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Design of Premium Top Tethers for Volvo Cars

Master Thesis in Product Development, IMSX30

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Cover: Picture showing the environment which the product is used in.
[Source : Volvo intranet]

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Abstract

The competition is tremendously tough in the premium sector of the automotive industry. The demand is high on having thoughtful designs in every part of the vehicle and achieving zero defects is simply not enough. The customer plays an important role and has a big influence on the perceived quality of the car. Volvo Cars has developed an interest in making their current top tether, which is the part of an ISOFIX system used to connect a forward-facing child seat in a car, stand out from the crowd and give an impression of premium design. To assist Volvo in making that happen, this thesis work has been carried out and aimed to discover the framework for how to develop a premium top tether. A guideline was created along with a final prototype to visualize how it should be done. One main challenge that has been encountered during the course of this project is how to objectify the subjective customer experience. The methodology that was used during this project follows the typical product development approach combined with a novel technique for collecting the voice of the customer.

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1
Introduction

This report will represent the work that has been carried out for developing the next generation top tethers of Volvo Cars sedan models, S60 and S90. The project is executed at Volvo Cars in Gothenburg and this chapter introduces the background, aim and limitations.

1.1 Background

Volvo Cars is one of the most well-known and respected premium car brands in the world[3] with multiple manufacturing plants in Sweden, Belgium, China and most recently the US. Premium segment refers to the particular segment of the automotive industry which offers top of the line features, materials and functionality for a specified price[4]. The company offers a large range of passenger vehicles that they manufacture, market and sell in over 100 countries.

In a global automobile market where there exists many functionally similar products companies want to be unique, satisfy customer needs and offer premium quality design solutions. That is the case for Volvo Cars as well, they are therefore always in need of implementing premium design solutions into every part of their vehicles to successfully gain and maintain a stable position in the premium car market.

The two sedan models that are offered by Volvo Cars are the S90 and S60 shown in figure 1.1.

[5]

Figure 1.1: Volvo Cars two sedan models

The company also offers different trim levels of each car to suit the different needs and lifestyles of their customers.

However, despite the desire of wanting to be on top it is not always straightforward how to live up to the customer's expectations. Players in the automotive industry, including Volvo, tend to develop their vehicles in shifted focus. The front half of the vehicle is often considered to be of more importance and therefore a huge amount of resources are spent on that. This is one of the reasons behind why some products lag behind when it comes to being perceived as premium as for the case of a top tether in a Volvo sedan car. There is no indication of how a premium top tether should be or look like and that is the main motive for this project. Volvo wants to know the steps they will need to take to transform their present top tether to become more premium and also what appearance it will have.

1.2 Aim

The aim of this project is to utilise both product development methods and quality ranking tools to investigate how a premium design solution can be implemented to a top tether in a Volvo sedan car. The main focus will, therefore, be on finding the most suitable solution that increases the perceived premium quality of the current solution.

The scope will only cover certain aspects of providing a premium outlook, which would be design, material and appearance. A tangible solution along with a written report with suggestions and guidelines will be the end result of this project work.

1.3 Limitations

Eight main boundaries for the aim of the project were set:

- The project looks into finding a premium solution for Volvo sedan cars such as S60 and S90. Other vehicle models are not included in the report.
- The main focus is on customers perspective on premium quality for a top tether.
- Only parcel shelf top tethers are considered.
- Design changes should follow the legal standards.
- Regulations regarding safety are not taken into consideration when developing the final prototype.
- The developed product concept should be seen as a suggestion and serve as a guideline for Volvo Cars future development of top tether solutions.
- Cost is not taken into consideration.
- The project has a time frame of approximately 5 months.

2
Literature Study

This chapter presents the literature aggregated to acquire an understanding of the topic and be able to start the project.

2.1 Perceived Quality

One of the many factors underlying success in today's automotive companies is the perception of quality of the vehicle. Perceived quality plays an important role in this area, but it is subjective and varies from customer to customer. It depends on the emotional response the person experiences from a particular design[6]. It's very important to be able to combine customer views and engineering understanding to come up with a solution. This section describes the theory behind the users perception and how it is mapped to the Perceived Quality Framework(PQF).

2.1.1 Gestalt Theory

The Gestalt theory focuses on the perception of the human mind on a particular design. According to the theory people focus more on the object as a whole than on the individual components[7].

Gestalts principles could help a designer make decisions on the designs by understanding the human behaviours. Some principles like *proximity* and *similarity* outlines how similar objects or patterns bring a feeling of coherence and harmony to user's eyes. Furthermore, the idea of *closure* could be used when designing closed objects[7].

The theory is mainly used in both development of web user interface and new product development projects as well. Though the theory has some discrepancies, it is applicable for most of the development projects[7].

2.1.2 Perceived Quality Framework

One of the main challenges is to convert the user needs into engineering expression that could be used during the development process. This can be applicable in the premium segment of automotive industry where the level of competitiveness is very high and achieving zero defects for instance is simply not enough[8].

Therefore, for a premium automotive company to be successful it's very essential to understand the dimensions of perceived quality through understanding their customers perception of that it. By doing so, identification of influences that affect the customer's perception of a product is needed, as well as the ranking of each product attribute according to importance level. Measuring and assessing those attributes gives an idea of the impact on the customer's choice.

The customers are influenced by a various number of factors such as aesthetic, functional and emotional which could affect the product outlook. All these remain subjective to the customer who uses basic senses and cognition for evaluation. This doesn't really help the engineer to know what the customer appreciates, letting the engineer rather rely on experience and intuition[8].

An objective approach is therefore much needed in order for an engineer to be able to make crucial design decisions for the product to succeed among customers. In other words, objective assessment of the subjective product attributes needs to be done with regards to different perceived quality aspects.

That is done by creating a common terminology framework that can act as a way of communicating products between industry and customers.

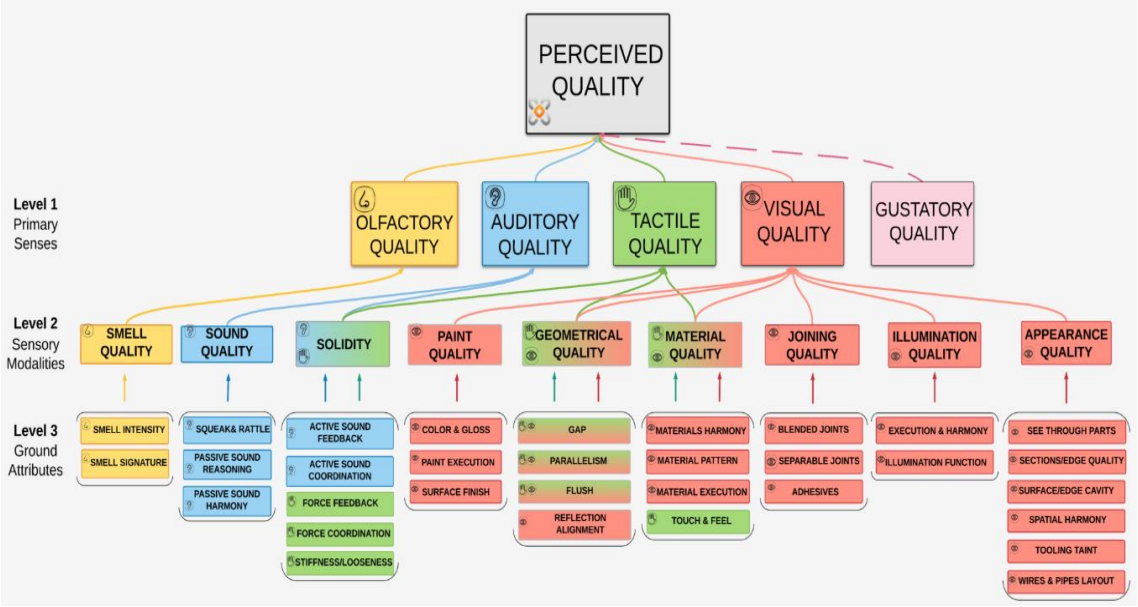


Figure 2.1: Perceived Quality attributes on all levels

According to multiple authors, perceived quality can be viewed as a set of both Value Based Perceived Quality (VPQ) and Technical Based Perceived Quality (TPQ). The VPQ accounts for the whole subjective customer experience with regards to external factors, such as brand heritage and core values. While the TPQ on the other hand represents an engineering approach and serves as a subset of the VPQ. It is based

on individual technical aspects of the product that are perceived with the purpose of fulfilling customer requirements and competitiveness[8].

The first stage of the framework is based on the human senses excluding taste. External factors are also included in this stage. The next level is referred to as sensory modalities, which includes 9 elements that are derived from the primary senses. The last level in the framework consists of 32 sub-attributes of the sensory modalities. They are called ground level attributes and serve as the communication between engineers and customers. This sectioning of the framework can be best seen in figure 2.1.

The Perceived Quality Framework has been used in combination with Best-Worst Scaling (BWS) methods to determine which ground level product attributes engineers should focus more on. That in order to receive a high level of customer appreciation when it comes to a complete vehicle[9].

2.2 Best-Worst Scaling Method (BWS)

Best-Worst Scaling method (BWS), which is also known as Maximum Difference Scaling , is a technique used to achieve importance or preference scores for various items through survey research[10]. It is based on the Method of Paired Comparisons (MPC), which is an almost 100 years old, well-appreciated trade-off approach among paired items[11]. The BWS can be thought of as an extended MPC and customized to work with larger sets of items[10].

Researches often need to measure the importance or preference of various items and seek for scaling approaches that avoids the following common problems[10]:

- Lack of discrimination among items
- Scale use bias (people use scales differently)
- Difficulty for respondents to understand how to use a rating scale

There are a few possible solutions that could avoid the above problems, for example ranking or constant-sum allocation. The drawback of these is that they become quite impractical with more than seven items to compare[10]. The MPC on the other hand works really well with more items. It uses forced trade-offs, where the respondent is prohibited from stating that all items are equally important. This enables a huge amount of comparisons between items, which leads to greater discrimination among items[10].

As mentioned earlier, the BWS is an extension of the MPC where a minimum of three items are evaluated. Figure 2.2 below shows a case in which a respondent evaluates four items, A, B, C and D. Through the respondent's answer, information about five of six possible comparisons can be obtained. If the respondent answers that B is the "Most Important" and D is the "Least Important", it can be concluded that B>D, B>A, B>C, A>D and C>D. The only comparison that is not obtained is A vs C.

Please choose the Most Important and Least Important item below.

4 / 8

Most Important		Least Important
○	A	○
○	D	○
○	C	○
○	B	○

Figure 2.2: Example of a BWS case [1].

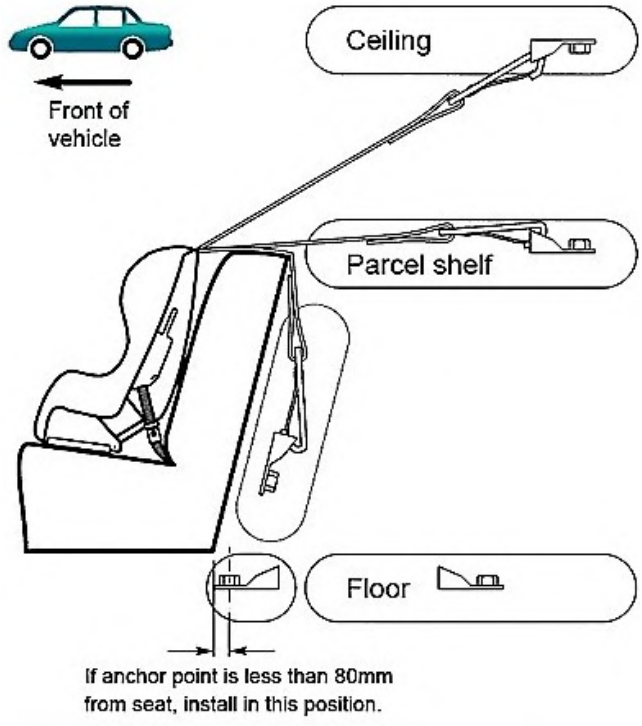
A BWS questionnaire is easy to understand, since humans are a lot better at evaluating items at extremes rather than distinguishing among items of average importance[12]. It is also free from scale use bias since the responses are aimed at choices of items rather than expressing preference. This method was later used to conduct a survey (see 5.7).

The figure 2.2 shows an interface of the software used for the survey later in the market analysis. The software is provided by Sawtooth[1] and is called the MaxDiff systems. This was used by the team to do MaxDiff or Best worst scaling experiments.

2.3 Top Tether

Having talked about the perception of products and how to possibly evaluate different product attributes, it is time to describe the product at hand.

Top tether is the part of an ISOFIX(International Standard for attachment points for child safety seats in passenger cars) system used to connect a child seat in a car. It provides the third anchorage point to firmly secure the child seat. The system consists of an anchorage, a connector and a strap. To secure the child seat, the user takes the webbing strap which has a hook or a connector and attaches it to the anchorage. The anchorage is placed such that it can transfer the load to the vehicle body [2]. The anchorage point can be located at different positions in a car. This is shown in figure 2.3.



[13]

Figure 2.3: Different anchorage points

Furthermore, research using child test dummy has found that having a third anchorage tend to reduce the load exerted on a child's head and neck region during a crash. This reduces the extent of injuries in a car crash[14]. The use of top tether also causes the decrease in misuse caused by use of regular seat belt[15]. Recent legislation has made it mandatory to have a third anchorage point for forward facing child seats[16].

"For the purpose of easier understanding and consistency, in the following chapters Top Tether would include only the anchorage and the housing/compartment"

3
Current Solution

Volvo has two solutions of top tethers based on changes in legal requirements. The legal requirements will be described later on in this chapter. Volvo's two current solutions that are implemented in the S90 and S60, are shown in figures 3.1a & 3.1b.

(a) S90

(b) S60

Figure 3.1: Top tether in Volvo sedan models

The solution for the S60 is designed according to the new legal requirements and that is also the focus of this report.

3.1 Design

As seen in figure 3.1b Volvo Car's have three top tethers placed on the parcel shelf, one behind each rear seat headrest. The top tethers can be described on two different levels.

Component level

The component level design is mainly focused on functionality and design. The top tether is positioned on the parcel shelf in relation to the headrest. It contains two parts, the lid and the body, shown in figure 3.2b. The component is available in two colours, charcoal and blonde, and is usually coloured to match the parcel shelf.

(a) Assembled view of top tether **(b)** Exploded view of top tether

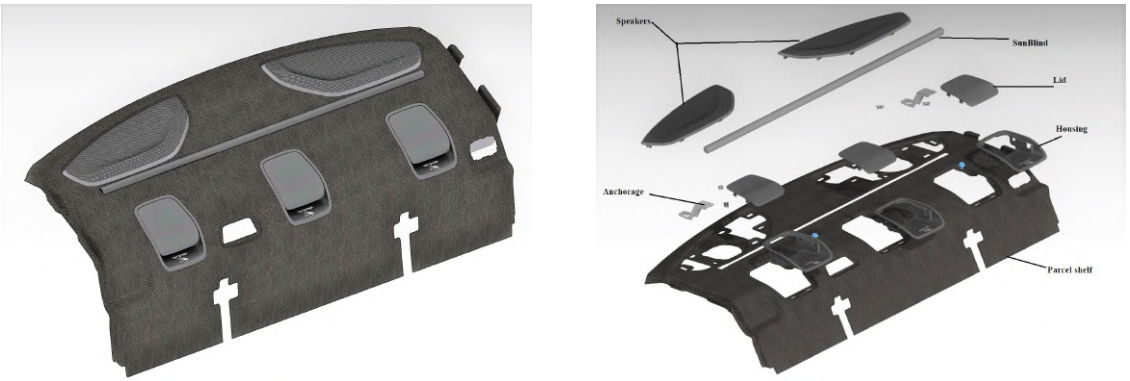
Figure 3.2: Component level of the top tether

Both lid and body are made of plastic. The lid is secured to the body through six attachment points. It is detached from the body by the user to access the anchorage point. To disengage the lid, the user has to pull it up and to place it back down, the user has to press it back down in its position. The body is firmly attached to the parcel shelf and has a hole cutout for the anchorage. The body has enough space for a human hand to access the anchorage without obstruction.

System level

The top tether system consists of the lid and body, described in the previous section, the anchorage, the parcel shelf and hook & strap from the child seat.

The anchorage is a metallic loop designed according to its legal requirements. It is mounted on the Body In White (BIW) of the parcel shelf and is aligned behind the headrest. The parcel shelf consists of three such anchorages. The anchorages at the far ends are bolted to the BIW whereas the middle anchorage is pre-welded in place at the supplier. The parcel shelf currently has a textile surface with holes cut out to accommodate the top tether compartment. Figure 3.3a shows the parcel shelf with the three top tethers in place.



(a) Assembled view of top tether system **(b)** Exploded view of top tether system

Figure 3.3: Component level of the top tether

The system level has many dependencies which make it difficult to come up with solutions for the whole system. To decrease the complexity, parts of the system such as the parcel shelf and the hook & strap from the child seat are not fully included in the development.

3.2 Legal Requirements

The legal requirements vary in different regions with the main regulations coming from US, Canada, EU and Australia. Volvo offer their vehicles to all those regions and therefore need to adjust their products to be universal and applied to all markets. Here follows a shared definition of the main parts of a child seat system:

Definitions

Child restraint system:
The system used for restraining a child under the age of 12 or 36kg during a collision to decrease the impact of injury. It consists of a child seat, buckle, adjusting devices, connectors and supplementary devices. The system should be possible to attach to the car seat[2].

Anchorage:
"ISOFIX top tether anchorage" is a metal bar that can be located in the zone specified in fig 3.4 and an ISOFIX top tether strap connector can be connected to transfer load to the vehicle structure[2].

Hook:
"ISOFIX top tether hook / connector" is used to connect the tether strap to the anchorage[2].

Strap:
"ISOFIX top tether strap" is a webbing harness from the child restraint system consisting of connector and length adjustment device[2].

Configuration

There is an ongoing proposal from the "National Highway Traffic Safety Administration" in the US to revise the legal requirements which would amend the *FMVSS No. 225* regulation to make the child seat restraint system more accessible for the user and with better load transfer properties[17]. The following changes were proposed:

- The zone for the location of top tether should to be reduced. This can be seen in fig 3.4.
- The anchorage should be a rigid metal bar.
- The anchorage should be accessible without any tools.
- The minimum distance from the reference point "R" to the tether anchorage should be 165mm. This can also be seen figure 3.4
- The anchorage point should be marked using ISO specified symbols, see figure 3.5.

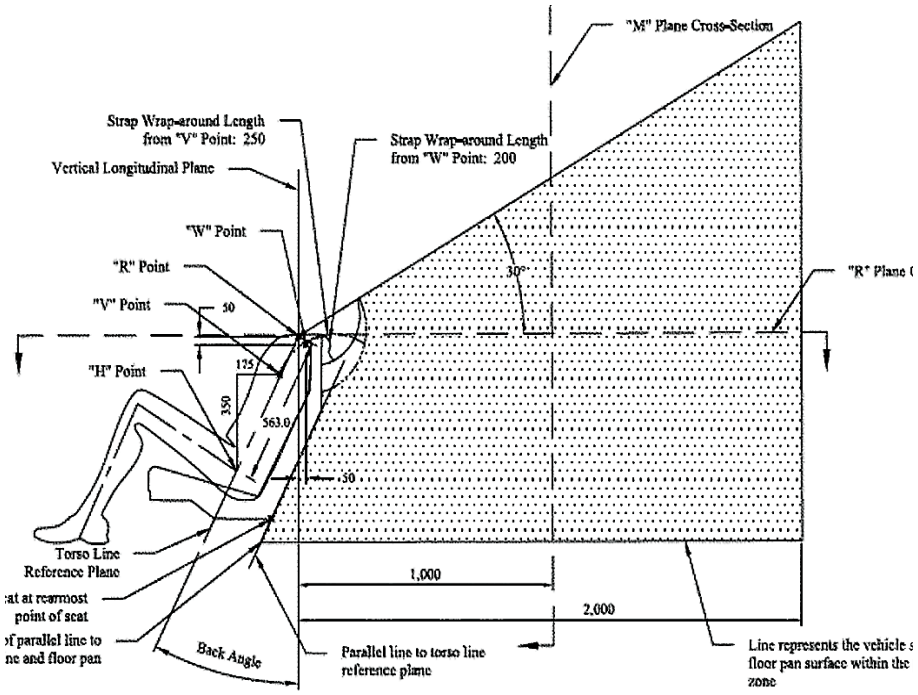
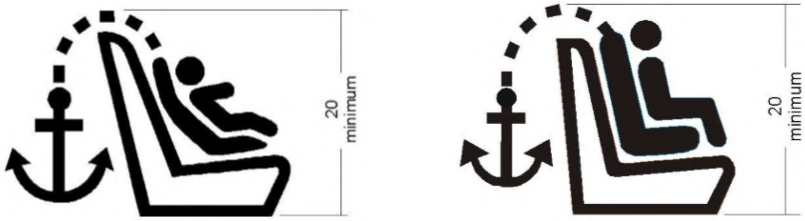


Figure 3.4: Zone for top tether placement[2].

Symbol

The new law calls for marking of top tether with symbols specified by the regulation. The symbol should be clearly distinguishable by contrast in colour or by embossing or engraving. It should also have a minimum dimension of 20 x 20 cm[17]. The two types of symbols that can be used for the top tether are shown in 3.5
The position of the symbol should be such that the shortest distance from the center of the top tether anchorage to the symbol should not be more than 25mm.



(a) (b)

Figure 3.5: Types of symbols used.

The symbol could be placed either on cap or flap used to cover the anchorage or separately. This is dependent on whether the cap or flap is attached permanently or can be detached from the vehicle. If it is permanently attached symbol could be located on the cap or flap, otherwise elsewhere where it is visible[17].

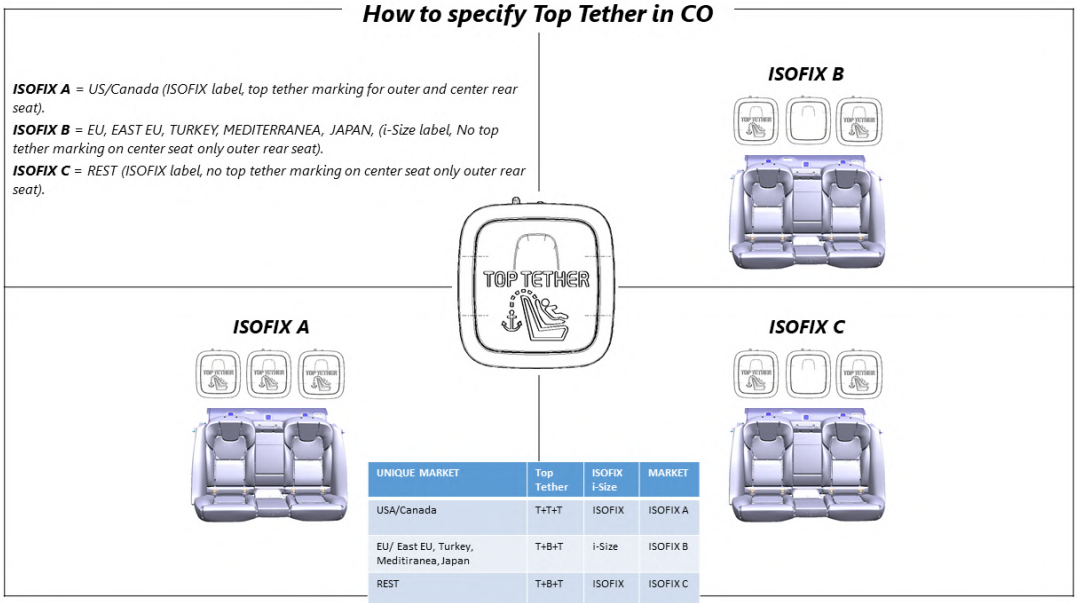


Figure 3.6: Markings in different countries.

The top tethers that should be marked varies in different regions. This is summarized in fig 3.6

3.2.1 Problems with current design

According to perceived quality department at Volvo, the current top tether design is not positively appreciated and is considered to have four main problems. In addition to Volvo's internal assessment of the product, two more problems have been experienced by the project team through examining the product. The six problems are listed below where some of them can be seen in figure 3.7.

Volvo

- The part has unacceptable execution, Which means that it has both a bad design and appearance.
- The part consists of large plastic parts. According to Volvo, the larger the plastic part the less premium it is perceived.
- The gap for belt is too large and should be made smaller.
- The space inside is not covered which leads to having visible foam, body colour and spot welds.

Project team

- The lid is not in any way attached to the body when opened and can therefore easily be lost.
- The backside of lid is not as clean as the front side.

(a) Backside of lid

(b) Big plastic part/Bad execution

(c) Big gap for belt

(d) Visible foam

Figure 3.7: Pictures of some of the main problems.

4
Method

This chapter visualizes the development process utilized in this project. The different steps are organized in a chronological order.

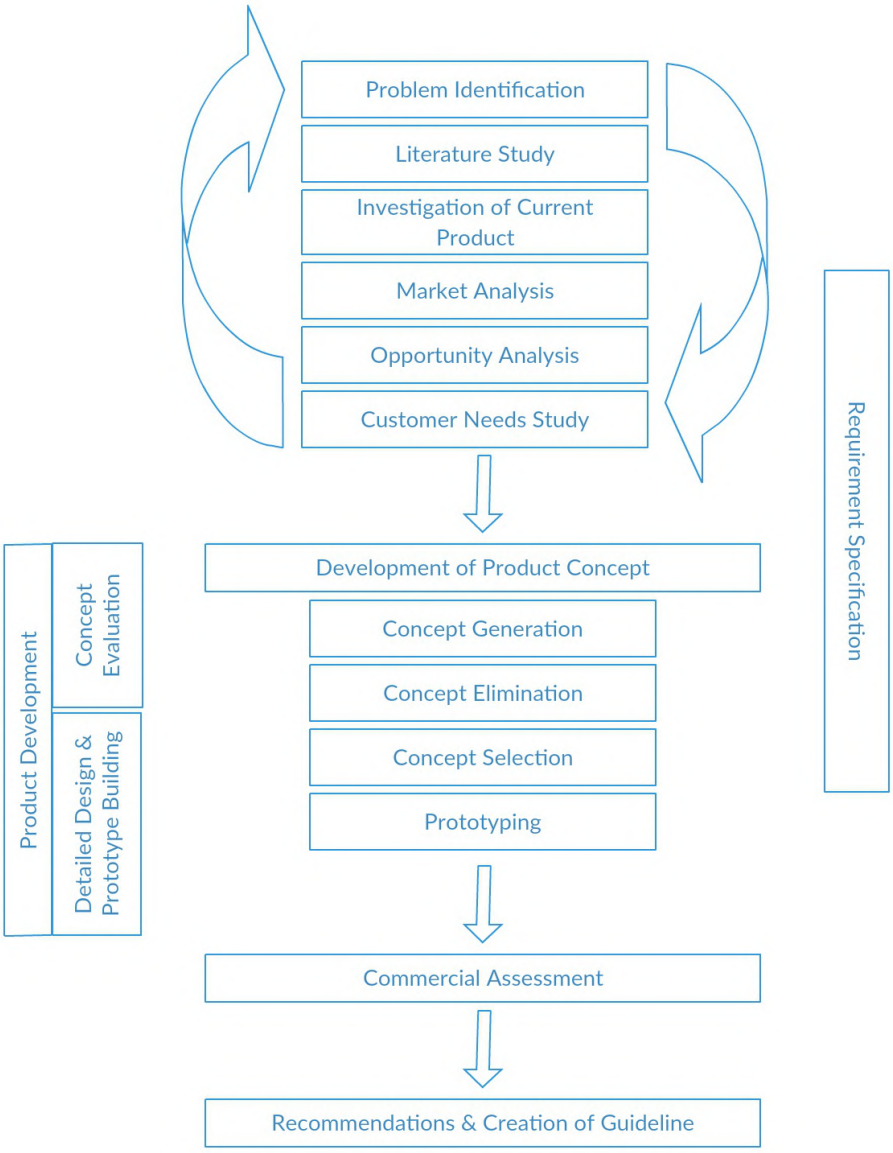


Figure 4.1: Flowchart of the development process.

4.1 Market Analysis

Market analysis was done to identify the customer needs, current solutions and the gap in the market. For this, three different approaches were used, which consisted of both Qualitative, Quantitative and Research Analysis. This provided a solid foundation for the study.

Qualitative Analysis

The qualitative analysis was done by means of semi-structured interviews. The questions asked were open-ended such as 'how' and 'why' to probe the interviewees. Some questions were also confirmatory questions to confirm the teams findings. The interviews were then analysed by grouping the data according to different areas and summarizing them in respect to unique attributes.

Research Analysis

Research analysis consisted of tools such as SWOT and benchmarking.

SWOT (Strengths, Weaknesses, Opportunities and Threats) was used to find the internal and external factors affecting the product and the company. A SWOT analysis is commonly executed when trying to gain an overview of the environment in which a project is to grow. In order for an organization to succeed in their projects, strengths and opportunities need to be taken advantage of and capitalized on, while weaknesses and threats need to be responded to, minimized and overcome[18].

Furthermore, benchmarking was also done to compare competitors products and the features available in the market. They were measured against the current solution of Volvo S60. The benchmarking study was done at car dealers within the city. The steps involved finding the main competitors for Volvo Cars and the sedan models available. This was followed by capturing various pictures in predefined scene for uniform results. Along with this, the competitors products were also evaluated by certain attributes such as material, function and execution[19].

Quantitative Analysis

This analysis was done using an online survey. More information about the survey can be found in section 2.2 & 5.7

4.2 Concept Generation

The concept generation phase consisted of multiple tools that helped trigger and nurture design ideas and pave the way for further evaluations.

Function Tree

The main purpose of creating a function tree was to pinpoint the products primary function and decompose that into smaller sub-functions. By doing this in a hierarchical manner, the relationships among main function and sub-functions are found. This to help generate alternative solutions for the sub-functions as well as the primary function. Function tree is a usually applicable when developing new products that are not too complex[20].

Moodboard

Moreover, in order to get the right feelings and to be in the right state of mind while developing the product, moodboards were created. The idea behind moodboards was to form a collage of pictures that each team member thought gave a feeling of premium and have that accessible throughout the entire concept generation phase.

Morphological matrix

A morphological matrix was also created. This to begin exploring the range of possible solutions for the pre-defined main function as well as the sub-functions. The benefit is to not miss out on possible solution combinations since many unforeseen combinations of solutions can be extracted through a morphological matrix[20].

Brainstorming

In conjunction with the other generation tools, brainstorming was used as a creativity method. The method had some rules that promoted and encouraged a big amount of generated concepts without any restrictions. The focus is on coming up with as many concepts as possible without being critical[20].

4.3 Concept Elimination

This section describes different tools used to screen and eliminate concepts according to different criterion.

Elimination matrix

This method is employed in the first phase of elimination and can be easy to use. The concepts are evaluated against a basic set of criterion. If the concepts pass through the criteria it gets a '+' otherwise it gets a '-'. By evaluating all the criteria a final decision is taken on whether a concept should be further developed or not[20].

Pugh Matrix

This tool uses the wishes and demands from the requirement list to evaluate the remaining concepts. A reference solution had to be picked for the Pugh matrix

and for that the current design was chosen. The concepts were given points in each criteria according to how well they fulfilled the criteria in comparison to the reference solution. The following scoring system was used:

- -2 = Expected to have a bad performance
- -1 = Expected to have a sub-par performance
- 0 = Expected to have an average performance
- 1 = Expected to have a good performance
- 2 = Expected to have an excellent performance

This scoring system was used to be able to distinguish the concepts in a more decisive way and eliminate mediocre concepts. Usually a scoring system of three levels is used (-1, 0, 1). The scores were added for each concept and in the end only concepts with positive values were allowed to pass through this gate to the next elimination phase[20].

Kesselring

This method is employed in the last phase of elimination. It is a tool similar to Pugh Matrix but each of the criterion is weighted from 1 to 5. The concepts are evaluated and ranked against a datum. This aids in prioritizing requirements that are important and eliminating concepts accordingly[20].

5

Market Analysis and Need for a New Product

The chapter contains the market study done for the project. It include Qualitative, Quantitative and Research Analysis.

5.1 Interviews

To get more information about top tethers and Volvo's idea of premium feel, a series of interviews with industrial professionals within Volvo were performed. The interviews were open-ended with a duration of 15-60 minutes which allowed room for discussion. Interview questions were related to the role of each interviewed industry professional which helped with gaining their perspective on premium feel and understanding the product even more. Some of the questions were also related to the design and legal requirements of the top tether. The following persons participated in the open-ended interviews:

Name	**Occupation**	**Area of Expertise**
Marcus Kollbratt	Team Manager	Carpets, Headlining & NVH Parts
Joakim Hermansson	Solution Business Owner	In Car Experience
Maria Uggla	Senior Design Manager	Colour & Material Design
Niklas Funke	Senior Studio Engineer	Interior
Mats Olofsson	Surface Material Engineer	Interior Surface Material
Sven-Olof	Senior Design Manager	Interior
Birgitta Carlsson	Design Engineer	Interior Surface Material
Casper Wickman	Technical Leader	Customer Experience
Gert Aldeborg	Concept Designer	Seatbelt & Child Restraints
Sara Alpsten	Analysis Engineer	Ergonomics
Åke Sandberg	Analysis Engineer	Testing Exterior & Interior
Anna-Maria Lignell	Quality Engineer	Quality
Carl-Johan Kaudern	System Architect	Carpets, Headlining & NVH Parts

Analysis

In the following section an analysis of the conducted interviews is done. The interviews were summarized under various headings according to different areas.

Design

Design plays an important role while developing a product. The premium feel is perceived differently by different people. Design of product includes aspects like colour, material, geometry, and tolerances. Sven-Olof and Maria talked about having a minimalistic and clean design. This could help in cutting the cost of production and having an intuitive design. The gaps, flush and parallelism also plays an important role. The product with a good fit and finish appears premium. According to Sara Alpsten, ergonomics of the design also plays a vital role. Factors such as force of operation, shape, identification and placement should also be taken into account.

Niklas Funke mentioned that the cost acted as a constraint while developing the current top tether. The company doesn't want to spend too much money on the top tether since it's one of the lesser important areas in the car.

On the other hand the top tether should look good even when in use. This calls for a good design inside the compartment. The focus should therefore not be only on the product's outer surfaces. Other requirements such as covering the attachment points, hinges, hiding visible foam, touch and feel were also suggested by the interviewees.

Materials

Materials is directly linked to how a design is perceived by a customer. It is self-evident that certain materials are perceived to be better in terms of quality. At the same time there are several factors and aspects that must be taken into account in order for a design to be appreciated by a customer. It is not just about the price of the material. The interaction between material and functionality is very important and has a big impact on how a product may be perceived.

Leather is an expensive material and is considered to be premium, but it is for instance difficult to use leather on the parcel shelf where the temperature can get really high. Chrome details are nice and much appreciated by customers, but exaggerating the use of chromium can have a more negative than positive effect. Plastic details are good to have on surfaces that are excessively used, but there is always a risk that the car will feel too plastic.

Volvo sees that the trend in the market right now is to use high gloss black and wood details. What is interesting to know is that there are possibilities to, in different ways, be able to manipulate the surface of a plastic to create patterns.

Legal Demands

The upcoming legal demands mentioned in 3.2 provides as a guideline when developing the new top tether. The rules and regulations may vary in different markets. They can be summarized into three main groups: US, Europe and Australia. In this, Australia has the toughest set of regulations.

Takeaways

Some interesting ideas and facts were pulled out from the interviews. Each industry professional contributed in a different way but still they all had some similarities in their way of thinking when it comes to premium feel and perceived quality from a Volvo customer. A common thread could be followed when summarizing the interviews. It provided that the premium feel is to be perceived through three main areas. Those areas are Function, Design and Execution. "For a product to be perceived as premium it has to have a certain function and be correctly adapted to that function, have a good and appealing design that catches the eye and last but not least have a good execution where everything within the product is in harmony", cited from one of the interviewees.

5.2 Competitor Benchmarking

To learn more about competitor's top tethers and their position in the market, a benchmarking study was carried out. Conducting a benchmarking helps providing a scale for measuring and judging performance compared to other industry leaders. It's very important for a company to understand competitor's products and technologies and its comparative position in order to identify customer needs, improve concept generation, establish product specifications, etc. The following section summarizes benchmarking of top tethers.

Methodology

The initial strategy was to use benchmarking portals such as A2Mac1[21] & Calidat Go[22]. However, this didn't provide intended results as photos and details were scarce or even non-existent. The team then decided to visit car dealers within the city. The interviews and the literature study done earlier provided a base to evaluate the premium feel in a car. It was summarized into three main areas: Function, Design and Execution. Questions related to these areas were formulated to compare the top tether in sedan models of other car brands to Volvo S60. While conducting the benchmarking photos and videos of the top tethers in different views were taken for further analysis. The material of the top tether and parcel shelf was also examined and taken into consideration

Main competitors of Volvo Cars

Nowadays, Volvo Cars position themselves in the premium car segment and according to internal sources in the company it was found that their main competitors are

the three big German car manufacturers: Mercedes Benz, BMW and Audi.

Mercedes Benz

Mercedes Benz is a car company owned by Daimler. It started its production in 1901. The company is one of the pioneers in the premium segments with record number of sales in the past years. Their tagline 'The best or nothing' attracts customers from all age groups. They have well integrated development and customer experience programs to incorporate premium and luxury feeling to their customers[23].

The top tether was investigated for following Mercedes cars:

(a) **(b)** **(c)**

Figure 5.1: Mercedes coupe AMG

(a) **(b)** **(c)**

Figure 5.2: CLA 220d Coupe

(a) **(b)** **(c)**

Figure 5.3: Mercedes S400D

Advantages (+)

- All of the Mercedes Benz solutions for a top tether have a lid that is mounted with hinges.
- When the lid is up, the space inside is mostly covered. If not then visible details are coloured to match the surroundings.
- Anchorage colour to match car colour (5.2b).
- Top tether is placed behind headrest in some models. Parcel shelf looks clean.

Disadvantages (-)

- The top tether is hard to reach in some models. Not enough space for the hand. The headrest is in the way (5.3c).
- Thin plastic parts that look cheap.
- Text and symbol are not correctly aligned in some models (5.1c).
- Lid has different opening levels and cannot be fully closed.
- Non-adjustable headrest. No space between headrest and seat for tether strap to pass through
- The top tether is too near the speakers, which gives an impression of misalignment.
- Gaps visible between lid and outer frame.
- Counter-intuitive design. It seems that the lid can be opened in two different ways. One by pushing the lid in the far end and the other by pulling the lid upwards from the near end(5.2c).

BMW

BMW is a international car manufacturer owned by BMW group. They were able to strengthen their position in the premium market by including sport models, electric vehicles and implementing sustainable mobility. They have also expanded to China with their premium models[24].

The top tether was investigated for following BMW cars:

(a) (b) (c)

Figure 5.4: BMW 330i

(a) (b) (c)

Figure 5.5: BMW M5 Sedan

(a) (b) (c)

Figure 5.6: BMW M2 Coupé

(a) **(b)** **(c)**

Figure 5.7: BMW 740e M Sport

Advantages (+)

- Most of the BMW solutions for top tethers have a lid mounted with hinges.
- When the lid is up, the space inside is mostly covered. If not then visible details are coloured to match the surroundings.
- The model shown in (5.7b) has the interior covered entirely using plastics.
- Anchorage colour to match car colour (5.5c).
- In some of the models the lid can be closed when in use (5.4a).

Disadvantages (-)

- Some of the top tether solutions don't have any hinges and are just pressed into place (5.7a).
- Small gaps are visible
- Thin plastic parts that look cheap.
- Text and symbol are not correctly aligned in some models.
- Lid has different opening levels and cannot be fully closed.

Audi

Audi has been a coveted car brand for the last 20 years and played a big part as an auto manufacture with a clear philosophy and a brand that highlights sportiness, progressiveness and sophistication. "Progress through Technology" is one their main drivers[25].

The top tether was investigated for following Audi cars:

(a) **(b)** **(c)**

Figure 5.8: Audi A5

(a) **(b)** **(c)**

Figure 5.9: Audi A8

Advantages (+)

- All of the Audi cars have a hinge for the lid in the top tether.
- Material used for the top tether has rubber like feel (5.9c).
- Consistency in design across models.
- Simple but heavy and compact design

Disadvantages (-)

- Lid has different opening levels and cannot be fully closed.
- Gaps present between lid and the outer frame

Top tethers of other car brands were also examined. Many similarities were found but also a few differences. Among the cars investigated, Mustang GT was the only car with a circular shaped top tether (5.10a). Jaguar XF had a lid that is attached in one end through a plastic strap instead of hinges (5.10b). This is probably cheaper to have but the negative aspect of it is that the lid can not stay up. A few Lexus cars were also evaluated. The lid of Lexus LC 500 Sport is pressed down from behind when opening (5.10c).

Volvo's performance car, Polestar 1, which is an electric performance car was also benchmarked. Their focus is on uncompromised design and technology. They state

(a) Mustang GT **(b)** Jaguar XF **(c)** Lexus 500 sport++

Figure 5.10: Top tethers of other car brands

that their products are built without any compromises and are excellent, efficient and entertaining. "At Polestar, sky is the limit"[26].

The top tether of the polestar 1 is significantly different from all the other top tethers. More thought is put into the design and the function of it. Besides the fact that it is nicely integrated and coated with aluminium. It also offers additional features that provide the customer with more value. It has an inbuilt space for an SD-memory card. Figure 5.11 below shows the design, appearance and features of the top tether in the polestar 1.

(a) **(b)** **(c)**

Figure 5.11: Top tether of Polestar 1

5.3 SWOT

An organization is usually affected by internal and external factors that could be summarized as Strengths, Weaknesses, Opportunities and Threats[18]. A SWOT analysis has been performed with the following outcome:

5.3.1 Strengths

Positive internal attributes that are both tangible and intangible to an organization. They can be controlled by the organization.

Early development

The development process for the new top tether was started as early as 2016. The company even had the new design implemented according to the upcoming legal demands. This makes it easier to further develop and improve the product.

Modern Scandinavian design

Scandinavian design is associated with minimalistic and clean attributes with increased functionality[27]. Customers relate Scandinavian design to premium quality. Volvo being a Swedish car brand implements Scandinavian design in its models.

Safety as core value

One of Volvo's core values is safety and their expertise in this area could be a decisive part in the development of such a product.

5.3.2 Weaknesses

Weaknesses are also controlled by the organization and can be seen as the things that can be improved. They are factors that hinder the organization from reaching its goals.

Resources

The level of importance of the top tether is not as high as other areas in the car which could limit the amount of resources spent.

Thought lock

There is always a risk of getting stuck in a specific train of thoughts when trying to come up with new design ideas. It's therefore important to see beyond what already exists and try to explore novel ideas.

Design restrictions

The design of the Body in white (BIW) and parcel shelf is fixed for the car models. This makes it harder to come up with ideas that could result in significant changes to the structure.

5.3.3 Opportunities

External factors that give the organization reasons to keep on developing and improving.

New markets

Other premium car brands have only managed to achieve basic designs of the top tethers. Developing a new premium solution could make it the first in the market. This would help the company solidify its position in the premium segment and have an advantage over the competitors.

Integrated features

The project provides the possibility to integrate features to the top tether that could be exciting to the customers.

New regulations

New upcoming regulations means more accessibility to hook and a bigger space for the top tether. This makes it more visible on the parcel shelf, which opens up the possibilities for an optimal premium solution.

5.3.4 Threats

These factors are beyond organizational control and could place the organization at risk. It includes the obstacles that an organization may face and how well competitors are doing.

Experienced competitors

Competitors who have been big players in the premium segment for longer time can be a threat if working on similar projects and could introduce a solution to the market ahead in time.

Usage

The usage of a top tether is different in different markets and may not be as frequently used in Europe as in the US. This can be seen as a waste of resources, with no added benefit to the customers.

5.4 Key Takeaways

- There hasn't been a lot of innovation in the market and companies are only delivering simple and basic products, with no added value to the customer.
- Volvo Cars is one of the few companies that have started to change their design based on the expected new legal demands.
- There is a tremendous opportunity in the market for Volvo to be ahead of their competitors.

5.5 Product Positioning

Investigations of competitors, customer requirements and market opportunities shows a big potential for the top tether to enter new areas and break new grounds. Most of the top tether solutions on the market today are all more or less similar and do not stand out in any particular way. Biggest difference between Volvo's solution and the competitors is the detachable, loose lid. Competitors usually have a hinged solution for the top tether's lid.

Target vehicles for this project are, as mentioned previously in the report, the Volvo sedan models, S90 and S60, and thus the target customers would be the Volvo sedan car owners. With their products, Volvo Cars are targeting what they call the "Postmodern Cluster". Which is considered to be a group of people that are independent, conscious and confident. They have high demands on all products they surround themselves with and what kind of image they want to portray[28].

The ones that buy the S90 are usually conservative in their way of living and are attracted to prestigious and dynamic brands. Luxury for them should be characterized by thoughtful design and defined by experience rather than just a show off. Unique, high-end products reflecting their success is an important attribute for them[28].

The S60 is rather purchased by more progressive buyers that are always looking for the latest thing, the latest technology for example or something totally new. They value the human-centric attention to detail that Volvo implements into their cars and combines with the traditional, premium and luxury[28].

Figure 5.12 shows Volvo's position in the market, according to their top tether. Given that most brands, including premium brands, are only trying to achieve the most basic solutions when it comes to top tethers, then targeting a real business opportunity would include finding solutions that are valuable, rare, inimitable and non-substitutable, according the VRIN-framework. This means that Volvo would climb up the "Premium feel" axis and position themselves in the red box around polestar and ahead of their competitors. This could also be argued as a solution that falls under Volvo's consumer philosophy and provides "excitement" characteristics for the customers as well as serving as a new business opportunity for Volvo.

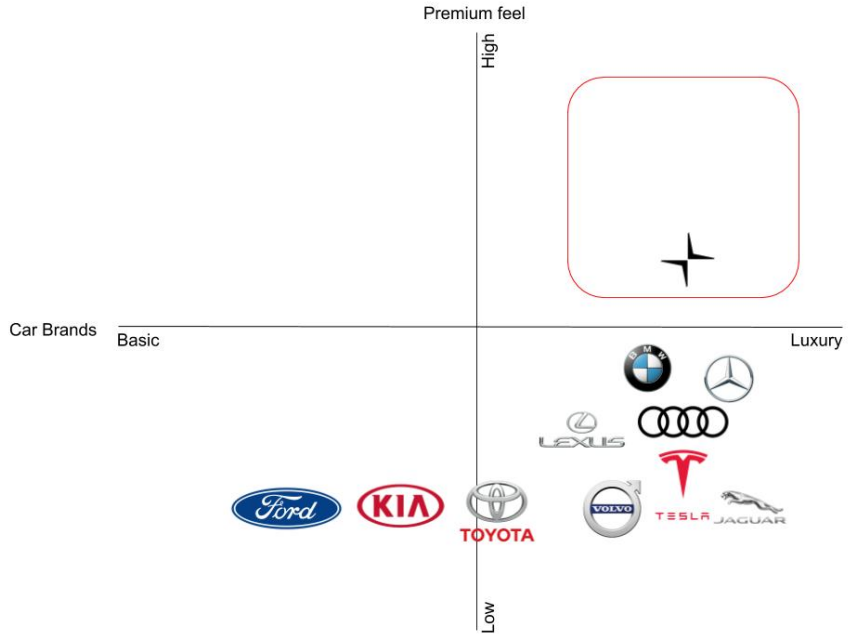


Figure 5.12: Product positioning

5.6 Requirement List

By starting the development process a requirement list was compiled. This was done using the information gained from literature, interviews, benchmarking, and the proposed new legal demands. The list is constantly updated during the development process. This would help the team to fine tune the list and in the end, help in making a guideline for premium top tether development.

The requirement list is divided into five different sectors, which can be seen in figure 5.13 below. For the detailed requirement list, see Appendix H.

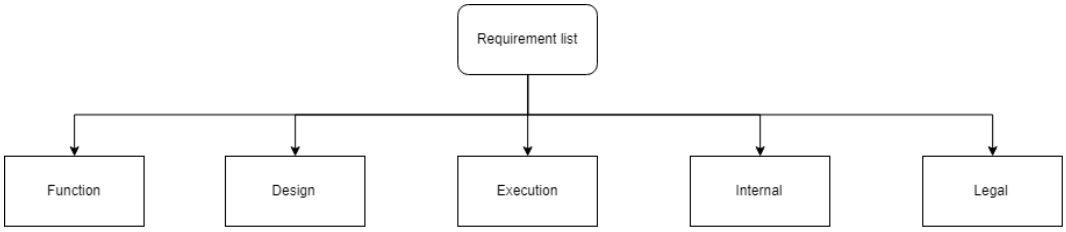


Figure 5.13: Requirement list is divided into design, function, execution, internal and legal requirement

5.7 Survey

To be able to communicate the top tether solution to the customers, parts of the requirement list were mapped against the previously mentioned Perceived Quality

Framework (PQF), described in chapter 2.1.2 . Each of the sensory modalities in the PQF is described and a group of ground attributes are assigned to it. For a top tether (to have an appreciated first impression) the visual quality becomes an essential part to target.

The sensory modalities that belong to the visual quality and that are important for obtaining a premium top tether are as suggested to be the following five, with corresponding ground attributes:

Geometrical Quality
- *Gap:* The distance between two parts.
- *Flush:* The alignment of two surfaces so that they fit evenly.
- *Parallelism:* Parallel relations between parts.

Material Quality
- *Materials Harmony:* A proper adjustment of the materials and their components regarding harmonization of colours and textures.
- *Material Pattern:* The appearance and direction of the texture on the surface.

Illumination Quality
- *Illumination Function:* The logical function of the illumination.

Appearance Quality
- *See-through Parts:* Parts that can be visible through gaps, for example foam and body colour.
- *Spatial Harmony:* Visual balance of parts and harmony in design.

Joining Quality
- *Separable Joints:* Appearance, number, and placement of visible attachment points.

The above attributes were used to conduct a survey research for evaluating and ranking the overall importance of each attribute.

5.7.1 Method

The methodology for the survey is described here.

Best-Worst Scaling (BWS) method was used as the quantitative survey technique for this. It was created through the MaxDiff Sawtooth Software[1]. A BWS study with all ground attributes was designed. The 6 sensory modalities are branched into their corresponding ground attributes as described earlier, whereas "Material Harmony" is divided up further into 6 different materials: Plastic, Wood, Leather, Carbon fiber, Metal and Metallic details. This resulted in a BWS study of a total of 14 ground attributes.

Each attribute, or item as it's called in the software, was shown to the respondent an equal number of times. Each item was also paired with other items an equal number of times. The survey design process is repeated a 1000 times by the software to achieve the best balance between the attributes. The order is totally randomized for each version of the survey[10].

The number of items and sets to show per question is recommended to be between 3-5 items and at least as many sets as the total number of items in the study[10].

When conducting the survey the respondent has to first answer a few background questions and then be presented with several images showing the different ground attributes with a short description of the attribute. The images were shown in a set of three and the respondent was asked to choose the most and the least important attribute for a premium look. This process was repeated 18 times, 4 times more that the number of attributes.

The average time to complete this survey is 15-20 minutes and Appendix C is showing a sample of the complete survey.

5.7.2 Results

The overall results of the BWS method can be seen in table 5.1.

Regardless of gender, age, usage or car interest, spatial harmony is the most important attribute according to survey respondents. This can be related to the gestalt theory saying that people focus more on the object as a whole than on the individual components. The task for the engineer would be to minimize the visual imbalances and create natural relations between the parts. The geometrical quality attributes, flush, gap and parallelism are the next top choices, which was rather expected. This can be explained by the fact that these ground attributes are the ones that engineers already do know that they should focus on.

Ground attribute label	Importance score (N=200)	Lower 95%	Upper 95%
Spatial harmony	12.66	12.07	13.25
Flush	11.89	11.33	12.46
Gap	11.31	10.74	11.87
Parallelism	10.72	10.15	11.30
Metallic Details	7.81	7.10	8.52
Metal	7.62	7.00	8.24
Separable joints	6.12	5.57	6.68
Carbon Fiber	5.66	5.06	6.26
Plastic	5.00	4.49	5.51
Illumination function	4.94	4.33	5.55
See through parts	4.88	4.22	5.54
Material pattern	4.83	4.30	5.37
Leather	3.28	2.80	3.75
Wood	3.26	2.78	3.74

Table 5.1: Importance ranking of Perceived Quality attributes obtained from the BWS conducted among customers.

5.7.3 Analysis & Discussion

The survey was intended to be answered by people without any technical background. This was done to avoid biased answers. Therefore, to begin with, the survey was distributed among only HR department at Volvo. This didn't provide enough answers which could be due to a lack of interest or survey being too time consuming. That led to the survey being circulated among all engineers in interior department at Volvo. The positive aspect of this is that a total of 200 responses could be collected and the survey technique could be utilized. The negative aspect on the other hand is that it's inevitable that the answers will be biased and based on engineers already existing knowledge about each attributes importance.

Furthermore, one reason behind the importance ranking of the three geometrical attributes is most likely due to the engineering background that the majority of the survey respondents had.

One interesting attribute that also ended up high on the ranking list in fifth place, directly behind the geometrical attributes, is the incorporation of metallic details. According to internal interviews at Volvo, metallic details are a dying trend. The survey shows that this does not necessarily have to be the case. This deviation could have its origin in the fact that perceived quality in the premium automotive segment is motivated, to a wide degree, by the fierce competition[8]. There is no space for assessment and evaluation if a material is good enough for 10 more years or not.

As mentioned earlier(5.7.1), the initial part of the survey consisted of a few background questions. Those questions were mainly used to obtain a base for better understanding of the demographics among survey respondents and also to better

target customers in line with their preferences. 75% of the respondents were males and the rest were females but there was no significant difference in their ranking of the attributes. Both sexes thought less of having leather or wood on the parcel shelf, which was quite unexpected. However, going through the feedback gave an explanation to why those materials were ranked low. The respondents highlighted the bigger importance of having a good execution rather than the choice of material. Moreover, the cost and the usage ratio of the top tether were commented. One of the many comments states "Top Tethers are not used by the main part of our customers. Wood, leather and carbon fiber looks wrong to me, it looks like wasted money and highlights a function seldom used".

This actually indicates that wood, leather and carbon fiber are considered to be high-end materials and would therefore be unnecessary to use on a part that is barely used by the customer. However, if the survey had been sent out to the intended audience, the results would have been different.

This gave inspiration to develop two different concepts. One concept that can act as a quick improvement of the current design, easy to implement and focuses mainly on solving the existing problems with the product and a second concept that is more on the innovative side and with greater focus on being appreciated as premium. The following chapters will describe the creation and development of concepts.

6
Development of Product Concepts

The following chapter will describe the developed product concepts, based on the findings from previous chapters and the process of concept generation and elimination.

6.1 Function-means Modelling

The concept phase started with the modelling of a function-means tree to establish the products main function and its corresponding means without stating any solutions. Figure 6.1 below shows the hierarchical tree for top tether at three levels. This is done to discover the range of decomposed sub-functions and start thinking about a composed total solution.

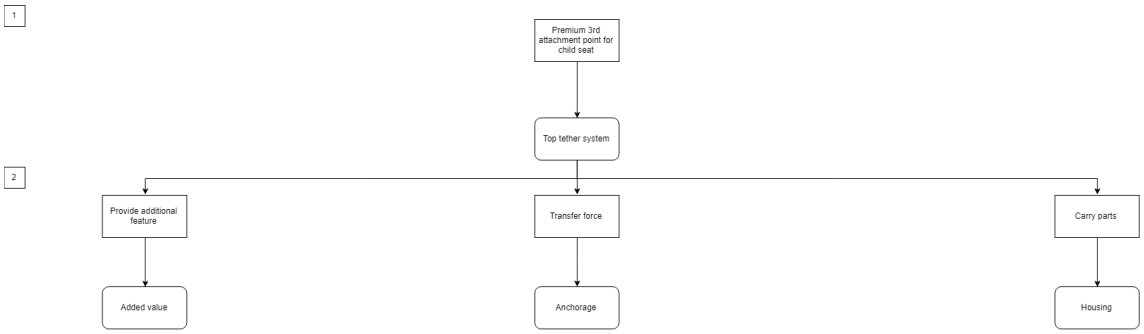


Figure 6.1: Function-means tree. See Appendix E for full function tree

6.2 Concept Generation

The concept generation section will outline the different tools used to come up with concepts that will solve the main problems described in 3.2.1.

6.2.1 Mood-board

The first step before idea generation was to create a moodboard with different visuals representing premium feel and techniques. This helped the team set the mood for the context of how a design could be conceptualized. The moodboards can be found in Appendix D

6.2.2 Morphological matrix

At the same time as the creation of moodboards a morphological matrix was developed. The idea of a morphological matrix is to come up with alternative solutions for each defined sub-function from the function-tree above. The sub-solutions are matched in different combinations to further come up with different unique concepts that act as a total solution[20]. The complete morphological matrix is shown in figure 6.2.

	Solutions ———— Subfunctions	Solution-1	Solution-2	Solution-3	Solution-4	Solution-5	Solution-6
Anchorage	Colour	Black	White	Same as parcel shelf	Same as car		
	Type	Metal bar	Loop				
	Mechanism	Hinges	Retraction	Spring	Rigid		
	Position	Original position	On the parcel shelf	Further back	Higher up		
Housing	Enable access to anchorage	LRE	Cover	Partially covered (cutout)	Curtain		
	Mechanism	Zipping	Sliding	Hinges	Thin plastic strap	Spring	Rotation
	Cover anchorage	Yes	No				
	Attachment	Pins	Velcro	Magnets	Clips	Metal buttons	None
	Hold parts	Frame	No frame				
	Hide attachment points	Have same colour as surrounding parts	No attachment points	Clever usage of frame			

Figure 6.2: Morphological matrix

Some of the concepts were developed as early as in this stage. Those concepts can be seen in Appendix B.1.

6.2.3 Brainstorming

After the morphological matrix a dedicated brainstorming session was held. The task was to generate as many concepts as possible independently of any restrictions. This resulted in almost 20 concepts and to ease communicating, they were all described and the majority were drawn on paper as well.

The concepts varied in how they solved the issue with the current product. Some solutions used lids in different shapes while other solutions were focused more on the anchorage in an attempt to push towards something new. The most common type of solution was to reshape the lid. See Appendix B for description and drawings of generated concepts.

6.3 Concept Elimination

The concept elimination section will outline the different tools used to evaluate and eliminate the majority of the concepts so that only a few promising final concepts are left.

6.3.1 First elimination

A first elimination was carried out using an elimination matrix with a set of basic criteria:

- Solves main problem
- Fulfills all demands
- Realizable
- Safe
- Enough information to develop

A number of concepts didn't solve the main problem and were therefore disqualified. Some other concepts were ruled out mainly due to the lack of information. The elimination matrix can be seen in Appendix A.

6.3.2 Mock-ups

Before moving any further it was decided that quick mock-ups of the remaining concepts should be built. This was done using anything that was close at hand just for the purpose of testing feasibility. This activity didn't discard any concepts but proved to be beneficial for a broader understanding of the concepts. Some of the mock-ups are shown in Appendix I

6.3.3 Pugh matrix

The next step into the screening of concepts a pugh matrix was generated with eleven selection criteria based on needs and desires from the requirement list. The Pugh matrix was approached with ten concepts but only five concepts made it through to the next phase. This as a result of disqualified concepts and that two concepts could be either combined into one or act as an alternative.

The flying lid solution, shown in figure 6.3, is thought to be compatible with all concepts that has a lid since its main function is to reduce the gap for the belt (see 3.7c). Therefore this concept was part of every lid concept. Moreover, the sliding cover concept, seen in figure 6.4 is thought to be a variant of the bread container.

By using the Pugh matrix, the number of concepts was halved, from ten down to five, whereas two concepts are focused on lid, two concepts are focused on anchorage and one concept is focused on integration. The complete Pugh matrix can be seen in Appendix F

Contradicting needs & Trade-offs

The Pugh matrix also revealed that there could be some trade-offs among the criteria. For example the potential to incorporate premium attributes vs size & weight. A general understanding from interviews and benchmarking was that to achieve a premium design, more materials are often required and compared to plastic the materials used for premium design are often heavier. Another trade-off could be between the appearance of the product when in use vs when not in use. This due to

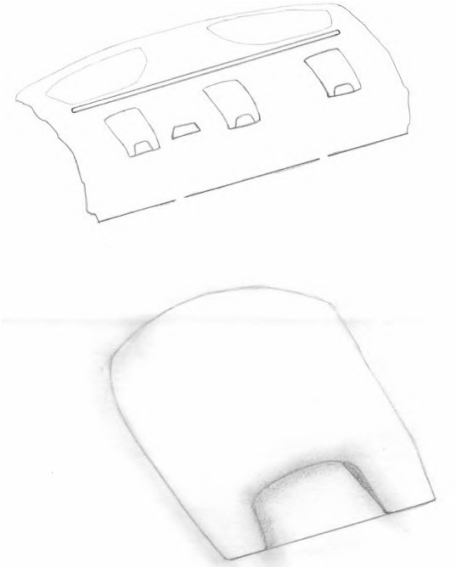


Figure 6.3: Flying lid.

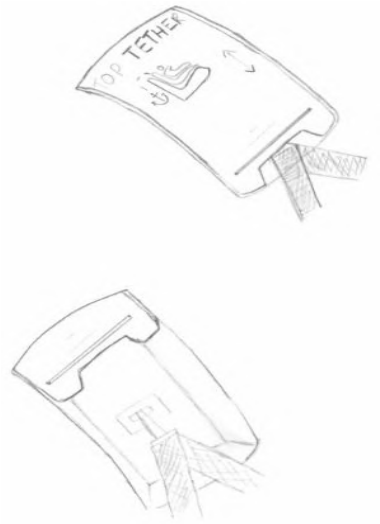


Figure 6.4: Sliding cover.

the fact that the product is seldom used but still has to be put in the car according to legal demands.

6.3.4 Kesselring

To counter the trade-offs the next step was to perform a final evaluation through a kesselring matrix. In this matrix each criteria was weighted from 1 to 5, depending on the importance of it, where 1 is not important at all and 5 is very important. The same criteria that were used in the Pugh matrix were used in the kesselring matrix, except that "Potential to incorporate premium attributes" was further divided into the highest rated attributes from the survey. This helped in ranking the five remaining concepts and determining the final candidates.

As mentioned earlier (see 5.7.3), the ambition was to end up with two concepts by the end of the concept development phase. The two concepts will both be developed and serve as two suggestions for Volvo.

Out of the kesselring matrix concept Harmony came out as a distinct winner and second place was gained by the Bread Container with LRE Top Tether and Top Tether Bars not that far behind. The Two Halves picked up the last place. The complete kesselring matrix can be viewed in Appendix G.

This means that Concept Harmony and the Bread Container are the two final concepts. The Bread Container is suggested to be the easy to implement quick improvement of the current design. It goes with the current anchorage, it has intuitive design and speaks the same design language as other components in the car.

Concept Harmony's position at first place is explained by its compatibility of working with a variety of different lid solutions. It was also the only concept that scored the highest on both "Potential to support additional value" and "Spatial harmony

& Integration". Therefore this concept was chosen to be the most novel one with great focus on being appreciated as premium.

On the other hand the two anchorage related solutions did not make it all the way due to the need of modifying how the load is transferred and the drawback of possibly having to make major changes to the current anchorage fixation.

7
Final Concepts

This chapter consists of detailed description along with prototyping and further development for each of the final two concepts.

7.1 Concept Harmony

The idea behind this concept was to integrate different parts on the parcel shelf to provide a feeling of harmony and balance. The design for the concept evolved during the development phases to make it more suitable to fit the needs and desires. One of the main advantage of this concept is that it can be combined with most of the other concepts the team came up with during the concept generation. This makes the concept more than just a design for a top tether but rather for the whole parcel shelf.

Materials & Design

The general design was to incorporate the three top tethers into a single unit rather than having three separate pieces. The first iteration consisted of a profile that outlined the three top tethers and the seat belt opening, see figure 7.1.

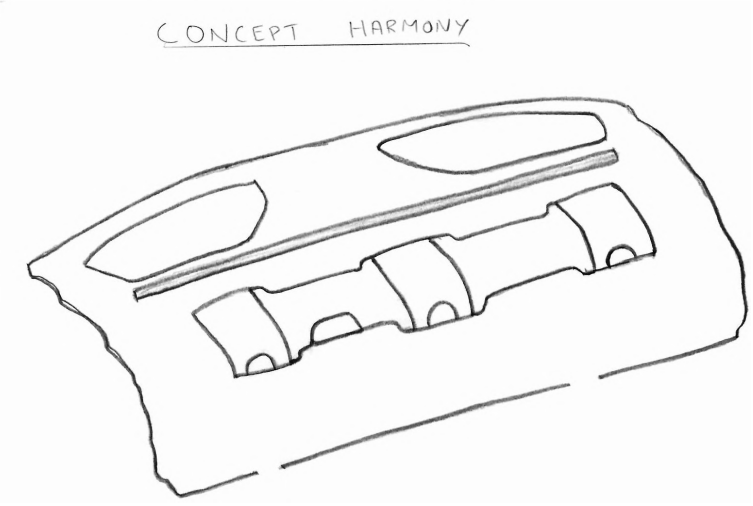


Figure 7.1: Concept harmony

Different variations were tried but it was later designed to have a rectangular profile so that it looks simple and minimalistic and adheres to the Scandinavian design. Two alternatives were rendered and can be seen in figures 7.2 & 7.3. One variant shows dark shaded wood on a charcoal parcel shelf and the other shows a blonde parcel shelf with light shaded wood. Both of the designs have chrome outlining. However, this was kept minimal to avoid reflections.

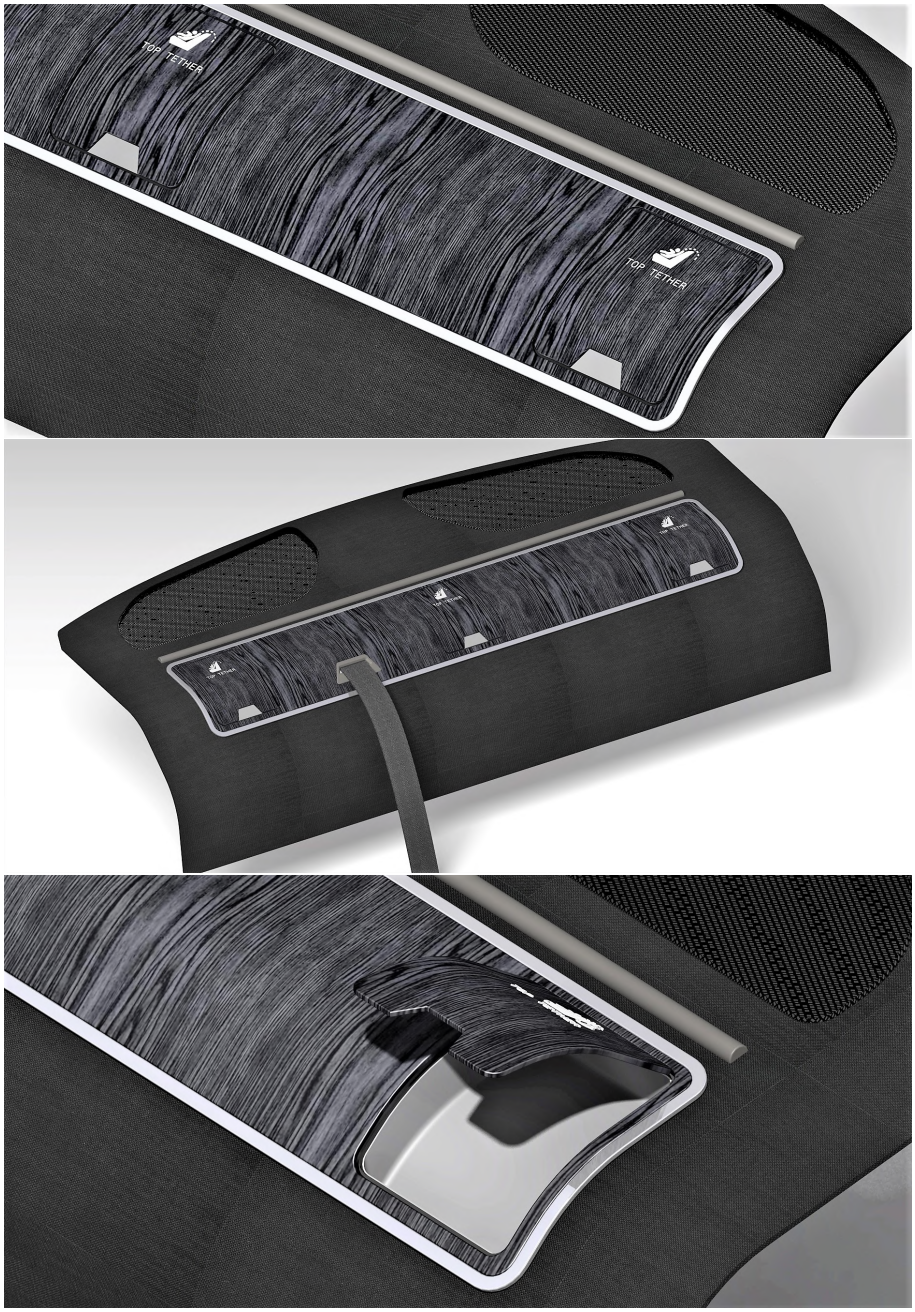


Figure 7.2: The fig shows a charcoal textile parcel shelf with concept harmony in dark shaded wood and chrome lining

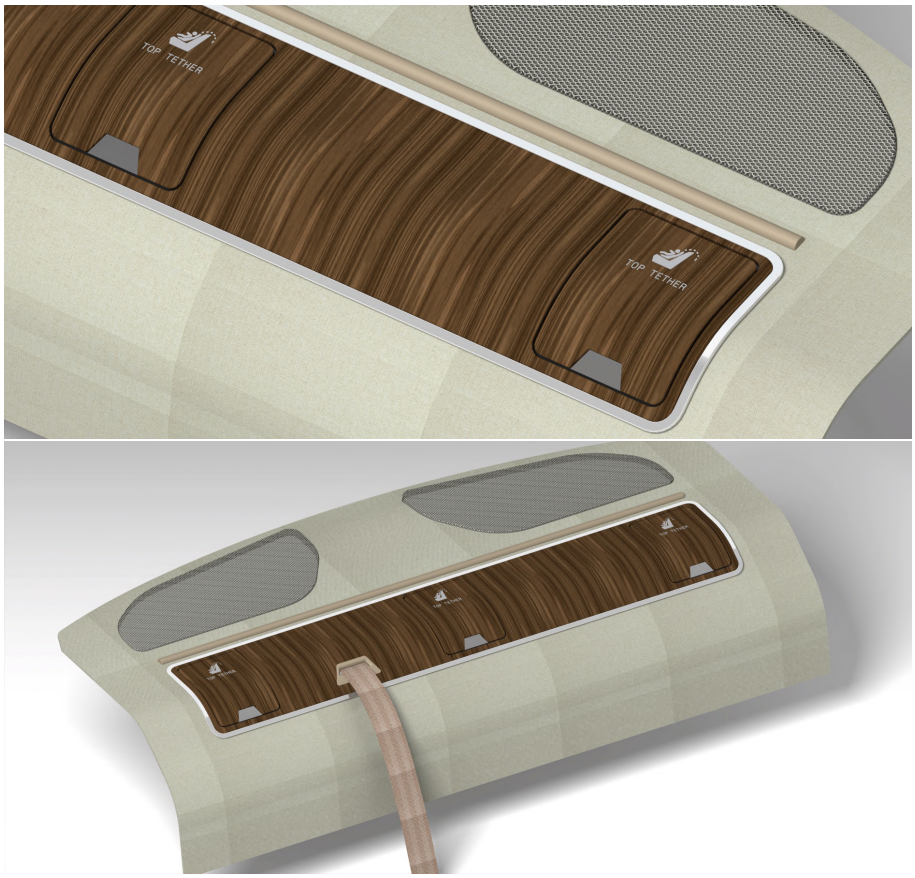


Figure 7.3: The figure shows a blond textile parcel shelf with concept harmony in light shaded wood and chrome lining.

High gloss plastic can also be used instead of wood. Most importantly the materials used for top tether should match the materials used for decorating the front portion of the car. This could help to create uniformity in the interior design of the car. Due to the time constraints a physical prototype for this concept was difficult to build. Therefore multiple visual renderings in CATIA were created to provide an understanding of how the concept would appear in real life.

Concept harmony is intended to be used in top trim of S90 i.e "excellence" and also be as an optional feature in "inscription" models as well. Furthermore the material used could be personalised according to the user.

Further development

The solution offered, provides integration to an extent but further study needs to be done to identify how it is perceived by the customers. Physical prototypes could be made to verify the concept and also to estimate the cost. Additionally the design should follow the Volvo standards and suitable manufacturing processes should be assigned in order to achieve cost efficiency. To increase the value for the product, accessories like U.S.B port, infotainment display or even a small storage compartment can be implemented. Furthermore, different integrated designs could also be

developed and customer study could be conducted.

7.2 The Bread Container

The bread container derives its design from the jalousie concept that is used in the front storage compartment in a Volvo car, near the gear lever. The solution solves the main problems mentioned earlier in section 3.2.1 and also adds premium feel by incorporating the spatial harmony aspect through relating it to the jalousie (see figure B.8b).

Materials & Design

The concept consists of small blocks or ribs of material that slides on a rail which can be seen in figure 7.4. The blocks are attached and held together by a surface of material. The surface along with the blocks make up the lid. The lid has a small gap in the front for the belt to go through. The compartment is opened by pushing the lid with the help of the handle. The lid then goes underneath the parcel shelf providing space for the belt to be attached.

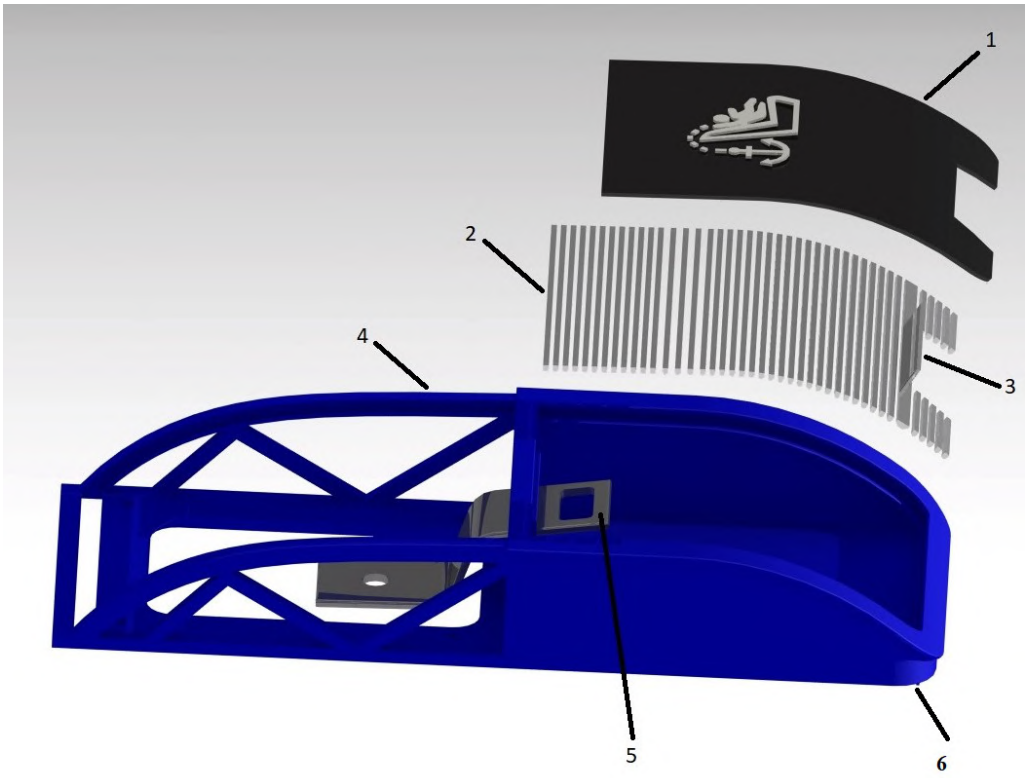


Figure 7.4: The figure shows the exploded view of the bread container. (1) represents the top surface,(2) shows the rib in closed position, (3) is the handle on the rib that users use to open and close. (4) is the body where the left half of it would go underneath the parcel shelf.(5) shows the anchorage. (6) shows where on of the clips is situated, used to attach to the parcel shelf.

There are two different designs of jalousies available. One design requires the surface, attached to the block, to be the top surface (A-surface) and that is what is visible to the user. For this type, only flexible materials like rubber or textile could be used. The second design involves the blocks to be the A-surface and the attached surface only have the functionality of holding the blocks together. The design utilizes materials such as wood, high gloss plastic or polished metal to provide a premium appearance. This design is commonly found in the top trim levels.

The same ideology was used in the bread container by having different materials for different trim levels. The figures 7.5 to 7.8 show the different trim levels for the bread container.

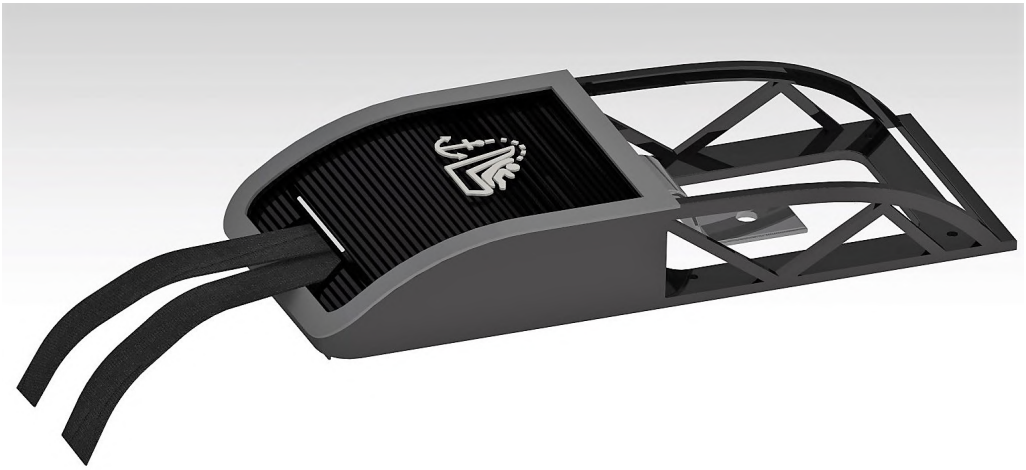


Figure 7.5: The figure shows the rendering for the base trim level. It consists of rubber material for the lid and plastic material for the body.

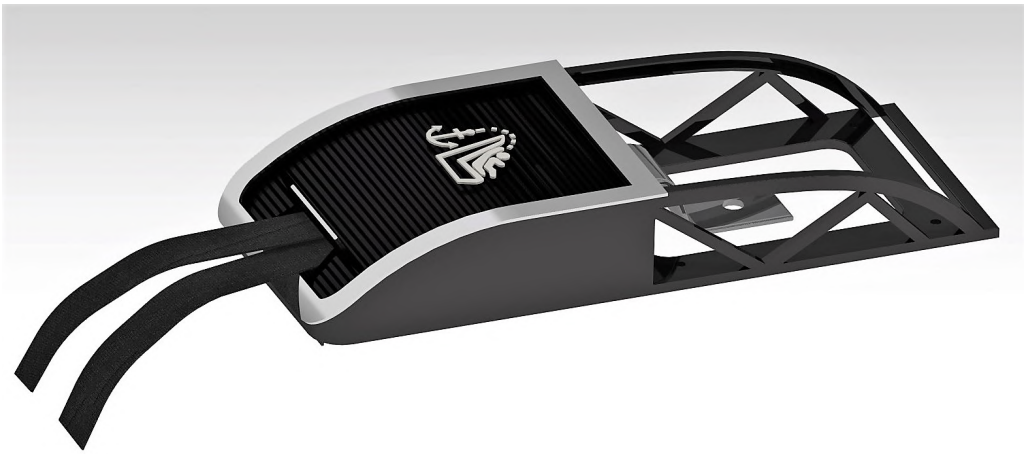


Figure 7.6: The figure shows the rendering of the second trim level. This can be chosen as an option and used in higher trim levels. It consists of rubber material for the lid and plastic for the body but it has metallic details on the outer edges.

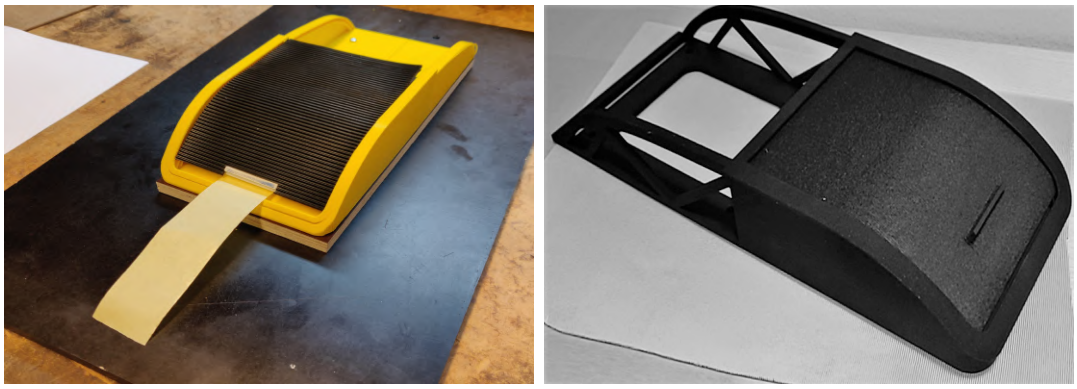
Figure 7.7: The figure shows rendering for one of the highest trims of the top tether. It consists of lid made of wooden blocks and uses the second design of jalousie with blocks as the top surface. The body has metallic details so that it is similar to the jalousie in the front.

Figure 7.8: The figure shows rendering for another top trim level. It is same as the wooden bread container but the blocks are made up of high gloss materials.

Prototyping

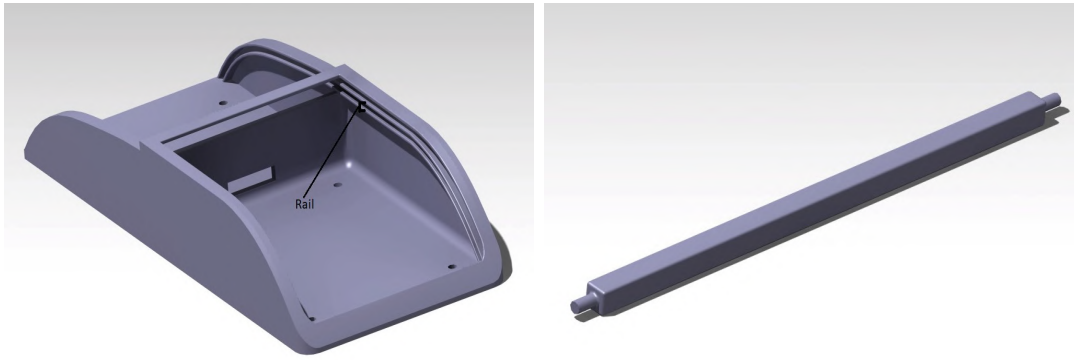
The prototyping of the top tether consisted of three parts, body, ribs, and the top surface. The figures 7.9 show the complete assembled prototype.

For prototyping the first design of jalousie was adopted where rubber surface was used as the A-surface. The body and the ribs were designed in CAD and 3D-printed. In the first phase of prototyping the design for the body and the rails can be seen



(a) Prototype- 1 **(b)** Prototype-2

Figure 7.9: The figures show the assembled 3D-printed prototypes.

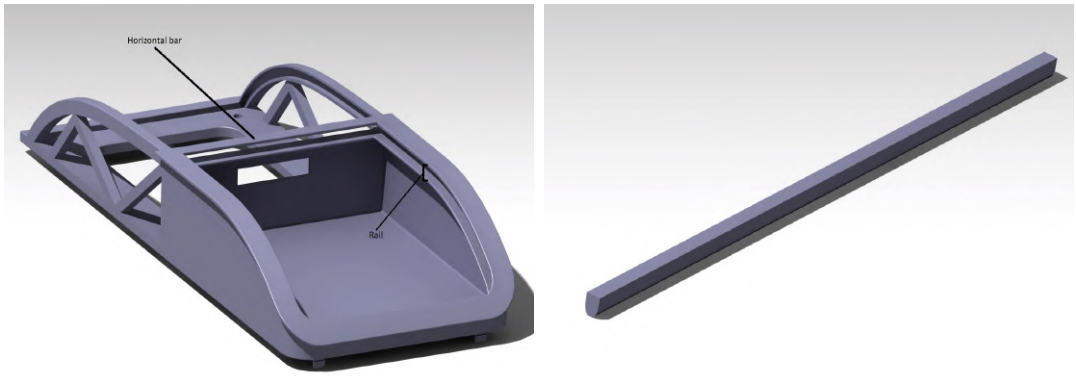


(a) The figure shows the body of the top tether. **(b)** The figure shows the rib used for the lid.

Figure 7.10: The figures show the body and rail used for the first prototype.

in figure 7.10. The ribs had cylindrical shape that makes it possible to slide inside the rails which are below the A-surface. This created considerable amount of flush and was not acceptable. Another problem was that the lid cannot be inserted as there was not enough space and it was not flexible enough as it was thought be. This caused the part to be 3D-printed in two halves. The lid was inserted and then the two halves were screwed together using a wooden plate. Discussions within the company helped solve the flush problem by either increasing the material thickness or by moving the rail closer to the surface.

The design was changed to move the rail closer to the surface. This helped decrease the flush between the surfaces. The rails and ribs were also modified such that the top surface goes inside the rail (see figure 7.11). While designing the rail one of the important aspects to consider was that the arc length should be such that the handle stops near the horizontal bar (see figure 7.11a). A slot was also included at the end of the rail for the lid to be inserted. This allowed the part to be a single solid structure than two halves as in the first prototype.



(a) The figure shows the body of the top tether.

(b) The figure shows the rib used for the lid.

Figure 7.11: The figures show the body and rail used for the second prototype.

Further development

The prototyping phase showed that the concept is achievable and can be used in that area of the car. More work should be put into the design to make the flush nominal. Furthermore the force on the rail should be adjusted to obtain a good user experience. Different manufacturing techniques and materials could be tested to decrease the production cost. Also the rails could be developed as a separate part and then attached to the main body, as they do in the existent jalousie to make it more suitable for manufacturing.

8

Commercial Assessment

This chapter contains a brief proposal of how the market offering of the developed product might be and also mentions what benefits can be gained from selling the products.

8.1 Product Offering

According to the US Federal Register[17], one fixation point needs to be positioned behind each headrest of the three rear seats. What this means for Volvo is that they always need to have three top tethers in their cars in order to qualify for that market. As of now the three top tethers are included as a standard in every Volvo sedan car without the customer having to pay any extra money.

As mentioned earlier in the introduction, the two sedan models offered by Volvo are the S60 & S90 series. The company also offers different trim levels of each sedan car to suit the different needs and lifestyles of their customers. The Volvo S60 can be purchased in two different trim levels, Inscription and R-Design[29]. The S90 on the other hand is offered in two additional trim levels, Momentum and Excellence[30].

Customers looking for a perfect blend of strength and style are recommended to go for the Momentum trim. The R-Design is the sport trim, it adds shiny styling details as well as improvements to the engine, suspension, wheels, and brakes. The Inscription trim focuses on upgrading comfort, convenience, and style and last but not least, the Excellence trim which is the perfect choice for the high-end luxury customer.

The same segmentation can be applied to the product offering. Since both developed concepts, the Bread Container and Concept Harmony, are compatible with different materials, the product can be offered accordingly to each trim level. The more luxurious trim level the more high-end material the product would be made of. Same with the value adding details.

However, Concept Harmony is suggested to be exclusively for the high-end customer and therefore only implemented in the S90 excellence trim. It is optional to have in the inscription trim as well but not available for either momentum or R-design. The Bread Container, on the other hand, is to be offered for all sedan models with the possibility to have in different colours and materials as was specified earlier in section 7.2. Table 8.1 below visualizes the market offering proposal.

Trim Level	S60	S90	The Bread container	Concept Harmony
Momentum			Rubber lid + Plastic body	
Inscription			Rubber lid + Plastic body with Metallic details	Optional
R-design			Glossy lid + Plastic body with Metallic details	Optional
Excellence			Wood lid + Plastic body with Metallic details	Wood + Metallic outlines

Figure 8.1: Market offering proposal

When it comes to selling the products. The company will benefit from selling the Bread Container through economies of scale. That is due to the fact that this product uses the same technique as other already existing components in the car which would mean that this kind of parts can be produced on a much larger scale and the cost per unit will drop.

The selling of Concept Harmony does not follow the same logic. Since it is included only in the s90 excellence trim, there is a possibility for this concept to be manufactured and sold at a higher price considering that the excellence trim is quite expensive.

9
Recommendation

In addition to the two developed concepts, this chapter links back to the aim of the project and presents a list of recommendations regarding what Volvo should focus on when it comes to getting their top tether to be perceived as premium. The recommendations are based on the findings from this project and can be seen as a guideline when developing the next generation top tether.

As defined earlier (see 2.3) the top tether system is referred to as the anchorage and the compartment. Therefore what instantly seems like a good way to structure the recommendations is to split up top tether into anchorage and compartment which is the housing and the lid.

Anchorage:
When it comes to the anchorage, it is a question of either maintaining the current shape and design or spending the resources on exploring new ways of transferring a load. The latter usually means uncertainty and modifications to both the anchorage itself and the BIW. One main reason behind why anchorage concepts were eliminated is the criteria used in the elimination matrices concerning how well current anchorage can be used with the developed solution. There is no clear recommendation if modifying the anchorage is better than maintaining the current one. It is rather related to the desired visibility of the solution. Modifying the anchorage would mean less part size, less visibility on parcel shelf and easier access. But at the same time the solution needs to be visible on the parcel for the customer to notice and use.

Redesigning the anchorage would also mean, in a more practical term, finding new connection points between anchorage and BIW so that anchorage is elevated and brought closer to the parcel shelf.

However, the two final concepts need no changes to the anchorage at all and for such concepts that do not require changes. It is more important to focus on the small details instead, for example that the anchorage itself should be painted in the same colour as the car.

Housing:
The most important aspect considering the housing is to cover everything that is not necessary for the customer to see. Visible see-through elements such as foam, parts of the BIW and attachment points are very far from being perceived as premium and thus should be highly avoided. This suggests the simple solution of adding more

material to surround the anchorage and maintain a clean appearance. Once the space around the anchorage is covered, one can focus on other details that are found appreciated. According to the survey metallic details such as metallic outlining of the housing is appreciated.

Lid:
A lid is commonly used to complete the housing. One recommendation is that the lid should never be detachable, always be attached to the housing and be able to close while using. However, there is no particular way of attaching the lid that is more preferred or appreciated. The choice can rather be based on synergy among the rest of the interior. Another detail that is left free for imagination is the opening and closing technique. All the benchmarked models had hinges, while the developed concept "Bread Container" uses a sliding mechanism due to unity in design. What is quite important though is to obtain a solution that maintains the same appearance, function and execution both when in use and when not in use. This indicates for instance that the backside of the lid should be as clean as the front side. One last feature regarding lids is that they should be designed to cover the gap for the belt as much as possible. The flying lid solution can be one way of solving that problem.

The top tether symbol is also part of the solution and is usually either, printed, embossed or engraved on the lid. A suggestion where the symbol was illuminated was presented to the customers through the survey. However, that solution was evaluated as not an important attribute for premium look. The one thing that certainly should be focused is to have distinct colours, usually white symbol on a darker lid.

Besides all the former, it is crucial to maintain good execution throughout the entire product. Geometrical attributes such as gaps, flushes and parallelism are of great importance for the overall impression of the product.

In conclusion, this project has indeed led to how a premium concept for top tether may be. But this area is still undiscovered and a more detailed study would be needed to really explore that space and determine what the ultimate solution would be. Spatial harmony is undoubtedly an attribute that is appreciated to achieve, but what does spatial harmony really mean for the design of a top tether? It is certainly related to integration and that the top tether needs to have a natural interplay with near parts as well as with the rest of the interior. However, that does not necessarily narrow down the design aspect. An integrated design could be hidden, for example making the top tether in the same material as the parcel shelf, or stand out by designing the whole parcel shelf around the top tether.

In the end it all lands in the hands of the designer. The product still needs to be appreciated by the customer and for that to be done a future comparison between the current design with the two developed concepts should be conducted.

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Appendices

A

Elimination Matrix

Elimination Matrix								
Concept name	Solves main problem (Explain in current design)	Fulfils all demands	Realizable	Cost(Comparing with current solution)	Safe	Enough information	Comment	Decision
Concept Harmony	+	+	+	-	+	+	Two variants	+
Three-fingers	+	+	+	?	+	+	Two variants	+
Flying lid	+	+	+	-	+	+		+
The zipper	+	!	+	?	+	-		+
The bread container	+	+	+	-	+	-	Check space for the lid to slide into	+
The reverse bread container	-	+	+	-	+	-	Can't be closed when in use	-
Four legs	-	-	?	-	+	-		-
The twister	+	+	-	-	-	-	Size could be a too big	-
LRE top tether	+	!	+	-	+	-	Check with legal demands	+
Retractable top tether	+	?	?	-	+	-		-
Top tether bars	+	+	+	+	+	+		+
Sliding cover	+	+	+	-	+	-	Check space for the lid to slide into	+
Anchorage on lid	+	-	?	-	+	-		-
Press bar	+	!	?	?	+	-		?
Velcro lid	+	+	+	+	+	+		+
Slot	+	?	?	?	-	?	Further research needed	?
The two halves	+	+	+	-	+	+		+
Covered anchorage	+	+	+	-	+	+		+

Main problem: Unacceptable execution, large plastic parts, gap for belt is too large, visible foam body color and spot welds		**Criteria fulfilment:**	**Decision:**
		(+) Yes	(+) Continue
		(-) No	(-) Remove
		(?) More info needed	(?) More info needed
		(!) Check with specification	(!) Check with specification

B

Concepts

This appendix is divided into different sections according to the tools used for concept development

B.1 Function Tree & Morphological matrix

This section includes concepts that originated using function tree and morphological matrix. The sub-functions of the function tree were used in the morphological matrix to come up with different solutions.

B.1.1 Hinged lid with retracting anchorages

The design consists of hinged lid which is connected to the anchorage. So as the lid opens up the anchorage moves forward making it more accessible. This could lead to decrease in size for the top tether and better finish.

B.1.2 Velcro lid

This concept aims to camouflage the anchorage opening using textile that matches the parcel shelf. The lid is made up of textile and Velcro attachment points are used to close the space. This concept could help in providing a clean parcel shelf but has low premium feel. The concept was also considered as not robust and was eliminated using elimination matrix.

B.2 Brainstorming & Moodboard

This section includes concept that came out through brainstorming process. The moodboard was used to instigate the brainstorming.

B.2.1 Concept Harmony

This concept focuses on integration. The three top tethers and the space for the seat belt to come through are connected in one large piece on the parcel shelf as shown in figure B.1. The idea behind this was to provide a clean parcel shelf rather than having three separate plastic parts. In the initial stages of the concept development opening for the anchorage works as the current design. During the later stages it

was found out that other concepts that focuses on different openings and anchorages could be incorporated in this design.

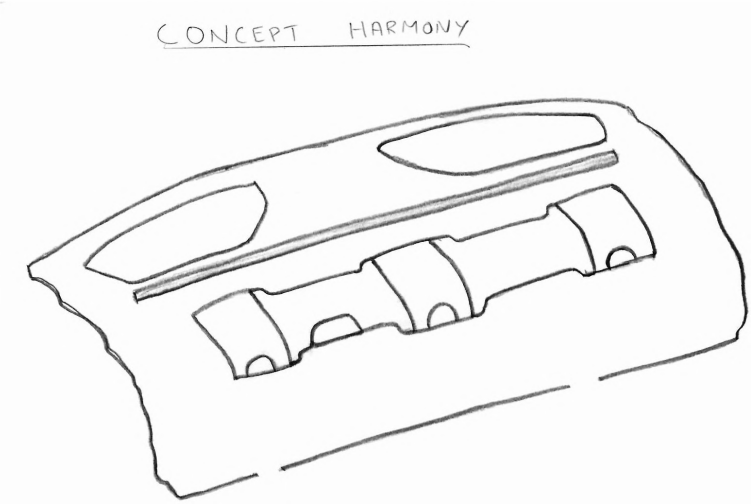


Figure B.1: Concept Harmony.

Since the combined big piece provides a larger area for including premium attributes, materials such as wood and chrome lining was proposed to be used. The area also could provide space for integrated display that could provide added value. Further research along with interior team was needed for the fully functional concept.

B.2.2 Retractable top tether

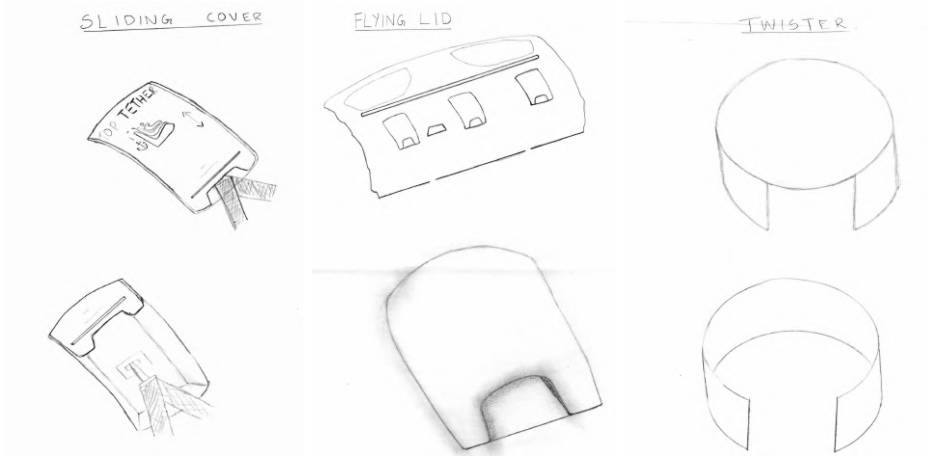
Consists of a solid anchorage attached to a retractor as in a seat belt. It is pulled out using a loop made of leather/textile. The loop comes out through a slit in the parcel shelf. This concept was eliminated because it couldn't fulfill the legal demands.

B.2.3 Sliding Cover

The cover has a sliding mechanism. It slides upward by means of a curved rail. It is similar to the compartment in the front of the car. The cover has a projection to facilitate the sliding direction. The concept is illustrated in B.2a
The lid surface could be made of wood or high gloss plastic to resonate with the interior of the car in the front section.

B.2.4 Flying lid

This concept focuses on enhancing the current lid. The lid is made with longer edges to cover more of the gap. A curtain can also be used to cover the additional gap. The lid is assembled with hinges. This concept can be combined with most of the concepts with a lid. See figure B.2b for reference.



(a) Sliding Cover (b) Flying Lid (c) The Twister

Figure B.2: Sketches for different concepts developed through brainstorming.

B.2.5 Four legs

It is another sliding concept where the lid slides in the vertical direction. You press down the lid and lid pops up by "four legs". Uses similar mechanism to existent compartment in the car. This concept was eliminated due to the difficulty in coming up with a optimal design.

B.2.6 The Twister

Unlike all other concepts this one has a circular lid that is manually rotated to access the anchorage. It consists of mainly two parts B.2c. The "carrier" which is circular in shape, surrounding the anchorage and firmly in place. And then there is the lid which is also circular and can rotate around the outside of the carrier. The lid has a cut-out for the anchorage to be able to access.

B.2.7 Slot

Consists of claws instead of anchorage. The claw locks the hook when inserted. Hook could then be released when pressing the symbol.

B.2.8 The Two Halves

This concept has two halves of a lid. To access the anchorage you press a depression in the centre between the two lids and that would make both halves go up. To close, you simply bring the two halves back down again.

This concept has an advantage of the lid being in two halves to not interfere with the rear window or the sun-blind.

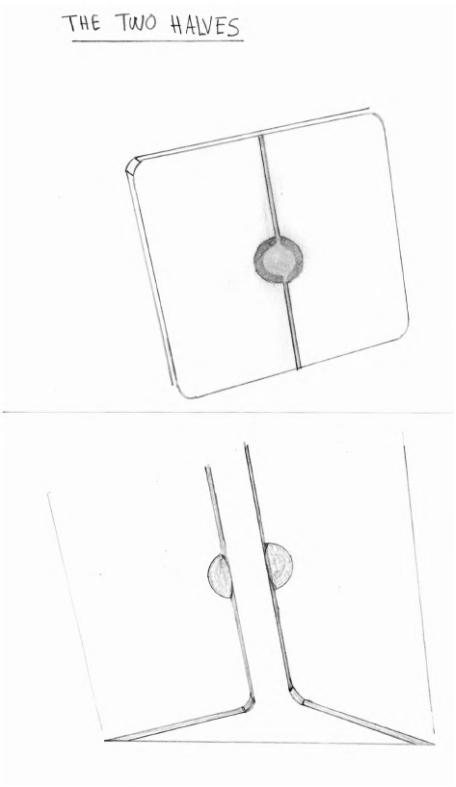


Figure B.3: The Two Halves.

B.3 Benchmarking

This section includes concepts developed using benchmarking. The process also includes ideas that were inspired from other openings in the interior of a car.

B.3.1 LRE Top Tether

The concept gets inspiration from the load retention eyes. The anchorage is hinged in a similar way as in an LRE B.4. For this concept to be realizable the BIW should be modified for incorporating the hinged anchorage. The main advantage is the minimal appearance it would have on the parcel shelf.

The anchorage could be inclined for the hook to always be positioned in the centre. The bottom edge of the housing is provided with a slit for the child seat hook. The LRE should be made in metal parts to withstand the load.

B.3.2 Three-fingers

This concept contains a lid with hinges. The hinges are on the side near the user. To use, the lid is pressed down and the anchorage becomes available through a cut-out B.5.

Figure B.4: LRE Top Tether.

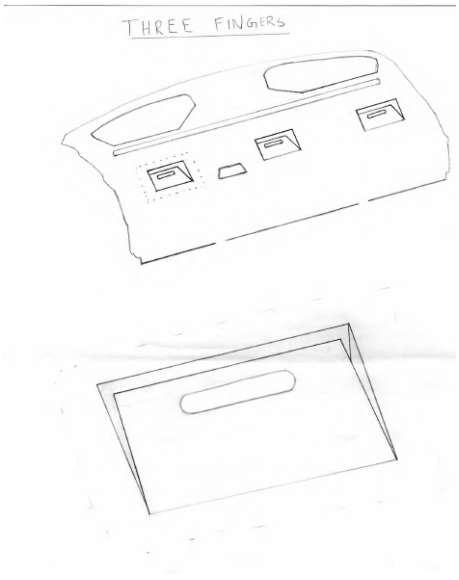


Figure B.5: Three-fingers.

This could be done in two variants. In the first variation, the lid is aligned with the parcel shelf. This leads to no flush but gaps could be visible. The second variation consists of the lid placed under the parcel shelf surface creating no visible gap but only flush.

B.3.3 Top Tether Bars

The current top tether is replaced with a metal bar as seen in the back of the rear seats of SUVs and hatchbacks B.6. This could help in reduced cost by reducing inventory. Adjustments should be made in the BIW to incorporate the metal bar.

Figure B.6: Top Tether Bars.

The ability to add premium attributes such as material, touch and feel or appearance is limited to an extent.

B.3.4 The zipper

This concept focuses on having a clean parcel shelf. An invisible zipper is used to access the anchorages B.7. The only visible part would be the pull tab of the zipper, which is metallic, circular and with the top tether symbol printed on it.

B.3.5 The Bread Container

This concept is based on a sliding mechanism. The lid is built up by small pieces of equal sized blocks that are put together to make the body of the lid more flexible when it slides B.8. It gets inspiration from a jalousie. The lid goes all the way down the edge of the carrier and opens by sliding underneath the parcel shelf. It can be partially closed when in use. This could be provided with the flying lid and the covered anchorage.

The materials that can be used for the jalousie are wood, high gloss plastic and rubber plastic. The housing is made of plastic and has rails for the jalousie to slide.

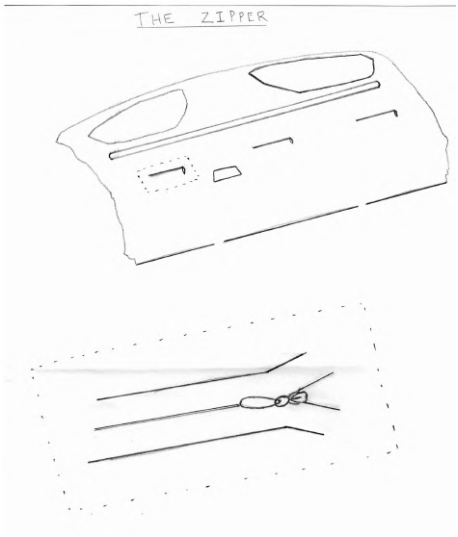
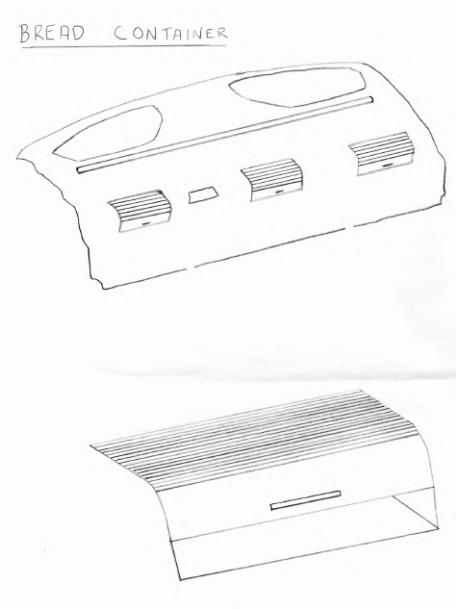


Figure B.7: The Zipper.



(a) Bread Container

(b) Jalousie

Figure B.8: The figure shows the sketch for Bread Container and the actual Jalousie in the car.

B.3.6 The Reverse Bread Container

Very much similar to the Bread Container but that the lid slides downward instead B.9. This means that it cannot be closed while in use.

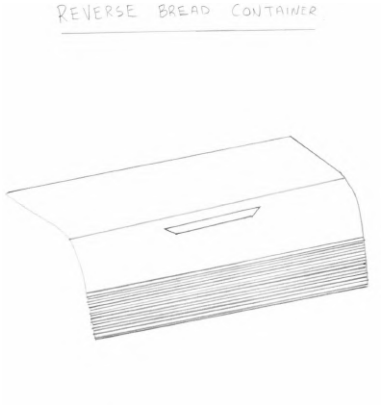


Figure B.9: Reverse Bread Container.

B.3.7 Anchorage on the lid

The anchorage is placed on the bottom surface of the lid as shown in figure B.10a. This helps in covering the compartment entirely and making all the fixations and see-through parts hidden. The lid should be modified and made of metal and be able to hold the load. Considerable changes in the parcel shelf for including the lid with the anchorage. The material of the lid should be solid metal, whereas housing could be made up of plastic.

B.3.8 Covered Anchorage

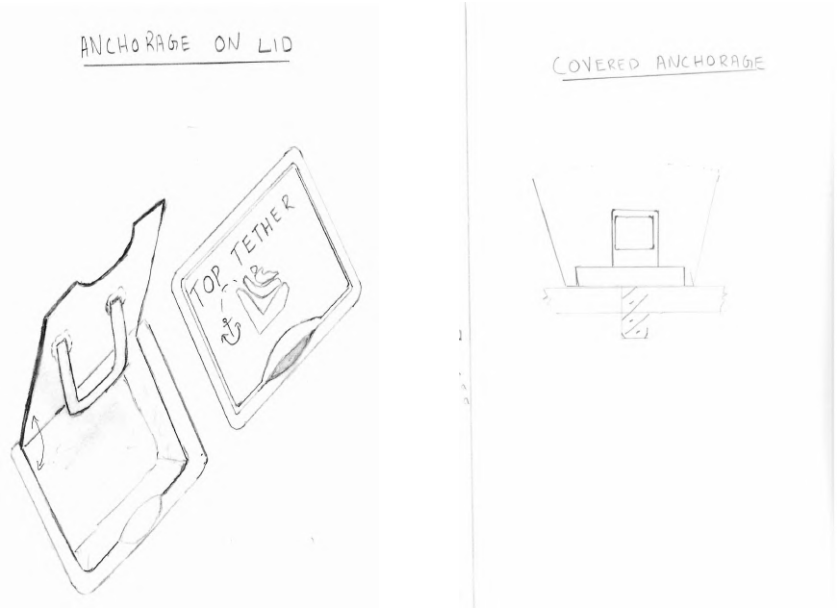
This concept is focused on covering the see-through parts in the housing by means of better design and material B.10b. It gets inspiration from 5.7a.

This could be used in most of the other concepts that include a housing for the product.

B.3.9 Press Bar

The concept consists of a retractable anchorage (metal bar). In its initial stage it is inline with parcel shelf near to the top tether symbol. To activate, the user presses on the symbol and a spring mechanism causes the anchorage to move forward. This allows easy access to the anchorage.

The top surface is made of rubber type material and the bar has a chrome lining to increase the premium feel. The concept was eliminated due to the unavailability of resources.



(a) Anchorage on lid **(b)** Covered Anchorage

Figure B.10: Concepts from brainstorming.

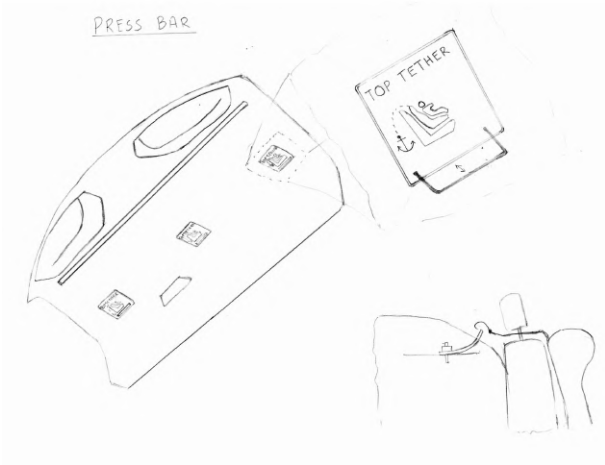


Figure B.11: Press Bar.

C

Survey

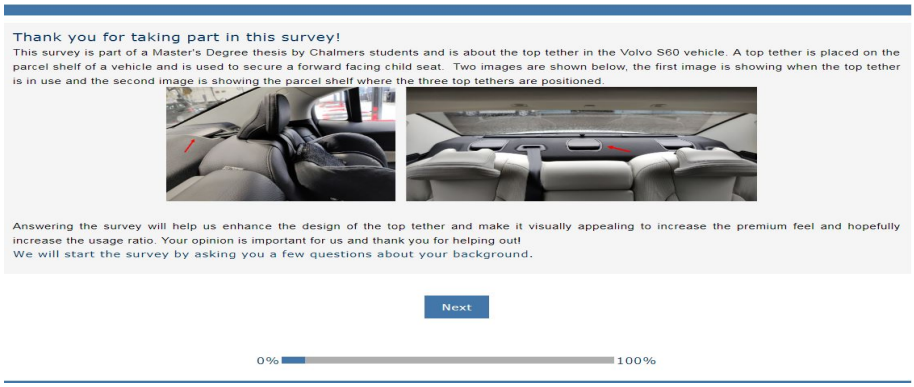


Figure C.1: The figure shows the description used in the survey

Figure C.2: The figures shows one of the demographics question

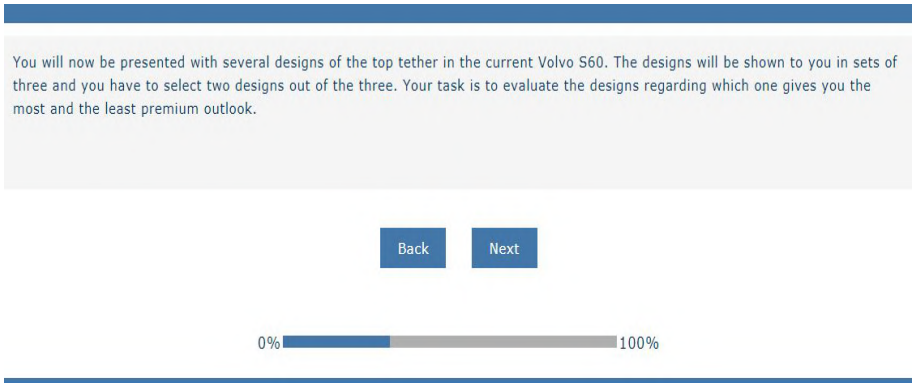


Figure C.3: The figures show how the to answer the BWS questions

Figure C.4: The figure shows the choice shown for Gap

Figure C.5: The figure shows the choice shown for metallic details

Figure C.6: The figure shows the choice shown for spatial harmony

D

Moodboard

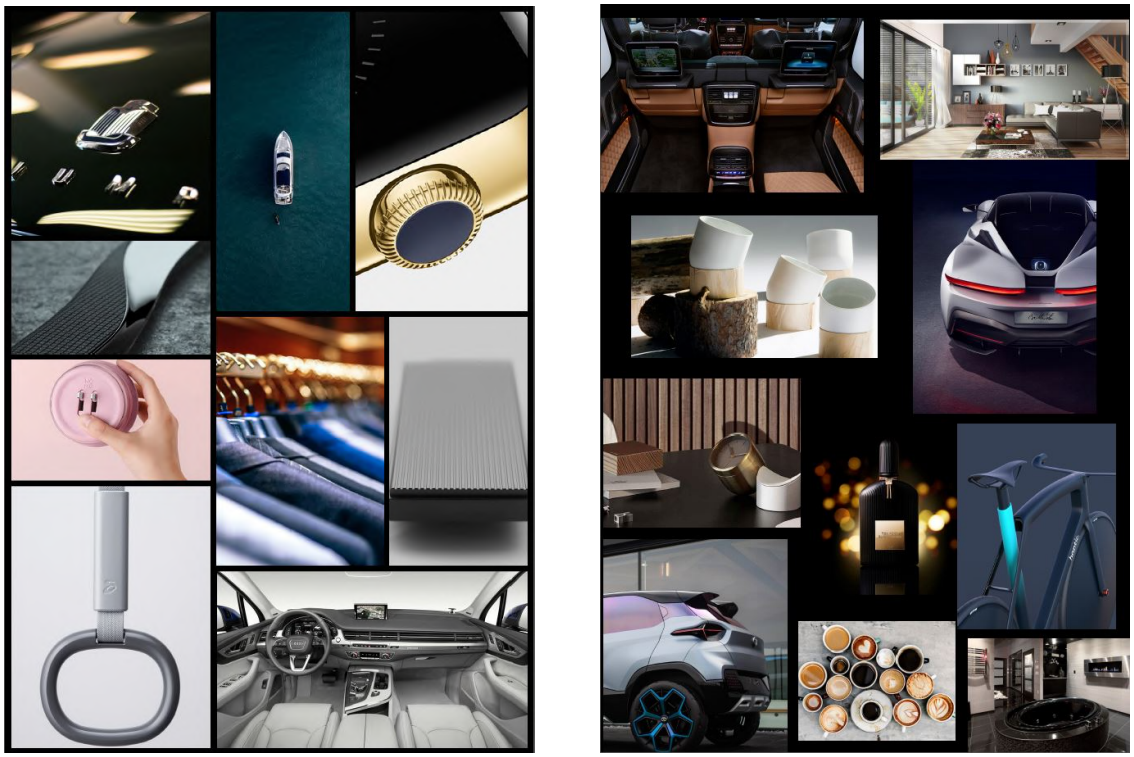


Figure D.1: The figures shows the two different moodboards the team came up with.

E

Function Tree

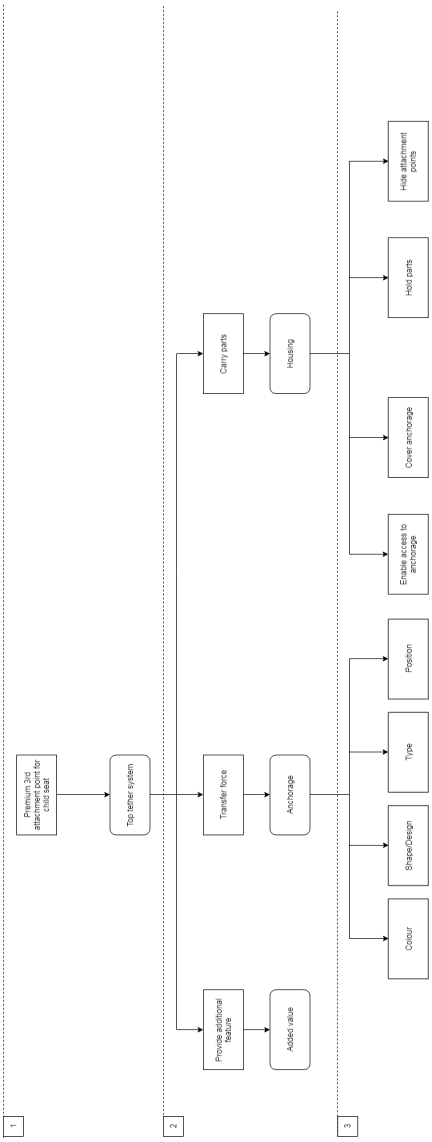


Figure E.1: Function Tree for a premium top tether

F

Pugh Matrix

Pugh Matrix											
Criterion	Reference	Alternative concepts									
	Current top tether	**Concept Harmony**	**Three-fingers**	**The zipper**	**The flying lid**	**The bread container**	**LRE top tether**	**Top tether bars**	**Sliding cover**	**Velcro lid**	**The two halves**
Apperance when in use	Datum	1	-1	-1	1	0	-1	-1	1	-1	1
Apperance when not in use		1	1	2	1	2	1	-1	1	2	1
Goes with the current anchorage		0	-1	0	0	0	-2	-1	0	0	0
Complexity level of design		1	-1	-1	0	-1	-2	-1	-1	1	-1
Intuitive design (Simplicity, Steps involved, Number of hands needed)		1	1	-1	1	1	1	2	1	0	1
Potential to incorporate premium attributes		2	1	-1	1	1	1	-2	1	-2	1
Interference with hook and webbing		0	-1	-1	0	0	1	1	0	-1	0
Interference with surroundings		-1	1	1	-1	0	2	2	0	1	1
Size		-2	1	2	0	0	2	2	0	0	0
Avoids see through parts		0	1	0	0	0	2	2	0	0	0
Robustness		1	-1	-1	-1	-1	1	2	-1	-2	-1
Total positives		7	6	5	4	4	11	11	4	4	5
Total negatives		-3	-5	-6	-2	-2	-5	-6	-2	-6	-2
Total		4	1	-1	2	2	6	5	2	-2	3

G

Kesselring Matrix

Kesselring Matrix													
Criterion		Reference		Alternative concepts									
		Ideal solution		Concept Harmony		The bread container		LRE top tether		Top tether bars		The two halves	
	w	v	t	v	t	v	t	v	t	v	t	v	t
Apperance when in use	**3**	5	15	4	12	4	12	3	9	3	9	4	12
Apperance when not in use	**5**	5	25	4	20	4	20	3	15	3	15	4	20
Goes with the current anchorage	**1**	5	5	5	5	5	5	1	1	1	1	5	5
Complexity level of design	**2**	5	10	4	8	3	6	4	8	3	6	3	6
Intuitive design (Simplicity, Steps involved, Number of hands needed)	**4**	5	20	4	16	4	16	4	16	5	20	3	12
Potentail to support additional value	**3**	5	15	5	15	3	9	1	3	1	3	3	9
Spatial Harmony (Integration)	**5**	5	25	5	25	4	20	3	15	3	15	4	20
Gaps, Flushes and Paralleism	**5**	5	25	4	20	3	15	4	20	4	20	3	15
Metallic Details	**5**	5	25	3	15	3	15	3	15	2	10	3	15
Material compatiblity	**4**	5	20	3	12	4	16	3	12	1	4	3	12
Ability to hide attachment points	**4**	5	20	4	16	3	12	4	16	5	20	3	12
Interference of with hook and webbing	**1**	5	5	5	5	5	5	5	5	5	5	5	5
Interference with surroundings	**4**	5	20	4	16	5	20	5	20	5	20	5	20
Size	**3**	5	15	2	6	3	9	5	15	5	15	3	9
Robustness	**4**	5	20	4	16	2	8	4	16	5	20	2	8
T			265		207		188		186		183		180
T/Tmax			1.00		0.78		0.71		0.70		0.69		0.68
Ranking					1		2		3		4		5

H

Requirement List

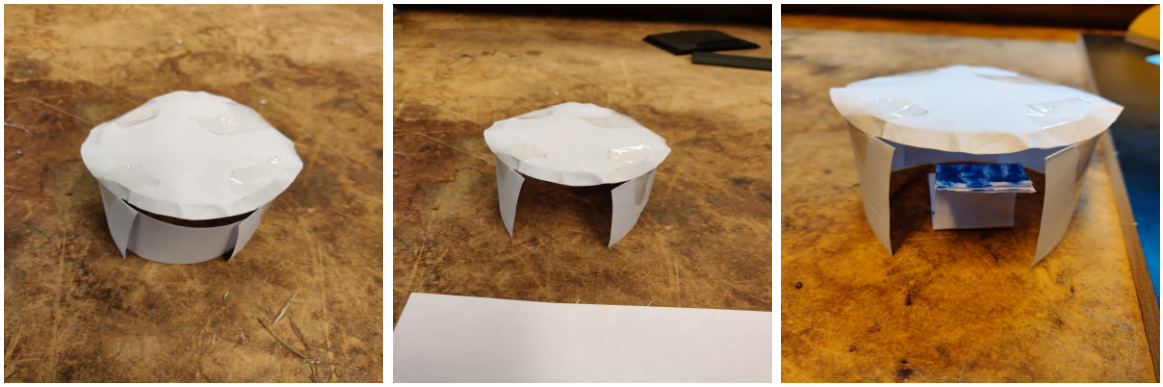
* 5 is most important, 1 is the least		Statement	Unit	Type	Importance (1-5)*	Target value	Source	Evaluation	Comment
Function	Opening	Closure should not be detached	Binary	Need	5	TRUE	Benchmarking	Visual assessment	Detachable parts are easier to be lost
		Have a pleasant signature sound during opening	Subjective	Desire	2	Yes	Interviews	Sound assessment	Have similar opening sounds to other compartments in the car & having a distinct sound can be perceived as premium
		Should be intuitive to open	Subjective	Need	5	Yes	Interviews & Internal	User tests	Easy to open
		Force feedback	Scale	Desire	4	Low	Literature & Interviews	User tests	Receiving an active force response
	Closing	Can be fully closed when in use	Binary	Need	5	TRUE	Benchmarking	User tests	To look similar both when in use & not
		Should be intuitive to close	Subjective	Need	5	Yes	Interviews & Internal	User tests	Easy to close
		Have a pleasant signature sound during closing	Subjective	Desire	2	Yes	Interviews	Sound assessment	Having a distinct sound can be perceived as premium
		Interference with the child seat hook	Binary	Need	5	FALSE	Benchmarking	CAD models	Virtual cone
		Force feedback	Scale	Desire	4	Low	Literature & Interviews	User tests	Receiving an active force response
	Visibility	Should be visible on the parcel shelf	Binary	Desire	3	TRUE	Literature & Interviews	Visual assessment	
		Should not be visible on the parcel shelf	Binary	Desire	3	TRUE	Literature & Interviews	visual assessment	
	Accessibility	Number of steps required to access the anchorage	Steps	Need	4	≤ 2	Benchmarking	User tests	User observation
Design	Material	Tactile feel	Scale	Need	3	High	Literature & Interviews	Ergonomic assessment	Tactile feel is an important indicator for the perceived quality.
		It should be resistant to scratch	Binary	Desire	3	TRUE	Literature	Hardness test- Rockwell hardness	Materials that scratch easily are not perceived as premium.
		The colour should match with the parcel shelf and the interior trim	Binary	Need	5	TRUE	Benchmarking	Renderings	To have material harmony.
		Colour	Subjective	Desire	3	Yes	Interviews	Visual assessment	Should resonate with current trend on market.
		Material pattern	Subjective	Need	4	Yes	Interviews	Material selection	The closer the surface texture is to a human fingerprint, the better it feels.
		Metallic details	Subjective	Desire	3	Yes	Benchmarking & Interviews	Renderings	
		Recyclable	Scale	Need	4	100%	Volvo	LCA	
	Size	As big as the current one or smaller	mm	Desire	4	<= previous design	Volvo	CAD models	Bigger solution look clumsy and has poor material finish.
	Weight	Lightweight	g	Desire	3	<= previous design	Internal		
	Spatial harmony	Alignment	mm	Need	5	<= previous design	Literature	CAD models	
		Interference with surrounding parts	Binary	Desire	4	FALSE	Benchmarking	CAD models	
		Symmetry	mm	Need	5		Literature	CAD models	Alignment and Symmetry is important for a good design - Gestalt
		Integration	Subjective	Need	5	Yes	Literature & Survey	Visual assessment	
	Illumination	Symbol illumination	Binary	Desire	3	TRUE	Interviews & Survey	Visual assessment	
		Carrier ilumination	Binary	Desire	3	TRUE	Interviews & Survey	Visual assessment	
	See through parts	No visible fixation parts	Binary	Need	4	TRUE	Interviews	Visual assessment	Visible undesired parts decrease the premium feel
		No visible foam	Binary	Need	4	TRUE	Interviews	Visual assessment	
	Anchorage	Colour should match the parcel shelf	Binary	Need	4	TRUE	Benchmarking	Visual assessment	
		Should be near the parcel shelf	mm	Desire	3		Benchmarking internal	CAD models	For easy access & more design possibilities. Further research.
		Reduced weight	mg	Desire	3	< than previous design	Internal	Engineering analysis	
	Shape	Scandinavian design	Subjective	Need	4	Yes	Volvo	Design assessment	Simple and minimalistic. Smooth & curvy design.
Execution	Squeak and rattle	System should not rattle	Binary	Need	4	TRUE	Interviews		
		System should not squeak	Binary	Need	4	TRUE	Interviews	User test assessment	To avoid undesired noise.
	Integration	Gaps and Flushes	mm	Need	4	0	Literature & Interviews	Geometrical assessment	
		Parallelism	Degrees	Need	4	180	Literature & Interviews	Geometrical assessment	Important to get a feeling of unity and integration.
	Solidity	Robustness	Subjective	Need	4	Yes	Literature & Interviews	Geometrical assessment	To get a feeling & an impression of safety. Strong & solid design.
Internal	Service and maintenance	Does not require service and maintenance	Binary	Need	5	Lifetime of the car	Volvo	Durability analysis	Should withstand until the car is scrapped
	Cost	Production cost	SEK	Desire	3	<= previous design	Volvo	Cost analysis	Advised to keep the cost as low as possible
		Purchase cost	SEK	Desire	3	<= previous design	Volvo	Cost analysis	
	Assembly	Similar to current design	Binary	Desire	3	Binary	Internal	Time	
	Manufacturability	Surface finish	Scale	Need	5	Excellent	Literature & Interviews	Visual assessment	
		Paint execution	Scale	Need	4	Excellent	Literature & Interviews	Visual assessment	
	Compatibility	Suits all Volvo sedan models	Binary	Desire	4	S60 & S90	Internal	Engineering assessment	Less inventory --> less cost
Legal Demands	Anchorage	The anchorage should be at least 165 mm from the Torso	mm	Need	5	>=165	Legal Demands	CAD models	New legal demand.
		The anchorage should be accessible within a virtual cone	mm	Need	5		Legal Demands	CAD and virtual cone	Restricted space for the user's hand to reach the anchorage.
	Symbol	The symbol should be visible	Binary	Need	5	TRUE	Legal Demands	Ergonomic assessment	It's important for the user to see the symbol.

I

Mock-ups

(a) **(b)** **(c)**

Figure I.1: Mock-ups of "Flying Lid" & "Three Fingers"



(a) **(b)** **(c)**

Figure I.2: Mock-ups of "The Twister"