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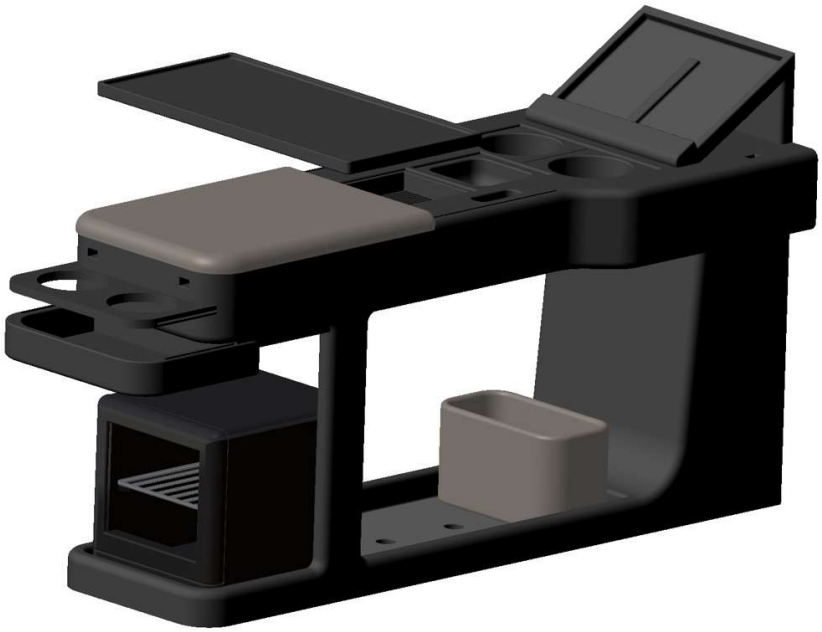

Product development project of a new modular center console for BEV interiors

Master's thesis in Product Development

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Cover: A Catia V5 rendering of the final concept of a modular center console

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ABSTRACT

This master thesis presents the design and development process of a modular center console for Volvo's future battery electric vehicles (BEVs), undertaken at Chalmers University of Technology in collaboration with Volvo Car Corporation. The evolving automotive industry and the rise of electric mobility creates a need to redefine the interior design of BEVs, including the center console. This thesis aims to enhance user experience and functionality within the BEV interior.

The project involved a comprehensive exploration of market trends, user requirements, and technical possibilities. Creative brainstorming sessions were conducted to generate innovative ideas for modular interfaces and modules, contributing to the development of a scalable and customizable center console. Through iterative development and stakeholder engagement, a final concept was refined to meet the demands of Volvo Cars and its customers. Utilizing CAD modeling and 3D printing techniques, the team was able to visualize and prototype the final concept in a 1:1 scale, ensuring accuracy and feasibility.

The outcome of this project exemplifies the successful integration of modular design principles, empowering customers to personalize their center console based on individual preferences and needs. Through this thesis, valuable insights and recommendations are provided to inform the future design and development of the center console.

Key words: Product development, Design thinking, Modularity, Center console, Electric vehicle.

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Gothenburg, June 2023

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1. INTRODUCTION

This master thesis report regards documenting the concept development of a new modular center console for BEV interior in Volvo cars. The project was carried out at Chalmers University of Technology as a compulsory element of the master's program Product Development and corresponded to 30 ECTS (Master academic credits). The master thesis work has been performed during the spring of 2023 for approximately 20 weeks and was delivered by the department of Industrial and Materials Science. The thesis work was commissioned by the company Volvo Car Corporation, specifically the Center console team within the Product Creation department. The project aimed to develop a modular center console based on research of existing products and analyses of customers' and stakeholders' inputs. The work also included collaboration with other departments at Volvo Cars, such as the design department and the ergonomics department.

1.1 Background of The Project

The automotive industry is experiencing rapid changes, including a shift in technology and a constantly evolving market. These changes do not only impact the car's technology but also its interior, particularly the center console. The introduction of flat battery floors in Volvo's electric cars (BEVs) has had a significant impact on the center console's design, creating new opportunities and a larger space to work with.

As the market changes, so do customer requirements and expectations. Customers expect products to be more functional, sustainable, and of higher quality. With increasing competition, companies like Volvo Car Group need to adapt and stay ahead of the curve. To achieve this, Volvo has enlisted the help of two master thesis students with this project to bring fresh perspectives and contribute to the product's evolution. This approach enables the company to explore new ideas outside of its usual way of working and think innovatively.

1.1.1 Company Description of Volvo Car Corporation

Volvo Car Corporation is a Swedish car producer that was founded upon the concept of safety in 1927, although the Volvo trademark was first registered in 1915 ("Volvo Cars", 2023). Volvo Car Group is the largest company in Sweden in terms of turnover ("Volvo Personvagnar", 2022). The company launched their first car the same year they were founded, in 1927, and ever since they have been producing and developing cars. Volvo Car Group manufactures station wagons, SUVs, and sedans, and one of their produced cars, Volvo XC60, is presented in Figure 1.1. The main marketing arguments for the company are safety and its Swedish heritage and design. Today, Volvo Car Group has facilities located in Sweden, Belgium, China, Malaysia, India, and the United States. ("Volvo Cars", 2023)

Figure 1.1. *Volvo XC60 (Volvo Car Group, 2023)*

In 1976, Volvo introduced its first electric car and highlighted the importance of using climate-neutral electricity for charging. However, the technology for electric cars at that time was not as advanced as it is today, and the battery could only last for 50 kilometers or two hours of driving, which was not sufficient for the market demands. Although Volvo launched other electric and hybrid cars over the years, gasoline and diesel cars remained the main focus. (Sjöholm, 2023) Today electric cars are coveted on the market and Volvo Car Group produces both electric hybrids and fully electric cars.

Volvo Car Group is striving to work after their values; personal, sustainable, and safe, (Volvo Cars, 2023) and in the year of 2021, Volvo Cars announced that the brand should be fully electric by 2030 ("Volvo Cars", 2023).

1.1.2 Overall Feature of The Center Console

The center console in an automobile refers to the module between the driver's and front passenger's seat. It provides a control-bearing surface that starts at the dashboard and continues beneath it, and frequently merges with the transmission tunnel that runs in front of most cars' front seats. ("Center console (automobile)", 2022) Traditionally, the gear stick is located where the console and transmission tunnel sections converge, or towards the rear of the console in front-wheel drive models without transmission tunnels. ("Center console (automobile)", 2022) But since modern automatic cars do not require a gear stick, it is offering more possibilities for center console design.

In addition to housing instrumentation and controls, the center console can also offer storage compartments, armrests, cupholders, and climate control with air vents ("Center console (automobile)", 2022). The design and equipment of the center console can be very different in different car models and brands. And since the electric cars don't have a transmission tunnel, the design of the center console is gaining more possibilities. An example of a center console design can be seen in the Volvo S60, as presented in Figure 1.2.

Figure 1.2. *The center console in Volvo S60 2020 (CARBUZZ, 2023)*

1.1.3 The Evolution of The Center Console

The center console has evolved significantly over time, and it continues to do so with the emergence of new technologies and design possibilities in electric cars. Initially the console was a simple control panel which was designed for cars with transmission tunnels, where the gear stick needs to be placed in a certain way. An example of what a center console could look like years ago is shown in Figure 1.3. Today, however, when electrical cars are being produced, the traditional need for a transmission tunnel and gear stick disappears, the center console can be reimagined to better serve the needs and preferences of drivers and passengers. This offers exciting opportunities for customization and personalization, as well as the incorporation of new features and functionalities, such as advanced infotainment systems, wireless charging, and intelligent storage solutions. As such, the center console is poised to remain a key element of car interiors, playing an important role in both aesthetics and functionality.

Figure 1.3. *The center console in Oldsmobile Startfire from year 1961 (Niedermeyer, 2021)*

1.2 The Purpose of The Project

The purpose of the master thesis work was to develop a modular center console for Volvo BEV cars that meets and exceeds customer expectations, making the product more attractive in the market. The project was carried out at the Product Creation department, Center console, at Volvo Cars, but also focused on collaboration with other departments within the company, such as design and ergonomics. During the project, input from both the stakeholders within the company and future customers was highly considered.

The new interior design of BEVs presents an opportunity for the center console to be redeveloped. These newfound opportunities were extensively explored to create a final design that enables Volvo Cars to stay competitive and maintain the heritage of premium interior experience.

The center consoles in Volvo's cars on the market today are designed according to guidelines that the customers should feel that the car is recognizable, where all center consoles are the same across the platform for different car models. Unlike the current design, the goal of this project was to create a console for a new platform for the different car models, but with more individual choices. By doing this, the center console aims to increase customer satisfaction and facilitate their everyday life. The center console was designed to fulfill the needs of a wide group of users with the opportunity to be adjusted on an individual level. The primary markets that were taken into consideration during the project is the European, Asian, and the USA. As such, the project required research and an understanding of the different needs in each of these markets.

The developed center console is scalable and adjustable, allowing it to fit into different car models. The development process was guided by Volvo Cars' purpose of delivering "Freedom to move in a personal, sustainable, and safe way." (Volvo Car group, 2023). To achieve this, the center console was designed with a focus on personalization and sustainability, and with consideration given to key design elements, including versatility, modularity, robustness, circularity, and sustainability.

1.3 Objectives

The objectives reflect the purpose of the project and are the key criteria and the values the project aimed to fulfill. The objectives that specifically was addressed are the following:

- Increase customers' satisfaction
- Accommodate stakeholders' inputs and requirements
- Customization of a modular center console
- Creation of an adjustable center console for different BEV Volvo Car models

1.4 Scope

The scope was to develop a modular set-up for a center console which accommodates the expectations of the BEV customers. The project strived towards developing one or more concepts which should be scalable for the different types of cars regarding size, premium levels, and types of ownership. It should still contain the key features within the center console like cup holders and armrest as in the traditional design. When designing the concepts, inputs from various stakeholders within Volvo Cars were considered. In addition, the project strived to find the balance between these inputs and the customers' expectations.

1.5 Delimitations

Setting delimitations is a crucial step in the project as it helps to define the scope and focus of the work. By setting clear delimitations the project achieved the purpose, while also providing room for creativity and innovation within the defined boundaries. The delimitations set for the project are defined as following:

- A life cycle analysis was not performed on the product. This was due to the focus of the project being the development of the physical appearance and the functions of the center console.
- A budget or a deeper analysis of the costs was not considered in the project. The cost regarding the developed concepts was considered through performance/cost ratio.
- No calculations regarding the strength of material and construction were carried out. Therefor the safety in cases of collisions where the airbags placed in the side of the seats are released won’t be investigated thoroughly. However, the safety aspect was considered during the concept elimination phase.
- Research of all the possibilities for the center console was not possible. The timeframe and the feasibility of the solutions set the limitations.
- Market research was limited to primarily Europe, Asia, and the USA.
- Material set-up was selected for the presentation and rendering of the models, but there were no detailed considerations regarding the materials.
- The project was performed during work hours for 20 weeks, 40 hours a week per person. This was limiting the whole project, including the creation of solutions.

1.6 Research Questions

Throughout the project, various questions have been answered. The key questions that have been addressed are outlined below:

- What are the customers' opinions on the center console in the existing car models that Volvo Cars produce, and what do they want for the future?
- How can the center console be customized for future BEV car models with focus on the customers, regarding the values and guidelines of Volvo Cars?
- How can a modular center console be adjusted to different car models?

1.7 Key Activities

The project comprises several key deliverables that are crucial to achieving the project's objectives and ensuring its success. The key activities included the following:

- Identification of customer's expectations and gaps in current fulfillment
- Identification of stakeholder's expectations and requirements
- Proposition of a modular set-up and suggestions on interfaces
- Visualization of the concepts, including
    - Sketches of suitable concepts
    - CAD models (Catia V5) of the final concept of a modular center console
    - Suitable prototype of the final concept
- Presentation of the final concept of the modular center console
- Creation of the final report of the master thesis 19,09 cm

1.8 Methodology

This chapter provides an overview of the methodologies employed for various activities throughout the project. The activities are listed and described below in sequential order, starting with the planning phase which helped set the framework and direction for the entire project. During the planning phase, a planning report was created to establish the project's objectives. An overview of the methodology, including activities and methods, is presented in a methodology diagram in Figure 1.4. The activities and methods used in the process diagram are created according to *Product design and Development* (Ulrich et al., 2020).

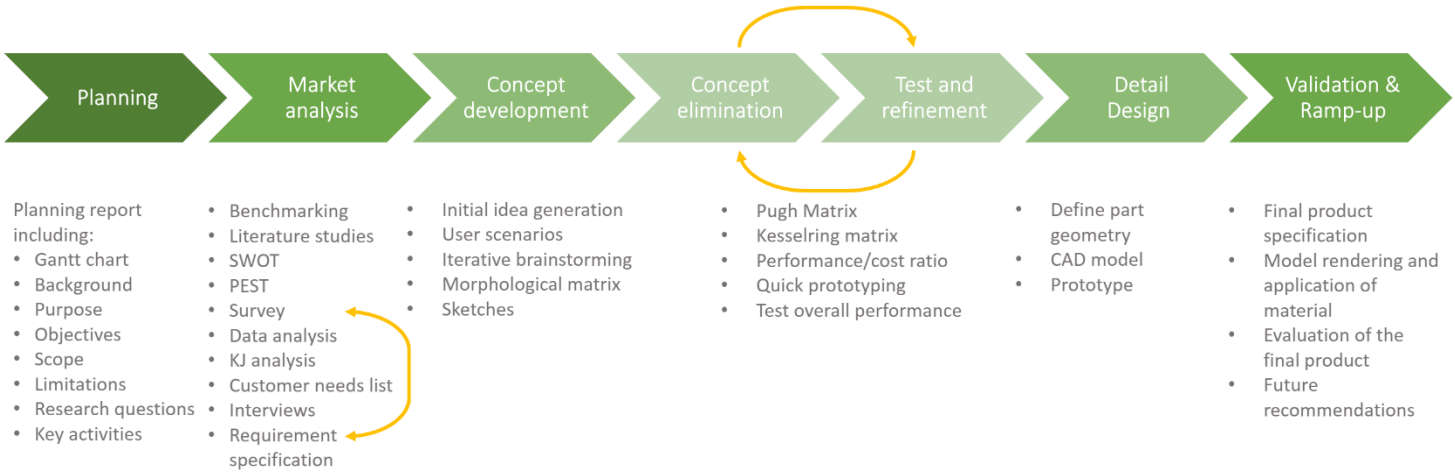

Figure 1.4. *Methodology diagram, mapping methods with activities of the process*

The project was executed in several phases, each with specific goals and methods. The first phase was the planning phase, which resulted in a planning report that served as the basis for the project. The second phase was market analysis, where various methods such as benchmarking, literature studies, etc. were used to collect necessary information about the current market. During the concept development phase, initial idea generation, user scenarios, iterative brainstorming and morphological matrix were methods used to create respective combine ideas into whole concepts.
The created concepts were later tested, refined, scored and eliminated until two concepts remained. These concepts were then both modelled in CAD and further tested and evaluated through quick prototyping. The concept elimination and test and refinement stages were iterative processes, with one final concept being selected for detailed design. The detailed design phase involved improving the CAD models and adjusting them to the 3D printing machine in order to create a final prototype.

The final phase was the validation and ramp-up, where the final product specification was documented, and the final concept was presented and illustrated. This phase also included ramping up for future production, evaluation, and recommendations.

2. MARKET ANALYSIS

To successfully carry out the product development project, extensive market research was essential to identify the areas where a newly developed center console could gain a competitive edge. This involved conducting a comprehensive benchmarking analysis of existing car brands and both SWOT and PEST analyses were performed to assess internal and external opportunities and threats. Additionally, a survey was conducted to gather valuable insights from potential users.

2.1 Benchmarking of Existing Center Console

In order to gather information about the competitors on the market a benchmark was implemented. Equivalent or similar products from other companies were examined. Both from companies who are estimated to have the greatest market share along with companies that are assumed to become competitors. Benchmarking is a strategic process of comparing and evaluating the performance, practices, and strategies of a company or product within a specific market. It involves analyzing key market indicators, competitor performance, customer satisfaction levels, and market trends to identify areas for improvement and best practices (Kaplan & Norton, 1996). The benchmark was gained from sources such as competitor's webpages, articles, statistical organizations, and the benchmarking website Iceberg.

The benchmarking started out by writing down the competitors worth looking into, approximately 20 companies. The selection of car models was narrowed down to electrical cars due to the focus for this master thesis, even though nonelectrical cars could be inspirational as well. With the research of only electric vehicles there were still many different types of cars, different price ranges, and cars developed for different segments investigated. Then the process of going through all these companies began. To collect the information needed from each company the companies' websites were visited along with a website called Iceberg (Iceberg, 2023), which is especially made for benchmarking car brands. Pictures were taken of the center console from different angles by itself and seen in the right environment of the car to get an overview. The benchmarking also involved visits to different resellers to compare and see the car models in real life. These visits also enabled the project team to open compartments and see what was hidden under the lid, also to feel the materials, see how things were opened, to try distinct functions out. A table with headlines was filled for each electrical car model that was investigated, such as: storage, built-in functions, special functions, and general comments.

The outcome of this benchmarking study was that only a few cars of the car models investigated have used the new possibilities that come with an electric vehicle regarding the design. In an electric vehicle the console doesn't fulfill any critical needs, such as fuel cars (transmission tunnel, gearstick in a certain place) and can therefore be designed in endless ways. Many center consoles that were investigated are remarkably like the "older" design that nonelectrical cars have. Although, there were many different designs of the console and many different functions that led to inspiration for further work. In some cases, a few brands also showed future design projects or vision car models on their webpages. These center consoles were also interesting to investigate to gain inspiration and see what the future could bring and the direction the design evolution might be headed. Most of these visions have been inspired by people's living rooms.

Summarized outcomes of the benchmark

- The features that many car models possess in their center consoles are the:
    - Cupholders, some of them with an opportunity to adjust the size.
    - Armrests.
    - Smaller and bigger storages, in either the armrests or if it is a more spacious design under the center console.
- There are different ways to open the armrests and storages.
- There are different ways to shape the center consoles, some models have worked with more open spaces. The center consoles can be built as bridges, completed solid bodies (old way), or just a shorter body.
- Some center console models are integrated with other parts of the car, as the display in front etc. and others are not. A few center consoles come in two pieces.
- Some have buttons and a gearstick placed in the middle, others do not.
- It is quite common to have air vents in the back, placed for the backseat users.
- Some models work with digital displays to replace buttons while others are more “old school”.
- The ergonomically aspect could be discussed regarding each design, but mostly the same features are placed the same.
- Improvement areas can be seen regarding a few designs, ergonomically or practically.
- Some center consoles had a sliding compartment to cover up cupholders and the smaller compartments.
- All the consoles had charging options, either with USB/USBC outlets or inductive charging. Although, both the placement of the charging differed for the different consoles and the number of outlets differ. Some consoles also had the opportunity for the backseat passengers to charge.
- The different consoles investigated contain different amounts of controls, screens, gear shift etc. If these functions are not placed in the console, they are placed somewhere else in the car. Some of the consoles investigated had remarkable designs, such as Volkswagen iBuzz where you can replace the whole center console with a fridge (Rabe, 2022) and Ford F-150 Lighting Lariat (Cortina, 2022) where you can fold out a table from the armrest.

Overall, the benchmark has given many new ideas and ways to shape a new center console. There are many similarities between the existing cars brands regarding the design and chosen features. A question worth asking is if this is the best way to design the center console or if it is just because it's always been designed this way.

2.2 SWOT Analysis of Volvo Car Corporation

A SWOT analysis is a widely used tool for evaluating a company or project. It enables a comprehensive assessment of the organization's internal strengths and weaknesses, as well as external opportunities and threats. This analysis helps in understanding the competitive landscape and positioning of the company within the market (Rundquist & Grönevall, 2004). In the case of Volvo Cars, a reflection on the company was conducted, and the information obtained was documented in Table 2.1. The insights captured in the SWOT analysis are a combination of common knowledge and inputs from Volvo Cars themselves, ensuring a well-rounded understanding of the company's strengths, weaknesses, opportunities, and threats.

Table 2.1. *Result of SWOT analysis*

Strengths:	Weaknesses:
- Already have a customer base in Sweden, the US and Asia - Volvo is a large company – bigger financial means and resources - Many people within Volvo – a lot of competence - Already have established supply chains of manufacturing plants and suppliers - Up to date with the increasing demand on electric cars - Volvo has high safety standards - Volvo has a well-known signature Scandinavian design - Reliable brand - Many years of experience within the company - A demand of new BEVs	- Volvo Cars is a big company - difficulties knowing who to contact regarding different matters. - It is not the center console itself that will sell, it is the whole car as a product that will sell. The center console can only raise or lower the customer value within the car. (Limitation with this thesis)
Opportunities:	Threats:
- Large possible market - New technical possibilities with the BEV cars - The market for electrical cars is constantly growing - Growing market for software and digitalization - New opportunities to charge an electric car – parking lots and gas stations with charging opportunities - New formation of the center console due to the battery floor - New formation of the center console due to new technologies that makes it possible to move some of the functions from the center console to other parts of the car	- The product has already existed on the market for a long time - Many competitors within the car manufacturing industry, well-established companies. Already a very strong and defined market. - There are also companies that are emerging in the different markets around the world, with exciting new concepts. Some that might revolutionize the interior of the car. - Difficult to come up with something new, something that differs from the rest.

Summarizing the collected data in a single table proved to be valuable as it provided a clear and concise overview. This information significantly aided in understanding how the project should be approached and highlighted key areas to be mindful of. The summarized data enhanced the overall comprehension of the project and reinforced the significance and necessity of undertaking it.

2.3 PEST Analysis of Market Trends Affecting Volvo Car Corporation

A PEST analysis is an essential tool that focuses on examining market trends that have the potential to impact Volvo Cars as a company and its future products. This method explores the current political, economic, social, and technological landscape while also considering future developments and their potential implications (The Economic Times, 2023).
The information presented in Table 2.2, which is summarized in the boxes below, was derived from a thorough evaluation of global circumstances and factors that could influence the project or Volvo Cars as an organization. The insights provided are based on common knowledge and extensive literature studies conducted to support and contribute to the bullet points.

Table 2.2. *Result of PEST analysis*

Political:	Economic:
- Electrical cars seem to be the future – political standards, regulations against diesel/gasoline cars - Material regulations/material standards (sustainability) - European parliament and California: A sales ban on combustion engine vehicles 2035 - EU is seeking to become climate neutral by 2050	- Electric vehicles sell more and more for each year - Carpools might revolutionize the ownership of cars, which probably will affect the production of cars. - Tax benefits (in some countries) to own/drive an electric car
Social:	Technical:
- Trends regarding travel - Lifestyle trends - A status mark - An environmental choice - A lot of support from customers for the electric vehicle market - Carpools might revolutionize the ownership of cars, which could lead to a different way of travel	- New technical trends – products become more digital - More technology on smaller surfaces, (compressed technology) - Product innovations in general - Material innovations in general - Flat battery floor due to the newly developed BEV - Longer battery rage - Autonomous cars: vehicles which require no human intervention. Would change the behavior of customers and the interior of the cars.

Summarizing the collected data in one table was helpful to get a clear and more concise overview of the trends that could impact the project. By having this knowledge summarized, it significantly enhanced the overall understanding of the project and its potential challenges and opportunities. While many of the bullet points in the table are self-explanatory, some may require further discussion and analysis.

Political

Some existing political restrictions regarding the development of a center console are ISO standards. ISO 10204 regarding material authentication, and ISO 14001 regarding environmental impact of the company, limit the selection of materials on the center console and requires an environmental aspect. (Velling, 2018). Although the development of the center console did not encompass this aspect due to project limitations, it remains a crucial aspect to keep in mind for future development of the center console.

Another political impact is the coming new regulations in different parts of the world, including Europe and the states, according to the climate as an important question. To be able to reach the global goals, the European Parliament will implement a sales ban on combustion engine vehicles by 2035. This will therefore increase the sales of electric vehicles even more (DW, 2022). California is also going to make the same arrangements (Hanley, 2022). The European Union is seeking to become climate neutral by the year 2050, and this is a step towards that (DW, 2022).

Economic

Electric vehicles are becoming more popular each year and the sales between 2020-2021 increased by 108%. This is a very rapid increase, and the sales are predicted to increase even more this year (2023). A few factors that affect the increased purchases of Electrical vehicles could be due to the fuel crisis and the sustainability perspective, but also that more and more car brands launch new models of EVs. The electric vehicles offering has become larger and more easily accessible for customers. Proportionately the prices of EVs are predicted to fall even more in the coming years, which will make the sales proportions of EVs significantly higher. (Taller, 2022)

In some countries there already are tax benefits of owning an electric car versus a diesel or gasoline car, and other countries are willing to implement it as well. For example, in Norway there is high taxes for high emission cars and low taxes on low emission cars. (ZEV community, 2023) Other economic advantages of driving an electric car in Norway is at least 50% reduction on road fees, ferries, and parking fees. (OECD, 2022)

Social

One social trend that is on the tableau but has not yet conquered the market is Carpools. If Carpools became more popular in society, it would probably lower the total production of cars since every produced car would be shared by several people. In the UK the car is parked 90% of the time and during an investigation, 48% of the people are willing to not have their own car if the possibility to share cars exists (Taller, 2022). Other social trends that can affect the way of traveling by car, or the development of electrical cars could be traveling trends, environmental trends, lifestyle trends for example. Owning or driving an electric car can also be a status mark and an environmental choice.

Technical

The complexity of the development of cars will continue to increase and become more digital. The future holds more technology on smaller surfaces. The software that is being integrated in the cars expands every year and new features are involved in the different displays etc. The software is built around codes that are powering features such as driver assistance, safety, entertainment, and map features, which are features that customers are expecting in newly developed cars. (Taller, 2022)

When it comes to technical trends, the time and the constant strive of development results in product and material innovations. Innovation that includes the creation of new products or the modification of an already existing product. One product innovation that has been in the headlines for a while and is expected to come is autonomous cars. These cars do not require human intervention which will open many new possibilities when it comes to, for example, public mobility platforms or to offer individual mobility to new user groups. Autonomous cars will probably change the demands and behaviors of the customers, they will not have the same needs as before. (Kuhnert et al., 2018)

The range of electric vehicles has improved during the last years which creates a higher demand. In the year 2011, the maximum range was 94 miles, and in 2020 the maximum range has already increased to over 400 miles, see Figure 2.7. With the new battery chemistry, the range will continue to increase, and that is one reason for the expected demand to increase as well. (Donnelly, 2021)

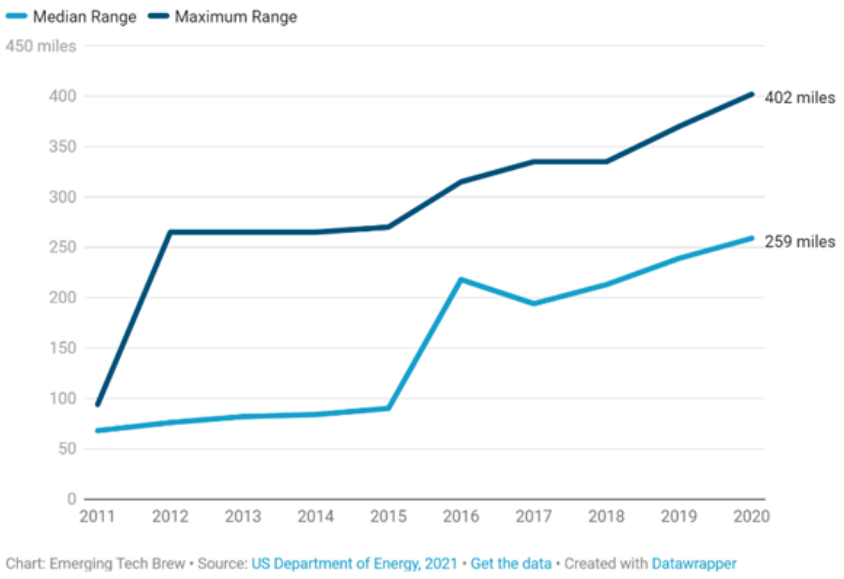

Figure 2.7. *Graph of the development of the car batteries rage (Donnelly, 2021)*

In summary, the outcomes of the PEST analysis indicate that the automotive industry will experience significant changes regarding all the categories mentioned in the analysis in the foreseeable future. Technological advancements, environmental considerations, and evolving social trends in car usage are all critical factors to consider when developing a new concept for a center console. Success now hinges on a thorough understanding of the strategic positioning and desired objectives of a new product launch.

2.4 Survey to Collect Customers' Input

A survey was conducted to collect quantitative data from future customers. The purpose was to receive the users' perception of the product, how it is used today, what functions they are missing and ideas of how the product could look like in the future. The choice of a quantitative survey instead of a qualitative survey was to reach out to as many customer segments as possible. Owning a car does not come with a specific background or personality, therefore the importance of the quantity. This method is based on participants answering questions about the investigated subject. The survey contains both open questions and direct questions. It was created digitally in Microsoft form, and released in multiple forums, both externally and internally to employees in Sweden and Asia. Two identical survey forms were created, one for internal and one for external purposes. This was done to be able to separate the answers from people with more insights into the automotive industry.

The ethical aspects of the external participants were also considered and therefore it was voluntary to take part in the survey. The data that is connecting names and answers is irrelevant for the project and therefore the names were left out. However, relevant personal information such as personas and their characteristics, was collected to facilitate the analysis of distinct needs among individuals.

The questionnaire started with general questions regarding the people answering the survey, like age, gender, where they live and two questions regarding their traveling-by-car situation. The following questions, the main questions, began to investigate what features and storage spaces the customers truly value and the ones they feel are unnecessary. The investigation continued by asking questions regarding the shape and design, showing pictures taken during the visit to the car resellers. The questionnaire also gave an opportunity for the participants to come up with improvement potentials on existing car models and to think outside the box for future ideas. Additionally, a few questions regarding modularity were discussed to get an input on how and to what extent they would appreciate a new center console to be modular.

When planning this survey there are many aspects that could be included that have not. To collect a reasonable number of answers the survey needed to be conducted rather short. There were for example no questions regarding the placement of the features in this survey, that will be investigated at a later stage due to the difficulty of deciding what features to investigate and to illustrate the questions properly.

Compilation of survey

The survey received 307 answers in total, 173 from Volvo Cars internally and 134 externally. When analyzing both the internal and the external surveys it was stated that most of the answers collected were from people between the ages of 26-55 years old. Although, answers from people under the age of 18 and people over the age of 66 were received. A difference between the two surveys was that 76% of participants from the internal survey was men, and 75% of the participants in the external survey were women. When these two surveys were combined, it together created a gender-neutral outcome. The surveys reached out to almost only European participants, only 8% of the internal survey got participants from Asia.
The result of the survey regarding customers' habits was that the car is most often used as transport to work or for shorter arrands and with no passengers, only a driver. Although, there were very often 2-4 passengers in the car but rarely 5 persons. This creates an opportunity for restrictions of the length of the center console. If the middle seat in the back is not often used, then the center console can take up space further back. It could also be stated that it is common to use the car for longer trips occasionally.

The majority of the participants either own the car themselves (40%) or lease the car (40%). This is an important analysis from the perspective of modularization and personalization. If the car is bought by the person who is going to drive it, the personal choices regarding all interior and exterior when buying the car are their own. For the people who lease the car, there is often no choice of personalization. If the console were developed for modularization during the time when the car is used, after the purchase, it can be utilized by both the customers who own the car and the customer who leases the car.

73% of the participants who use a hybrid or electric car answered that they usually charge the car at home. This is an indication of not spending any time in the car while charging.
The most important feature of the center console is, according to the survey, armrest, cupholders, and USB/C outlets, and the least important is storage for sunglasses and locked or hidden storages. The differences between the internal and external survey are the importance of storage. In the internal survey the big storage and small storage are prioritized as important, see Figure 2.8. While in the external survey the inductive charging, mechanical controls, and phone holders are prioritized more important than big storage, see Figure 2.9.

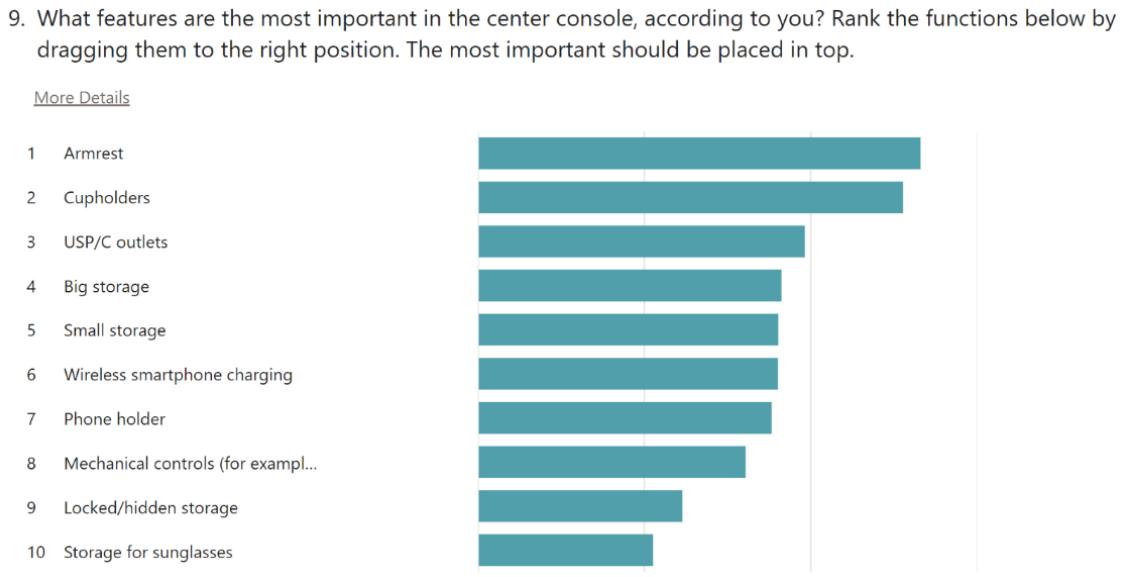

Figure 2.8. *Ranking of importance of features in the center console, internal survey.*

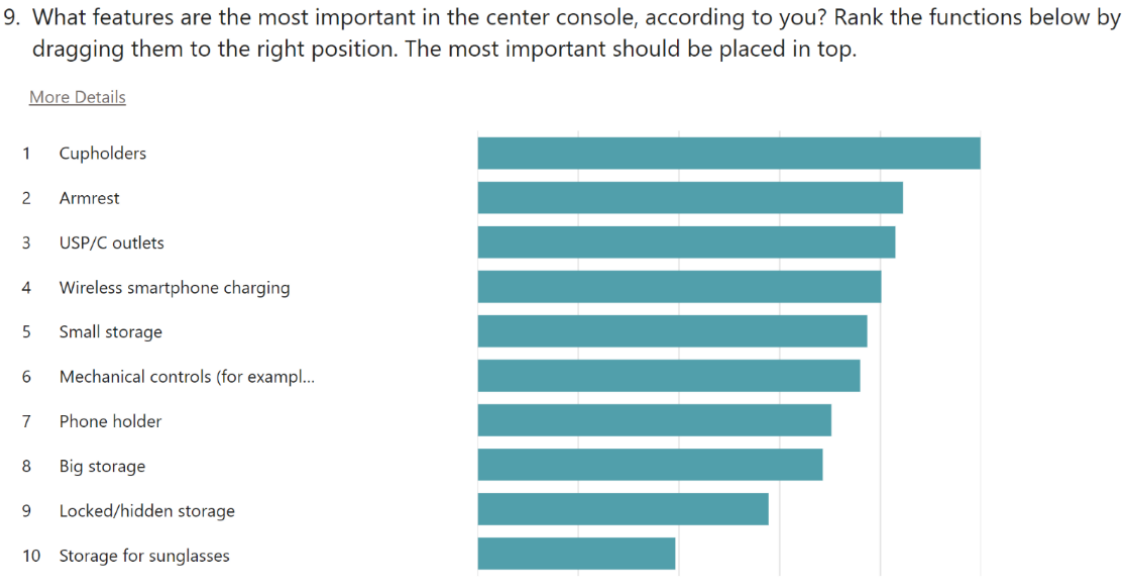

Figure 2.9. *Ranking of importance of features in the center console, external survey.*

The most important functions in the center console for the backseat passengers were USB/C outlets, air vents, seat heater, and temperature control. The least important of the features mentioned, see Figure 2.10, was hidden storage and table.

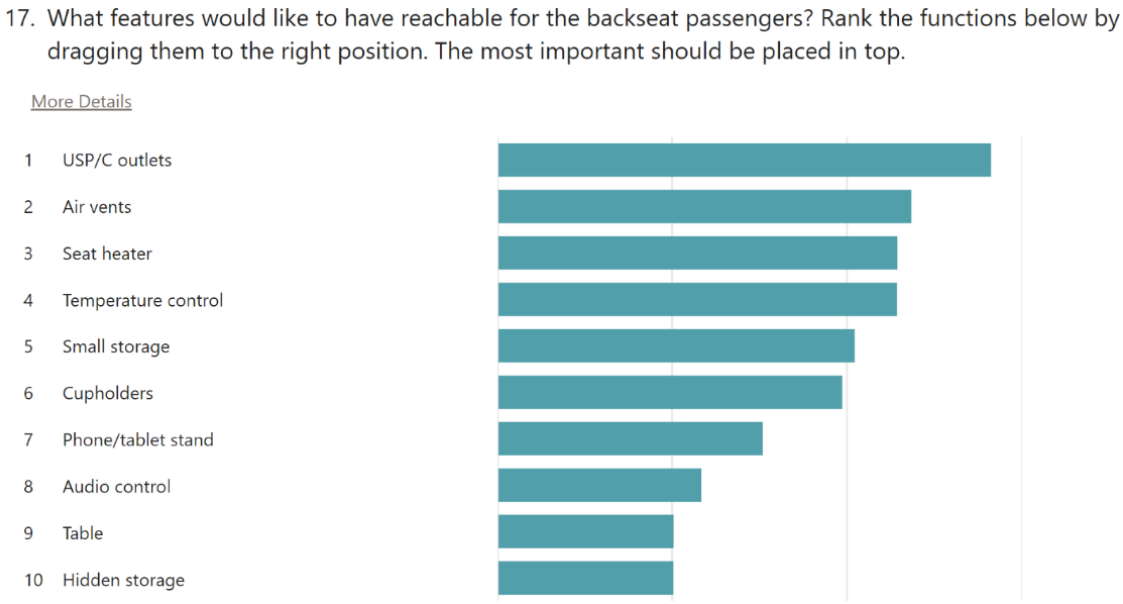

Figure 2.10. *Ranking of importance of features in the center console for backseat passengers, external survey.*

Even though USB/C outlets are rated as a very important feature, the survey indicates that most of the participants are satisfied with only 1-2 charging opportunities. One hypothesis of the result is that the participants might not have the whole center console in mind when answering the question. The console also includes the functions of the backseat passengers. The reason for the hypothesis is also that almost no one answered that 5 or more charging options are needed.

Regarding the design of the center console, around half of the participants preferred a bigger console with more storage space, and the other half a smaller console with an airier design. The majority also preferred a practical and minimalistic design, and a few wanted to customize the console for a luxury or sporty attribute. The most appealing design to the participant of both surveys is a center console with a bridge formation. The second most appealing design differs from the two surveys. On the internal survey the second was a center console with a table formation, but on the external a solid design. The solid design of a center console is the most well-known design, and often the design needed for a car with a transmission tunnel. This design might be highly rated by the external participants because it is what they know and recognize. The internal participants, however, might have another mindset regarding the interior in a BEV with other possibilities than a diesel or gasoline driven car. When the participants were asked to do this rating, pictures of the different designs were shown. This might affect the choice of design since some of the other interiors were visible in the pictures. The results of the survey question are shown in Figure 2.11 and 2.12.

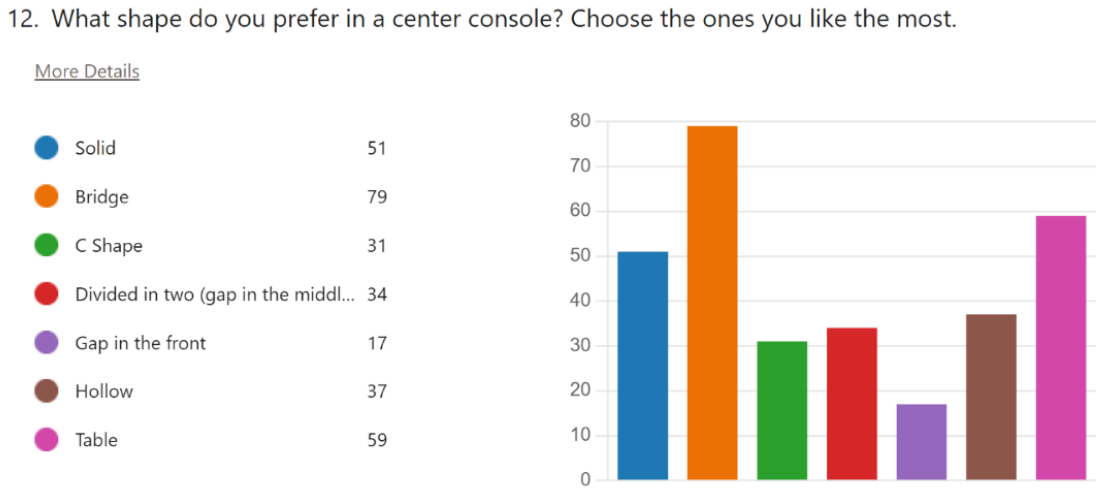

Figure 2.11. *Staple diagram of the most appealing design of a center console, internal survey.*

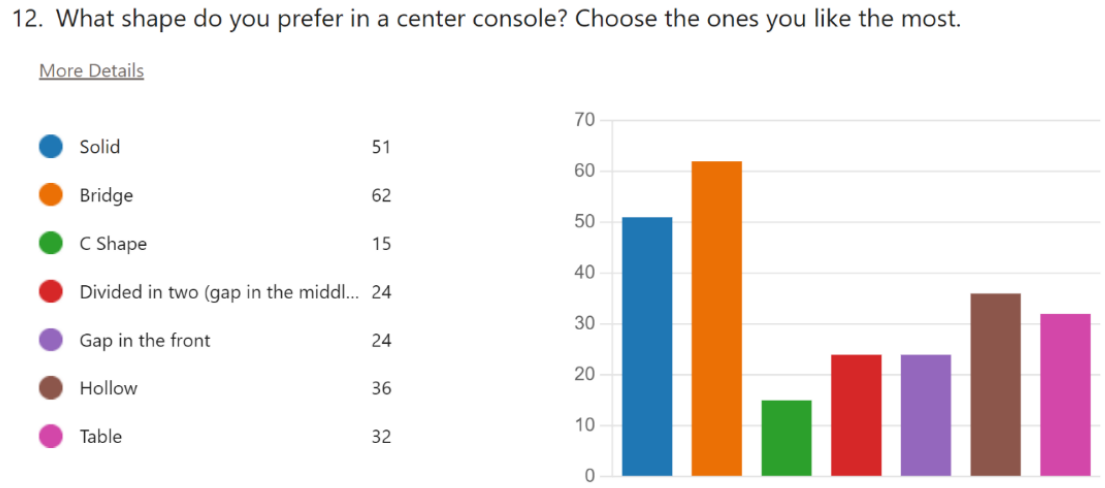

Figure 2.12. *Staple diagram of the most appealing design of a center console, external survey.*

Around 50% of the participants wanted to have the gear shifter in the console, and 25% preferred to have it placed somewhere else. Regarding the other functions in the center console, the external participants seem to prefer the mechanical controls in the center display, while the internal participants prefer to have the controls in the center console.

Due to the answers of the survey, it can be concluded that the storage in the center console is well used. Almost 90% of the participants are using the storage under the armrest. It was also concluded that long-term storage is almost as much used as short-term storage. Modularization of a center console by movable features was in demand, although modularization by moving the center console back and forth did not seem to be. This can be an effect of the users not knowing how it would make the console better if it was movable.

2.4.1 KJ Analysis – to compile the information gathered

After the gathering of information during the tasks mentioned above, an analysis was carried out. It was done through a process of compiling the collected information that later was the basis for the requirement specification. A KJ analysis was used in order to compile and get an overall picture of the stakeholder's requirements, points of view and ideas. The most common opinions and distinguishing trends that were observed during the interviews were cut out as quotes, grouped and organized. (Dam & Teo, 2020)

To summarize the information gathered regarding the open questions, a lot of the participants demands a place for their handbags/briefcase, a particular place for their phones or a phone holder, wireless charging opportunities, two adjustable cupholders, both small and bigger storage spaces, and room for their legs. A few commented that they would want a mini fridge/cooling box for cold drinks, which was more surprising. Other new ideas were waste bins, foldable/flat tables where you can place your food from a drive-thru or place a computer while charging the car etc. Also, a movable center console or movable armrest/storage units. Additional quotes from the survey, stated by the participants, were compiled in a KJ analysis, shown in Figure 2.13.

Figure 2.13. *KJ analysis of surveys*

2.5 Stakeholders' Input from Relevant Departments

As this thesis is commissioned by Volvo Cars, stakeholder input plays a vital role in the development process. The valuable contributions from stakeholders include their requirements, perspectives, and ideas. The concept cannot be solely shaped by the center console department's knowledge and inputs, inputs from other departments were also essential. To gather these inputs, meetings were conducted with relevant departments at Volvo Cars. The interviews and the information gained from these meetings can be seen as qualitative information from experts. Interviews can in general be seen as structured, semi-structed or unstructured (Gillham, 2000). Applicable for this scenario would be to have more of a discussion with some prepared questions for the stakeholders at Volvo Cars, typically a semi-structured interview. During this part of the project and all contact with the stakeholders, the ethical aspects of Volvo Cars as a company were considered.

The departments that were contacted were Ergonomic, Design, and Business/Market. The contact information was provided by the supervisors at Volvo Cars and the interviews were around one hour long. The meetings started with a brief explanation of the main objectives of the project and an introduction from their side of what respective departments are working with. The main questions asked were what objectives the project team needs to relate to when developing the new concept of a center console from the different departments. What are their thoughts regarding this project, what are their thoughts of modularity? What do the customers want in a new center console? What has been working so far and what has not? etc.

By performing these interviews/discussions an approach of how to relate to respective department, insights of the work process, and new ideas and inspiration from the participants point of view, was gained. From the design department future thoughts of the customer's behavior was obtained, and what to have in mind while developing a new center console from a design perspective. The economics department highlighted the importance of new innovations that can create a story that can establish headlines. Other inputs were different approaches to the modularization. It can be done before the purchase or during the use of the car and there should also be options for the owner of the car in second life to remodel the interior. The transcribed texts from each interview were used to later fill the requirements specification list.

2.6 Compilation of Customer needs list

After gathering and analyzing information and opinions from customers, a customer needs list was created to gain a clearer understanding of their wants and needs. The customer needs list includes essential requirements and expectations that customers have for a product or service, helping to prioritize features, functionalities, and attributes based on their importance (Ulwick, 2005). The importance of different statements in the customer needs list was rated on a scale of 1-5, reflecting the feedback received from the customers. The customer needs list is shown in Table 2.3.

Table 2.3. *Customer needs list*

No.	Features for the frontseat passengers	Importance
1	2 cupholders	5
2	1-2 charging USB/C outlets	5
3	4 charging USB/C outlets	3
4	Inductive/wireless charging	4
5	Cooling box/temperature regulated cupholders/storages for drinks	3
6	Trash bin/waste bin	3
7	Placement for handbag/briefcase	4
8	Small storage	5
9	Gear shift	3
10	Big storage	5
11	Hidden/locked storage	2
12	Armrest	5
13	Phone holder/placement for the phone	5
14	Mechanical controls	2
15	Storage for sunglasses	1
16	Storage under armrest	4
17	Movable features	3
18	Movable armrest	2
19	Moving center console back and forth	1
20	Spacious design/more room for legs	2
21	Foldable table	3
22	Easy to keep clean (avoidance of smaller spaces/interfaces)	4
	Features for the backseats passengers	
23	Air vents	5
24	Seat heaters	5
25	Temperature control	5
26	Table	1
27	Hidden storage	1
28	USB/C outlets	5
29	Cupholders	3
30	Small storage	4
31	Tablet stands/phone holder	3
32	Audio control	2

2.7 Requirement Specification

To establish a clear direction for the project team in developing a new modularized concept, a requirement specification list was generated. This list serves as a reference point for the platform that the team should align with. It is important to note that a requirement specification is typically based on a customer's needs list, which is expressed in their own language. However, the requirement specification itself offers a more detailed description of the key variables that the product must fulfill (Ulrich et al., 2020).

In order to compile the requirement specification, inputs were gathered from various stakeholders and potential future customers. These inputs were then categorized as criteria, with some being designated as explicit requirements and others as desirable features that the future product should strive to achieve.

3. CONCEPT GENERATION

The concept generation chapter outlines the steps from the initial brainstorming to the composition of whole concepts. With the requirement specification as a basis, brainstorming sessions regarding both different features of the center console and the design of the center console were performed. The outcome of the brainstorming sessions was to find possible sub-solutions for the different parts of the center console and the console as a whole. After generating ideas for sub-concepts and features, a morphological matrix was used to identify 10 potential solutions that were selected for further development.

3.1 Initial Idea Generation

The initial idea generation was carried out early in the project, with the aim of generating unconstrained and innovative ideas. This was done to allow unfiltered creativity to flow and explore potentially infeasible but novel ideas. At this stage, the quantity of ideas was emphasized over the quality, and it was important to encourage unconventional and radical thinking. A key guideline during the session was to avoid criticism, both of one's own ideas and those of others, in order to create a safe and open space for ideation.

To approach the initial idea generation phase, a framework for execution was established. The approach involved brainstorming and creating sketches or written descriptions of potential features and functionalities customers want in a center console. Both the driver and passengers' needs and preferences were taken into consideration, as well as viewing the console from the backseat passengers’ perspectives. Throughout this process, the following guiding questions were identified and used to steer the ideation towards meaningful and practical ideas.

- What functions would we want in a center console?
- How could the design of these functions look like?
- How could the whole center console look like?
- Where are the functions placed?
- What feeling do they convey?

The initial brainstorming session did not yield the desired results due to lack of inputs, but it successfully ignited the creative mindset and established a way of thinking. As a result, the project team began contemplating the placement of functions, the importance of having certain features within close reach, the overall design of the center console, as well as the positioning of gearshifts and buttons. These considerations became focal points for further exploration and development.

3.2 User Case Scenarios

Prior to the brainstorming process, four user scenarios were created, which are illustrated in Figure 3.1 and described in greater detail below. User scenarios are a valuable design tool to understand users and how different users interact with the product. By enabling product developers to empathize with the user's perspective, it becomes easier to identify the user's objectives and create solutions that enable users to accommodate their needs. (Costa, 2020) The scenarios outlined below encompass various common ways of using an electric vehicle, providing a comprehensive understanding of user needs and preferences.

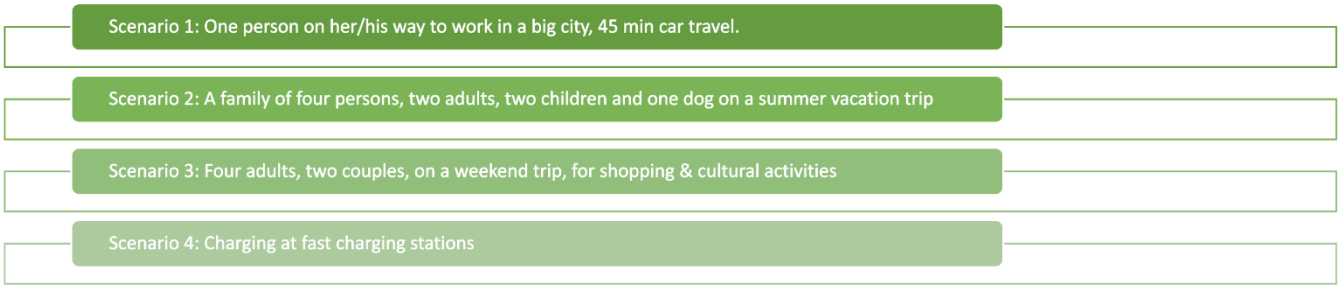

Figure 3.1. *The four user scenarios*

Scenario 1: One person on her/his way to work in a big city, 45 min car travel.

To envision this scenario, one could consider a user who intends to bring along a laptop, a handbag or briefcase, a cup of coffee, and small items like keys and headphones. As this may involve minimalistic use of the car and center console during the trip, it is important for the driver to have easy access to a cupholder and the ability to charge their phone while driving.

Scenario 2: A family of four persons, two adults, two children and one dog on a summer vacation trip

To meet the needs of a family traveling in a car, it is important to consider the requirements of all four individuals. As they are likely to carry bags and entertainment such as toys and tablets for kids, it is essential to have storage space. During a long trip, snack and drink breaks would be necessary for the entire family, and they would appreciate a sense of connectivity between the front and back seats. Additionally, an adult in the family may have a high-end luxury handbag that requires safe and secure storage.

Scenario 3: Four adults, two couples, on a weekend trip, for shopping & cultural activities

This scenario differs from the second one since there are now 4 adults in the car, which requires different needs. During the weekend trip, the two couples would prefer an inclusive environment where they can socialize comfortably. They might bring or buy drinks for all of them, so a cup holder or a bottle holder would be necessary and carried-on weekend bags and purchased shopping bags need storage space. Additionally, a larger space is preferable in the backseat to accommodate a person with long legs.

Scenario 4: Charging at fast charging stations

When charging electric vehicles, people spend some time waiting in the car. To make the waiting time productive, somewhere to place food, drinks, or laptops would be useful. Additionally, easy access to charging cards and credit cards for gas stations, shopping, and drive-throughs is preferable for the driver.

3.3 Brainstorming

In the initial phase of the concept development two different approaches of brainstorming were conducted, one of sub-functions that a center console potentially can or already do possess, and one of the whole concept. Brainstorming is a method that can generate a large number of ideas in a time efficient way. The method helps the participants share their thoughts and work creatively (Wikberg Nilsson et al., 2015). The brainstorming sessions were done by pen and paper by sketching and writing down solutions. During the sessions a mindset regarding modularity, standard to premium levels, user scenarios and the kinder egg principle was applied. The kinder egg principle refers to integrating multiple functions in one feature. A visualization of some results from the brainstorming of features can be seen in Figure 3.2.

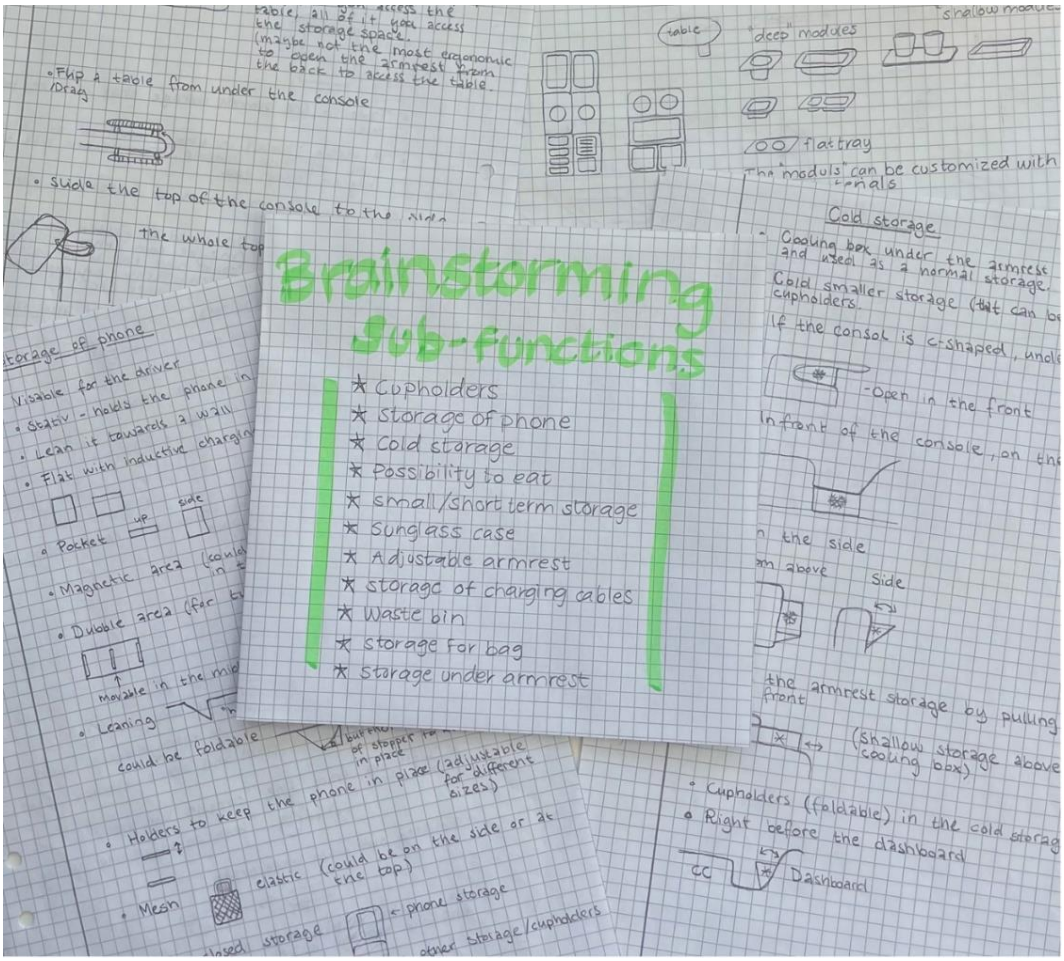

Figure 3.2. *Illustration of the results from the brainstorming session of subfunctions*

The first approach used when executing the brainstorming was a “bottom up”-method, dividing the whole center console into sub-functions that later can be merged into a whole concept. The categories regarding the features were selected from the requirement specification list and the subfunctions were following:

- Cupholders
- Storage of phone
- Cold storage
- Possibility to eat
- Small/short term storage
- Sunglass case
- Adjustable armrest
- Storage of charging cables
- Waste bin
- Storage for handbag/briefcase/tissue bags
- Storage under armrest

The second approach, that later was performed, starts from the top, observing and brainstorming ideas for the whole center console. The focus of this approach was on the shape and placement of sub-functions. When the two different types of brainstorming sessions were done these sub-functions and ideas on shape were merged into concepts by using a Morphological matrix.

3.3.1 Brainstorming on Interfaces

Given the emphasis on modularization in the master thesis work, supplementary brainstorming sessions were conducted specifically to explore modular interfaces and modules. The objective was to devise solutions for an interface that enables seamless integration of various features and shapes in a convenient and customizable manner. The ideas during the session of how the interfaces could appear can be seen in Figure 3.3.

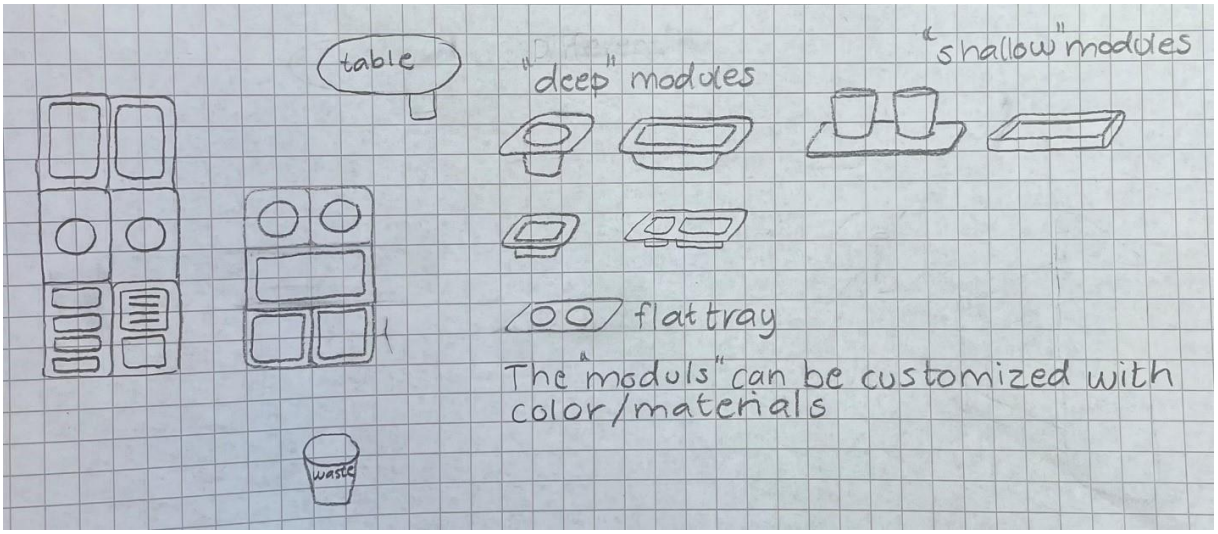

Figure 3.3. *Ideas of interfaces and shape of modules*

The interface could have different shapes for starters, it could be rectangular, circular or built out of squares. The depth of the interface can also differ, depending on the depth of the surface it is placed on. It can either contain features that are flat, like trays, contain features that arise from the flat area or a third option where the features follow down the depth.

It is possible to personalize even more with materials and colors, etc., by applying a differentiation between premium levels. The standard offer could be more basic with modules of black plastic while the premium version could offer materials such as wood, glass, or involve corporation partners like for example *Orrefors* to develop glass modules for cupholders/champagne glasses.

Ideas that also came up during this brainstorming was what to create certain modules for, the result can be seen in Figure 3.4.

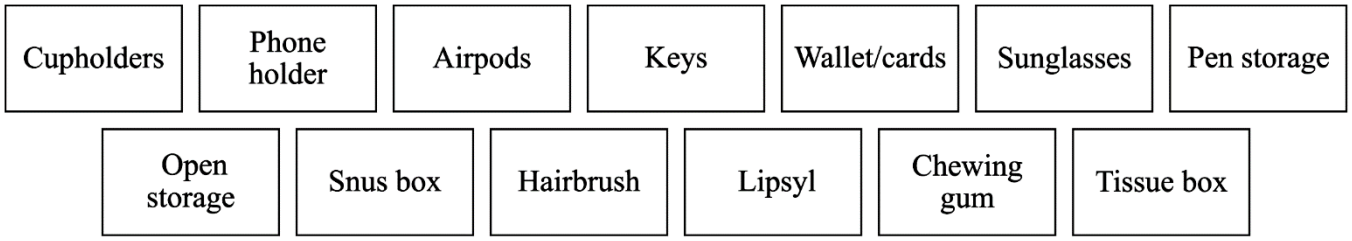

Figure 3.4. *Examples of things to develop modules for*

3.4 Idea Generation Using Morphological Matrix

After the brainstorming sessions were completed, the generated sub-solutions were put together into whole concepts by using a morphological matrix. When using a morphological matrix, a large number of concepts can be created in a short period of time by integrating different combinations of the sub-solutions. It breaks down the main problem into smaller problems, which helps to stimulate the brain and think beyond the main problem that otherwise can be overwhelming. (Wikberg Nilsson et al.,2015) Since the matrix provided many concepts, they were evaluated and the 10 concepts that seemed most feasible were collected. In this chapter, the collected concepts are documented and explained by descriptions and sketches.

Concept 1 – The detached slidable center console

Concept 1 is a solution with a detached center console that is slidable and an equipped dashboard, presented in Figure 3.5.

Features and functions located in the dashboard, divided in two levels

- Level 1, closest to the floor, contains a storage space for a bag/briefcase. A hook is placed between the two levels to keep the bag steadier.
- Level 2 contains inductive charging and small storage.
- USB/C outlets are placed between the levels and there are clips placed on the surface under level 2 to keep the charging cable in place.

Features and functions located in the detached slidable center console

- The cupholders are placed in the front of the center console, and by pressing a circular button the cupholders pop up. When the cupholders are pressed down, it is only a flat surface.
- The department under the armrest can be equipped with a detachable cooling box used for cold drinks or a deportable waste bin. Otherwise, it is just a closed storage space. The storage is opened with butterfly armrests.
- The butterfly armrest is possible to open to use as a table.
- There is an organized small storage space right in front of the armrest that is possible to cover.
- On the wall under the cupholders there is a pocket and a "clip" function where sunglasses can be placed.
- Outlets and air vents for the backseat passengers.

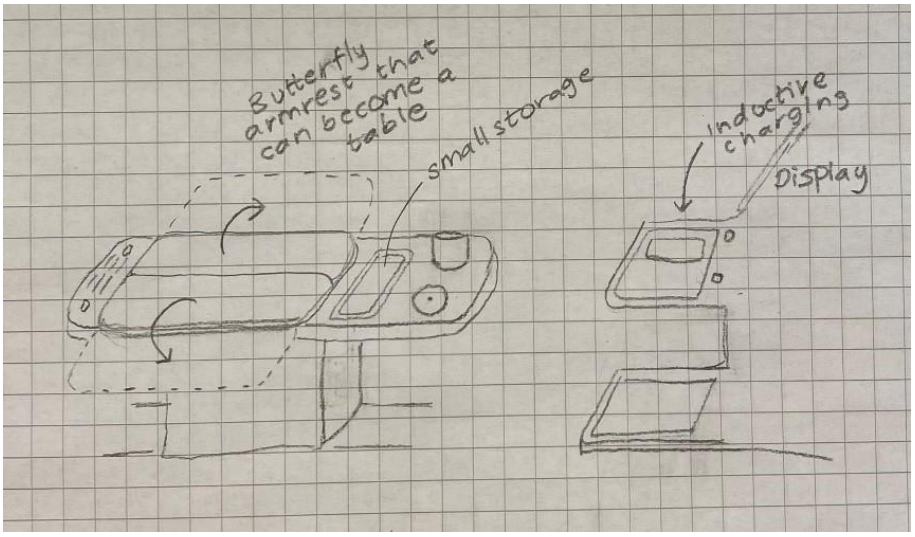

Figure 3.5. *Sketch of concept 1 - dethatched center console and with an equipped dashboard*

Concept 2 – The 4 passengers' adapted center console

Concept 2 is a center console that can be split into two where the part in the back can be either connected with the front part or slid all the way back over the middle rear seat. The concept is visualized in Figure 3.6.

Features and functions located in the front part of the console

- A table in the front of the console that can be turned 90 degrees in both directions.
- Cupholders in the front of the console.
- Storage for handbag under, in front of the console.
- Hard pockets on the side of the console.
- USB/C outlets on the front and back of the console.

Features and functions located in the back part of the console

- The back part can slide all the way over the middle seat in the back, or be connected to the front part, which makes it possible for a fifth person in the car to sit.
- Smaller storage under the back armrest with a modular interface.

Features and functions located in the dashboard

- A larger storage in the glovebox in the center of the lower part of the dashboard.
- An area for phone.

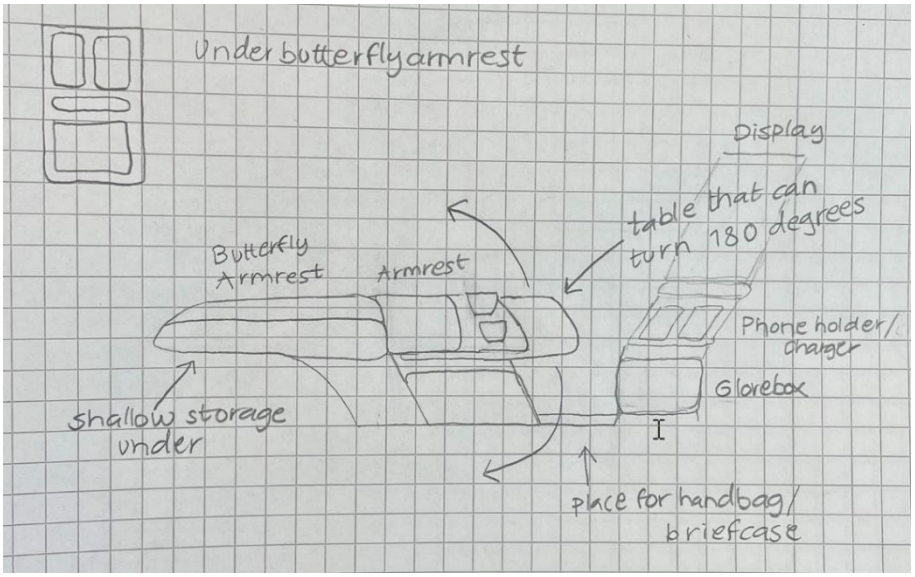

Figure 3.6. *Sketch of concept 2 - Slidable back part*

Concept 3 – The slidable armrest

This concept contains a slidable armrest that slides over the console, from the back to the front, see Figure 3.7.

- The console is designed in a bridge model.
- The front of the console contains a modular interface.
- The back area contains a big storage area with a separator to create shallower storage. It is also possible to fasten a wastebin in the storage.
- The armrest works as a classic one, where it is opened from the back, to access the bigger storage. It is also possible to fold it out as a table by opening it from the sides, as a butterfly armrest. To prevent it from opening from the sides when not needed, the table is magnetically fastened.
- On the underside of the armrest, there is a pocket and a cardholder that is accessible when the armrest is folded up from the back, see Figure 3.8.
- A storage for handbag is placed under the console. To keep the bag better in place, a hook can be folded out from the underpart of the console.

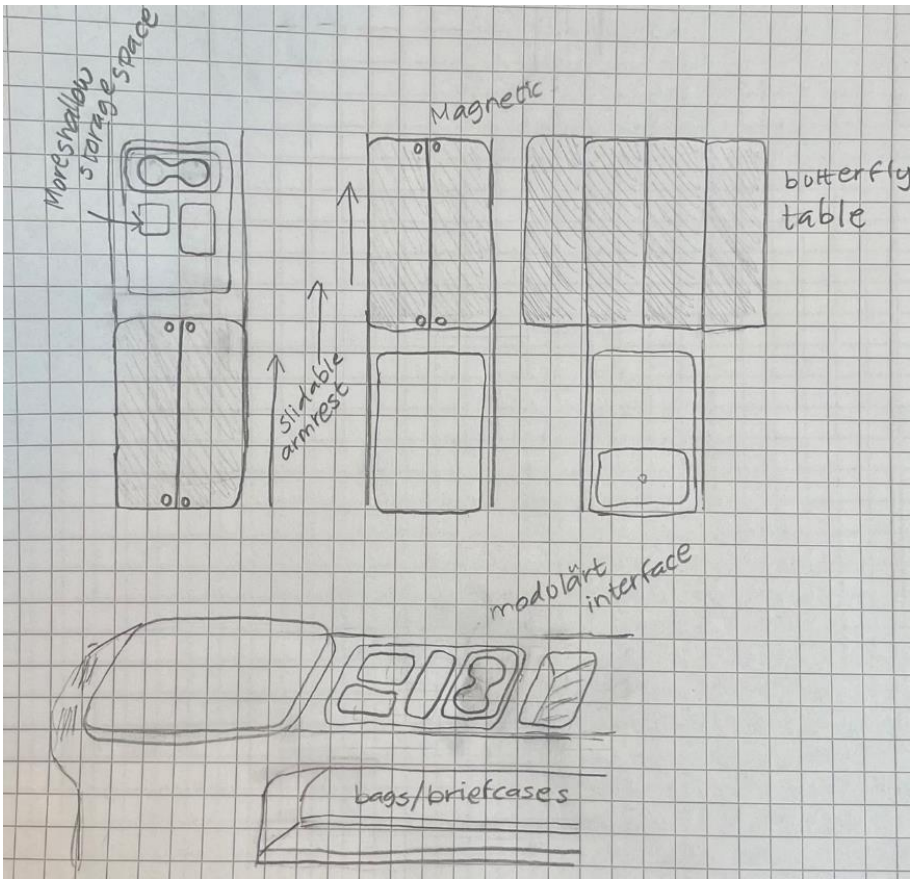

Figure 3.7. *Sketch of concept 3 - Slidable armrest*

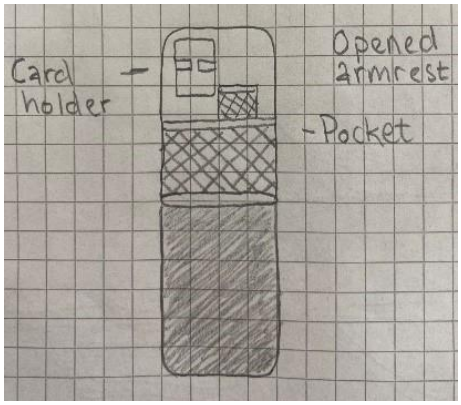

Figure 3.8. *Storage under the armrest*

Concept 4 – The hidden storage

This solution is presented in two different design approaches, see Figure 3.9 for design approach 1 and Figure 3.10 for design approach 2. The concept is divided into two parts, where the two parts are slidable. The concept enables the use of new surfaces when slid apart.

Features and functions located in the front part of the console

- Cupholders that can be folded out are placed in a small storage space, see Figure 3.9.
- Phone holder
- Table that can be dragged out from the end towards back.

Features and functions located in the back part of the console

- Bigger storage in the second part, that is hidden while the parts are put together. It could be equipped with a cooling box or a waste bin.
- In design approach 1, Figure 3.9, a storage space is placed in the back. Could be equipped with a waste bin.
- Table that can be dragged out from the end.

Features and functions located in the dashboard

- Inductive charging under the display, pocket where a phone can be placed.
- USB/C outlets under the display

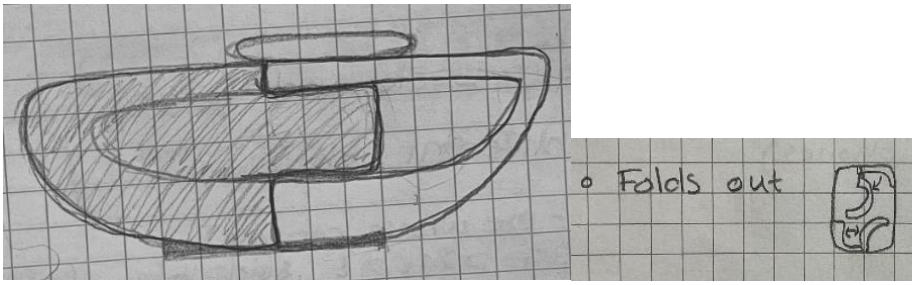

Figure 3.9. *Sketch of concept 4 – Design approach 1*

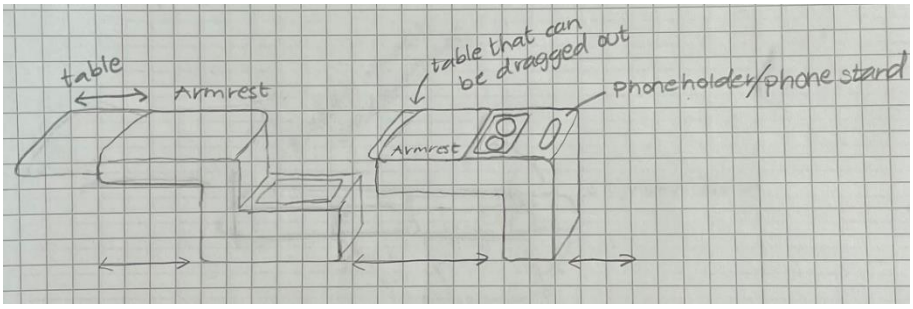

Figure 3.10. *Sketch of concept 4 - Design approach 2*

Concept 5 – The lifting armrest

Concept 5 is a center console with a modular interface where the customers decide all of the features it should be equipped with, see Figure 3.11.

- Modular interface: A detachable tray for one or two telephones, a detachable tray for one/two cupholders, a module for sunglasses storage and one for small storages.
- Premium selection: Cooling box/fridge in the dashboard/glovebox (possibility to turn on/off).
- Adjustable armrest that can be higher/lower (bigger storage under it).
- A small storage fastens under the console that can rotate to the side for accessibility.
- Outlets under the table with rubber bands that fasten the phone's charging cords.
- A plastic bag can be fastened on the side of the console by a waste bin holder that is folded out.
- Handbags can be placed in front of the center console, a smaller wall that makes the bags stay in place.

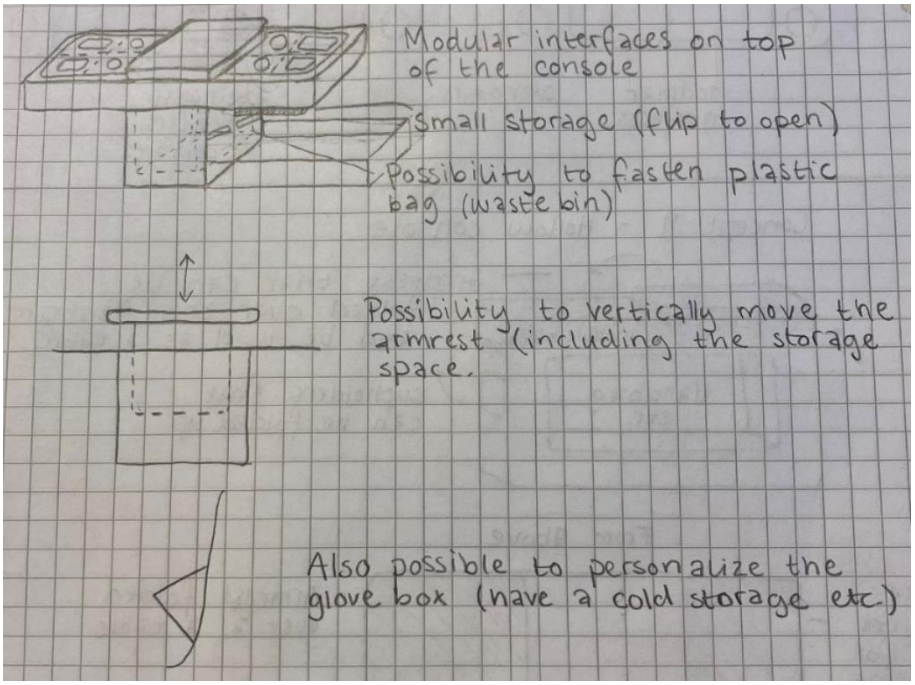

Figure 3.11. *Sketch of concept 5 - Modular interface*

Concept 6 – The piece of cake

Concept 6 is designed as a bridge solution with a circular modular interface (Cake solution), shown in Figure 3.12 and 3.13.

- Circular interface on the bridge where you can add different features - cupholder, smaller storage spaces, waste bin, table, etc.
- Equipped with inductive charging of phones which is placed in front, by leaning the phones towards the wall under the display.
- Table that can be lifted and turned over for the backseat passengers.
- Bigger storage under the center console for handbags/briefcases.
- Small storage under the armrest that is organized with different boxes.
- A circular table can be placed in a cupholder-module and be rotated to gain access to the features in the interface while used.
- The circular interface can rotate for easier access to the modules if desirable.

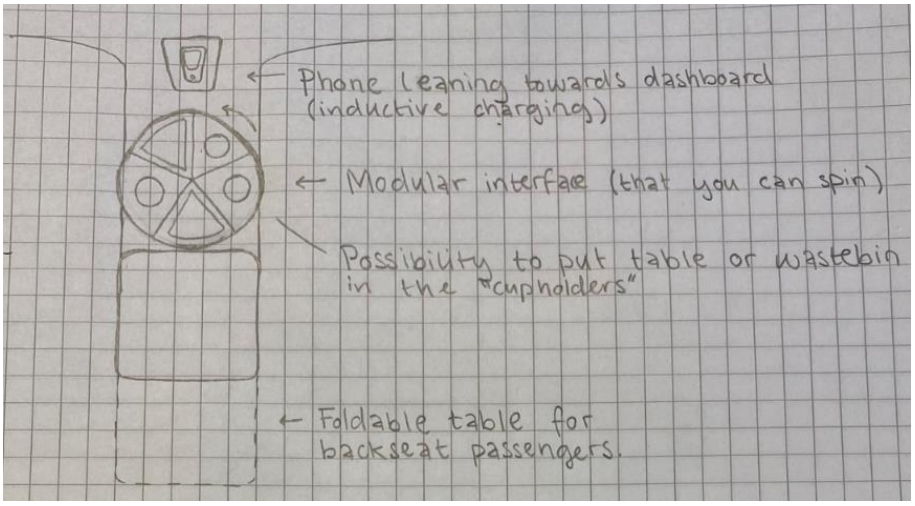

Figure 3.12. *Sketch of concept 6 - Circular modular interface*

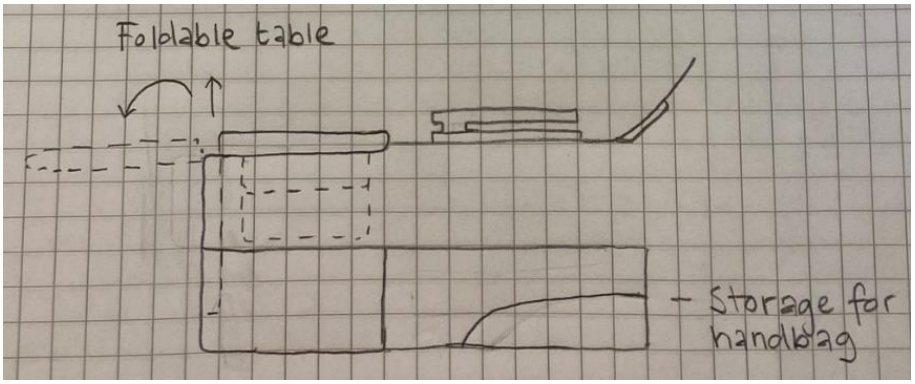

Figure 3.13. *Sketch of concept 6 in profile*

Concept 7 – The rolling table

Concept 7 is a center console that is able to slide back and forth in the car, see Figure 3.14.

- The placement of phones is in front of the center console with an inclined wall that is pushed down. When it is not used, the wall goes back up and connects with the surface of the center console.
- Detachable cupholders (a tray with holes for the cups) for both front- and backseat passengers are placed in an interface/storage space.
- Possibility to buy an extra pillow that can be fastened on the armrest. Makes it higher, more comfortable and the pillow could also be used for other occasions. The pillow is fastened with the same mechanism as for "boat interiors".
- A table is placed on the surface under the console and can be flipped/dragged to the top, see Figure 3.15.
- Storage for sunglasses under the dashboard.
- Small waste bin placed in the bigger storage under the armrest.
- Smaller walls in front of the center console that separate the floor in front of the seats, possibility to store bags/briefcases.
- Outlets under the dashboard and rubber bands that make the phone's charging cords stay intact.

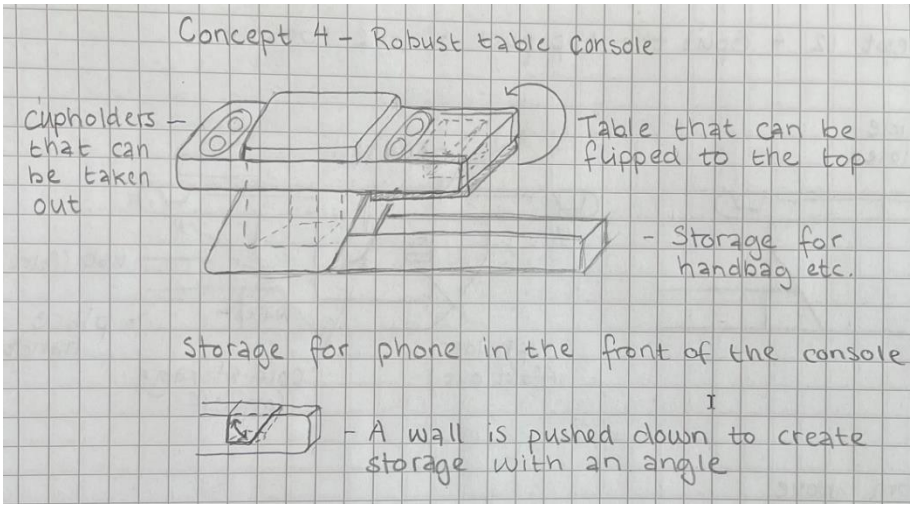

Figure 3.14. *Sketch of concept 7 - Slidable center console*

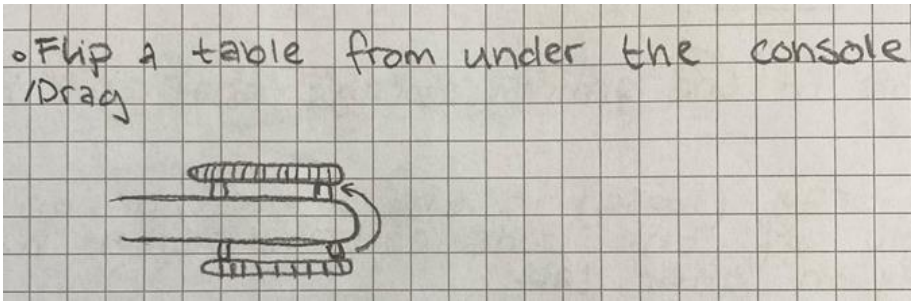

Figure 3.15. *Table solution of concept 7*

Concept 8 – The hollow one

Concept 8 is visualized in Figure 3.16. and is a slidable hollow center console.

- Cupholders are folded out from the front of the console.
- If the armrest is opened from the back, it can be folded to the front and used as a table.
- Shallow storage is placed under the armrest.
- Storage for handbags in the hollow space in the console.
- To cover the hollow storage space, “walls” can be slid up.
- USB/C outlets in the front and back, where the outlets can be pushed further in to store the charging cables.
- A wastebin can be placed in the hollow space by a click-mechanism.

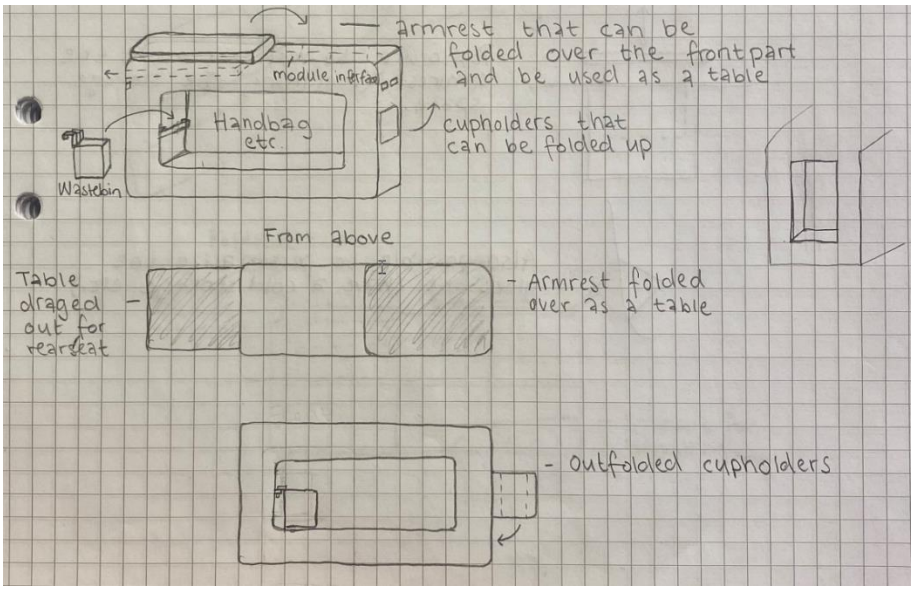

Figure 3.16. *Sketch of concept 8 - Slidable hollow center console*

Concept 9 – The epic fridge

This concept is a center console where the top-part of the console is divided in two and opens the accessibility to the storage space when the parts are slid apart. Concept 9 is shown in Figure 3.17.

- When the top-parts are slid apart from each other, a bigger storage is revealed. The storage is a cold storage that can be turned on and off. It also contains two foldable cupholders, which makes it possible to store cold drinks.
- On the surfaces of the two parts, there are modular interfaces where the customer chooses the modules, which can be:
  - Storage of phone
  - Small storage
  - Storage for sunglasses
- Two cupholders are placed in front, and two are placed in back
- A portable wastebin can be placed in front of the console, close to the floor, before the storage for handbag.
- USB/C outlets are placed in front and in back and reveal when a small compartment is opened. In this compartment the charging cables can be stored – both when not used and when used.

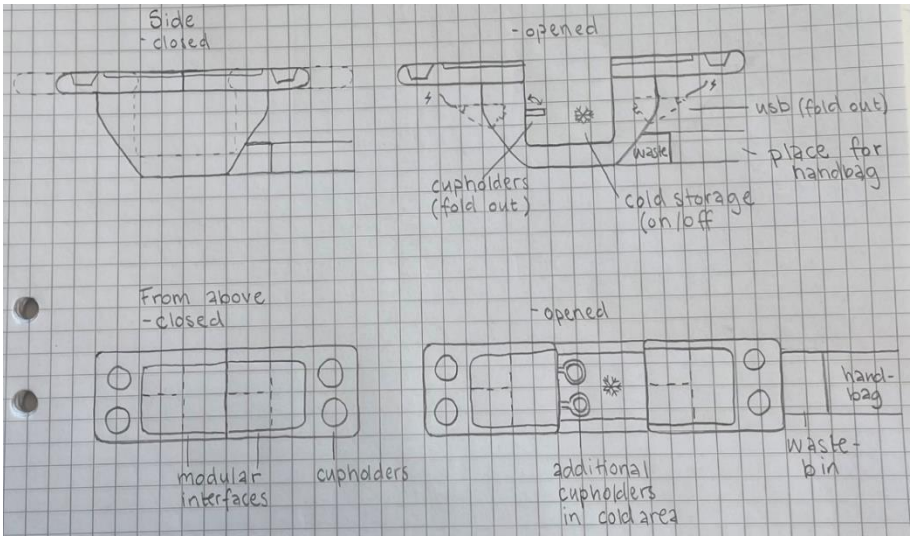

Figure 3.17. *Sketch of concept 9 - Top-part are divided into two and can be slid apart*

Concept 10 – The extended dashboard

This concept is extended from the dashboard, see Figure 3.18.

Features and functions located in level 1

- Storage with smaller walls for handbags/briefcases.
- Glove box between level one and two.

Features and functions located in level 2

- Phone holder/inductive charging with an inclination under the display
- Small storage under that is possible to cover. It also contains coin/cardholder.
- There are two USB/C outlets under the phone holder, outlets for the back seat passengers are in on the backside of the front seats.
- Two stationary cupholders for the front seat and the possibility to drag out two additional cupholders for the back seat passengers.

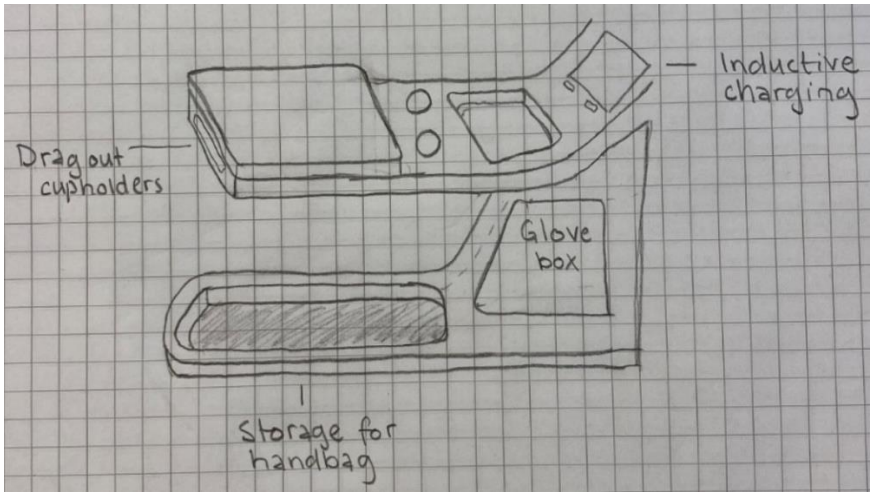

Figure 3.18. *Sketch of concept 10 - An extended dashboard.*

The ten created concepts consist of many different functions and features developed during the brainstorming process. When selecting concepts, priority was given to leveraging a wide range of previously developed sub-functions to ensure a well-balanced distribution of outcomes. The concepts created were improved and evaluated throughout the development process.

4. CONCEPT EVALUATION AND ELIMINATION

When whole concepts for the center console were created, they needed to be valued and eliminated so that the best concept, regarding several factors, could be chosen. The methods used to evaluate and eliminate concepts were Pugh matrix, Kesselring matrix, calculation on performance/cost ratio and quick prototyping. The methods were used in an iterative process to evaluate the concepts more thoroughly.

4.1 Stakeholder Inputs Regarding The 10 Concepts

The 10 concepts generated in Chapter 3.4 were presented during a meeting with different stakeholders at Volvo Cars. The meeting involved a detailed discussion of each concept, covering aspects such as customer and mechanical features, feasibility, and innovation. Additionally, the criteria outlined for the elimination matrixes of the 10 concepts were discussed to obtain the stakeholders' perspective regarding the significance of each criterion and its relative weightage. This process aimed to gather expert insights on aspects related to safety, cost, and improvement features of the concepts.

4.2 Pugh Matrix – evaluation and eliminating concepts

The evaluation and elimination process began after the sketches and descriptions of the 10 concepts were completed. The first step in the evaluation process was accomplished by using a Pugh matrix. A Pugh matrix is an evaluation method where each concept will be compared to a reference concept based on criteria from the requirement specification. Each concept gets scores from “+” if it is estimated to perform better than the reference, “0” if equal, and “-” if inferior. This is done repeatedly by changing the reference concept to make sure that the reference is not biased. The least performing concepts during the generations will be eliminated. This results in a reduction of remaining concepts and enables further work with those that are adding value for customers and stakeholders. (Ulrich et al., 2020)

The Pugh matrix was set up by 15 criteria regarding different aspects that the center console should fulfill. This included two types of criteria regarding features: customer features (e.g., cupholders, tables, storage, cold area, phone storage) and mechanical features (e.g., sliding console, sliding table, opening mechanism). The safety criterion takes into account the potential impact of a collision, where the airbags in the front seats are released. In such cases, the forces must be supported by the area between the seats located under a traditionally placed armrest. If the center console concept covers this area, it will be assessed higher on safety.

When performing the Pugh matrix an iteration process of improvement of eliminated concept was done by refining the eliminated concepts to better fulfill the criteria with a potential improvement of performance. This was achieved by exchanging sub-solutions generated during brainstorming sessions, integrating new ideas or combining concepts. The matrix was iterated three times and the three references were randomly selected. Out of the ten concepts the references chosen for iterations were concept 2, 3 and 5. In the first round of elimination, concept 7, 8 and 10 was eliminated since it was the least performing concepts when observing the ranking. Although concept 10 was eliminated, it was taken into further consideration and

development since it possesses potential. The new concept, 10*, was created based on the original concept 10 with added features such as an additional modular surface and a table, similar to the one concept 4 possesses. In the second performance of the matrix, concepts 1 and 9 were eliminated due to the raking as the least performed concept. Prior to this round the new concept 10* was added. Before the last round, two more concepts were improved. Concept 4 was improved by integrating a modular surface and concept 5 by limiting the modular surface in width. After the last round there were five remaining concepts, which can be seen in Table 4.1.

Table 4.1. *Pugh matrix, iteration three*

			Concept								
		10*	1	2	3	4*	5*	6	7	8	9
New innovation/innovative solution		REFERENCE		0	-	0	-	-			
Modularity				0	-	-	0	-			
Amount of features	Customer features			0	0	-	-	-			
	Mechanical features			+	+	+	0	0			
Storages	Small storages			0	0	-	+	-			
	Big storages			0	+	-	+	+			
Differentiation between premium levels				0	-	-	0	-			
Ergonomic	Easy access to cupholders			0	0	0	0	0			
	Easy access to small storage			-	0	0	+	0			
	Easy access to phone			0	0	0	0	0			
	Armrest in a ergonomic position			0	+	+	+	0			
Safety				0	+	+	+	+			
Complexity/Technically feasible				-	-	-	0	0			
Utilization of surfaces				+	0	+	+	-			
User friendly/not to advanced/complicated				0	-	0	0	0			
	Number of "+"			2	4	4	6	2			
	Number of "0"			11	6	5	7	7			
	Number of "-"			2	5	6	2	6			
	Sum	0		0	-1	-2	4	-4			
	Ranking	2		2	3	4	1	5			
	Further development	YES		YES	YES	YES	YES	NO			

4.3 Kesselring Matrix – weighting of concepts

To eliminate the concepts further, a Kesselring matrix was utilized. The Kesselring matrix is a tool for evaluating and scoring concepts throughout the development process. Prior to the execution of the matrix, it is crucial to establish weight factors and grading scales for criteria fulfilment. During the assessment process, the concepts are evaluated, their scores are calculated, and inferior concepts are eliminated. Compared to the Pugh method, the Kesselring approach is more time-consuming, but it provides more accurate and precise assessments. As a result, it is more appropriate when the solutions have been developed in greater detail. (Almefelt, 2023, p. 99-100)

The five concepts remaining after the Pugh matrix, concept 2, 3, 4*, 5* and 10*, were continuing the elimination process. In the Kesselring matrix the concepts were scored based on how well they fulfilled the chosen parameters. The parameters were assigned weighted factors (w) after importance which resulted in different scores on the parameters, on a scale from 1-5. Every concept was rated against each parameter with a rating score (v) that emphasized how well the criteria is fulfilled. To get a weighted score (t) for each concept the weighted factor was

multiplied with the rating score (t = w × v). The sum of the weighted score (T) for each criterion and concept was calculated to compare the concepts against each other.

Although the result of the Kesselring matrix shows a small differentiation in scoring between the concepts, the least scoring concept, concept 3, was eliminated with supporting input from stakeholders. The Kesselring matrix is visualized in Table 4.2.

Table 4.2. *Kesselring matrix*

Criteria		Weight (1-5)	Concept											
			Ideal		2		3		4*		5*		10*	
			v	t	v	t	v	t	v	t	v	t	v	t
New innovation/innovative solution		5	5	25	5	25	3	15	5	25	3	15	5	25
Modularity		4	5	20	4	16	4	16	4	16	4	16	4	16
Amount of features	Customer features	2	5	10	4	8	4	8	4	8	3	6	3	6
	Mechanical features	2	5	10	4	8	2	4	5	10	1	2	2	4
Storages	Small storages	3	5	15	2	6	4	12	3	9	4	12	3	9
	Big storages	3	5	15	2	6	4	12	3	9	4	12	3	9
Differentiation between premium levels		2	5	10	3	6	2	4	3	6	3	6	4	8
Ergonomic	Easy access to cupholders	4	5	20	4	16	4	16	4	16	4	16	4	16
	Easy access to small storage	3	5	15	2	6	4	12	4	12	4	12	4	12
	Easy access to phone	3	5	15	4	12	4	12	4	12	4	12	4	12
	Armrest in a ergonomic position	4	5	20	3	12	4	16	4	16	4	16	3	12
Safety		5	5	25	3	15	4	20	4	20	4	20	3	15
Technically feasible		5	5	25	4	20	3	15	3	15	4	20	4	20
Utilization of surfaces		4	5	20	3	12	3	12	5	20	4	16	4	16
Required features		5	5	25	5	25	5	25	5	25	5	25	5	25
User friendly/not to advanced/complicated		4	5	20	4	16	2	8	4	16	4	16	4	16
T = Sum			290		209		207		235		222		221	
T/Tmax			1		0,72		0,71		0,81		0,77		0,76	
Ranking			-		4		5		1		2		3	
Further development					YES		NO		YES		YES		YES	

4.4 Performance/Cost Ratio of Remaining Concepts

An important aspect in the elimination process was to consider the cost of the different concepts. This was carried out through a performance/cost ratio and done separately from the Kesselring matrix to avoid suppression of the consideration of cost. The performance/cost ratio is a valuable method for analyzing the feasibility of concepts, but it requires careful consideration of the relative importance of cost. This approach involves calculating the performance of each concept in relation to its cost, which helps identify the most cost-effective options. By using this ratio, one can determine which concepts provide the best value for money, which is a critical factor in decision-making processes. (Almefelt, 2023, p. 102)

The estimated cost for the respective concepts was calculated after input from the Center console team at Volvo Cars and based on a reference. The center consoles are becoming more and more expensive to produce, and the cost of existing center consoles was not needed to consider for this project in terms of being cost competitive. The primary attributes for the higher cost of a console are movable features and mechanical features, but also square centimeters of visible surfaces.

The reference for the calculations on the four remaining concepts (concept 2, 4*, 5 and 10*) was the latest released center console of the car model EX90. The reference value was divided into

costs for different parts of the center console, framework, armrest, side panels, and cupholders, among others. When the estimated costs were calculated, the calculation of the performance relative to the cost was done for each concept by the following equations:

$$\frac{Performance}{Cost\,ratio} = \frac{OWV}{Cost}$$

$$OWV = Overall\,weighted\,Performance$$

$$OWV = \frac{T}{T_{max}}$$

(c.f. Miles, 1961; Pahl & Beitz, 1995)

In addition to the calculation, the performance/cost ratio was visualized through a linear graph with an estimated product cost on the x-axis and the overall weighted performance, calculated in the Kesselring matrix, on the y-axis. The cost index that is illustrated in the x-axis is calculated by transforming the mean value to a reference index 0,5, and the actual costs of each concept were given an index calculated based upon the reference. By visualizing this though a graph, it facilitates the understanding of the ratio. If one concept performs well during the Kesselring matrix but is very expensive, the concept will be placed high on both the y-axis and the x-axis, which results in a console that is overprized for the customer value it possesses. In this analysis concept 10* and 4* showed the best ratio. Concept 5* performs less than concept 10* regarding the prize and could therefore be eliminated and likewise for concept 2 against concept 4* regarding performance. The linear graph is shown in Figure 4.1.

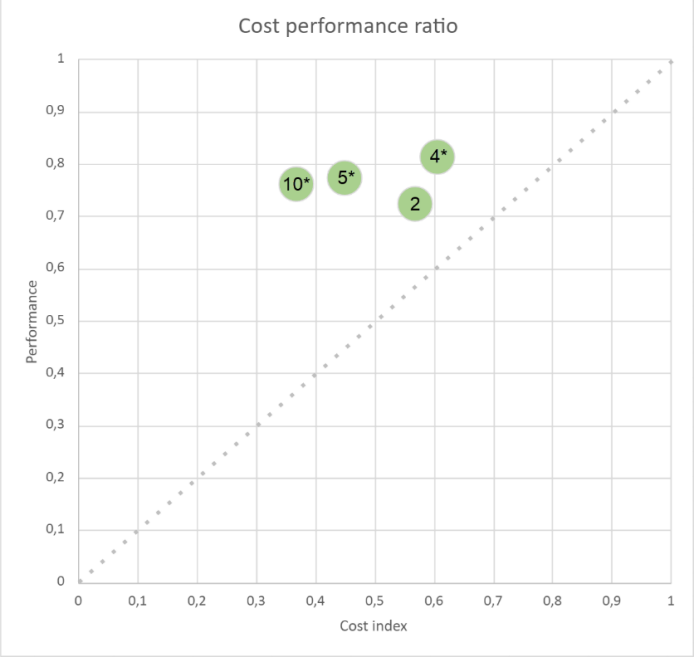

Figure 4.1. *Performance/cost ratio - Linear graph*

4.5 Quick Prototyping

To be able to analyze the two selected concepts from the evaluation process and perform the last elimination, quick prototyping was done through models in Catia V5. The two concepts that remained, improved versions of concept 4 and 10, can be seen in Figure 4.2 and 4.3. The quick prototyping facilitated the understanding of the volume, measurements, and proportions, as well as the application and integration of different features. The quick prototyping process opened a discussion of how realizable and well the two concepts could fulfill the customer value. The result of the quick prototyping process and the discussion regarding it along with stakeholder inputs lead to the selection of a final concept.

Reflections on concept 4

During the construction work of concept 4 in CAD some difficulties appeared regarding the proportions and placement of features. The front part of the center console is supposed to be able to slide back and forth and due to that the body of the console must be shorter in total. The console is more compressed and offers less space for other parts and surfaces. For example, one important insight was that the surface for the two cupholders in width is limited. The edges around them are thin and might not support the cupholders enough. All edges around the features in the interface are in general too narrow and since the concept is compressed in the other dimension there is not much room for rearranging.

Also found when building concept 4, was that the positioning of the table in front was very low. Placing it at a height of 30 cm from the floor proved to be inconvenient from a user perspective. It is the modular interface that inflicts on the height of the table since the cupholders and storage space needs to have a depth. Stakeholders also raised concerns about the table's impact on other surfaces, as it was not feasible for the table to occupy space on the dashboard when the front part slides towards it. A solution to this was to replace the original table with one that can be placed in a cupholder in the modular interface. When the table is not used, it can be stored where the table is originally placed. Moreover, to maximize utility, it was suggested that the table would be rectangular in shape, providing a more practical surface area. Since the interior of cars is focusing more and more to create a living room feeling, a table should preferably be included, but it also needs to be easy to use. In concept 4 the usage of the table could be more complicated than useful.

The sliding front part introduces a smart storage solution that can be conveniently concealed while maintaining an optimal height. Customers also have the flexibility to open only the desired portion of the storage. This feature not only allows for greater personalization of the armrest, benefiting shorter drivers, but also creates an armrest-free area when the front part is slid forward. However, this arrangement may pose challenges for some drivers who need to simultaneously access the storage space between the parts and maintain an ergonomic position for the armrest. Additionally, the cupholder placement changes when the front part slides, which can bring both advantages and usability concerns.

While concept 4 has the potential to enhance customer value, it comes with significant drawbacks. It is an expensive and technologically advanced option that necessitates multiple compromises. Concept 4 is shown as a quick prototype in Figure 4.2.

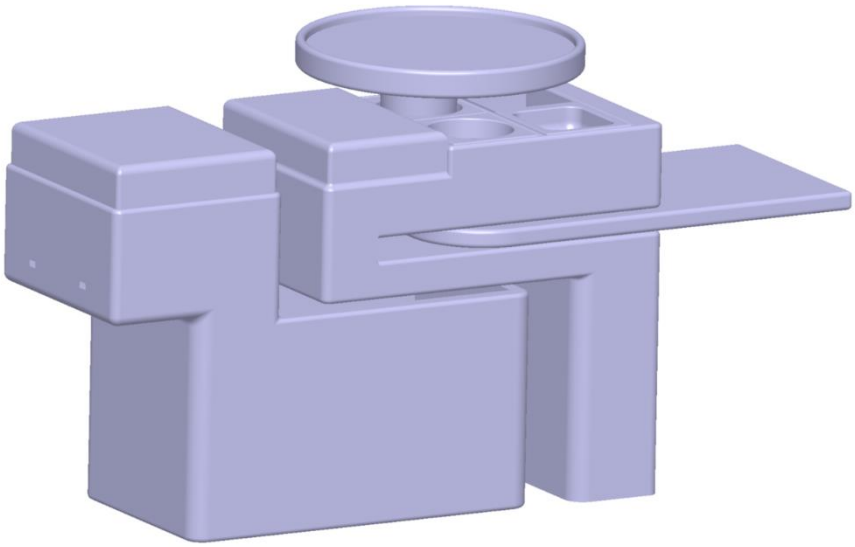

Figure 4.2. *Quick prototyping of concept 4*

Reflections on concept 10

According to the stakeholders at Volvo Cars, concept 10 has great potential. This innovative concept introduces new surfaces, creates a more spacious and open atmosphere, and allows for the integration of a wide range of modules, which can be seen in Figure 4.3. Concept 10 includes the backseat passengers in a way that existing center consoles does not, and the stakeholders favor the idea of providing larger space for the fifth person, enabling comfortable leg stretching for the passenger in the middle backseat. It changes the layout of the interior and creates more of a living room feeling. Additionally, the concept introduces a new storage area, reducing the need to place items on seats or the floor, and ensuring easy access for both front and backseat passengers.

As mentioned earlier, Concept 10 exhibits great potential for various accessories. The modular interface, consisting of cupholders, smaller storage compartments, and the adaptable table that fits into a cupholder, opens up opportunities for incorporating new modules that cater to customer preferences. For instance, modules such as a portable fridge, dog seat, or dedicated space for a weekend bag could be developed to further enhance customer value. These modules, when integrated at the floor level, add versatility and customization options to the concept. Differentiation levels, ranging from basic to premium, can be achieved by allowing customers to choose which features they wish to include, both at the time of purchase and in subsequent years. This flexibility ensures that the concept remains adaptable to evolving customer needs and preferences. Another notable advantage of this concept is its airier design, which enables the removal of most side panels. This streamlined construction simplifies the production and assembly processes, ultimately helping to keep prices competitive and affordable.

The table positioned beneath the upper level in Figure 4.3 can be rotated 180 degrees; however, it faces the similar challenges as Concept 4 in that it is positioned too low. Stakeholders and the ergonomic department find the table positioned in the cupholder to be in a significantly better position for usability. To address this issue, one proposed improvement is to implement a table

that can be placed in a cupholder, which offers a more optimal position for use. When not in use, the table can be conveniently stored beneath the top level, where it was originally placed, ensuring efficient utilization of space.

A difficulty with concept 10 is that it requires a robust top-part that can bear a force on the area where the armrest is placed. To enhance the stability of the concept, poles can be strategically placed near the seats. Also, the top part of the console can be stabilized with a wider connection to the bottom part at the area integrated in the dashboard since the console is thin where the interface is placed. Although there could be difficulties with the force from above, the stakeholders argue that the forces from the airbags could be supported by the concept by adjusting the placement of the deformation zone. Another area for improvement is the narrow margins of the interface, which restrict design options and choice of materials. Placing two modules side by side may also pose a challenge. However, a possible solution is to widen the console towards the front and narrow it further back between the seats to accommodate the desired modules effectively.

Further development of this concept would be to investigate customer value, as well as a comprehensive examination of the interfaces, modules, and design aspects. Additionally, it is essential to thoroughly investigate the forces that the concept is intended to withstand. A particular area of focus should be the region surrounding the armrest. The presence of the rear seat cupholders and the underlying box impose certain constraints on the feasibility of incorporating a sliding or opening mechanism for the armrest. Another limitation that arises from these features in the back, is that the air vents for this concept need to be placed in the b-pillars to ensure adequate airflow. To optimize the concept, these considerations warrant attention and analysis.

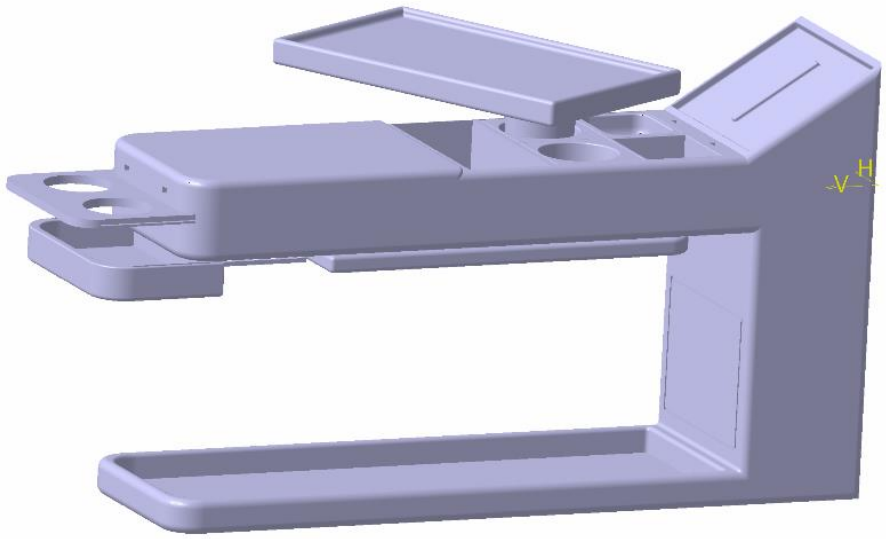

Figure 4.3. *Quick prototyping of concept 10*

Based on the insights gained from the quick prototyping and extensive discussions with stakeholders, concept 10 emerged as the preferred choice for the final concept. This decision was based on several factors, including its higher customer value, greater potential for improvement, better cost performance ratio, and enhanced user-friendliness. Compared to concept 4, concept 10 exhibited additional capabilities in terms of modular interfaces and the ability to fulfill the diverse needs of different personas.

However, it is important to note that concept 10 still requires optimization to address the improvement areas mentioned earlier. These optimizations will further refine and enhance its overall design and functionality.

5. FINAL CONCEPT

This chapter focuses on the final stage of development and improvement for the selected concept, along with the reasoning behind the new implementations. In addition, a detailed product specification is provided to offer a comprehensive understanding of the final product. The chapter also covers the process of building the prototype and includes visualizations of the prototype for a better understanding.

5.1 Further Development of Final Concept

After selecting Concept 10 as the final concept, further development was carried out, as shown in Figure 5.1. However, an issue was encountered during the analysis of the concept. The placement of the glove box between the two levels of the console made it difficult to reach and use and was therefore removed. A potentially improvement area of the console was the armrest. Since it could not be opened like a regular armrest, a lot of unused space was left under it. To address this, the armrest was divided into two parts, with the front part being slidable along with the console. When the armrest is moved forward, a new storage space becomes accessible. A sliding armrest also allows the driver to find a more ergonomic driving position while using it. Additionally, poles were added under the armrest to make the console capable of bearing the forces it will be exposed to.

Furthermore, the concept was too narrow for two modules in width. To address this, the front part of the console was widened to fit two modules, followed by only one module in width since the space between the seats is limited. This created new space on the sides, where fastening holes for a table were added. This made it possible to use both the cupholder and the table simultaneously. To create a more spacious feeling, the area under the inductive charging was cleared out. A support was added at the base of the inductive charging to hold phones securely while charging. Moreover, a modular interface was created on the first floor to keep the modules in place. New modules were also created to fit into the interface, and additionally modules for both interfaces were designed.

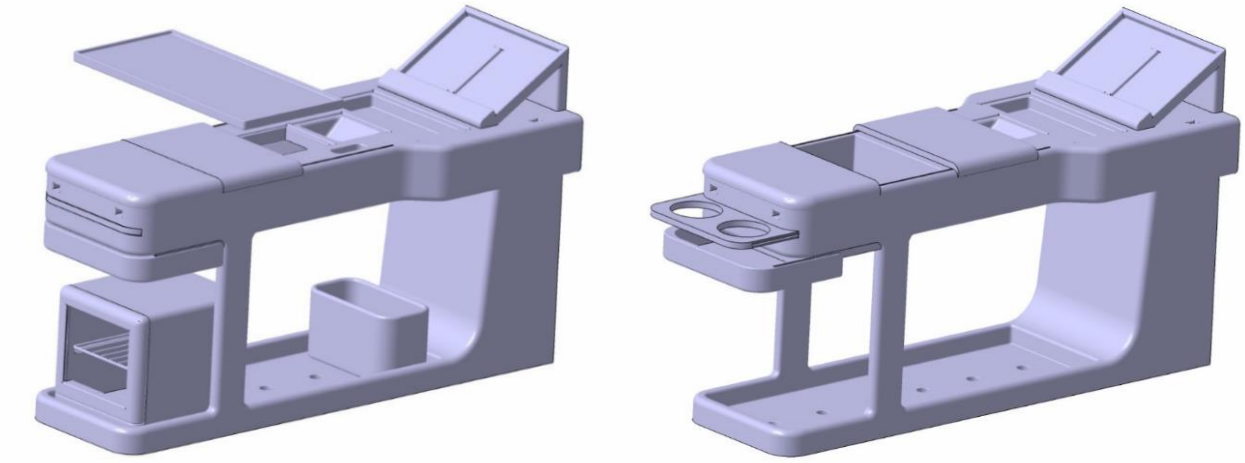

Figure 5.1. *Design of concept 10 with final improvements. Added features (left) extended features (right)*

5.2 Final Product Specification

The final concept is a console that extends from the dashboard to the rear seats in two levels, with a storage space between them. Two different modular interfaces are included - one on the top level and one on the floor level. These interfaces are designed differently and can be used with various types of modules. There is a wide selection of different modules that the customer can use and replace as they wish. The purchase of the modules can be done both at the same time as the car is purchased or afterwards. This allows car owners to update the car with new modules as their needs change or new modules become available.

The console features an inclined inductive charging for two phones, integrated from the dashboard. To keep the phones in place while driving, a bar is placed in the center and a 1cm edge surrounds the charging area. Additionally, a support is placed at the bottom to keep the phones more secure. The console is also equipped with two USB-C outlets as additional charging options for the front row.

The top-level is designed to be wider in the front and narrower towards the seats due to width restrictions. It is made wider to accommodate an increased use of the interface at the top level. The interface can accommodate four modules, with room for two modules in width at the front, followed by two areas that can fit one module in width each. On the sides of the interface, there are two oval holes with the purpose of placing a constructed table, one on the driver's side and one on the passenger's side. This allows either the driver or the passenger to use the table. When the table is not in use, it can be placed on the surface under the top level by inserting it into an oval hole and using a strap to keep it in place.

The top-level interface is adapted for cube-shaped modules, that have been developed as cupholders, cardholders, headphone holders, small storages, and phone holders. The first interface located at the front of the console can accommodate either two modules in width or one wider module, see Figure 5.2.

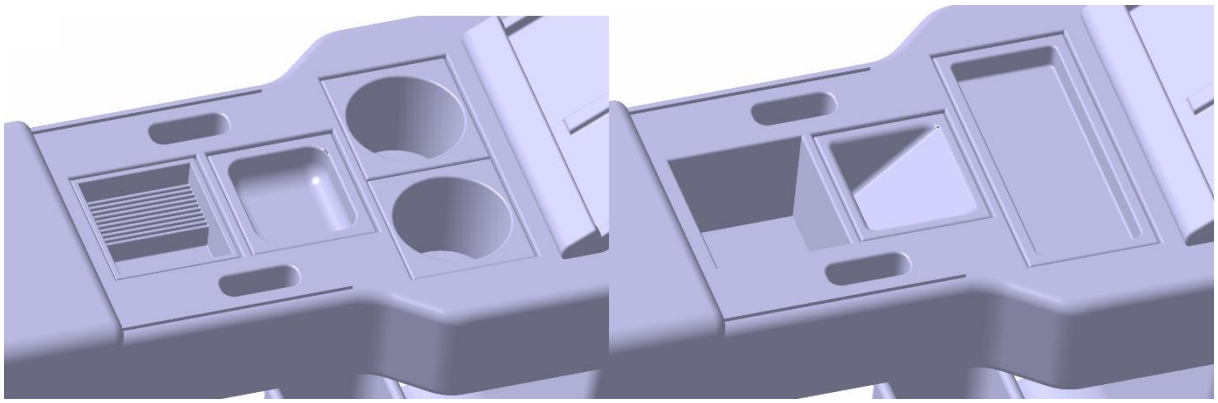

Figure 5.2. Two different *options of modules in the interface and the oval holes for the table*

Some of the modules designed are two-in-one, meaning that one side of the module is a space for small items, like e.g., headphones, and when turning it 180 degrees there is a cardholder. This module can be seen in Figure 5.3. The floor-level interface contains round holes in the bottom of the console, where specially designed features can be placed. Developed features for this interface include a mini fridge and a wastebin.

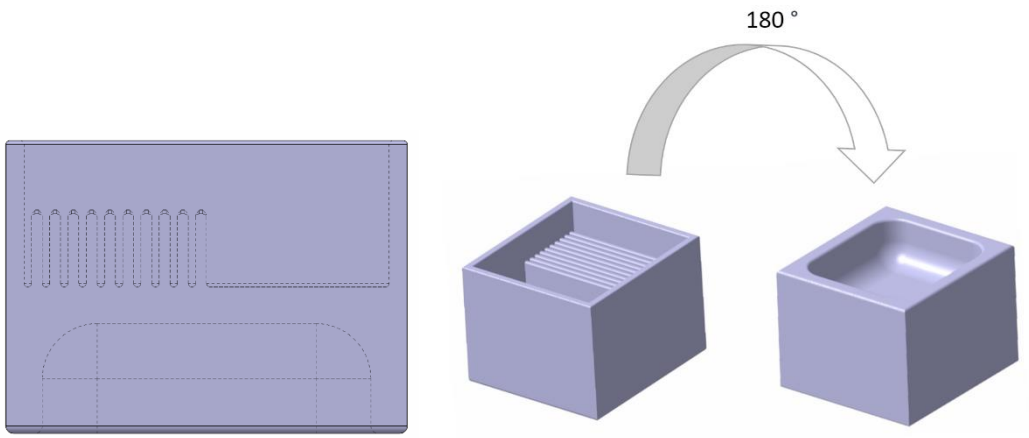

Figure 5.3. *Two-in-one module*

Implemented features for the backseat passengers are two USB-C outlets, cupholders and a small box for storage, se Figure 5.4. The cupholders can be pushed in and out of the console and are supported by the box when cups are placed. If the cupholders are not used, the box can be used as storage or as a phone/tablet stand. The box can be pulled out and pushed in under the console, which creates a small hidden storage.

Since the design needs to be able bear a force located on the armrest, poles are implemented on both sides. This makes the construction stronger without interfering with the open area between the two levels. The armrest is located at the end of the console and is split in two, with the front part being able to slide along the console. This reveals storage under the armrest and allows for personalization of the positioning.

The final concept is depicted in Figure 5.4 and 5.5, showcasing the design with added material for visualization purposes. The chosen material represents a color illustration, providing an impression of its appearance. However, the specific material selection is not detailed further in this context.

Figure 5.4. *Final design of concept 10*

Figure 5.5. *Final design of concept 10 – side view*

5.3 Physical Prototype of The Final Concept

The physical prototype was created through 3D-printing of the CAD-model, especially adjusted for the 3D printing process. The CAD-model was made hollow to save materials and supported by extra materials where the model is particularly exposed to forces. The margins of each interface between parts were set to at least 0,5 mm to manage the tolerances of the printing.

The meaning of creating a physical prototype was to facilitate the understanding of the product and again visualize the final concept but this time in another format. The prototype is a complement to the already existing CAD model, giving a more hands-on grip regarding the product. Although, it is not the final concept itself but a tool to visualize it. To get the most value of the prototype and to facilitate the use, it was created in scale 1:1. The prototype created is visualized in Figure 5.6 and 5.7.

Figure 5.6. *3D-printed prototype of final concept*

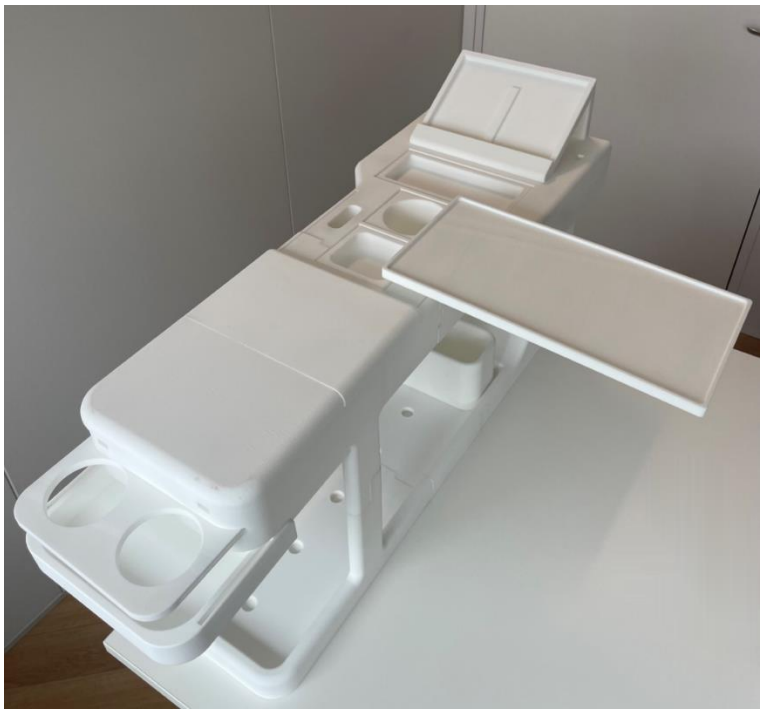

Figure 5.7. *3D-printed prototype of final concept with a suggested set-up of modules*

5.4 The Fulfillment of The User Case Scenarios for Concept 10

An evaluation of how well the final concept aligns with the needs of the four different user case scenarios, presented in chapter 3.2, was carried out. By doing so, it was determined that the concept met the requirements and expectations of the intended users.

Scenario 1: One person on her/his way to work in a big city, 45 min car travel.

For this scenario it can be imagined that the person wants to bring a laptop, a handbag or a briefcase, a cup of coffee and some small items like keys, headphones etc. During the trip it is probably minimalistic use of the car and center console, although the person driving should have easy access to a cupholder and be able to charge their phone. To accommodate these needs the phone can be placed on the inductive charger, cupholder, shallow module for keys etc. and module for headphones in the modular interface, and the laptop and handbag or briefcase in the open area in the console.

Scenario 2: A family of four persons, two adults, two children and one dog on a summer vacation trip

When a family is traveling with the car, four persons' needs should preferably be fulfilled. The bags that the family wants easy access to could be stored in the open area along with toys. For this trip, a minifridge also comes in handy if the family gets thirsty. In this scenario the cupholders for the rear seats are used, and two cupholders could be placed in the interface for the

front seats. When the cupholders for the rear seats are not used, the rear seat box can be used for storage or to place a tablet for watching movies etc. The trip probably includes snack-time, and when that is finished a wastebin placed in the open area in the console is useful. The design of the console also creates an open, living room-feeling, which could contribute to affinity.

One of the two adults owns a high-end luxury handbag, that the one truly holds dear. The bag is quite sensitive, and the adult would not want the bag to be placed in the backseats together with the two kids and the family's dog. Luckily for him/her, there is a perfect seat for the handbag on level one in the center console where the bag does not need to be placed on the floor, nor interfere with something else.

Scenario 3: Four adults, two couples, on a weekend trip, for shopping & cultural activities

For this scenario, the four cupholders comes good in hand. The interior of a car that possesses this center console has an open and inviting interior that could resemble a living room which likely would be welcomed by this traveling constellation. The open area between level one and two carries possibilities to either store shopping bags, weekend bags or the long legs of a tired middle-aged passenger. If the passengers get thirsty, cold beers or beverages could be placed in the mini fridge. Furthermore, if the passengers have made a visit to IKEA on their way home, larger furniture items can be placed in the center of the car between the levels of the center console.

Scenario 4: Charging at fast charging stations

While charging electric vehicles people spend a lot of time just waiting in the car. During that time people either go and buy something to eat, take some time to work or watch something on their laptops. For these occasions, the portable table would be of great use. A place to put your food and drinks or laptop while waiting for the car to reload. The table could be placed for either the driver or the passenger while waiting, depending on how many people there are in the car. For this scenario the cardholder module would also come quite handy and the small storage for keys, air pods case etc. It is preferable to have easy access to charging cards for the gas station along with credit cards for shopping, drive-throughs etc.

6. DISCUSSION

During the project, numerous decisions have been taken and paths have been chosen, each backed by discussions and analyses that culminated in the final outcome. This chapter aims to provide a comprehensive analysis of various aspects related to the product development work and its output.

6.1 Discussion of Market Analysis

The market analysis performed in this project was crucial to gain a solid understanding of the industry and to develop a successful product. The benchmark process was thorough and time-consuming, but provided valuable insights into the market, which were crucial during the product development process. Visiting car dealers and understanding how customers use the consoles was also essential to gather important information. Although the process was time consuming for the project, the time spent was less than for a usual project with a longer timeline. Despite this, the knowledge gained during the benchmark was confirmed as thoroughly performed by stakeholders at Volvo Cars.

To cater to the markets of Europe, Asia, and the USA, it was important to gather the opinions of possible future customers about the center console currently available in the market and their desire for the future. Although the survey conducted mainly focused on customers in Europe, complementary information from Volvo Cars helped to gain a better understanding of the Asian and American markets. However, the limited number of responses from Asia and the USA due to the survey's platforms and range of people answering was a limitation. If the survey had been more widespread and the responses more varied, it would have resulted in a better understanding of the customers' opinions on a center console. Nevertheless, the results of the survey were reinforced by Volvo Cars, as they reflected the company's own research.

The requirement specification process was challenging because the information gathered from the survey mainly focused on customers' desired features. With no demand from Volvo Cars for this project, the opportunity to think innovatively was encouraged. This led to a more difficult compilation and difficulties in weighing the criteria's importance. However, this provided an opportunity to create a unique and innovative product without being restricted by existing console designs.

In conclusion, the market analysis played a vital role in this project, providing valuable insights that helped create a successful product. The benchmark process, dealer visits, and customer surveys provided a thorough understanding of the market and its requirements. Although limitations existed in the survey responses, complementary information from Volvo Cars helped to fill the gaps. Overall, the requirement specification process was challenging, but it provided an opportunity to create a unique and innovative product.

6.2 Discussion of Concept Development

The process of concept development is a crucial phase in product development, especially in creating innovative solutions. In this project, the initial idea generation was an important step to enhance creativity and provide a fresh perspective. However, it did not exchange significant outcomes due to limited information about the typical design and features of a center console. In hindsight, utilizing tools like Google to search for images and gain inspiration could have greatly benefited the process.

In contrast, the subsequent brainstorming sessions conducted at a later stage proved to be highly productive, resulting in numerous sheets of paper filled with ideas and sketches. The decision to break down the center console into smaller parts and features was an excellent initiative as it allowed the team to brainstorm on sub-solutions. This approach not only generated a greater number of ideas but also facilitated the organization of thoughts, with a collection of papers dedicated to each sub-function.

Regarding the morphological matrix, the project team had the responsibility of making their own reasonable assessment to determine which concepts/sub-concepts were worth further development. The availability of the sheets of paper with ideas proved to be invaluable. The team referred back to them multiple times to explore improvement possibilities and ensure that good ideas were not forgotten.

Throughout the entire development process, there was an ongoing dialogue between the project team and Volvo Cars regarding information sharing. The company made a conscious decision not to reveal too much information too early, as they wanted to avoid influencing the team's thinking prematurely. As a result, the project team was encouraged to think more creatively and outside the box during the brainstorming sessions. The eventual release of information after these sessions proved to be highly beneficial rather than hindering. The timing of the information disclosure turned out to be favorable in hindsight, as it complemented and enhanced the team's brainstormed ideas.

In conclusion, the concept development process involves multiple steps, and the timing and approach of each step can significantly impact outcomes. Utilizing available tools and breaking down complex problems into smaller parts can facilitate idea generation. Effective assessment of concepts/sub-concepts and ongoing dialogue with stakeholders can ensure that good ideas are not forgotten, and that the final product meets market needs.

6.3 Discussion of Concept Elimination/Test and Refinement

In the final stages of concept development, the project team had to conduct concept elimination to determine the most viable options for further development. However, there were some issues with the criteria used for concept elimination, which could have been more thoroughly investigated to ensure their relevance to the development of a center console. The weighting of the criteria also needed to be carefully considered to maintain an unbiased view of the concept.

To improve the elimination process, a further discussion regarding how to measure the criteria would have been beneficial. This would have helped the team to maintain an objective view of the concepts and ensure that all aspects were taken into account. In addition, the selection of concepts for elimination was based on the stage of development and possible areas of improvement. If there had been more time available for the project, the team could have spent more time enhancing all 10 concepts. As a result, the focus was on the concepts that were assumed to possess the greatest potential. Despite the limited timeline, all the concepts were developed or combined to some extent.

Quick prototyping through CAD models was a highly successful component of the final elimination stage. This approach allowed the team to assess what was achievable and what was not, as well as identify any potential design flaws. During this stage, features and functions from eliminated concepts were incorporated into the two remaining concepts which let the iteration process proceed.

The refinement process was also vital in ensuring that the final product was of high quality and met the needs of the end-users. Overall, the concept elimination and testing process played a crucial role in the development of the center console, ensuring that the final product met all requirements and was of high quality.

6.4 Discussion of 3D-Printed Prototype

The outcome of the physical prototyping was successful. All movable features were functional, and the tolerances were suitable for their intended purpose. The modules fitted perfectly within the smaller interface. However, one notable observation while fitting the modules was that they could have been easier to remove, and therefore it would have been preferable for the modules to have some form of enhanced grip for easier handling. The cupholders and box for the rear seat aligned well with the design of the center console, indicating added value for passengers in the back seat. Nevertheless, the rear seat box could have been shallower to improve access to modules between the levels of the center console and to create more space.

The movable armrest integrated well with the stationary armrest and is easily adjusted along the console. The inductive charging area in the front could have smaller surrounding edges, and the bottom support could be downsized to allow for easier phone usage during charging. The portable table, positioned close to the smaller interface, is set at a suitable height but is relatively narrow, making it challenging to accommodate a laptop.

The floor-level interface proved more challenging to use than anticipated. Placing the modules within the interface posed difficulties in determining the appropriate attachment points due to limited visibility when the module is held over the interface. However, both the mini fridge and the waste bin are conveniently positioned for easy access and use. The mini fridge fits perfectly at the back of the center console, allowing for the storage and retrieval of four drinks.

The prototype provided valuable insights regarding the size of the console, affirming its feasibility for installation in a car. Overall, the prototype appears reasonable, but certain parts

could have been scaled down. For instance, the edges of the level 1 interface could have been reduced, without compromising its functionality. The placement of the poles is satisfactory and does not interfere with the interface.

6.5 Discussion of Final Concept

Throughout the development process, the final concept underwent a comprehensive refinement process, which involved carefully considering the improvement potential and necessary compromises. This process was a continuous iterative process, driven by the team's insights and new information from the surrounding environment, as well as valuable inputs from stakeholders.

Stakeholder inputs played a crucial role in shaping and enhancing the final concept. By actively engaging with stakeholders, valuable perspectives and requirements were considered, ensuring that the final concept aligns with their expectations and needs.

The final concept received a positive reception from Volvo Cars and stakeholders, indicating its potential for further development. While it is currently in an early phase, it holds promising possibilities for future progress. The result serves as a solid foundation for further advancements, whether it involves expanding and refining the entire concept or focusing on the development of specific sub-solutions.

Overall, the well-received final concept marks the beginning of an exciting journey towards further development. Its great potential sets the stage for exploration, iteration, and refinement to maximize its potential and deliver an even more robust and innovative solution.

7. CONCLUSION AND RECOMMENDATIONS

This chapter provides the project's conclusive findings, addressing the three research questions originally outlined. Furthermore, valuable recommendations for advancing the final design of the center console will be presented, considering future development opportunities.

7.1 Conclusion

The aim of the master thesis project was to create a new modular center console for battery electric vehicle (BEV) cars. The project team successfully addressed the three research questions, stated in Chapter 1.6, during the process. By identifying customer's expectations and gaps in current fulfillment, important knowledge for the development of a new center console was gained. Additionally, understanding the stakeholders' expectations and requirements was crucial to the project's success. Based on this knowledge, the development process began with a proposition of modular set-up and interfaces.

The project involved market analysis, concept generation, concept screening, and concept scoring, leading to the final concept of the center console. The final concept of the center console was visualized in a detailed CAD model, as well as a 3D-printed prototype in scale 1:1. The final design features two interfaces, allowing customers to choose which features to use, improving customization and customer value. With a strong understanding of customer and stakeholder expectations, the project group was able to develop a center console that exceeded customer expectations.

Regarding the last research question about adjusting the concept to different car models, the project team was able to confirm that the final concept is scalable and can be adjusted depending on the volume it needs to accommodate. While the number of features and interface may need to be adjusted in smaller cars, the concept still offers great customer satisfaction and fulfills its purpose.

In comparison to the already existing center consoles on the market, this center console offers customers a higher level of flexibility in determining the features they desire. It allows for extensive customization, including a sliding armrest and the freedom to choose the placement of various features. Moreover, the console incorporates a larger storage compartment that offers versatile functionality, enabling the custom use of modules within the designated interface area. Furthermore, the console design considers the preferences of rear seat occupants, providing them with the option to utilize the cup holders and box as either storage compartments or cup supports, according to their individual needs and preferences.

In summary, the project successfully achieved its objectives and key activities, resulting in a modular center console that is adjustable to different BEV Volvo Car models, customizable to fulfill a wide range of needs, and exceeds customer expectations. The design of the center console, particularly its integration with the dashboard, as well as the modules and interface, were specifically noteworthy and highly valued by Volvo. The final design is a significant step towards enhancing the driving experience of BEV Volvo Car owners and improving the overall satisfaction of customers.

7.2 Future Recommendations

The presented final concept in this thesis report is in its early concept phase and holds a great potential for further development. Aspects of the design and development process are limited due to time constraints and project limitations, which require further investigation to implement the final concept successfully.

Since the product is in a very early stage, it is limited to both shape and how the features can be placed. To refine the concept, it is recommended to focus on improving its aesthetics, ergonomics, and utilization of surfaces. It is suggested to implement the concept in a car for better understanding and a clearer path for development. User testing would be helpful to analyze ergonomics, aesthetics, functionality, and identify any desirable features that are missing. Investigation on how the concept can bear forces should be simulated, and the poles holding the console should be improved to handle the load case.

Since the material of the console is not selected this needs to be done based on strength, aesthetics, and sustainability. Additionally, the materials should be easy to clean and provide a premium feeling. A selection of materials and colors should also be provided for the customer. Another aspect of the design and material of the console that was out of scope for this project is the console's integration with the surrounding interior of the car. Also, how the console can be integrated in the dashboard and how the dashboard can be improved with its features. The possibility of using more space under the dashboard for the console to take place is a question in mind during this process. This could open an even bigger storage in the console, and after investigating this, the area in the front of the console, between the two levels, could be improved for utility.

An improvement to utilize the surfaces is to implement a small storage space under the inductive charging. It can be two boxes, divided in the center of the console, and be opened by sliding the box to the side, one box to the driver and one to the passenger. The modules and interfaces can be improved further and a solution on where to store the modules when not used also needs to be found. Further investigation and improvements to find the best solutions for fastening the table under the first level properly could also improve the concept further.
The final concept presents a well-developed console, both regarding the market and innovation. When proceeding with further development, it is recommended to maintain the interfaces, overall shape, and living room-feeling of the console. Another aspect during further development is to keep the modules that have more than one function integrated to accommodate the personalization.

In summary, it is recommended to conduct further investigation and testing to refine the design, improve materials, and implement the final concept successfully. The concept's potential for further development and its well-developed features makes it a promising solution for the market and a valuable asset to the industry.

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