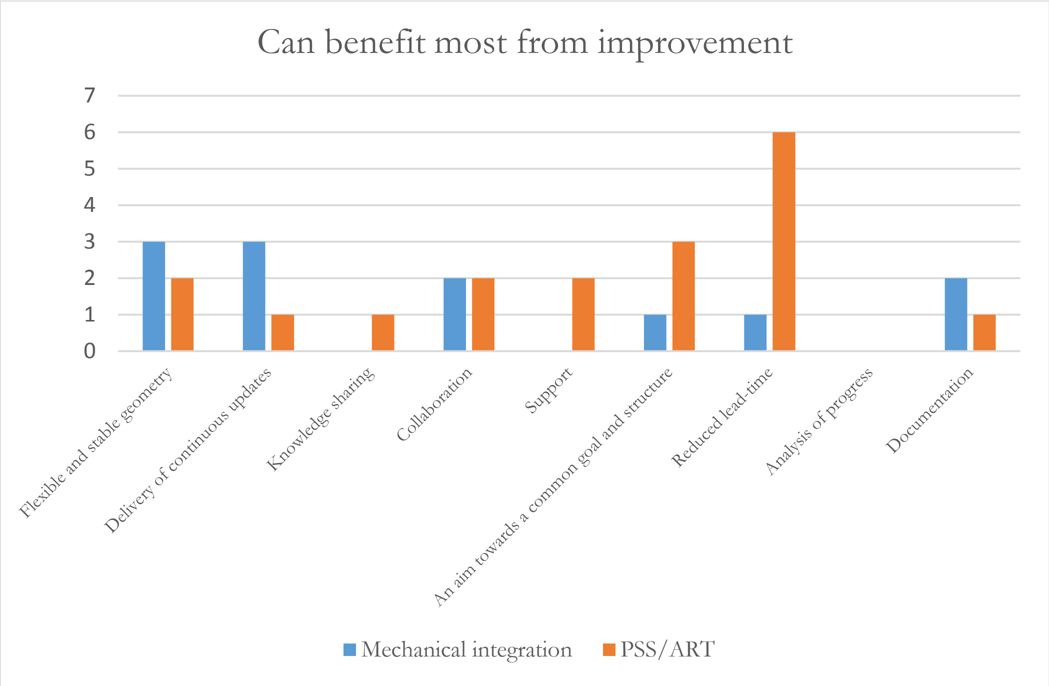

Figure 11. Survey result regarding benefit from improvement

Regarding areas to benefit most from improvement, the focus area analysis of progress get no votes. Employees at PSSes/ARTs votes most for reduced lead time while the mechanical integration votes equally for flexible and stable geometry as well as delivery of continuous updates. Detailed comments can be seen in appendix D.

Question 6

Today, engineering templates are to some extent automated at a mature stage. However, it requires manual input from designers and mechanical integration in order to verify the validity of the content. How would you react if artificial intelligence, AI for short, would be integrated in engineering templates and thereby make the template process more automated?

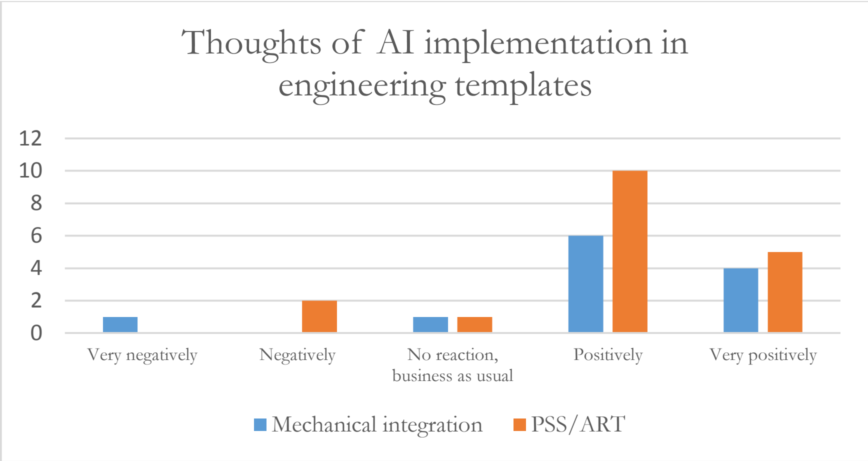

Figure 12. Survey result regarding AI implementation

Most employees see a positive benefit with future implementation of artificial intelligence. However, not everyone agrees as some sees it as something negative. Comments range from being doubtful and not believing AI can find the best solutions to thinking that AI can speed up the work and enable a more efficient process. Detailed answers are found in appendix D.

Question 7

Regarding engineering templates, how well do you think the continuous collaboration with design works? Please, answer based on the perceived quality of inputs and outputs during the projects.

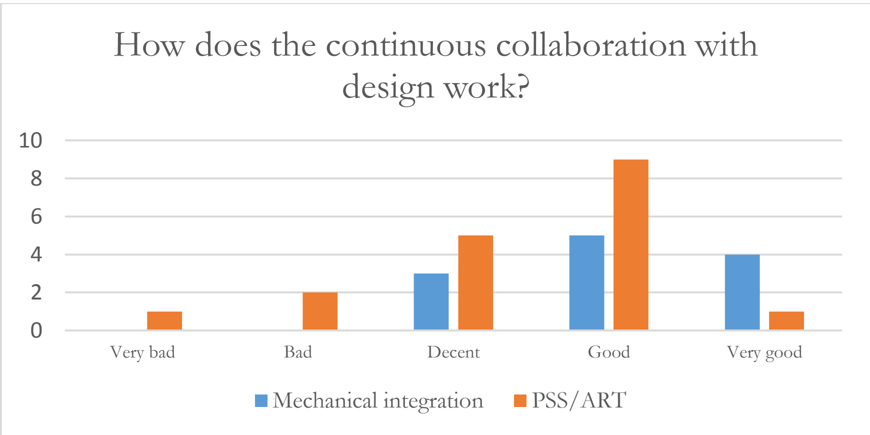

Figure 13. Survey result regarding collaboration with design

Employees at mechanical integration thinks the collaboration with design works well in most cases. On PSSes/ARTs the thoughts are mixed, ranging from very bad to very good. Comments relates to the need for better communication, that it is good to have a common direction and that results vary from input is mentioned. Detailed answers can be seen in appendix D.

Question 8:

Regarding engineering templates, how well do you think the continuous collaboration between mechanical integration and PSS/ART work? Please, answer based on the perceived quality of inputs and outputs during the projects.

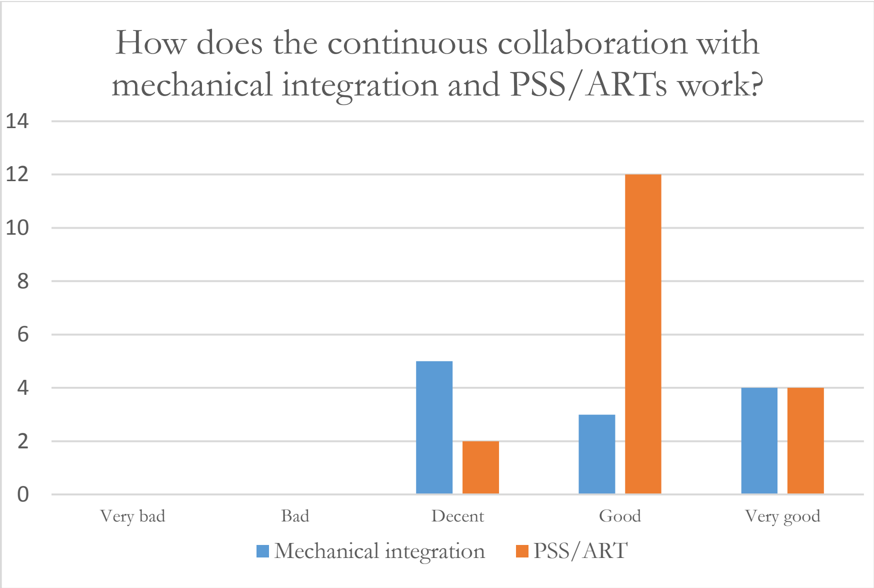

Figure 14. Survey result regarding collaboration between mechanical integration and PSS/ART

Employees at both mechanical integration and PSS/ART thinks the collaboration between the departments work well. On PSS/ART the thoughts are even more positive than at mechanical integration. Comments relates to good communication, positive collaboration trends and an improved scope on surroundings. Improvement can be made regarding alignment with time efficiency and deliverables. Detailed answers can be seen in appendix D.

Question 9:

Overall, how would you rate Volvo Car Corporation's engineering template adaptation? Pick one number between 1-5, where 1 is the worst and 5 is the best.

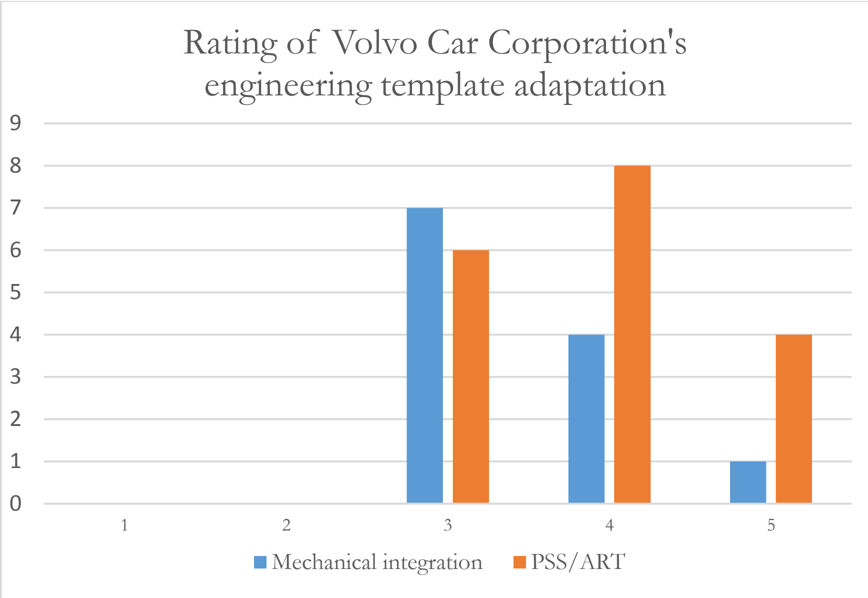

Figure 15. Survey result regarding rating of engineering templates

No one gave a rating below 3. However, mechanical integration seems to dislike engineering templates slightly more than PSS/ART. While the most common answer at mechanical integration is 3, PSS/ART had a 4 as most common. Overall, a positive grade. Though there is some room for improvement.

4.1.2. Requirements list

The requirements related to a C-pillar engineering template are presented in table 8. It contains requirements that were mentioned during the C-pillar interviews. The requirements are gathered as high level requirements and not detailed requirements. This due to the need from Volvo Car Corporation to get a proper view on requirements that are important for an engineering template in the C-pillar area.

Table 8. Requirements list

Type of requirements	Requirement/Legal requirement	Mentioned by PSS/MI Block
Design		
PQ	R	Rear end block
Strength	R	PSS120 and Rear end block
Stiffness	R	PSS270/271
Geometrical requirements		
Space requirements	R	Rear end block
Overslam	R	Door and side block
Ceiling	R	Door and side block
Door	R	Door and side block
Body	R	Door and side block
Trim	R	Door and side block
Plastics	R	Door and side block
Dog leg area - tight styling	R	PSS271
Cable harness	R	Rear end block
Structure sealings	R	PSS271
Black-off	R	Rear end block
Ergonomic	R	Door and side, Rear end blocks
Good sill height	R	PSS271
Vision	R	Rear end block
Field of view on upper part	R	PSS271
Manufacturing		
Connections	R	PSS270/271
Welding points and combinations/welding joints	R	PSS270/271
Material	R	PSS270/271
Attributes		
Sound	R	PSS330
NVH	R	PSS271
Stabilization - solid solution for trim panels	R	PSS330

Legal demands		
US/EU/NCAP	Rating R	PSS270/271
Safety	LR	
IC	LR	PSS120
No sharp areas – certain radius	LR	PSS330
Crash	LR	PSS270/271, rear end block
FMH	LR	PSS120
FMH head hits – strength	LR	PSS120
Rear crash	LR	PSS271, rear end block
Collision endurance	LR	PSS271
Side collision	LR	PSS271
Barrier	LR	PSS271
Pole	LR	PSS271
Catia and template development		
CAD Advance	R	PSS120
Waterfall information flow	R	PSS120
Template course	R	PSS120

4.1.3. Template model needs list

Table 9 shows the outcome of the interviews regarding components and interfaces that affects the C-pillar in relevant cars. It is complemented with which PSS/ART that mentioned the importance. Furthermore, the perceived importance values between 1 and 5 that relates to how often the components were mentioned. A higher number relates to higher importance. The only exception is the C-pillar inner and outer that are marked with an X, since they are synonymous with the C-pillar.

Table 9. Template model needs list

Areas in the car that affect	Mentioned by PSS/ART	Perceived importance
BiW Adapter model	PSS271	
C-pillar inner	PSS271	X
C-pillar outer	PSS271	X
Wheelhouse inner	PSS271, PSS270/PSS271	3
Wheelhouse outer	PSS271, PSS270/PSS271	3
C-ring	PSS271	1
Q-glass	PSS271	1
D-pillar	PSS271	3
D-pillar upper	PSS270/PSS271	3
Sill	PSS271, PSS270/PSS271	3
Sill front	PSS270/PSS271	3
Cantrail	PSS271	1
Cables	PSS330	4
Cable attachments	PSS330	4
Amplifiers	PSS330	1
Clips	PSS330	1
IC	PSS330, PSS120/Hard Trim	4
Trim panels	PSS330	1
Windcord front and end surface	PSS120/Hard Trim	1
Seat belt	PSS120/Hard Trim	3

BiW	PSS120/Hard Trim	2
Seat belt panel "shelf"	PSS270/271	3
Door striker	PSS270/271	1
Side plate	PSS270/271	1
Side member	PSS270/271	1
A-pillar enhancer	PSS270/271	1
Interfaces against…		
Cables	PSS120/Hard Trim	4
IC	PSS120/Hard Trim	4
BiW	PSS120/Hard Trim	2
Headliner	PSS120/Hard Trim	1
Belt guide	PSS120/Hard Trim	3
Seat belt	PSS120/Hard Trim	3
Windcord	PSS120/Hard Trim	1
Ingress/egress	PSS120/Hard Trim	1
FMH safety	PSS120/Hard Trim	1
Rear opening	PSS120/Hard Trim	1

4.1.4. Customer work needs list

The internal customer work needs, which relates to the C-pillar engineering template, are presented in table 10. Each need is complemented with an importance value between 1 and 5 where the latter is of the highest importance.

Table 10. Internal work related customer needs

Internal customer needs	**Importance 1-5**
Share knowledge	5
Use appropriate amount of time	4
Provide design interfaces/inputs	4
Enable good communication	4
Be efficient	4
Provide a base to work with	3
Deliver a functional process	3
Ease packaging/space	3
Have fast and improved speed	3
Share interest, experience and a common goal	3
Proper and relevant meetings	3
Early involvement as well as inputs/outputs	3
Provide correct and collected information	3
Hold down costs	3

Avoid double or added work	3
Deliver high surface quality	2
Proper resource allocation	2
Contain security aspects	2
Include basic surfaces	1
Follow CAD/CAD Advance	1
Enable benefits later in projects	1
Reduce unknowns/uncertainties	1

4.1.5. SWOT-analysis

The outcome of the SWOT-analysis is presented in table 11 below. The interviews tell that there are many possible strengths and opportunities with a C-pillar engineering template. There are also some weaknesses and threats that must be considered during the development phase.

Table 11. SWOT-analysis

Strengths	Opportunities	Weaknesses	Threats
Get required space	Be involved early	Could be a problem that it is three different packaging areas	Risk of added work
Get a base model early	Problems become apparent early which can reduce costs	If details are included that only a few people use	Possible double work
Be able to make fast decisions	Everything becomes collected and kept together	If being too rough in the end	If C-pillar is only released in template and not in Teamcenter and Teamcenter Visualisation
Enables transparency and speeds up the process	Extended away from door opening curve to another area could save working time	Standardized template could hinder creativity	
Better efficiency	Quick modifications	Could add some bureaucracy	
Secure and help packaging early	The time aspect		
Delete all unknowns	Connect body and side outer with inner with similar working processes		
Generates a technical input model to design	Overlap between templates		
Enables early feedback			
Enhances communication and knowledge sharing			
More steered up and less manual work			
Have much better status compared to areas without template			
Get the right info early and be able to work with it			

4.2. Engineering template development

In this subchapter, the results from the development phase for the C-pillar engineering template is presented. A proposal for an information flow and content in the engineering template is shown.

4.2.1. Information flow

In figure 16, the content of the C-pillar engineering template is presented as an information flow. Due to secrecy the individual objects names are not shown. However, the rest of the information flow is intact.

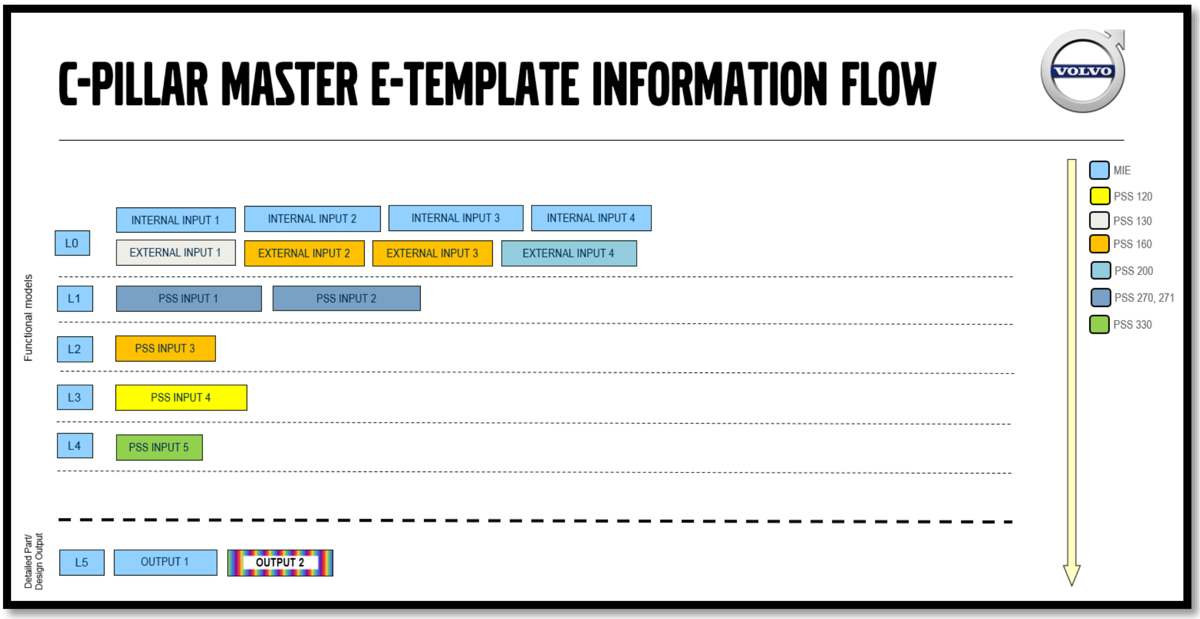

Figure 16. Information flow

4.2.2. C-pillar engineering template

Below, the final outcome of the C-pillar engineering template is presented. As was mentioned in the limitations of this report, it is supposed to be a proposal for what a C-pillar engineering template can contain and how it can look like.

4.2.2.1. Engineering template assembly model

Due to secrecy, the CATIA V5 assembly model cannot be shown. This is since the model is built on input that belong to an ongoing development project at Volvo. Instead, a representation of the C-pillar engineering template is presented graphically. In figure 17, the complete content of the C-pillar engineering template is shown. The engineering template is built from the left side only, due to symmetry between the left and right side. The graphical picture is grabbed from the computer software Teamcenter Visualisation. Content belongs to Volvo XC90 (2015). Some areas are dimmed in order to highlight the main locations of the C-pillar engineering template content.

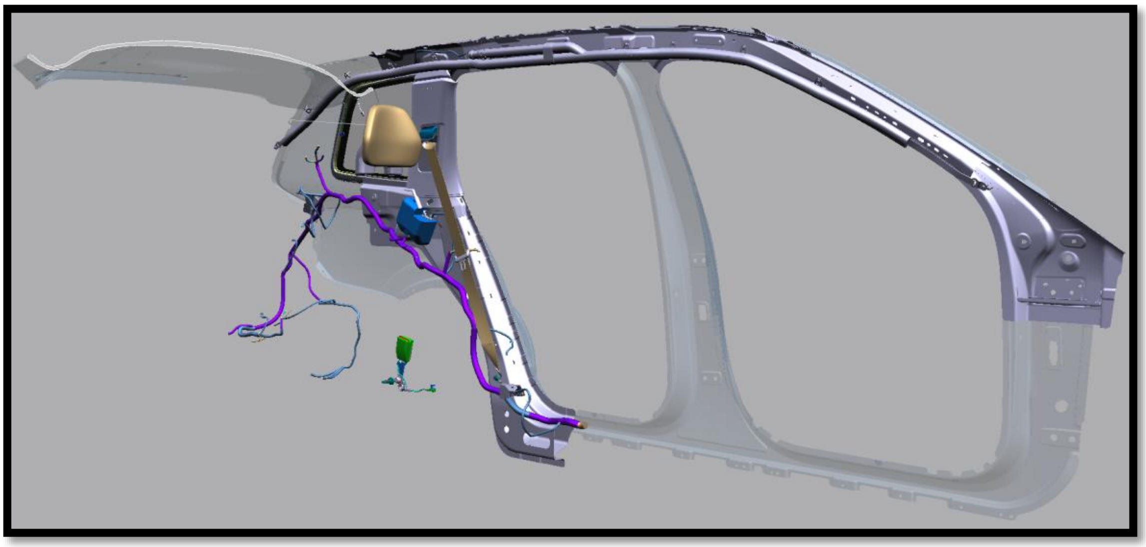

Figure 17. C-pillar engineering template content

4.2.2.2. Related components

The components that are included in the engineering template are presented randomly below.

Figure 18 shows a selection of the included components and their positions in the engineering template.

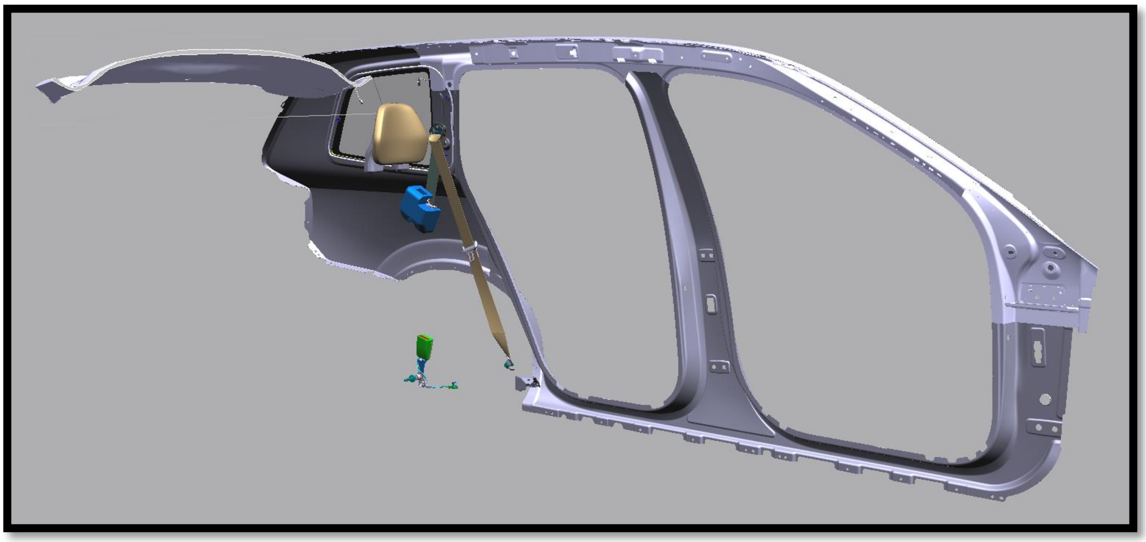

Figure 18. Selected C-pillar engineering template content

The names of the components in figure 18 are presented in random order in table 12. Child seat is excluded from figures due to practical reasons.

Table 12. Selected C-pillar engineering template contents names

Child seat
Seat belt rear
Head rest rear
Headlining roof
Body sider outer
A-pillar inner upper
Quarter glass body side
A-pillar reinforcement upper

Figure 19 shows the two main C-pillar components.

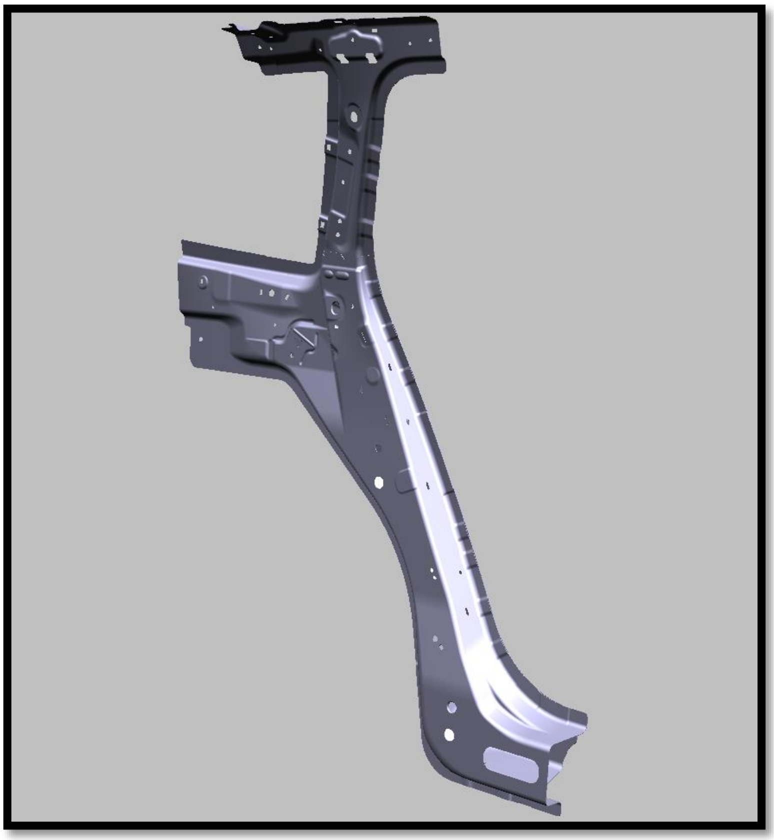

Figure 19. C-pillar components

Table 13 shows the names of the C-pillar components in figure 19.

Table 13. C-pillar components names

C-pillar inner upper
C-pillar inner lower

Figure 20 shows cables that comes in contact with the C-pillar area.

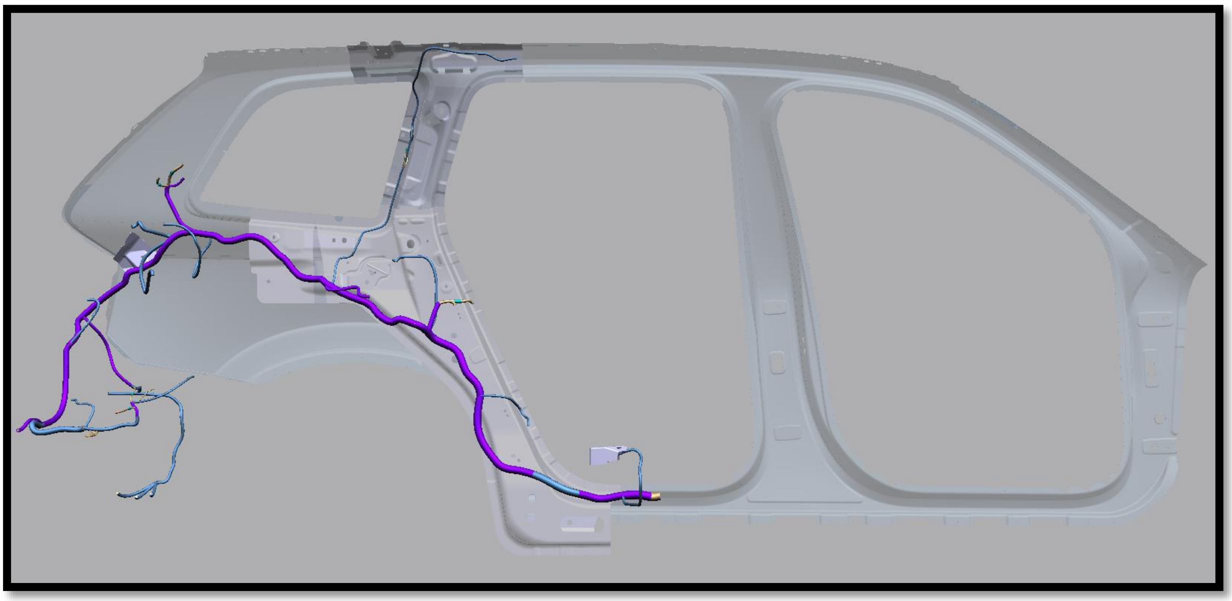

Figure 20. Cables

Figure 21 shows the combined C-ramp and IC-ramp in its position on the C-pillar.

Figure 21. C/IC-ramp

Figure 22 shows the inflatable curtain and its position in the car.

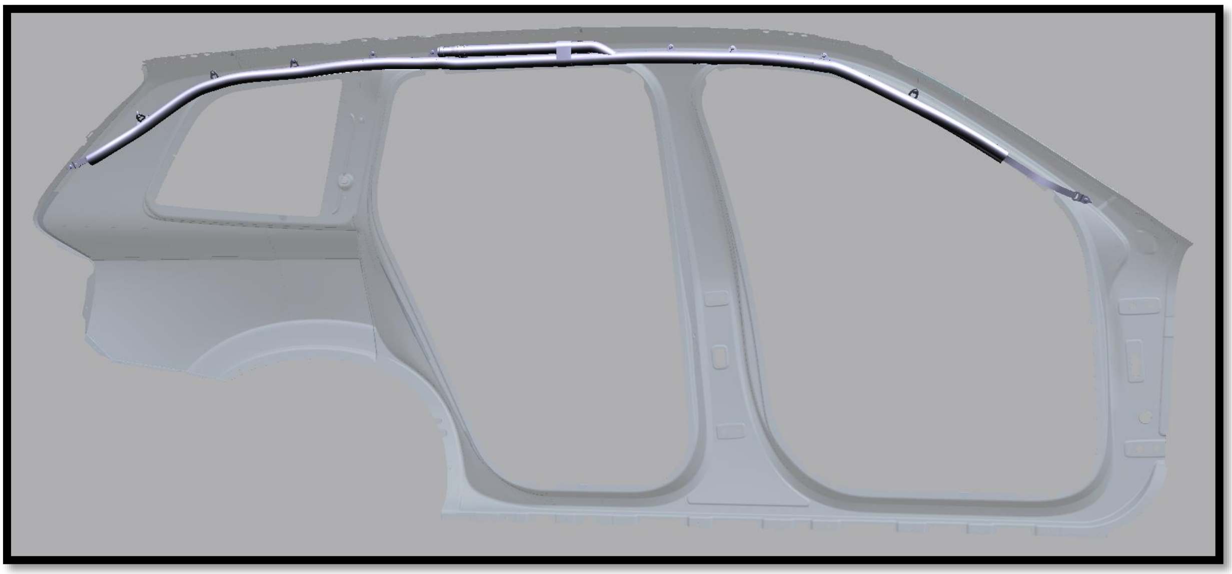

Figure 22. Inflatable curtain

5. Discussion

In this chapter the results and processes from the pre-study phase and development process will be commented. Additional aspects that needs to be highlighted and considered are discussed. Finally, a view on how ethics and sustainability relates to the thesis will be presented.

5.1. Pre-study

Discussions regarding the pre-study is made below. The focus is on the engineering template surveys, the process and results of the customer needs, the requirements list and the SWOT-analysis.

5.1.1. Engineering template surveys

The surveys were made for two reasons. The first in order to get an overview on how mechanical integration and PSS/ART thought of engineering templates at the start of the thesis. This was a way to quickly understand what engineering template was about as well as to give ideas on what to consider when starting to develop one. The other reason was to deliver new information to Volvo Car Corporation regarding areas of improvement with engineering templates. The results were appreciated among the template engineers and brought up on template agendas with the intention to use the outcome to improve all engineering templates.

The decision to use surveys was made in order to be able to allow for many relevant employees to take part of the questions. Moreover, employees' opinions at different blocks at mechanical integration and different PSSes/ARTs were interesting to gather to allow for answers from different perspectives. The surveys were also relatively easy to compile, which allowed for a proper presentation of the results.

Before considering surveys, it is important to consider the questions scope and to who these should go to. As mentioned, the target customers for the survey was employees that work with engineering templates. The questions were decided in collaboration with employees that work with template development. Ideas were communicated to these employees in order to check the relevance of them. The only question that was not directly relevant to the thought process of the thesis was the question about artificial intelligence. The reason that question was included was for future purposes, to investigate the company view on implementing artificial intelligence in engineering templates. In theory, artificial intelligence can be introduced in the C-pillar engineering template in the future. However, the result showed that the feelings regarding artificial intelligence were mixed. Due to this and the reality that artificial intelligence had not been researched prior to the thesis, it was not included in the scope of the thesis.

5.1.2. Identifying customer needs

As stated in the theory chapter, Ulrich and Eppinger (2011, p. 87-88) presents a set of reflective questions to think of regarding the outcome and processes used when identifying customer needs. The questions are repeated in table 14 below.

Table 14. Reflective questions (Ulrich and Eppinger, 2011, p. 87-88)

Question 1	Have all important kinds of customers in the related target market been interacted with?
Question 2	Can the latent needs of the related target customers be collected while seeing past needs that are solely related to present products?
Question 3	Should certain areas of inquiry be followed up in review surveys or interviews?
Question 4	Of the customers that were talked with, which could be appropriate participants in the current development attempts?
Question 5	Compared to the knowledge in the beginning, what has been learned? Have any of the gathered needs been unsuspected?
Question 6	Was every person inside the own organisation that must understand the gathered customer needs included?
Question 7	Looking at the used process, how can it be improved in upcoming attempts?

Considering the first question, the target market in this case was the internal departments that work daily with engineering template projects at Volvo Car Corporation. The most common departments that worked with engineering templates at the time of the thesis were mechanical integration and PSS/ART. These were also the departments that took part in the interviews to gather template knowledge and customer needs. Moreover, these were also the ones that took part in the additional engineering template surveys. One department that did not contribute with input to the C-pillar engineering template but is thought to later use the output is the design department. However, this department has not been a part of the C-pillar engineering template development. The main reason for this was because one limitation was that the C-pillar engineering template was going to be a preliminary proposal for future development. In order to get a proposal, it became more important to gather a development team and to get valuable components into the template rather than to discuss design preferences. However, when continuing to work with the template it is important and inevitable to include design in order to deliver a suitable output to them.

Regarding the second question, some unique latent needs were found among the answers in the interviews. By being unique, the needs were related to the C-pillar area in a way that is not common in other engineering templates. For instance, most of the current engineering templates were made for big exterior areas like the front, roof and rear end of the car. This engineering template was focused on the interior due to expressed need during an interview with the door and side block during the pre-study. Furthermore, due to that the area was uncommonly uncertain between every new project, some statements had to do with increased knowledge about certain aspects as well as uncertainty reduction for these. These statements were highlighted and transferred to the KJ-analysis.

The third question relates to areas of inquiry to follow up in upcoming interviews or surveys. In this case, the development phase became the opportunity to discuss areas of inquiry. Thus the need for additional interviews or surveys were not required after the pre-study phase. Of course, there were areas of inquiry to bring up after the pre-study. The main one was how to set the scope for the engineering development based on the collected needs. When trying to expand the template after the thesis, it would be interesting to include the design department in the development team. This to directly get feedback on how the engineering template can be evolved to be able to join full-scale developments.

The answer to the fourth question is that everyone that took part in the needs identification process were relevant participants in the development phase. This since all involved PSSes/ARTs had to do with components or features that related to the C-pillar area. However, one interviewed PSS, PSS230, did not have resources to contribute during the development phase. Another internal customer that was considered to be involved in the interviews initially was infotainment. Similarly to PSS230, it was not possible to involve infotainment in the thesis due to lack of resources.

Regarding the fifth question, everything that came out of the pre-study phase were new knowledge for Volvo Car Corporation regarding an engineering template around the C-pillar. This is simply because no research had been made before the start of the thesis. Thus, every aspect related to results from the needed components, the work related needs, high level requirements and SWOT-analysis were new knowledge within the engineering template area of focus. Even the survey results regarding general engineering templates were considered important findings in order to evolve the tool as a whole. Results from the surveys were brought up on meetings in the company to discuss how to improve engineering templates.

Reflecting on question number six, it is very difficult to include everyone at Volvo Car Corporation that possibly can be affected by the C-pillar engineering template. However, in terms of the chosen thesis scope, which was decided with an employee which role focused on engineering template development, there were at least one representative from the related areas of focus involved. In some cases there were two representatives. There is no doubt that more employees and more PSSes/ARTs could have been included if the project were longer than one university semester and if every department had close to unlimited resources. Then the scope of the project could have been larger and more employees could have been involved, resulting in a wider selection of needs. In reality however, that was not the case. Based on the amount of new information and the decision to include employees from the main areas of focus, the employees that had to know the needs were included.

Regarding question seven, the process to gather employees does not have much room for improvement. This is since the gathering of employees was made by contacting them through phone, skype and email. In other words how it usually works. The same can be said about the surveys, since they were sent out by email to related employees. The execution of interviews were done according to theory, by writing down notes and recording sound with the permission of the interviewees. One method that can be improved is the KJ-analysis. It worked well to use for the template needs list due to limited amount of content and by having content that enables an objective point of view. However, regarding the work related needs there are room for improvement. Since 115 statements were gathered from the interviews, the categorisation of the needs were extra affected by subjective choices. The method worked well to translate the statements into relevant customer needs. However, the preciseness of the translation into categories have room for improvement.

Moreover, some statements were similar to others which resulted in that some needs could be put in other categories. One example is the need for uncertainty reduction. This need only got an importance score of one out of five. It is possible to argue that uncertainty reduction fits into the need to share knowledge and should thus be included in that need. However, it is also possible to argue that uncertainty reduction can be included in other needs like enable good communication, be efficient and ease packaging. In the case of uncertainty reduction, it is a central need in engineering templates and a core reason why the tool exists. The same can be said by the need for the course CAD Advance, which is crucial to take part in to follow Volvo Car Corporation's CAD development methodology. It could be placed in several needs like to be efficient, deliver a functional process and enable good communication. One solution was to keep the needs separate, even though they strongly related to other needs. The drawback then became that the importance score on the smaller needs did not reflect the actual importance as well as it possibly could. It is thus important to consider every gathered need to be at least important and to discuss which of these to consider mandatory before continuing with further development.

5.1.3. Requirements list

The results that are presented in the requirements list are as mentioned in the result section high level requirements. This means that the overall areas that are written as requirements are not in precise detail. For instance, the geometrical requirements are only listed as what to think of and not in millimetres for a specific part. However, this still fulfils Volvo Car Corporation's aspirations to get knowledge about important requirements and areas to focus on. This means that, as a first requirements list to the C-pillar engineering template, this is valuable. However, in the future the requirements must become more detailed to enable a precise design of the engineering template. Moreover, the number of requirements must also expand as the scope expands.

5.1.4. SWOT-analysis

The outcome of the SWOT-analysis shows what was perceived as positive and negative with the C-pillar engineering template during the interviews. The method were used to get a view on how the C-pillar engineering template was thought of among the key stakeholders. In the interview template to PSSes/ARTs there were questions that were formulated towards strengths, weaknesses, opportunities and threats with a C-pillar engineering template. For mechanical integration a question was formulated regarding how a C-pillar engineering template would influence the daily work at the specific block. This because employees at mechanical integration owns the templates and have knowledge of how the current procedures work. Thus, statements regarding how the C-pillar engineering template could affect the organisation were brought up.

The results are interesting, especially the weaknesses and threats. This is because there are some answers that were unexpected prior to the start of the pre-study. For instance, how a C-pillar engineering template relates to bureaucracy was a point of view that added a new dimension to the template developers at the start of the development phase. Never had it occurred that bureaucracy was thought of when talking about engineering templates. This opened up for reflection of how engineering templates connects to bureaucracy and made the team aware of the issue before the start of the development phase of the C-pillar engineering template. In addition, the statement regarding how standardized templates can hinder creativity did also cause reactions. The threats were taken seriously, especially regarding added and double work. This since if stakeholders experience that they have to work more than needed, the morale can become lower due to lack of resources. Based on the scope during the pre-study, the SWOT-analysis contributed with valuable information. The analysis would have brought up more if the scope involved more PSSes/ARTs from the beginning. However, the main ones were involved from the beginning and quality of statements were well received. The outcome of the SWOT-analysis was thought of in the development phase.

5.2. Engineering template development

This sub-chapter discusses the processes and results during the engineering template development phase. This includes the information flow, C-pillar engineering template and a view on ethical and sustainable aspects related to engineering templates.

5.2.1. Information flow

During the kick-off meeting the gathered needs from the pre-study phase were shown and discussed. The template needs were given a favourable score while open conversations took place. In the end of the meeting the first information flow scope was set. This scope evolved during the course of the development phase. This was mainly through discussions within the development team when each stakeholder openly argued for their needs and wishes under a pre-defined agenda. As the discussions went on and the stakeholders learned how to work to deliver inputs that worked with each other, the scope's content grew. Later in the development, when each PSS/ART worked with their inputs, some additional research took place regarding to include other PSSes/ARTs into the development team. The ideas were most often born from the development meetings, otherwise they came from the engineering template developers. When the relevant content had been added, the scope was definitive.

As the scope evolved, content were added to the information flow. During the development meetings the content were strategically put on the most suitable levels. By doing this it became clear how the C-pillar engineering template would be built and what was connected to what. Thus, the information flow was a good tool to structure the logical order of the C-pillar engineering template.

5.2.2. C-pillar engineering template

At the start of the development phase there were divided opinions in the development team regarding the need and benefits of a C-pillar engineering template. Based on the answers from the C-pillar engineering template interviews, most participants mostly saw benefits with the start of the development. However, one PSS/ART was not convinced that it would provide any value. The stakeholder saw risks of double work, meaning to create an engineering template with content that already existed in other engineering templates. This was especially related to the door and side engineering template, as the C-pillar is located on that area. However, the difference was to build an interior engineering template rather than an exterior like the door and side engineering template was. As mentioned earlier, the idea for an interior engineering template originally came from interview answers from the door and side block. In addition, the concerned stakeholder in the development team was mostly focused on what benefits the represented PSS/ART would gain from the new template. In reality, other PSSes/ARTs were relying on input from that stakeholder in order to create appropriate input. The input from the interviews were based on sedan cars, as decided prior to the pre-study. However, due to various business reasons the scope moved to cars smaller than the XC-line. Every PSS/ART agreed that the input from the interviews were still as relevant as before the change of scope.

As the development went on, the need for collaboration became more and more apparent. The meetings were structured to enable valuable discussions where every stakeholders' point of view could be expressed. The discussions allowed for the involved stakeholders to reveal additional needs as well as uncertainties they had related to the CAD development. Since the C-pillar usually changes from one project to another, it was important to create a common understanding of the area and how everyone involved were affected. As the project continued, the sceptical stakeholder started to open up and see the benefits of the interior C-pillar engineering template.

One common issue during the development was the lack of resources to be able to create input to the CAD-model. Since there were many ordinary development projects running in the organisation, the C-pillar engineering template development had low priority. If more resources had been available during the development phase, the engineering template could have included more content. In the best of worlds, every input to the CAD-model in an engineering template should be a living model. This means that the model is continuously updated when the owner of the model changes something in the file. However, to enable the CATIA V5 development to start of the decision was made to allow dead content in the template. Thus, content that is not connected to real-time updates. The C-pillar inner upper and inner lower input resulted in dead surfaces based on information that was updated at the time of input creation. This decision allowed the other stakeholders to be able to include and create living models based on parameters from the dead surfaces. Even though the optimal scenario would have been to only include living models in the C-pillar engineering template, this allowed knowledge to be stored in the CAD-assembly. Moreover, if the dead content had not been implemented some of the living content would not have been possible to create. In the end, this compromise enabled the creation of an engineering template that were both appreciated and decided to be continued in the future.

5.2.3. Ethical and sustainable considerations

Template development at Volvo Car Corporation is an efficient method to ease the development of new cars as well as for incremental updates of already existing cars. By creating CAD models that are shared throughout the company, knowledge sharing increases and efficiency improves. With the right treatment the development lead-times can be shortened, thereby saving resources for the company. Furthermore, the procedure is also environmentally friendly since the car is prepared within a computer environment rather than being physically built with prototypes from the very beginning. The template development method will also allow car customers to access higher quality premium products at a potential lower price point than if the development process were not as efficient.

Moreover, engineering template development creates a structured standard for other departments to follow. An example is manufacturing, where waste of components and other materials becomes less common compared to the use of a more trial and error approach. However, due to the competitive edge that engineering templates gives the company the tool is protected by high levels of secrecy. Therefore, it is not allowed or appropriate to talk about the details of how template development at Volvo Car Corporation works outside of the company boundaries. If doing so, harm can be caused to the company. Thus, it is important to be professional and follow the company guidelines. This to ensure that Volvo Car Corporation can maintain its market position, increase its revenue and to make sure that the end customers can receive the best and most characteristic Volvo car possible.

6. Conclusion

When working with engineering templates it is important to make sure that the main stakeholders' needs are met as good as possible. By creating a pre-study that focuses on the behaviours and needs within the areas of focus, a development project can start off with a solid foundation of knowledge. The C-pillar engineering template development shows that a solid base of gathered information, that are relevant to the tool and the internal customers' needs, can enable development of an area that is known for its uncertainty between development projects. Apart from a proper pre-study, it is important to create an environment where knowledge sharing and collaboration can exist. This can be done through meetings where the involved stakeholders all contribute to open discussions to set and to follow a scope that relates to the needs of each one. Common understanding is crucial as well as being able to make compromises. If these aspects are met, as well as being combined with pre-defined agendas that fits well in the different phases of the development, it is suitable to work and possible to create an engineering template around a challenging area with a lot of uncertainty. The C-pillar engineering template is proof of this.

7. Recommendations for further development

In the future, the gathered content can be used to expand the scope of the C-pillar engineering template. As resources are put into the development, the current models can be refined until they achieve a level of quality that allows them to be fully applied in multiple projects. Technical output to design can be expanded and finalized. In the end of the thesis it was discussed to create an output regarding the inflatable curtain in the future. Additional output should be related to interior needs, as the template is built internally and since it already exists engineering templates that focuses on the exterior areas. Moreover, it is recommended to include ergonomics in the development to ease upcoming car development phases. If the engineering template is expanded, for instance towards the luggage area, it is recommended to check eventual differences between the left side and the right side of the interior. Depending on the direction of expansion, a decision must be made regarding which block that is going to own and continue the development of the C-pillar engineering template.

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Appendix

A. Template experience interviews

Questions:

1. Can you describe how it is like when working with a template?
2. What was the method to use before templates began?
3. What do you think triggered the birth of template development?
4. What are the prereqisites to work with templates in terms of skills and resources?
5. What are the most significant changes with template work compared to how it was before?
6. What are your positive experiences with templates?
7. What are your negative experiences with templates?
8. Is something critical missing in templates today regarding packaging?
9. Has something regarding packaging been vastly improved by working with templates?
10. How can a future template look like in order to keep the positive aspects while improving the negative aspects? A template 2.0.

B. C-pillar engineering template interview guide for PSS/ART

Collecting customer needs

PSS/ART:

Question 1

- What do you think of when you hear the term engineering template?
    - Why is that?

Question 2

- What experiences do you have with engineering templates in terms of technical functionality?
    - What are the positive experiences?
        - Please, specify why that is positive?
    - What are the negative experiences?
        - Please, specify why that is negative?

Question 3

- What experiences do you have with engineering templates in terms of human communication, knowledge sharing and support?
    - What are the positive experiences?
        - Please, specify why these are positive?
    - What are the negative experiences?
        - Please, specify why these are negative?

Question 4

- What is the main goal with using engineering templates at your PSS/ART?
    - Why do you pick this?

Question 5

- If a C-pillar engineering template would be created, in what way would that strengthen the work of your PSS/ART?
    - Why?

Question 6

- What opportunities do you think would open up for your PSS/ART with a C-pillar engineering template?
    - Why?

Question 7

- Are there any weaknesses with working with a C-pillar engineering template at your PSS/ART?
    - Why?

Question 8

- Do you see any threats or risks to your PSS/ART with the implementation of a C-pillar engineering template?
    - Why?

Question 9

- Which parts within your PSS/ART affects the C-pillar?
    - In what way do they affect?
    - Why do they affect?
    - What are the requirements for these parts, in terms high level requirements such as legal demands?
    - If there are any, which template do these parts belong to?

Question 10

- What would your inputs and outputs be in a C-pillar engineering template?
    - Why?

Question 11

- Do you experience issues with the C-pillar, regardless of templates?
    - How come?

Question 12

- What do you consider to be proper use of an engineering template?
    - Why do you think these aspects are important?

Question 13

- How does late changes affect your PSS/ART:
    - When template is used properly?
    - When template is not used properly?

Question 14

- How does engineering templates contribute with value to the daily work at your PSS/ART?
    - Why?

Question 15

- Describe your PSS/ARTs relationship to the mechanical integration department.
    - How well does the collaboration work, according to you?
    - Do you have any suggestions for improvement?

C. C-pillar engineering template interview guide for mechanical integration

Defining the C-pillar in Sedan cars.

Block:

Question 1

- How does engineering templates contribute with value to the daily work at your block?
  - Why?

Question 2

- How is your block connected to the C-pillar?

Question 3

- Which is your template of focus and how does it relate to the C-pillar?

Question 4

- Mention your experiences with the C-pillar.
  - What are they?
  - Which positive aspects would you like to highlight?
    - Why are these positive?
  - Which negative aspects would you like to highlight?
    - Why are these negative?

Question 5

- How is the C-pillar managed within your template today?
  - Has this way of managing the C-pillar been the same in the past?

Question 6

- Which PSSes/ARTs connect to the C-pillar within your template?
  - Which are your inputs and outputs for the C-pillar?

Question 7

- Explain as detailed as possible which parts that connects to the C-pillar in Sedan cars within your block?

Question 8

- Describe your blocks relationship to the related PSSes/ARTs within the C-pillar area.
  - How well does it work, according to you?
  - Do you have any suggestions for improvement?

Question 9

- If a C-pillar engineering template would be created, in what way would that influence the daily work of your block?
  - Why?
  - Regarding packaging, how would a C-pillar template influence it?

Question 10

- Do you have any final lessons learned regarding the C-pillar that you would like to share, that has not been mentioned during this interview?
  - Why is this relevant towards development of a C-pillar template?

D. Engineering template surveys

Below, the complete results of "Template survey for employees at mechanical integration" and "Template survey for employees at PSS/ART within an engineering template team" are presented. Each question are presented with statistical diagrams and, due to secrecy, a selection of received written answers.

Question 1:

What do you think of Volvo Car Corporation's engineering templates with respect to:

A) Technical productivity

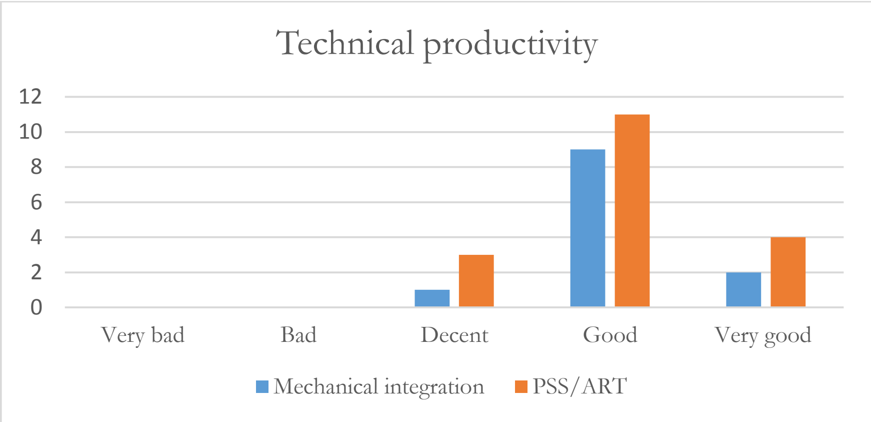

Figure D1. Survey result regarding technical productivity

a) Please, describe and clarify your answer shortly.

Written answers:

Mechanical integration:

Positive:

- It helps shorten the process time.
- Setting the big pieces aligns faster with template than without.
- Standardization of basic methods before complex solutions are added.
- Capturing engineering knowledge with technical constraints included and reusing it.

Feedback

- Not maybe as widely applied for all areas as it could be.
- Only keep what has to be in the template in the template, too much information and models will decrease productivity.

PSS/ART:

Positive:

- Improves the packaging investigations.
- Great place to design common interfaces.
- Quicker iteration of packaging and decisions taken.
- It is an efficient way to create parts based on the template output.

Feedback:

- Ok, but can be better. The problem is that you do not have that much time to spend on templates.
- The idea is good, but a lot more can be done. Might consider inviting/forcing more groups to join.

B) Feasibility

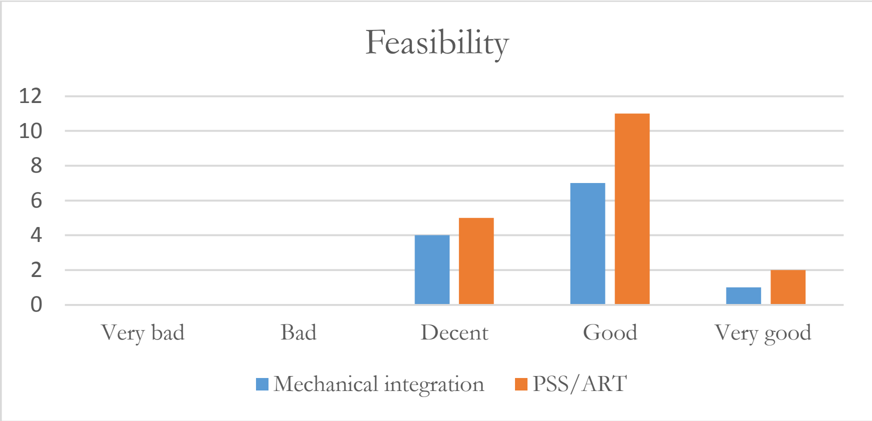

Figure D2. Survey result regarding feasibility

b) Please, describe and clarify your answer shortly.

Written answers:

<u>Mechanical integration:</u>

Positive:

- Can outline areas of potential risk early.
- Input regarding what to adjust goes to fewer people, ensuring that the big picture things are maintained.
- Feasibility checks are included in engineering templates. No need to wait for feasibility feedbacks in many cases.

Feedback:

- Does not cover all areas.
- Very good when we have standard solutions. Takes time to adjust the template to new concepts.
- Template may be hard to implement and in some cases advanced CAD skill and experience may be required to work with template models.

<u>PSS/ART:</u>

Positive:

- See the problem early.
- Helps to visualize issues in early stages.
- For the most part gives a good information on feasibility.

Feedback:

- Feasibility data from experience are built in to the template but to fully analyse, detail design is needed.

C) Efficiency

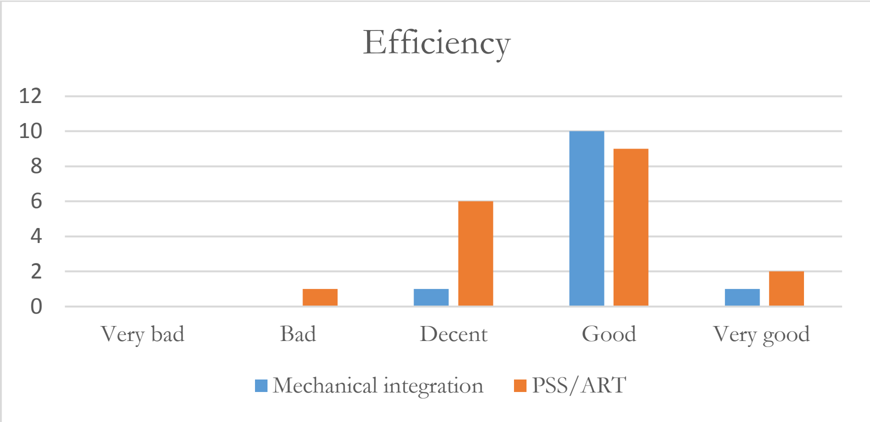

Figure D3. Survey result regarding efficiency

c) Please, describe and clarify your answer shortly.

Written answers:

Mechanical integration:

Positive:

- Allows quicker looping of variables to check.
- The template give us a good input to design.

Feedback:

- Very efficient for some areas. Requires more work in others.
- A lot of work is required in a template update but the exchange rate is large.
- Very good when we have standard solutions. Takes time to adjust the template to new concepts.

PSS/ART:

Positive:

- Improves performance.
- Fast input, early detections.
- Quick iterations of the template.

Feedback:

- Good but highly dependent on individual availability.
- Syncing of template levels can be very time consuming.
- They have to find a better way to get people to sync. Think it could be better if you had slots where you are expected to be finished.

D) Ease of use

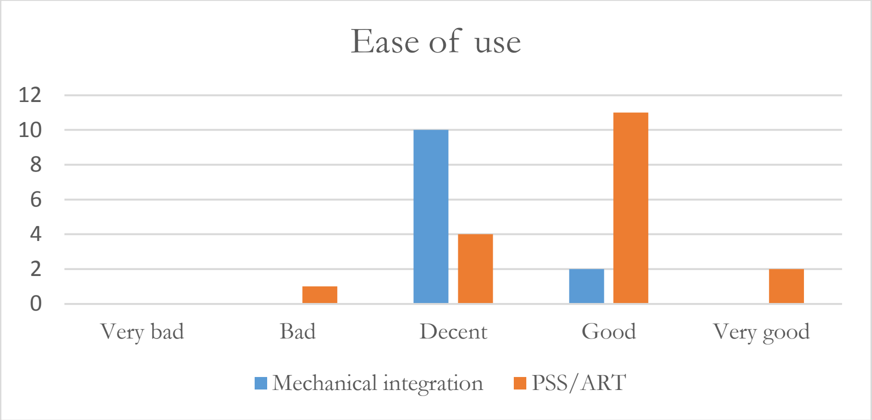

Figure D4. Survey result regarding ease of use

d) Please, describe and clarify your answer shortly.

Written answers:

Mechanical integration:

Positive:

- Quite easy to work with.

Feedback:

- Often requires a fair bit of maintenance.
- A bit complicated to understand for a new employee.
- Flow of information between models can be difficult to understand/visualize.
- Very good when we have standard solutions. Takes time to adjust the template to new concepts.
- Need certain level of CAD knowledge and template experience in order to use the templates in a correct way.

PSS/ART:

Positive:

- Easy to apply.
- Fairly easy to use.
- Easy to understand.
- Good documentation and descriptions.

Feedback:

- Perhaps complicated for very new designers.
- Pretty complicated, you need to know what you are doing.
- It is straight forward when you have a stable model and you know what to do.
- It's not very easy to find what you're looking for if you don't know where you have to start. Hard to tell what surfaces does what without asking.

E) Communication

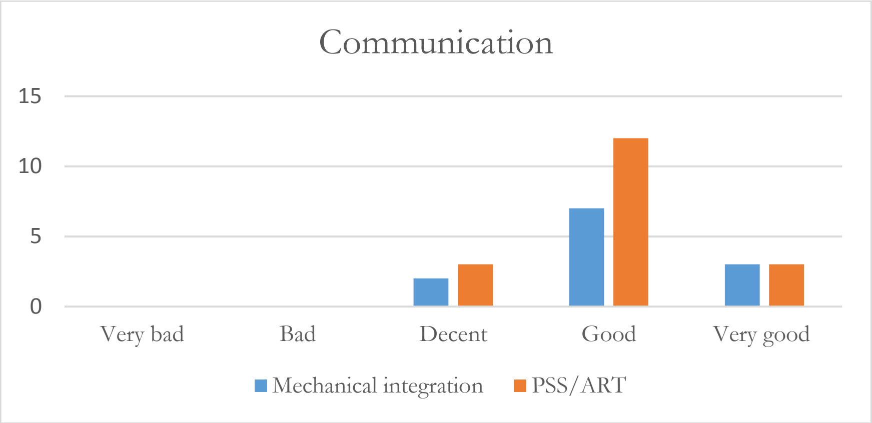

Figure D5. Survey result regarding communication

e) Please, describe and clarify your answer shortly.

Written answers:

Mechanical integration:

Positive:

- Probably the biggest thing to me...to avoid miscommunication.
- Clear what the status is and what interfaces everyone should keep.
- Excellent source of common discussion to highlight trouble areas.
- It is good to have colocation meetings to be able to talk and help each other.
- Engineering templates are one single source of information. Every downstream user gets same information at the same time.

Feedback:

- It depends on the template leader but with the right template leader the communication is good within the team and also between the Eng. Template team and the customers.

PSS/ART:

Positive:

- Good communication within template team.
- Every PSS has the same information with template.
- Shows problems clearly and direct, good for meetings.
- Weekly template meetings are good for communication.

Feedback:

- Lots of meetings and discussion.
- Only people involved in template looks here.
- Good during collaboration but needs to be strengthen with styling.

Question 2:

a) Approximately, how much time do you spend on engineering template related activities every week?

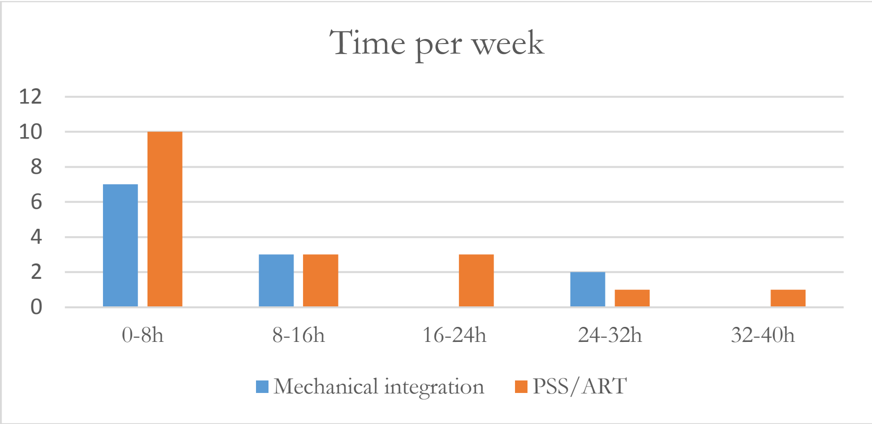

Figure D6. Survey result regarding time per week

b) Please, mention the three most common activities.

Written answers:

<u>Mechanical integration:</u>

- Updates.
- Meetings.
- Administration/communication.

<u>PSS/ART:</u>

- Synchronization.
- Meeting.
- Updates.

Question 3:

Mention the one most common activity you spend your time on regarding engineering templates.

<u>Mechanical integration:</u>

Meetings.

<u>PSS/ART:</u>

Updates.

Question 4:

a) Pick the one alternative where you think engineering templates contributes the most with.

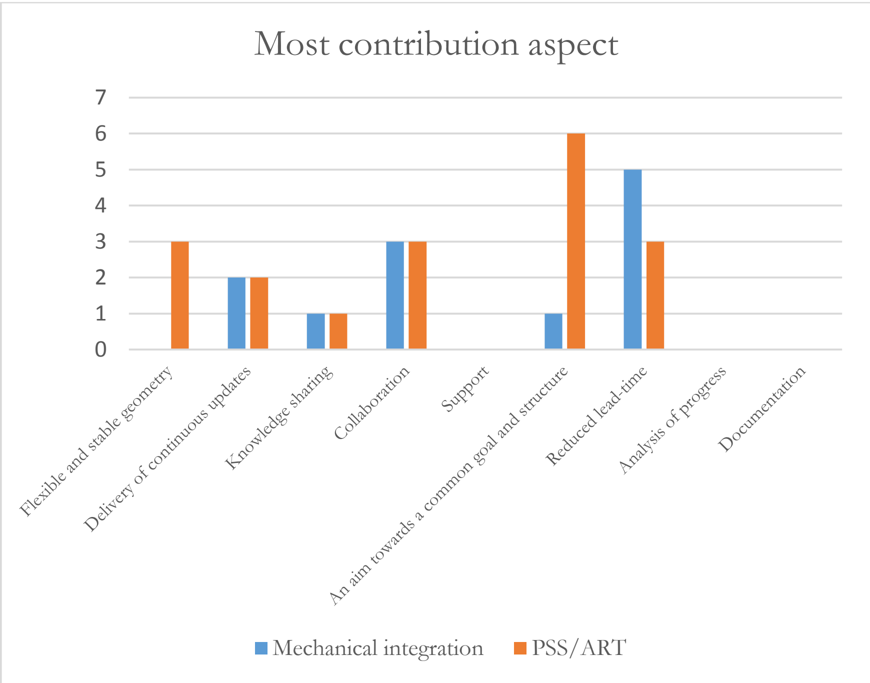

Figure D7. Survey result regarding most contribution aspect

b) Please, justify your answer by arguing for the selected alternatives.

Written answers:

<u>Mechanical integration:</u>

Comments:

- The time to give feedback to design has reduced.
- Agreed expectations and way of communication helps a lot.
- Engineering templates are structured way of working with defined information flow and common goal.
- We can give feedback to design faster and the ARTs/PSSes can update their models faster than if we did not use templates.
- Most of the alternatives above are true but I think the most important is that we now with eng template get the answers with good quality earlier that before.
- When integrating a vehicle, there are billions of different ways of doing it, so a lot of trial and error is needed in order to find the best solution. Template makes this work more efficient.

PSS/ART:

Comments:

- Quick input and output.
- Saves time to develop parts.
- Fairly quick to update models.
- Packaging issues becomes clear.
- Good to have some interfaces defined early and organised.
- Easier for all involved to get the picture when all inputs is there.
- All involved PSSes get the same output and know in which direction to go.
- The collaboration and knowledge sharing in the team secure a more reliable delivery.
- The template contains several stakeholders and their demands must be balanced for the common goal: a feasible and cost effective result.

c) If you feel the need to highlight more alternatives, you are allowed to write down up to two more alternatives here. If you write down two extra alternatives, specify which alternative that is number two and three of importance. Please, argue why you pick the extra alternative(s). This question is not mandatory.

Mechanical integration:

Comments:

Equal number of votes on:

- Delivery of continuous updates.
- Aim towards a common goal and structure.
- Collaboration.

PSS/ART:

No relevant comments

Question 5

a) Pick the one alternative where you think engineering templates can benefit the most from improvement.

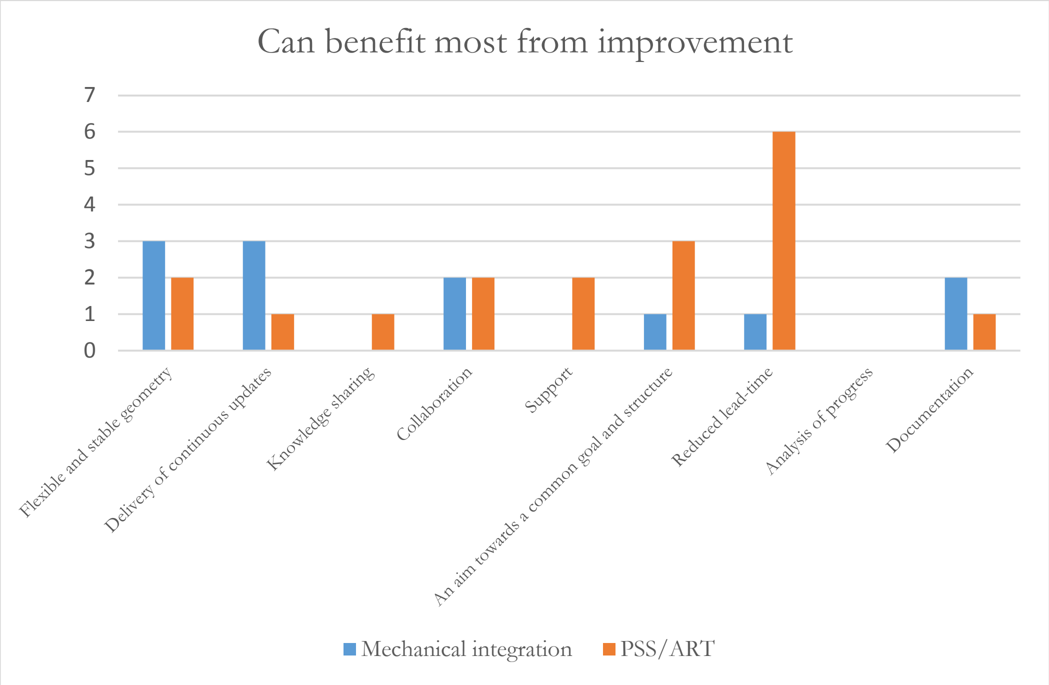

Figure D8. Survey result regarding benefit most from improvement

b) Please, justify your answer with one argument for the selected alternative.

Written answers:

Mechanical integration:

Comments:

- All teams need to collaborate more.
- Collect the efforts in same direction.
- More concepts needed in some areas.
- I think there is an opportunity to shorten the lead-times even more.
- Update of template with the knowledge and best practices learned from running projects.
- Continued documentation improvements needed to help new users come on-board quicker with correct knowledge of the working methods.

PSS/ART:

Comments:

- Highlights critical areas.
- If the process would be faster it would be good.
- Everybody speaks the same "language" with template.
- With quicker information thru template lead time will decrease.
- It could sometimes be hard to get all involved to attend meetings.
- Good to inform other PSS areas with latest status, and in an organized way
- The cross functional team works better when the team is collocated full time.

c) If you feel the need to highlight more alternatives, you are allowed to write down up to two more alternatives here. If you write down two extra alternatives, specify which alternative that is number two and three of importance. Please, argue why you pick the extra alternative(s). This question is not mandatory.

Mechanical integration:

Comments:

Equal number of votes on:

- Documentation.
- Knowledge sharing.
- Flexible and stable geometry.

PSS/ART:

Comments:

- Even collaboration is very important.

Question 6

a) Today, engineering templates are to some extent automated at a mature stage. However, it requires manual input from designers and mechanical integration in order to verify the validity of the content. How would you react if artificial intelligence, AI for short, would be integrated in engineering templates and thereby make the template process more automated?

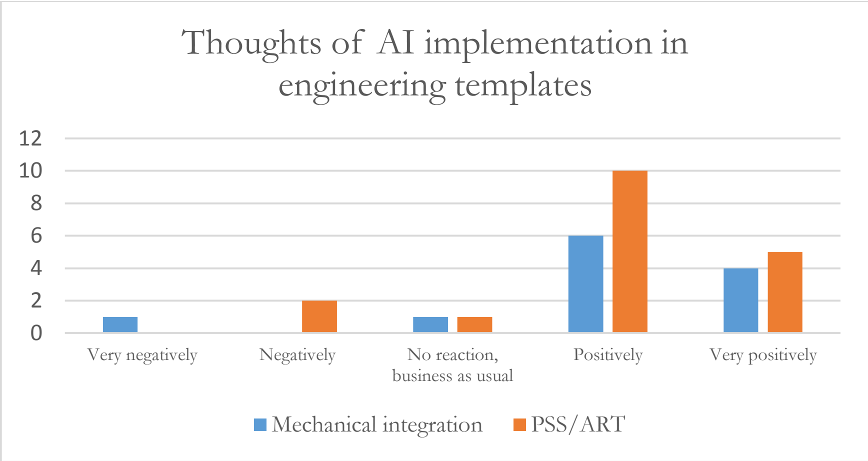

Figure D9. Survey result regarding AI implementation

b) Please, mention why you would react in the answered way.

<u>Mechanical integration:</u>

Comments:

- It would be exciting to see if AI can be used.
- I am doubtful that it will work but positive to trying.
- AI with proper engineering overview would speed up the work.
- We can focus even more on the communication and less on the manual work.
- It is positive but we need to be careful so the knowledge does not disappear completely from humans.
- I'm all for automation. This feels a long way away though. A first step would maybe be just more use of optimizations and similar functions.
- I do not believe that AI can find the best solution/compromise. It needs a very clear input on what to aim for, which we sometimes do not even know ourselves. Analysing and understanding what and why the AI has done would probably be more time consuming.

<u>PSS/ART:</u>

Comments:

- Well it cannot take over totally.
- Time can be spent more efficiently.
- This would save time for other work.
- Not sure how this would work though.
- If AI could do the work well. Why not?
- If the outcome is reliable. Then go for it.
- Spare a lot of work and time if the process is reliable.
- Whatever helps to increase the efficiency is welcome.
- As long it provides the results, I do not see it as an issue.
- Well it is our goal to have it that smooth so AI can take over.
- If implemented correct, everything that can save time is good.
- If the area of implementation is chosen wisely, I think the effect of AI could be very good.

- It might get more precise, but I think it is good that someone from each involved PSS are in charge of his/her own models which will lead to more knowledge and understanding for the design.

Question 7

a) Regarding engineering templates, how well do you think the continuous collaboration with design works? Please, answer based on the perceived quality of inputs and outputs during the projects.

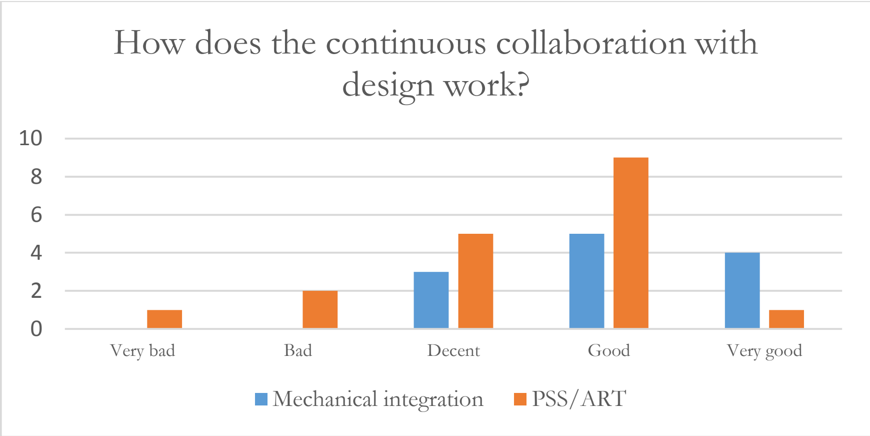

Figure D10. Survey result regarding collaboration with design

b) Please, describe shortly why you think like that.

<u>Mechanical integration:</u>

Comments:

- Communication could be better.
- Template output is very fruitful to the teams.
- The collaboration is continuously improving.
- Good collaboration about the requirements to input in the template.
- I think it is a fantastic tool to quickly assess what effects the design has on the packaging that is connected to it. It is also a good forum to provide feedback back to design, by putting a technical output model in the output level.

<u>PSS/ART</u>

Comments:

- The results from our input vary.
- Good to have a common direction.
- Better quality of surfaces than before.
- Early input to styling and fast check of new models from styling.
- Feels like they get the picture better now when we can show all impact.
- I wish we could have a better dialogue where we agree on the changes that are needed.
- I think they do their best, but very often their deliveries are moved due to lack of resources, while engineering is expected to keep same delivery of TI.

Question 8:

a) Regarding engineering templates, how well do you think the continuous collaboration between mechanical integration and PSS/ART work? Please, answer based on the perceived quality of inputs and outputs during the projects.

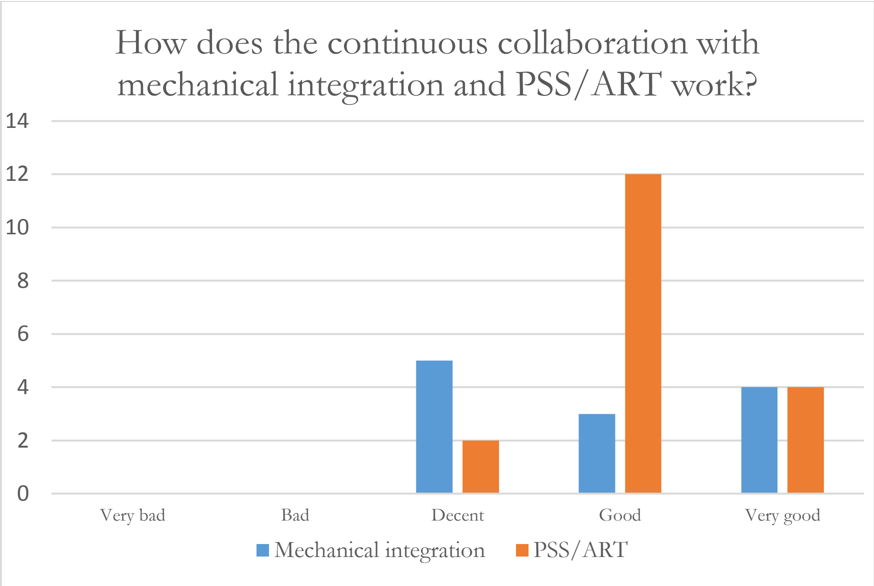

Figure D11. Survey result regarding collaboration between mechanical integration and PSS/ART

b) Please, describe shortly why you think like that.

Mechanical integration:

Comments:

- PSSes/ARTs are active in the template work.
- The collaboration is continuously improving.
- Sometimes it is hard for the PSS areas/arts to see the benefit.
- Some PSSes are very involved and engaged, while others are not.
- They join co locations and contribute with their models and ideas for development.
- Some PSSes/ARTs have very dedicated goals to build and work with the template, others have not.

PSS/ART:

Comments:

- We both understand the engineering part of it.
- More or less forced to work in same way, good.
- Good communication as far as I am concerned.
- If all are involved we will work faster and with better quality.
- It's good to have more scope on surroundings like the integration meeting provides already.
- Always available. Problem is the time that people from different PSSes can use for template work.
- Projects usually want input faster than Eng. template can provide. There could be a better alignment in time and deliverables.
- I think it is good, it feel safe that you can highlight problems that occur and we solve the problem together. They have to look over the collaboration meeting structure.

Question 9:

Overall, how would you rate Volvo Car Corporation's engineering template adaptation? Pick one number between 1-5, where 1 is the worst and 5 is the best.

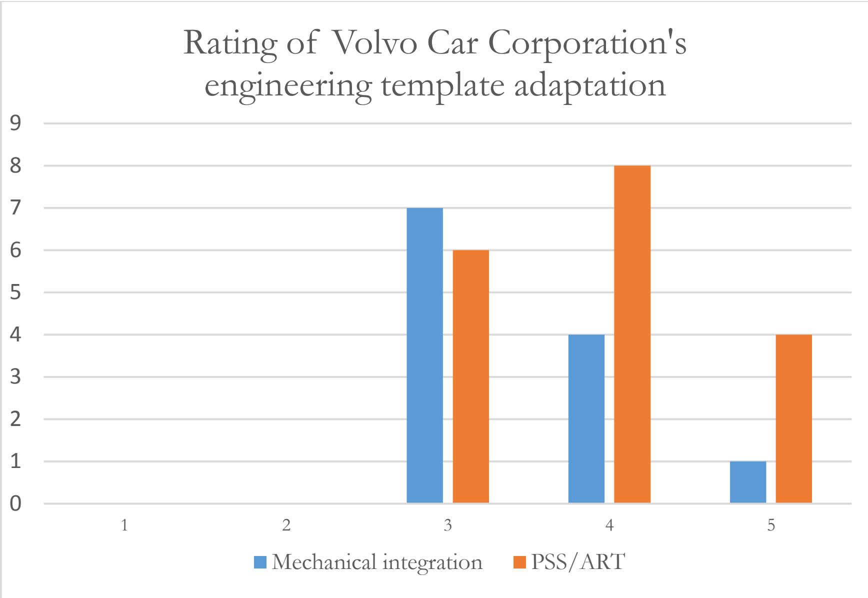

Figure D12. Survey result regarding rating of engineering templates

E. KJ-analysis for internal customer work needs

Engineering template needs					
Speed increase if focus were to get basic surfaces that the PSSs needs	Interview	PSS271	Speed	Basic surfaces	
More **detailed construction** done **in the part world** rather than template	Interview	PSS271	Construction		
Shorten template loops so they do not steal a lot of time from **construction**	Interview	PSS271		Time	
Higher **surface quality**	Interview	PSS271	Quality		
Reduce **information** from template in favor of common integration work	Interview	PSS271	Information		
Increase **efficiency** through **faster output** from template, more **time** for construction	Interview	PSS271			
Improve **communication**	Interview	PSS271	Communication		
Communication before release	Interview	PSS271			
More obvious who to **talk** to	Interview	PSS271			
Reduce **double work**, create one thing one time on one place	Interview	PSS271	Double/added work		
Slim tempaltes with data that have more users. Clear data that is not needed in the phase. **Efficiency**.	Interview	PSS271	Efficiency		
Avoid added work	Interview	PSS271			
Include **basic surfaces**	Interview	PSS271			
No **double work**	Interview	PSS271			
Base to work with	Interview	PSS271	Base		
Know **what you want** and **who to call**	Interview	PSS271	Knowledge		
Include everyone on **packaging meetings**	Interview	PSS271	Meeting		
Claim **space**	Interview	PSS330	Packaging/space		
Be included from the beginning	Interview	PSS330			
Facilitate **knowledge**	Interview	PSS330			
Claim the needed **space**	Interview	PSS330			
No sharp **edges** close to IC	Interview	PSS330			
Knowledge about cables	Interview	PSS330			
To get a **first glance** regarding how much that should get into the C-pillar in an **early stage**.	Interview	PSS330	Early		
Benefits later on in projects	Interview	PSS330	Benefits later		
Communication	Interview	PSS330			

Figure E1. KJ-analysis part 1

Model where you **quickly** can do **studies**, **updates** and **package everything that is needed** and of purpos	Interview	PSS120/Hard trim			
Package things and have known and wanted concepts with **known interfaces**	Interview	PSS120/Hard trim			
Extremely well made in **CAD**	Interview	PSS120/Hard trim	CAD		
Add in **security**	Interview	PSS120/Hard trim	Security		
Should be possible to **test** it through **fast investigations**, **move things** and the things should then **follow** whi	Interview	PSS120/Hard trim			
Save **time**	Interview	PSS120/Hard trim			
Have lot of **interest** and **experience** to understand and forsee issues	Interview	PSS120/Hard trim	Interest		
Model follows **CAD Advance** thoughts, should be **stable** and **very safe**	Interview	PSS120/Hard trim			
Has to be logical **waterfall** downward **information flow** with **good naming**	Interview	PSS120/Hard trim			
Having **own template structure** as a pre-structure with **collected information** that everyone uses	Interview	PSS120/Hard trim			
Built in a way that some should be able to get in and do changes and understand **without it being too hard**	Interview	PSS120/Hard trim			
Improve **speed** due to **lead-time** and **resources**	Interview	PSS120/Hard trim			Resources
Secure **packaging** in an early stage	Interview	PSS120/Hard trim			
More **transparancy** and **speeds** up process	Interview	PSS120/Hard trim			
Speed, **efficiency** and to **secure**	Interview	PSS120/Hard trim			
Delete all **unknowns**	Interview	PSS120/Hard trim	Unknowns		
Lower **costs**	Interview	PSS120/Hard trim	Cost		
Want an early **base**	Interview	PSS120/Hard trim			
Help packaging, make things **fit** and **compromise.** Get in our **attachements**	Interview	PSS120/Hard trim			
Initially, **early**, you want to **weight** them and then **BiW** sees them and **says this** cannot work and then we can re	Interview	PSS120/Hard trim			
Better to **make it work** and **add** things later.	Interview	PSS120/Hard trim	Functionality		
Having everything **collected**	Interview	PSS120/Hard trim			
Getting a **well functioning** C-pillar template	Interview	PSS120/Hard trim			
Secure packaging	Interview	PSS120/Hard trim			
Make **technical output** and be able to **trust** it	Interview	PSS120/Hard trim			
Save **time** and **resources**	Interview	PSS120/Hard trim			
Base **choises** on **certainty** and **facts**	Interview	PSS120/Hard trim			
Get **better details** early or all the **time**	Interview	PSS120/Hard trim			
Mechanical integration should dare to make more **decisions**, demands **knowledge**	Interview	PSS120/Hard trim			

Figure E2. KJ-analysis part 2

Base for construction as help models and design help	Interview	PSS270/271
Eases my work as constructor	Interview	PSS270/271
It is good to have **interfaces** in templates and it is a **help** with drawing the big surfaces first.	Interview	PSS270/271.
Better **surface quality**, better that it is fixed inside the template	Interview	PSS270/271.
Save own and total **lead-time**	Interview	PSS270/271.
Good way to **communicate knowledge**	Interview	PSS270/271.
Contact with very **commutative** template personnel that asks these **open questions**	Interview	PSS270/271.
Information sharing between different groups	Interview	PSS270/271.
Must provide more **value** than energy to create	Interview	PSS270/271.
Work more **efficiently** and work with **correct information**. **Lead-time**	Interview	PSS270/271.
If we work with **wrong information** it risks our own releases which can be **pretty costly** for the company in the e	Interview	PSS270/271.
Slightly scared for **double work**	Interview	PSS270/271.
Include some kind of **interface toward (tröskel)**	Interview	PSS270/271.
Create **generic interfaces** between the different cars. If it could be extended away from the door opening curve to	Interview	PSS270/271.
Cannot hinder **creativity**.	Interview	PSS270/271.
It sounds like **double work**	Interview	PSS270/271
Less **looping** due to lack of **surface quality**	Interview	PSS270/271.
To have a **shared interest** between **constructors** and **template engineering**.	Interview	PSS270/271.
Aim for the same kind of **goal**	Interview	PSS270/271.
Reduce bad **surface quality** from template.	Interview	PSS270/271.
Be **more involved** in the development as **constructor**. involvement in **discussions**	Interview	PSS270/271.
Ask simple questions, give relevant feedback to template engineers	Interview	PSS270/271.
Time efficiency	Interview	PSS270/271.
Realistic target **values**	Interview	PSS270/271.
Correct **input**	Interview	PSS270/271.
Synchronization, if there are several persons in the area that you work with the same target surface	Interview	PSS270/271.
Save **resources** and **time**	Interview	PSS270/271.
Meetings	Interview	PSS270/271.
With new **agile** working method it has become more messy since mechanical integration **plan** differently in anoth	Interview	PSS270/271.
Mechanical integration may **plan** one specific area under a certain period under one increment while we may not h	Interview	PSS270/271.
Mechanical integrations **plan** in one way that covers a longer period of time whereas we on our PSS like to **plan sp**	Interview	PSS270/271.
Start to **sync planning**. Mechanical integration **sync** their **planning** with other PSSs and **handshakes** before	Interview	PSS270/271.

Figure E3. KJ-analysis part 3

Base for **packaging** to be able to make **fast progress** and **change quickly**	Interview	PSS230.
Have an **agreement** approximately within an hour, and come to a **conclusion** so everyone involved can **work in**	Interview	PSS230.
Use of **parameters**	Interview	PSS230.
Knowledge, calculation knowledge	Interview	PSS230.
Important to know the tool **directions** and draft **angles** that are necessary for further progress.	Interview	PSS230.
Keep down the **part size**, **save money**	Interview	PSS230.
Today it **saves time**. Goes **fast** to **suggest parameters** and **communicate** these and make **preliminary de**	Interview	PSS230.
Keeping employees with working with templates and **taking care** of them. **Motivate** them to **keep working w**	Interview	PSS230.
Speed is needed, **time plans** must be kept.	Interview	PSS230.
Everyone **contributes** with their respective working areas	Interview	PSS230.
Speed, **efficient meetings**, **productive work** and **communication**	Interview	PSS230.
Early developed **model**	Interview	PSS230.
Fast decisions	Interview	PSS230.
Know the **sessions**, **packaging** aspects, what to **calculate**	Interview	PSS230.
Everything that is **drawn** and can **quickly be modified**	Interview	PSS230.
The **time** aspect.	Interview	PSS230.
Have to **educate** people in template. Also to convince the managers to **communicate** the **importance and mea**	Interview	PSS230.
Output model that the constructor **links to part mode**l and **connect** with other **links** in the **part model**	Interview	PSS230.
Design model, that you **divide** in the area and **read in what is needed.**	Interview	PSS230.
Knowledge	Interview	PSS230.
Often **discussions** regarding Q-glass, want to be able to look out. Can lead to **conflict**	Interview	PSS230.
That **all involved** through **meetings** are **satisfied** with the situation.	Interview	PSS230.
Template is **not** a **one man work** thing.	Interview	PSS230.
In the end of projects, everything should be **able to fall in place** if all is ok.	Interview	PSS230.
Communication is one big thing. Showing data and pictures, makes it easier to move forward.	Interview	PSS230.
It is important that **everyone contributes**, otherwise things slow down	Interview	PSS230.
See that things are not working and then **communicating** to design, ergonomics, requirements and so on.	Interview	PSS230.
Continuous **improvement**	Interview	PSS230.

Figure E4. KJ-analysis part 4

	Represents commonality in terms of mentions	Most important!
All main needs 1st grouping	Realated aspects mentioned nr of times	Mentioned nr of interviews
Speed	8	3
Basic surfaces	2	1
Construction/interface/input	16	4
Time	20	4
Quality	4	2
Information	6	3
Communication	15	4
Double/added work	5	2
Efficiency	12	4
Base	4	4
Knowledge	11	5
Meeting	7	3
Packaging/space	9	3
Early	7	3
Benefits later	1	1
CAD/CAD Advance	2	1
Security	3	2
Interest/experience/goal	8	3
Resources	4	2
Unknowns	1	1
Cost	4	3
Functionality	10	3

Figure E5. KJ-analysis needs categorization 1

	Represents commonality in terms of mentions	Most important!	
All main customer needs preliminary names	Realated aspects mentioned nr of times	Mentioned nr of interviews	Importance 1-5
Knowledge	11	5	5
Appropriate use of time	20	4	4
Construction interface/input	16	4	4
Good communication	15	4	4
Efficiency	12	4	4
Have a base to work with	4	4	3
Have a functional process	10	3	3
Packaging/space	9	3	3
Fast and improved speed	8	3	3
Having interest, experience and a common goal	8	3	3
Meetings	7	3	3
Early involvement and inputs/outputs	7	3	3
Correct and collected information	6	3	3
Hold down costs	4	3	3
Avoid double or added work	5	2	3
High surface quality	4	2	2
Proper resource allocation	4	2	2
Security aspects	3	2	2
Basic surfaces	2	1	1
CAD/CAD Advance	2	1	1
Benefits later	1	1	1
Unknown/uncertainty reduction	1	1	1

Figure E6. KJ-analysis needs categorization 2