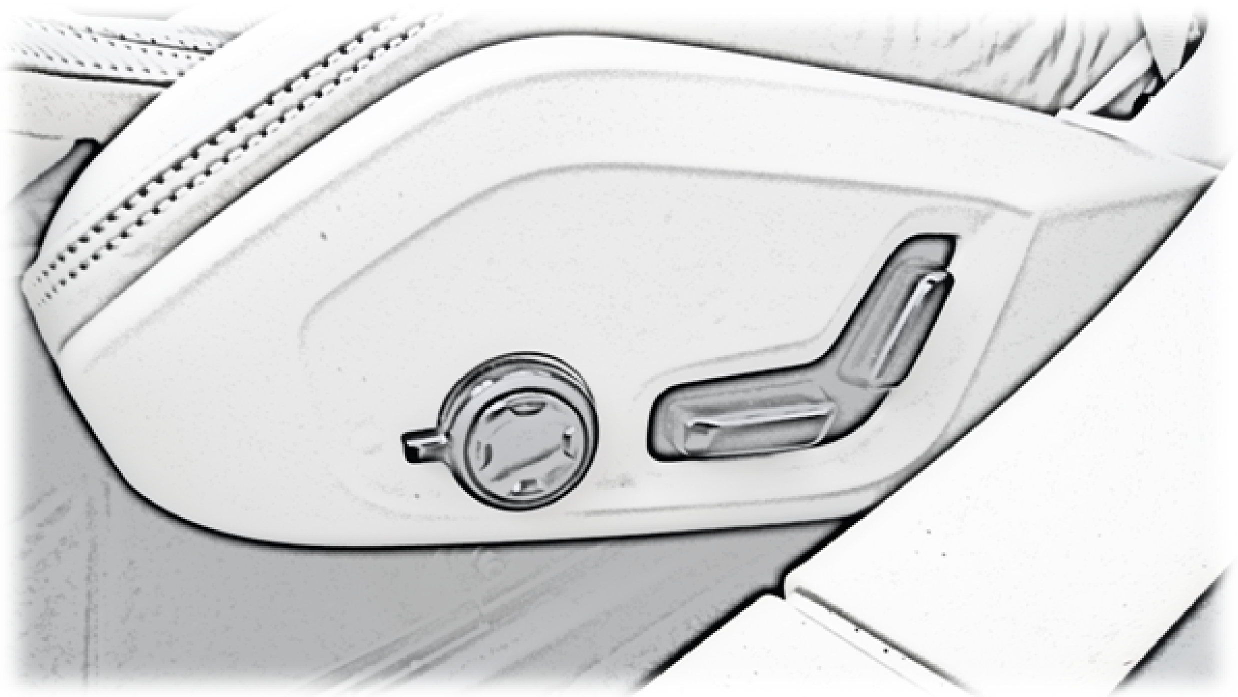
CHALMERS
UNIVERSITY OF TECHNOLOGY



# Human-Machine Seat Interaction

An investigation of how to design automotive seat adjustment controls

Master's thesis in Product Development

TOBIAS DARRELL

WILLIAM NORRBLOM

Department of Product and Production Development
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2017

Master's thesis 2017

# Human-Machine Seat Interaction

An investigation of how to design automotive seat adjustment controls

TOBIAS DARRELL

WILLIAM NORRBLOM

Department of Product and Production Development
*Division of Product Development*
Chalmers University of Technology
Gothenburg, Sweden 2017

Human-Machine Seat Interaction
An investigation of how to design automotive seat adjustment controls
TOBIAS DARRELL
WILLIAM NORRBLOM



Supervisors: Andreas Dagman, Chalmers University of Technology, Department of Product and Production Development. Adam Skagius & Peter Setterberg, Volvo Cars Corporation, Seats Department.

Examiner: Andreas Dagman, Chalmers University of Technology, Department of Product and Production Development.

Master's Thesis 2017
Department of Product and Production Development
Division of Product Development
Chalmers University of Technology
SE-412 96 Gothenburg
Telephone +46 31 772 10 00

Cover: Graphically modified image of a Volvo SPA-seat in a Volvo XC90.

Typeset in LaTeX
Printed by Chalmers Reproservice
Gothenburg, Sweden 2017

Human-Machine Seat Interaction
An investigation of how to design automotive seat adjustment controls
TOBIAS DARRELL
WILLIAM NORRBLOM
Department of Product and Production Development
Chalmers University of Technology

## Abstract

The aim of the project has been to develop a concept of seat adjustments controls that support the interaction with the user while providing a good user experience by having great intuitiveness. The need for the project derives from the need to more easily adjust the seat to provide better comfort, less irritation and distraction. Current solutions have a common base idea with different executions but create unnecessary complexity. The project is a collaboration between Chalmers University of Technology and Volvo Cars Corporation.

To develop this solution, a number of process stages were necessary, from a preparatory study to concept generation and development. A range of concepts were generated and screened in order to identify a feasible concept possible to be developed under the time constraints of the project. In order to fully comprehend the issues related to adjustment controls, a comprehensive user study and benchmarking with function-means trees were conducted. The learnings were later on implemented into the development of the new concept of the seat adjustment controls, solving the faults of the current solution with a holistic view. Continuously during the development the ease in which the new concept could be integrated with current seats and housings was kept in mind, resulting in a few delimitations and re-use of existing knowledge at Volvo.

The thesis concludes that adjustment controls should be created to correspond to the movement of the actual seat. The thesis provides a final concept that implements three buttons with a seat-like design as well as a round knob. The controls are placed on the side of the seat to achieve the corresponding movement to a high degree, without creating unnecessary complexity. The movement of the controls has been changed compared to the current solution, new buttons have been added, indents and new angles have been implemented into the controls. The massage function has been moved to the center display and a new design of the display interface has been created. Including dynamic feedback, a help function and just two different modes. The physical controls, the new design of the display together with more new sub-solutions have created the new concept. The concept provides suggestions where the adjustment controls should be placed and how to be designed in order to facilitate the understanding and usage.

Keywords: Human-machine interaction (HMI), interaction design, user centered design (UCD), adjustment controls, automotive seat, power seats, .

Acknowledgements

During this project, aid has been given from a number of people deserving special notice for their contributions in enhancing and allowing a completion of the project.

For providing regular support and guidance, acknowledgments are directed towards our supervisors Adam Skagius and Peter Setterberg from Volvo Cars Corporation and our project supervisor at Chalmers, Andreas Dagman. Without their guidance and expertise this project would have been a lot tougher to complete.

Further, acknowledgments are given to everyone who have helped us from the departments Seats, Ergonomics, HMI, DUX, Seat Electronics, Model & Design Prototypes at Volvo, and especially the people from Front Seats for providing new insights and questioning the project's decisions.

The project group would lastly like to thank all the people who participated in the user study, giving valuable insight of the problematics with seat controls.

Tobias Darrell & William Norrblom, Gothenburg, May 2017

# Contents

# List of Figures

# List of Tables

# List of Abbreviations

**CAD** Computer Aided Design
**DFM** Design For Manufacturing
**FMEA** Failure Mode Effects analysis
**HMI** Human-Machine Interface
**SUV** Sport Utility Vehicle
**SWOT** Strengths, Weaknesses, Opportunities, and Threats
**UCD** User-Centered Design
**VCC** Volvo Car Corporation
**SPA** Scalable Platform Architecture
**HCI** Human-Computer Interaction

# 1
# Introduction

This section aims to provide some background and underlying information of why this project is conducted. Thereafter, describing what the aim of the project is, presenting both the purpose and the objective of the project, as well as some delimitation's. Lastly, an outline of the report is presented.

## 1.1 Background

The human-machine interface (HMI) of cars has become an area of increasing interest in the automotive industry, creating a need for interfaces to both be able to meet human needs, safety concerns and more ("The Automotive HMI report 2013", 2013). For example, back problems is a common problem in the western world and seat design are one of the major reasons of this issue (Jordan, 2006). The reason for this is either because they are not sufficiently adjustable to fit the users needs, or because the user does not adjust the seat to their optimal seating position.

As stated in the article "Smart cars need smart seats" (2016) seating is one of the fastest changing parts of the vehicle today. The number of features in a car seat have increased rapidly over the last decade, hence increasing the number of settings which needs to be handled. Simultaneously, automotive HMI has evolved quickly, involving technologies such as multi-touch screens, voice recognition, head-up displays etc. (Vasantharaj, 2014).

The concern is that even if these features might provide the users with positive effects if handled correctly, the users need to understand how to handle them in order to be seated correctly, or as described by Bhise (2012) "If a user does not understand how a product or its features are to be used, then he or she will not be able to use the feature, that is, the user will disregard the feature or it will not exist as a usage choice in the user's mind". Thereby, the Human-Machine Interface (HMI) of the seat is crucial for the operators comfort.

This project is issued by Volvo Car Corporation (VCC), which is a Scandinavian car manufacturer whom design, engineer and build premium cars. In collaboration with Chalmers University of Technology the project will investigate how the HMI of car seats can be designed in order to promote user interaction. The project will include both a user analysis, a competitor analysis, a literature study and the development of a concept of a human-centered HMI for the car seat. Ultimately, the result will be a concept of a HMI for a car, and guidelines for what to consider when designing the seat HMI.

## 1.2 Purpose

The project will be in the field of product development and interaction design, with a focus on HMI. The main purpose of the thesis is to develop a concept for the HMI used to interact with the features of a car front seat.The purpose is formulated by the following questions:

- How might a user interface of car power seat adjustment controls be designed in order to support human interaction and increase the user experience?
- Where should the user interface of car seats be located in order to promote use?

## 1.3 Objective

The goal of this project is to explore and develop a new concept of adjustment controls of car power seats which will ease interaction as well as increase the user satisfaction. The final delivery is a concept prototype of the physical seat interface. The interfaces should be adaptable to be further developed to be used as a platform for all VCC seats. In addition to the physical interface a touchscreen interface which is adapted to the physical interface should be developed. The final deliverable will include evaluation of the developed concept, as well as recommendations of how the HMI can be developed further.

## 1.4 Delimitations

The project is a concept development project, and the time frame and knowledge areas of the project group does not allow the project to develop all areas of the HMI, parts such as electronics, programming of touchscreen etc., will not be developed.

Autonomous driving is a hot area for the future with many possibilities but this project aims at creating a solution for existing cars, and therefore it will not include autonomous driving in the main stages. However, with the knowledge learnt from the project, recommendations will be created on how to develop this project further into autonomous driving. Also, there will be standards and limitations set by VCC which needs to be taken into account when conducting the screening of generated ideas.

VCC have different types of seats; comfort, sport and vent seats with different kind of controls; mechanic, semi-automatic and full power seat. This project only focus on developing controls for a full power seat.

## 1.5 Report Outline

An outline of the information presented in each chapter of the report is presented in this section.

**Chapter 1:** The **Introduction** present some background information of HMI design of seats. Thereafter, the project scope is presented, presenting the purpose, objective and delimitations of the project.

**Chapter 2:** In the **Theory** relevant information for the project is presented, providing the reader with sufficient knowledge to understand and read the report and understand the decisions taken along the process. The section handles information about information processing, semantics, semiotics and product design, focusing specifically on HMI.

**Chapter 3:** In the **Execution & Methods** the project process is presented. This process is divided into four phases, with the methods used in each phase presented accordingly.

**Chapter 4:** The **Preparatory Study** starts by presenting the information gathered by a literature study that is bundled together into some design issues to consider along the project. The results and a review of VCC's seat HMI, a competitor benchmarking and a user study is presented, with their associated analysis.

**Chapter 5:** The **Concept Generation & Evaluation** chapter present the project process and results of the generated concepts and their evaluation. The process is presented in multiple steps presenting the procedure in the same order as conducted in the project process.

**Chapter 6:** In the **Concept Development** the developed concept of the adjustment control is presented, presenting information about the physical controls as well as the touchscreen interface and some additional thoughts and reflections.

**Chapter 7:** The **Implementation** chapter handles evaluations of the product concept. Involving aspects such as the material selection, manufacturing aspects, commercial assessment and an analysis of future impacts of seat adjustment controls.

**Chapter 8:** In the **Discussion** some reflections of the entire project process and reflections about the results of the project are presented.

**Chapter 9:** Some final **Conclusions** of the project is made, reflecting based on the initial scope and objective of the project.

**Chapter 10:** **Recommendations** of what further work would be most urgent to improve the HMI and what evaluations of the concept which are needed are presented in this chapter .

# 2
# Theory

Since HMI is a multidisciplinary subject the literature studied for this project handle a wide variation of subjects. Thereby, subjects such as human ergonomics, cognitive ergonomics, product design, HMI design and User-Centered Design (UCD) are studied, as well as reports from previous studies about vehicle HMI design. Some literature are focusing specifically on vehicle design while other literature approach the subject more general. The information will be presented first focusing on human information processing and cognitive ergonomics, thereafter evaluating product, interface and control design, and moving forward into more specific design ideas such as HMI-design and UCD.

## 2.1 Cognitive Ergonomics

This section handle the subject of how humans interpret the sensory data perceived by the senses. This includes both the human information processing, semantics and semiotics.

### 2.1.1 Human Information Processing

A model of the human information processing is presented by Wickens (1992), visualized in Figure 2.1. The model describe the human information processing and decision making to have a consistent input of stimuli from our surroundings. These stimulis' are received by the sensory processing, prolonging the physical stimulus for a short time period. Thereafter this information is perceived and recognize by the persons perception. The perception of the person is affected on how much attention is allocated to the task as well as the long term memory of the recipient, recognizing and correlating the information to earlier experiences. Based on the perception the person select a response action, which is affected by the attention as well as the short time working memory of the person. Thereafter, the chosen response is executed, which also needs attention allocated. The response execution is providing the person with feedback in the form of stimuli. Lastly, how much attention the person allocated to remember will affect the working memory of the person, and the working memory and long term memory is affecting each other as well. The working memory is used to process information temporary, such as sensory stimuli, with information only being available for a short time ($\sim$ 30 seconds) (Osvalder & Ulfvengren, 2010). Whilst, the long term memory is used to store information from a persons experiences.

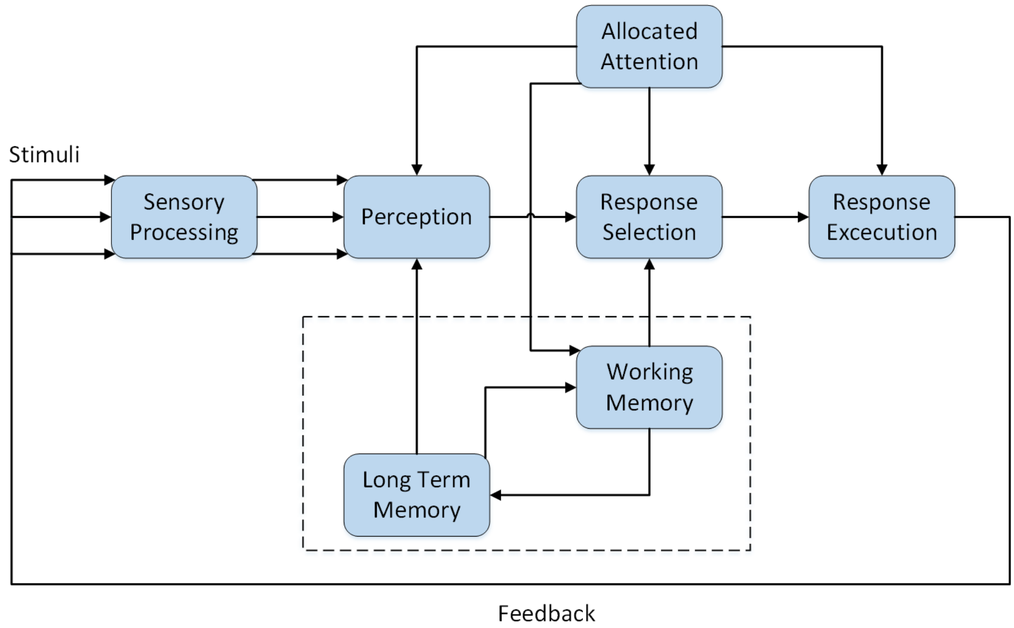



**Figure 2.1:** The human information processing model presented by Wickens (1992).

All parts of the cognitive process is happening continuously and in parallel (Osvalder & Ulfvengren, 2010). The quality of the decision making is influenced by the amount of information presented simultaneously, how discernible the information is, how much attention is allocated to understand the information presented and the persons memory from similar experiences (Osvalder & Ulfvengren, 2010).

### 2.1.2 Semantics

Semantics are the study of the relation between signs and their message (Monö, 2004). Semantics can be divided into four different functions:

**To describe**: Even with a product design that looks unusual, a simplistic sign design of peoples general view of the product will help to recognize certain characteristic features using the user's own experience.

**To express**: An object can express its' functions by its' appearance. There are examples everywhere of how a form can be manipulated to show a quality the product don't have or have very little of.

**To exhort**: By exhorting you intend to trigger a reaction in the person who uses the product. Aware industrial designers often end up with products that appear to exhort us to directly do something, by accentuating colors and forms that are associated with current trends or certain properties.

**To identify**: When looking at a product you identify and interpret its' origin, its' purpose, its' affiliations in product groups etc., its' placing and its' category. People also tend to humanize the qualities of things such as curvatures to be more gentle, or friendlier than sharp edges.

### 2.1.3 Semiotics

When people look at an object, no one sees the object in exactly the same way. Even if they look at the same picture and interpret their input in the same way, the image is always revised by the observer's personality and situation. Therefore is the study of signs and their structure and properties valuable (Monö, 2004).

According to Monö (2004) the different areas seat controls can be divided into in semiotics are signs which can be heard, seen, felt or smelt. For example by feeling an object with your hand you investigate the material's surface (tactile sense) as well as the form of the object (haptic sense, feeling of form). The surface and finish are signs you interpret differently. Our visual sense is of much importance but our tactile sense may sometimes replace it. Buttons with different surface finishes allow the operator to find them, without having to see them. We also have a kinaesthetic sense, muscle sense, which lets us know how we sit, if it's comfortable, if we want to tilt something or go forwards for example. Monö (2004) also states that industrial designs should be understood and adapted to the whole person in the way he or she perceives the object, by all senses.

According to Nielsen and Mack (1994) are there usability-related semiotic decisions that need to be made when designing HCI (Human-Computer Interaction). In the article some of them are described to be:

**Visibility of system status**: The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.

**Match between system and the real world**: The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions making information appear in a natural and logical order.

**Consistency and standards**: Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

**Error prevention**: Even better than good error messages is a careful design which prevents a problem from occurring in the first place.

**Recognition rather than recall**: Make objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

**Aesthetic and minimalist design** : Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

**Help and documentation**: Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

## 2.2 Product Design

The subject of product design is initially evaluated from a general perspective. Thereafter, areas which are more important for this project are specified into more subject-specific areas such as HMI-design and UCD.

### 2.2.1 General Product Design Directives

It might seem easy to design a product which sole purpose is to be easy to use, but according to Norman and Eucher (2016) that is far from true. The article states that developers need to understand that they don't inherently understand users, even though they might seem to be exactly the same (Norman & Eucher, 2016). The big difference is that once a development starts, the developer understand and think about a product in a way a user never will. They understand the issues and the needed compromises but can't grasp why users don't know about all smart features or even worse, they don't care, according to Norman and Eucher (2016). The users only care that it facilitates their lives, hence we need to design differently than traditional. Developers need to find out what they actually are trying to solve and a way of doing that is to understand their customers.Norman and Eucher (2016) argues that questionnaires and interviews are a bad way of doing so, instead you should observe the way users do their work. First then you might really understand the underlying problem with the product. The reason is that people don't know what they want, that is why it is important to observe and analysis the work flow.

Two of the most important characteristics of a good design are discoverability and understanding (Norman, 2013). Discoverability is about if you can figure out the possible actions, where they are and how to perform them while understanding what things mean, how the product is supposed to be used and what different settings mean. With complex products, discoverability and understanding require aid from manuals or personal instruction but with simple products it should not be necessary. A lot of products defy simplicity just because they have a lot of functions and controls. Faced with a confusing set of controls and functions, you simply memorize one or two functions and approximate your need (Norman, 2013).

In the book Jordan (2006) the topic of how to design pleasurable products are treated. They describe three important challenges to manage while designing products:

**Holistic understanding**: To get a holistic understanding of the users, address both how people use the product, how they are affected by the product and what role the product plays in their lives.

**Contribution to users**: In order to design a product which suits the users needs, you need to understand how the benefits the product contributes to the user is linked with the product properties.

**Methods and metrics**: Using the right methods and metrics for assessing how pleasurable a product is.

Jordan (2006) also present a good framework to use when developing pleasurable products, it is to consider how the user is pleased out of four perspectives:

**Physio pleasure**: Affect by the materials, surfaces, smell, touch etc. of the product.

**Socio pleasure**: Products effect on the users social life.

**Psycho pleasure**: The products cognitive demand and emotional effect.

**Ideo pleasure**: How the product please the user ethical values.

The unknowns, or knowledge gaps when first encountering a product can be divided into two categories, the Gulf of Execution and the Gulf of Evaluation (Norman, 2013). The Gulf of Execution is when you try to figure out how the product works and the Gulf of Evaluation is when you try to understand why something happened. In order to help the user close these gaps the developer need to design the product understandable. The Gulf of Execution can be bridged by using signifiers, constraints, mapping and a conceptual model and The Gulf of Evaluation may be bridged through feedback from the system and a conceptual model. When bridging these gaps Norman (2013) has concluded that users use seven stages of action. The steps are:

1. Goal (form the goal)
2. Plan (the action)
3. Specify (the action sequence)
4. Perform (the action sequence)
5. Perceive (the state of the world)
6. Interpret (the perception)
7. Compare (the outcome with the goal)

These seven steps of action provide a useful framework for understanding human action and create guidelines for designing products. In order to develop good user-centered designs, the developer must first understand the human. Questioning the user's action in each step, by asking why until the fundamental reason for performing the action is reached, is called root cause analysis. By doing that the underlying reason can be found and a better product to facilitate it can be created.

Designers often focus only on usability but advancements in psychology show the impact emotions have on rational thinking and decision making (Epstein, 1994). According to Epstein (1994) there are two ways of information processing, the rational and the experiential mode. The experiential mode is driven by emotion and consist of more rapid processing and decision making than the rational mode. By knowing this, the need to consider emotions is clear in order to create comfortable seats. According to Gkouskos and Chen (2012), designers need to look beyond usability and view the interaction between product and user holistically with emotions as an aspect to take into account. A process also called emotional or affective interaction design.

Norman (2013) also points out the importance of emotions, the visceral response. The book discuss its' immediate perception if a product is good or not: "the pleasantness of a mellow, harmonious sound or the jarring, irritation scratch of fingernails on a rough surface." Sound, touch, sight and smell all drive the visceral response to attraction or repulsion.

### 2.2.2 Interface Design

As described by Thimbleby (1990) designing user interfaces is a hard matter since it involve the two disciplines psychology and computer science, and to design a good user interface these difficult disciplines need to be united. Thereby, understanding the user is a vital part of interface design. Tidwell (2010) present some tools which might be useful to understand the users:

- Field Research of the behavior of the intended user and understand what the users want.
- Models such as personas, scenarios and prototypes.
- Empirical testing of users testing the design in real situations.

Tidwell (2010), also present some user patterns which has been observed, taking these aspects into consideration when designing a user interface will help the user to reach the users goals. Some of the presented user patterns are:

**Safe Exploration**: That you can go back and redo things when you do wrong.

**Instant Gratification**: Getting instant feedback from the system.

**Satisfying**: People take decisions before considering all the presented data, when an action is presented which is deemed suitable by the user they will use it.

**Changes Midstream**: People often change their mind of how to do things in the middle of a process.

**Deferred Choice**: If the user is task-focused they often prefer answering less important questions later.

Osvalder and Ulfvengren (2010) present some aspects to consider when designing in order to communicate visual information. Two important aspects which is affecting the result of a search after visual information are how conspicuous the object is, and if the users expectations of the objects appearance in comparison to the objects actual appearance. People look for information either by scanning, with a specific goal in mind, or by searching when the goal is unknown and the search pattern is more random. When scanning for an object the search is usually conducted top down and left to right, for some cases the same pattern is used when searching. Thereafter, the user wants to confirm that they have found the right object by the objects visual appearance matching the expectation. (Osvalder & Ulfvengren, 2010)

Many links can be found between these user patterns and design recommendations when developing interfaces which is presented in literature. Bhise (2012) present some general design considerations to take into account when designing interfaces for automotive vehicles:

1. The time required to use the interface should be minimized, including the time it takes to find, access, understand and operate the control or display.
2. Users want to conserve their energy, minimizing their physical as well as mental workload.
3. Minimize the information presented to the driver, only present the information the driver needs in order to keep the driver's attention focused on driving.
4. Visual displays should be located close to the driver's line of sight while driving, so that eye movement is reduced and the peripheral vision still can detect visual clues from the driving task, a deviation of less than 30 to 35 degrees from the driver's line of sight while driving is proposed.

5. If a person does not understand how to use a feature, then the feature will not exist in the user's mind, and consequently it will not be used.
6. Regarding the conscious attention, verbal interaction is generally superior to visual interaction, requiring less working memory to handle.
7. The integration of different features should be made seamless.

When designing a display interface some other important aspects are to consider the contrast, lighting and the viewing angle of the display. The display should be designed to be understandable for colorblindness and the combination of red and green, or blue and yellow colors should be avoided. (Osvalder & Ulfvengren, 2010)

### 2.2.3 Control Design

According to Osvalder and Ulfvengren (2010) response is important for all types of controls. Controls must be accessible, identifiable and understandable. Some important questions to ask yourself when designing controls are presented by Osvalder and Ulfvengren (2010):

1. What is the control used for and how does it affect the interaction with the entire technical system?
2. Should it be designed to support quick, accurate interaction or bigger forces?
3. For whom should the control be designed and under what circumstances will it be used?
4. What physical and cognitive demands are needed of the user?
5. What demands does the task apply to the operator?
6. What other tasks are operated by the user while handling the control?

Osvalder and Ulfvengren (2010) also present some general design principles for configuring systems containing controls and information feedback, presented as:

1. Good connection between the layout and the systems functions.
2. Avoid spatial transformation.
3. Ordering between controls is the same for different panels.
4. Use redundancy for important information.
5. Marking with text and symbols above controls.
6. Place the controls in an order based on the order of use.
7. The most useful controls closest to the user.
8. Warning-lights should be located close to the user.
9. Grouping of controls with mutual information.
10. Grouping of connected information means and controls.
11. Controls are placed to the right-hand side of the information means.

Regarding hand controls some issues which should be considered are presented by Bhise (2012):

**Accessibility**: The controls should be easy to find and not obstructed by other items. Some properties which can be used to enable accessibility are control size, color, luminance, contrast to background and placement.

**Identification Symbols**: Generally there should be identification labels or symbols located in proximity with the controls, the identification can be presented both visually or by touch.

**Intuitiveness**: Controls should be designed to support the operator to operate the control intuitively. Some aspects which can be designed in order to benefit the intuitiveness are the shape, appearance, touch feel and grasp area of the control.

**Control Size**: The size of the controls should be suitable to grasp with a hand, minimize the hand movement needed to move, considering Fitts' law of hand motion, the controls and there should be sufficient spacing for the hand to access it.

**Direction of Motion**: The direction of motion should meet the population stereotype, provide feedback of the movement and the muscle effort should be less than 20 % of the 5:th percentile female's maximum strength.

**Error Management**: Controls should be designed to minimize the risk of handling it incorrectly.

**Unintentional Interaction**: The controls location and design should not enable the driver to change the controls by accident, this is particularly important for controls that control the vehicles motion or the operators vision.

Mapping is a good way of arranging controls in the way they will be used. Good mapping enables for easy understanding while a bad mapping creates the need to remember, leading to more mental effort and a higher risk of error (Norman, 2013). Sometimes products come with clever small diagrams to indicate what does what, or sometimes there are labels, but a proper natural mapping requires no instructions. Norman (2013) states three levels of mapping:

**Best mapping**: Controls are mounted directly on the item to be controlled.

**Second-best mapping**: Controls are as close as possible to the object to be controlled.

**Third-best mapping**: Controls are arranged in the same spatial configuration as the objects to be controlled.

A mode error arises when a device has different states where the same controls have different meanings. Mode errors are inevitable in products which has more functions than controls or displays. This is a reoccurring problem as we put more and more functions into our products (Norman, 2013). It is tempting to save money and space by having a single control to serve multiple purposes and even though the design might appear to be simple and easy to use, this simplicity mask an underlying complexity of use. According to Norman (2013) a mode error is a design error and developers must try to avoid modes. If creating modes after all, the product most make it obvious to which mode is the current to facilitate the interaction, designers must always compensate for interfering activities.

### 2.2.4 Human-Machine Interface (HMI)

A HMI should be designed to present information to meet the goals of the user, not based on the technology used to provide the data (Gruhn, 2011). The article also present four basic concepts used regarding graphical design, which also can be used for HMI design:

**Contrast**: Different things should look very different.

**Repetition**: Visual elements are repeated.

**Alignment**: There should be a visual connection between different elements.

**Proximity**: Connected things should be placed together.

The location of hand controls or displays should be located according to the principles stated by Bhise (2012) as:

1. The controls and displays should be located so minimal hand and eye movement should be needed in order to perform a task, also taking the hand and eye position prior to the task into consideration of the design.
2. The location of controls and displays correspond to the drivers expected position.
3. Controls and displays which are important for the driver should be located close to the steering wheel and/or the drivers line of sight.
4. The controls and displays used most is located close to steering wheel and/or the drivers line of sight.
5. Associated controls and displays should be grouped together, keeping the controls and displays of one function close to each other.
6. Controls that needs to be accessed quickly by the user in order to handle a suddenly emerging situation should be located close to the steering wheel.

In the articles François, Osiurak, Fort, Crave, and Navarro (2016) and Bhise (2012) they review HMI design in the automotive industry. The studies present some important aspects to consider when developing a HMI to suit the user:

**Usability**: The interface should be easily understandable, making it easy for the driver to interact with the interface.

**Distraction**: The driver should use a minimal mental and physical effort when using controls or displays, in order to keep disturbances of the drivers attention from driving as small as possible.

**Acceptance**: The interaction system should be incorporated into the driving, designing it taking respect to the conditions such as the driver's information needs, other tasks, environmental conditions, time constraints, and so forth.

**User characteristics**: Taking regard to the users anthropometry, age, expectations, body positioning, the variation of the users, etc..

As the HMI of the automotive industry evolving quickly, some new technologies are on the brink, or recently, introduced to the market. Vasantharaj (2014) present some of the most recent trends in the automotive HMI:

1. Voice control & recognition
2. Multi-touch
3. Proximity and gesture recognition
4. Face/Eye Recognition
5. Head-up display
6. Augmented reality
7. Haptic feedback
8. Nomadic Devices
9. Multi-functional buttons

### 2.2.5 User-Centered Design (UCD)

HMI design has lately moved from a more technology driven approach into more human-centered approaches. User-centered design is a human-centered approach which has become the standard for automotive HMI, designing a system to be usable out of the users perspective (François et al., 2016). Gruhn (2011) present three principles which can be used in order to create a UCD:

1. Organize technology around the user's goals, tasks and abilities.
2. Organize technology around the way users process information and make decisions.
3. Keep the user in control and aware of the state of the system.

Williams, Attridge, and Pitts (2011) executed a customer study of user-centered design, evaluating the design of automotive seat adjustment controls of Sport Utility Vehicle's (SUV). The study was conducted with 101 participants with driving experience of driving SUV's, reviewing the adjustment controls of six premium SUV models. The most frequent positive responses of the study, in descending order was:

1. Ease of use
2. Accessibility
3. Smooth
4. Functional aspect
5. Size
6. Easy to find

The most frequent negative responses being, in descending order:

1. Accessibility
2. Ease of use
3. Hard to find
4. Functional aspects
5. General criticism
6. Poor sound

The seat memory controls is an area which was an area of many negative comments compared to the number of positive comments in the study, however the reasons varied much across different car models. The study also investigated where the users preferred positioning of the controls are, with 68 % favored the controls to be located on the seat, 17 % preferring it to be located in the door and 10 % preferring the dashboard or center console. (Williams et al., 2011)

Some of the conclusions made by this study is, firstly, that the door trim and associated components contribute to the users satisfaction of the adjustment controls. Another finding is that a central control system to manage memory function result in a negative user experience. One key consideration when designing HMI for the automotive industry is usability, and this aspect is reflected by Williams et al. (2011), presenting three design recommendations:

**Accessibility of controls**: The controls positioning towards other components needs to be taken into account, understanding how the users reach the controls.

**Intuitiveness of operation**: Basic functions such as seat positioning, tilt and backrest angle can be controlled intuitively by touch, but secondary functions as memory settings should be located away from the basic controls, preferably in the user's line of sight.

**General usability**: The controls should be ergonomically shaped to resemble the the base and back of the seat, and sized proportionally to each other.

# 3
# Execution & Methods

The following section describes the process of the project, which is divided into four different phases, one planning and three execution phases. This enables the project process to be evaluated continuously, having deadlines and milestones regularly. The division gives structure, were deliveries and methods more easily can be set up for each phase, simplifying the detailed planning. The chapter is divided into four sections firstly describing the execution in each phase, with the methods used in each section presented in their associated sub-chapter.

## 3.1 Planning phase

Firstly in the planning phase an initial plan for the project process is established. This involves establishing deliverables of the project, formulating a purpose and the final objective of the project, and deciding the delimitations. When the objective is set a plan of the project process is established, using a gantt chart. The project plan is used to guide the project into a certain direction as well as setting time deadlines for the different phases and tasks of the project. It starts with a preparatory study in order to have a good foundation of knowledge before starting with the actual development. The study includes a literature study, a user study, an own review of the current design and a competitor benchmarking. The knowledge gathered is compiled as a base for the project work later in the process, and it is used to create a requirement specification for the concept of a HMI developed. After the information gathering phase the idea generation start. Different methods is used to generate lots of ideas and then an initial feasibility screening will be conducted. The remaining ideas are then refined into better concepts and screened again based on their performance. When all inferior concepts are removed and one concept is left, it will be developed further into a finalized concept/prototype.

### 3.1.1 Gantt Chart

As defined by Kerzner (2013) a gantt chart is a bar chart, which can be used to visualize the activities and events of a process. The activities are formed independently of each other, but established toward a common time-line showing their time frame as well as starting and finalization point.

## 3.2 Preparatory Study

The main purpose of the preparatory study is to gather data and knowledge which is useful further ahead along the project process. This phase starts of with a literature study, which will focus on HMI design, interface design, controls design, human centered design, cognitive ergonomics, human information processing and how other areas in the industry have solved their problems concerning these subjects. A user study is conducted, complementing the theory from the literature study with information specifically about seat adjustment controls used by VCC today. Seeking answers to questions which has been established about the design, such as how users experience the HMI, how user friendly it is, how it feels and so on. In the user study data received of how the participants of the study actually uses the controls are complimented by interviewing the participant about their thoughts and opinions of the interface. Alongside these steps a competitor benchmarking is performed both by first-hand product testing and by collecting information of how competing car manufacturers have implemented their seat adjustment controls. The information gathered is compiled and analyzed in order to provide information of alternative ways of how to design the HMI and information of the benefits and drawbacks of different implementations.

A review of the seat adjustment controls of VCC:s larger car models, called the SPA-seat is conducted. The reviews core is an evaluation of the whys' and hows' design decisions have been made in development of the current design, and VCC's view on seat settings today. Initially the seat controls are tested and evaluated by the project group in order to provide basic information of the controls. A tree diagram is established in order to connect the location of the controls to the control actions. Learnings from Product Development courses at Chalmers University of Technology have always pressed on the importance to learn from previous projects. With that in mind interviews with developers of the current HMI is held in order to get more knowledge of the design, such as the positive and negative about the design and the design process of developing the current solution. Findings from all of these phases are compiled into a SWOT chart, describing the strengths, weaknesses, opportunities and threats of the current HMI design of VCC. The SWOT chart is established initially based on the information of an internal review of the SPA-seat and thereafter complemented with information from the benchmark and user study. Based on the findings from the different parts of the study a requirement specification is established continuously, providing guidance for requires and demands of the controls.

### 3.2.1 User studies

One way of conducting a user study is to use semi-structured interviews. According to Gillham (2017), semi-structured interviews are the best way of conducting a research interview. It is because of its flexibility balanced by structure, and the quality of the data. By using this structured way the same questions can be asked for all interviewees, the kind and form of the questions go through a process of development to ensure topic focus and equivalent coverage with focus on the subsequent comparative analysis can be ensured. At the same time this structure allows the interviewees to control the interview to a certain degree, coming with inputs not thought of by the interviewer. Another strength is that it facilitates a strong element of discovery, while its structured focus allows an analysis of commonalities.

A good formulated question can be achieved with regard of four criterion: brief, objective, simple and specific (Larossi, 2006). Another way of creating good questions is to first put yourself as the respondent, in order to understand its' point of view. Also, questions should be short and not be leading towards a specific answer. Using technical jargons and concepts can be confusing and delude the respondent's focus and should hence be avoided. Double-barreled question is something to be avoided, instead the questions should be separated into two questions. At the start of an interview, respondents might be suspicious regarding the study and insecure about their part as informants. Therefore, the first questions should be easy, interesting and pleasant. The questions should stimulate their interest and participation and build up their confidence in the survey's objective.

### 3.2.2 Benchmarking

Can be used to understand a set of competing products. The process involve both identifying the competing products and analyzing the products performance and design. The metrics of different products are gathered and the metrics of the products are collected and compared (Ulrich & Eppinger, 2011). A way of using benchmarking is as an improvement tool, finding out other organisation whom are good at something, finding out how they do it and adapting it to your situation (Stapenhurst, 2009).

### 3.2.3 Function-Means tree

To get an overall understanding of what the existing solution does and how it does it, and to inspire for upcoming concept development, a Function-Means model can be created (Almefelt, 2016b). It is a method used to create a deeper understanding of the functions and the means controlling it. In this project this will help to give guidance to what the new solution should be able to do and to inspire how to solve it. It can also help create more clear boundaries of what should be developed and what is outside this project's scope.

### 3.2.4 Strengths, Weaknesses, Opportunities, and Threats (SWOT)

In the article Ghazinoory, Abdi, and Azadegan-Mehr (2011) they explain SWOT as a tool used to analyze internal and external environment as support for decision-making. The tool uses a matrix in order to link the internal strengths and weakness, to the external opportunities and threats, compiled in a 2×2 matrix.

### 3.2.5 Requirement Specification

The requirements of the concept developed will be compiled in a requirements specification. A requirement specification is used to guide a development process when generating solutions, as well as being used to evaluate the finalized product (Almefelt, 2016a). The requirement states a performance property which the product needs to meet, in addition desires (desirable requirements), justification (why is the requirement needed) and verification (how will the requirement be evaluated) might be added to the requirement specification.

## 3.3 Concept Generation and Evaluation

Initially, ideas which have been identified earlier in the development process are recorded continuously and are compiled into a list. The functions of the seat adjustment controls are decomposed into smaller comprehensible sub-functions, which is useful when creating possible ideas. Brainwriting and brainstorming are used in order to generate ideas of how the entire product can be designed, evaluating the ideas to make sure that they take all of the sub-functions into consideration. Thereafter, a Morphological matrix using these sub-functions are developed in order to support the generation of more ideas. With help of the Morphological matrix, another brainwriting and brainstorming is performed in order to generate even more concept ideas.

When ideas have been generated, they are clarified and developed in an initial stage. The first screening will evaluate the feasibility of each idea and eliminate those that don't pass the requirements, using an Elimination matrix. Thereafter, a patent analysis is conducted to provide inspiration of other design solutions. The remaining ideas are developed further, and additional resembling solutions are generated and developed. A Pugh matrix is used in order to screen away the solutions which are inferior to the design of Volvo's current adjustment controls, reducing the number of ideas further.

The remaining ideas are developed even further, clarifying even more accurately how the concepts are structured, but not making any specific decisions of the shaping design of the controls. Multiple solutions of how the different concepts can be implemented are generated. System design is developed, known knowledge gaps are closed and the interaction design is evaluated. When enough information have been compiled an performance based screening is executed, using a Kesselring matrix. The information from the Kesselring matrix as well an evaluation of the pro's and con's of the concept ideas are used to choose the concept which is developed further into a final concept prototype.

### 3.3.1 Generating concepts

Generating concepts isn't something that can be done right away. Different kind of information needs to be gathered and explored beforehand. This is a comprehensive task which take detail planing and information gathering from different sources. A way of doing it in a structured way and to enable as many ideas as possible is to use a five step concept generation method (Ulrich & Eppinger, 2012), see figure 3.1.

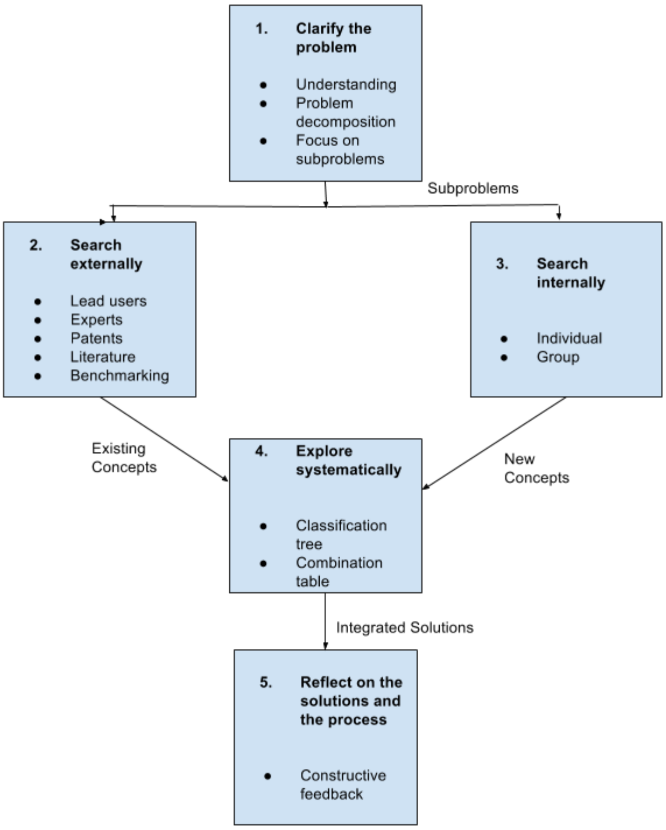



**Figure 3.1:** The five step concept generation method presented by Ulrich and Eppinger (2012).

The first thing to do is to clarify the problem by understanding and decomposing it. It may be done by using the product and creating a Function-Means model as it will facilitate the understanding of sub-problems. Understanding the sub-problems will help the developers to generate novel ideas as it might give new insights of what really needs to be solved. After the sub-problems and functions have been found they need to be solved. The search for new concepts should be done both by using existing information externally but as well use own ideas to create completely new concepts. When concepts from different sources have been collected they should be explored more. Combining different concepts into new concepts is a very good way of taking the best out of something and combining it with other good parts to create something better. The last step is to reflect on the solution and process. Reflection should ideally be done frequently during the process but especially at the end asking question such as

- Are there any more ideas not incorporated into concepts?
- Are there alternative ways of decomposing the problem?

- If external sources have been thoroughly pursued?

### 3.3.2 Brainwriting

Is a method used to generate ideas by having participants writing down their ideas, and thereafter possibly exchanging their written ideas with each other (Litcanua, Prosteana, Orosa, & Mnerieb, 2015). In this project ideas where written down and thereafter exchanged, in order to spark new ideas when reading each others ideas.

### 3.3.3 Brainstorming

According to Ulrich and Eppinger (2011), brainstorming is a type of internal idea creation from knowledge possessed inside the development team. The workflow is creative, with the participants formulating ideas spontaneously based on memory and past experiences, either individually or in a group. Four guidelines to foster idea creation presented in the article is to: suspend judgment, generate lots of ideas, welcome ideas that might seem infeasible and use graphical or physical media (Ulrich & Eppinger, 2011).

### 3.3.4 Morphological matrix

A morphological matrix can be used to find more concepts of those already generated. It is used to find new solutions by combining solutions from each sub-function into diverse concepts (Almefelt, 2016b). This entails optimized concepts with the best sub-functions from different concepts.

### 3.3.5 Elimination Matrix

When having a large number of concepts in the early phase an Elimination matrix is good to use as a first screening of feasibility (Almefelt, 2016b). The matrix consist of main and critical requirements that the concepts need to meet, otherwise they get eliminated. This is a good way of eliminating inferior concepts early and not spend unnecessary resources on them.

### 3.3.6 Pugh Matrix

In a Pugh matrix a number of concepts, presented at the same level is compared with respect to a number of input criterion. A reference concept is chosen which all concepts are compared to. Thereafter, all concepts are ranked as better than ("+"), same as ("0"), or worse ("-") than the reference. The score is summarized and the net score of each concept is calculated and the concepts are ranked based on their net score. Thereafter, the project group verify that all concepts make sense and evaluate if the concepts can be combined or improved, before decisions are taken of which concepts are selected for further refinement and analysis (Ulrich & Eppinger, 2011).

### 3.3.7 Kesselring Matrix

Late in the screening phase a Kesselring matrix can be a good choice. The Kesselring matrix is a more detailed elimination matrix than the regular Elimination matrix with weighted criterion based on their importance from 1-5 where 1 is the lowest (Almefelt, 2016b). The remaining concepts get a rating from 1-5 on how much they fulfil the criteria and together with the importance rating receive a total score for that criteria. This results in more detailed grading of every concept for every criteria which enables easier analysis and different final score comparison. This weighted method creates a more subjective view than other methods but the Kesselring matrix is a method thought to be used in the end when a lot of knowledge have been collected and thereby should the subjectivity be decreased.

## 3.4 Concept Development

After the screening process is finalized and only one concept idea is remaining that concept is developed. That concept is developed into a detailed design, developing a prototype of the physical controls and the touchscreen interface. The physical control is developed as a CAD-model, and a 3-D printed prototype is developed. Materials selection of the model is decided with help of the software CES Edupack. The concept is evaluated using Failure Mode Effects analysis (FMEA). A concept model of the touchscreen interface is developed, showing the design of the interface but not involving software development. Evaluation from a functional as well as a business perspective is conducted and a prototype is created. Finally, recommendations based on the learning's from the development, how to further develop the concept to completion and future possibilities are formulated.

### 3.4.1 Failure Mode and Effects Analysis

Using FMEA is a way to identify and detect potential errors and problems that might occur during the product's life cycle in order to prevent them before they occur (Quality-One, 2017). The way FMEA works is that you list different failure possibilities that can occur and their respective effect. Every aspect is then scored on how likely it is to fail, how critical it is and how likely it is that the failure will be discovered. The total score then entails which potential errors are critical and need to be prioritised. The FMEA is used used to evaluate the final concept and improve it.

### 3.4.2 Business Idea Identification

When a solution has been developed its' different advantages need to be presented in a good way to prove it's something worth further investment. Using Business Idea Identification is a good way of doing so in a clear way (Brud, 2016). The BII uses a matrix design with four columns. The first is for the unique properties of the solution. The second shows the benefits the solution gives the users and customers. The third column describes the advantages of using the solution, it is often described in terms of higher/lower/faster etc. and the last column shows the benefits in terms such as $ and %.

# 4
# Preparatory Study

A preparatory study, that complements the literature study was conducted to get an increased knowledge of how to design seat adjustment controls to be as pleasing as possible for the user. Firstly, a list of important design issues, based on the results of the literature study, are compiled into a list of questions which should be answered by the study. By investigating and analyzing the concepts currently on the market and executing a user study, a broad knowledge base is obtained. The gathered information provides the project with information on how to design HMI interfaces, both from a theoretical standpoint as well as how different implementations are perceived by the users. The main findings of the study is summarized in the last section of each respective section and the chapter is ended with some concluding remarks of the entire study.

## 4.1 Design Issues & Properties

A list of important design issues are compiled into a list of questions, which should be answered to get an understanding of a design solution of a seat HMI. The questions are based on the information gathered by the literature study, presented in Chapter 2. The majority of the information used to formulate the questions were gathered from Williams et al. (2011) and the ergonomics summary chart, presented in Bhise (2012). The information is analyzed and revised by the project group, and some additional information is added into the questions based on the project groups thoughts and knowledge. The questions are used when reviewing competing solutions and in the user study, but in the compilation only the most relevant information of the solution is presented. Thereby, all the questions are not reviewed for each part of the report, but they should be answered or evaluated by the entire data from the literature study, the benchmarking and the user study.

**Ease of use**

1. Intuitiveness of the controls, is it positioned and controllable as expected?
2. How hard/easy is to use different functions?
3. Is the magnitude of movement as big as expected when using the controls?
4. How much focus does it take to adjust the seat while driving?
5. Does the control direction correspond to the intended movement?

**Accessibility**

1. Where is it located?
2. How easy/hard is it to find it?
3. Can the controls be reached from a seated driving posture?

4. Is there any controls which are hard to use or reach ergonomically?
5. Are the controls visible from the driver's normal posture, how do you need to move to find them?
6. Are the controls located at one place or spread out?
7. Is there sufficient clearance to operate the controls?
8. Are there any obstructive objects of moving the controls?
9. Are the controls controllable with gloves and/or long fingernails?

**Design**

1. Size of controls?
2. Do the size of the controls vary much?
3. Feeling of controls?
4. Are there any physical design hints showing where to operate the controls by touch?
5. Can the functionality controls be identified by touch?
6. Is there some coding method of the controls?
7. How are the controls labeled?
8. What media is used for interaction between the HMI and the user?

**Feedback**

1. Is there haptic feedback provided to the user from feeling in the seat?
2. Information for the user from the instructions, design or haptic feedback from the buttons?
3. Is it clear what you are adjusting?
4. Is it clear how you are adjusting it?
5. Are there feedback provided from a screen or alternative media?
6. Do you need feedback to understand how to adjust the seat?
7. Do you need feedback to understand what you are adjusting?
8. Where is the feedback presented, how far from the drivers normal line of sight while driving?

## 4.2 Review of VCC seat

The seat chosen to be reviewed was a fully equipped comfort seat from VCC SPA-platform as that is a full power seat, which means electric powered seat adjustment controls and electric motors are used for the adjustment. Reviewing a fully equipped seat will provide a good insight on how VCC's most advanced HMI looks like and getting a basic understanding of its benefits and drawbacks. A fully equipped comfort seat contains ten different functions or actions activated with three controls, see Figure 4.1, located at the outer side of the seat and a touchscreen in the center console panel. The seat adjustment controls can be combined with different implementations and with different number of functions attached to it. Different versions as mechanical basic adjustment of the seat's length, height and angle, an electric powered with some functions, and a fully equipped electric powered seat with all functions such as massage, ventilation and lumbar support. The comfort seat can also be exchanged for a sport seat, but that seat has less functions available for it. Hence, the fully equipped comfort seat has the most complex HMI.

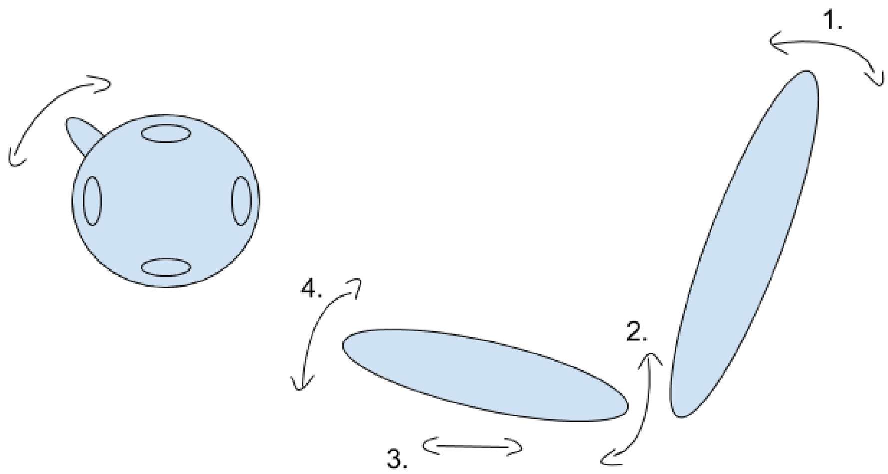



**Figure 4.1:** A drawing of the design of the HMI currently used by Volvo Cars.

To understand how the controls worked they were tested in a Volvo S90 and described with a Function-Means model shown in Figure 4.2. The model clearly show that there are three different ways to activate a function, via the touchscreen, the rotary knob or the two oblong buttons seen in 4.1. The two oblong buttons adjust the basic seat movements such as adjusting the tilt of the backrest, the depth of the seat cushion, moving the seat back and forth, and tilting the seat cushion. These functions have existed for a long time and has been refined until satisfaction.

The last way to activate a function is through the round knob. Functions activated here are newer seat functions and that could be the reason why they are not connected to the basic movements. As the controls of the basic movements might have worked well earlier and instead of changing that, an add-on have been added instead of creating something completely new. The new functions seem to have been fitted on the interface where they could be, instead of where they should be. Also, it could be that the newer functions are selectable and the easiest way was to separate them from the basic selection. The seat heating function is located in the center console panel, which is the traditional placement of the control. The seat ventilation is located in proximity to the seat heating control, being two alternatives in a pop-up menu at the bottom edge of the touchscreen. Both of these functions are quite similar and that might be the reason they are grouped together.

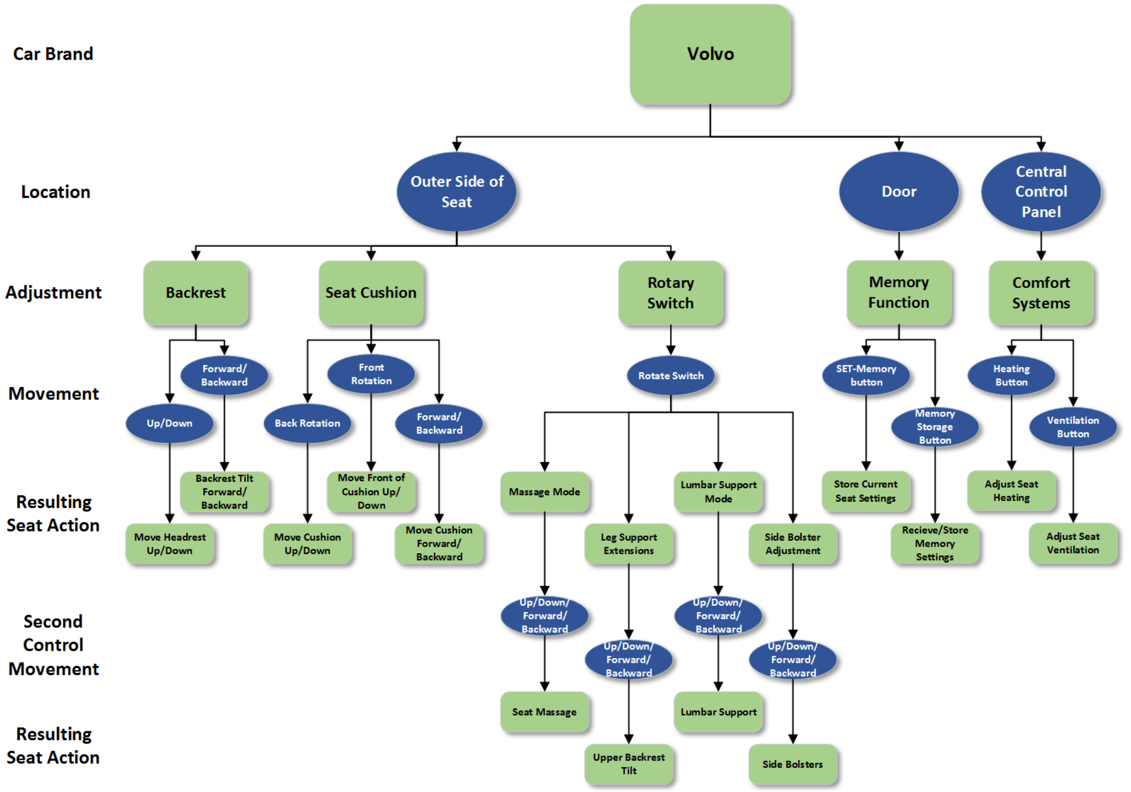



**Figure 4.2:** A Function-Means model of the seat HMI in a fully equipped Volvo SPA-seat.

One of the most commonly asked questions which occurred while testing the controls was how to know when the seat is adjusted in a good sitting posture, as it is unknown for the project group how to sit for best comfort and safety. Having this problem whilst driving may lead to fatigue and pain, decreasing the driver's awareness and comfort, as well as safety concerns regarding how the posture affect the safety systems of the vehicle. It was also hard to adjust the side bolsters as the knob has four buttons, two for adjusting and two having no function in this mode. The mapping of the knob and bolsters in different axises made it hard to understand which two buttons to press. Also, since the bolsters are inflating/deflating slowly, not much haptic feedback was received from the system. Having heat and ventilation on the touchscreen looked good, but proved to be a small struggle to press while driving. In order to press the right thing you had to look away from the road quite some time as you had two functions with three modes respectively.

In addition to these comments the knob felt redundant in some cases. It could both be rotated and pressed to do the same movement sometimes, and sometimes not, which felt unnecessary and confusing. It was also discovered that VCC had designed the controls without a pre-planned movement pattern which could have facilitated a more user-friendly design. The information gathered by reviewing the SPA-seat, complemented with information gathered by the competitor analysis and the user study is compiled into a SWOT-chart, presented in Table 4.1. In the SWOT-chart the strengths and weaknesses of the design is evaluate, also looking into the future opportunities and threats of VCC's situation regarding their adjustment controls.

**Table 4.1:** SWOT of the current HMI in a fully equipped Volvo SPA-seat.

| **Strengths** | **Weaknesses** |
|---|---|
| Feedback of what the control used is adjusting when using the rotary knob.<br>Intuitive and traditional placement of the controls.<br>Good feel of the material and surfaces of the buttons, providing a sense of high quality.<br>The basic functions of the seat are easy to adjust.<br>The sound of the control is pleasurable.<br>The rotary knob are provided with bumps indicating where/how it is controllable on top of the control.<br>The controls have a clean look, making it beautiful visually.<br>The basic seat adjustment controls resemblance of a seat is quite clear visually. | No feedback of which direction functions are adjusted in.<br>Visual feedback is received from a screen located more than 30 degrees from the drivers normal line of sight while driving, leading to distractions from the road.<br>Adjusting heat/ventilation takes focus from driving, needs both visual focus and multiple control actions.<br>Having three functions in one button (adjusted by 2 rotations & 1 horizontal motion) increase the risk that the user misunderstand one control move.<br>Lack of haptic feedback for some buttons, not giving feedback of what is controlled.<br>Not intuitive what functions are controlled by the rotary knob, instead there are a need of receiving feedback from screen in order to use it.<br>The adjustment movement of the side bolsters are not logically mapped to the corresponding movement of the adjustment control action.<br>The system does not provide help of how to sit or adjust the seat for an optimal seating position.<br>The controls are spread out to three different locations, making them harder to recognize (touchscreen, door and seat). |
| **Opportunities** | **Threats** |
| The market hasn't been settled to one standard, meaning there is possible to find a superior solution.<br>VCC has a high seat comfort standard and combined with a good HMI, the seat can exceed competitors.<br>There seem to be somewhat of a dissatisfaction of many of the older HMI:s at the market today.<br>The introduction of many new technologies and the introduction of new information media provides many new possibilities. | Using inferior adjustment controls will affect the operators opinions of the entire seating comfort.<br>Some competing companies have started to test new concepts for the adjustment controls, not being aware of new trends might result in the company lagging behind these competitors. |

## 4.3 Benchmarking

The benchmarking was conducted in a stepwise procedure as proposed in Section 3.2.2. The work is conducted in order to understand the drawbacks and benefits of different implementations of car seat adjustment controls. The competing adjustment controls are evaluated in order to answer the questions phrased in Section Section 4.1. However, information about all of the questions was not found and all questions are not answered in the report. Lastly, a review of the competing solutions investigated are presented, the data is analyzed, a selection of the car brands presented are compared and the key findings of the investigation are presented.

The participants of the study were chosen to be some of the top performing car manufactures in Sweden, as well as some lower performing car brands to get comparison. Since the study focus on comfort seats, sports cars are excluded from the benchmark. Thereby, the study mainly include car companies being generally high performing, having high sales, and having products focusing on the premium car segment. Several of the car brands had more than one type of adjustment controls, but only one implementation of the adjustment controls of each brand was analyzed.

The reviews are of different types of adjustment controls, with some being the newest of its car brand, some being a bit older and some being concepts which could be implemented in future car models. Thereby, the study can not be viewed as representative of the seat adjustment controls of a car brand but rather as an example of how they might implement it. The information is gathered by a field study and information search. The data of the different models differ dependent of what information is found, and thereby the depth of the analysis differ as well. Some models are tested with all systems running, some are tested with some features missing and some are studied without physical interaction. Also, only physical, visual and to a lower extent audible feedback is evaluated, and thus missing information of some aspects.

### 4.3.1 Main Competitors

Three of the main competitors on the market, using three different ways of implementing their HMI are investigated more thoroughly in order to get a good knowledge of the designs. A review of the designs are provided with a function-means tree relating the positioning to the control actions and a list of the positive and negative aspects of the implementation is provided.

***Audi***

The seat adjustment controls of an Audi Q7 are located on the outer-side of the seat, the door and the center console panel. The controls located at the outer side of the seat are the ones controlling the shape of the seating, consisting of the controls presented in Figure 4.3. With the controls resembling the appearance of a seat, with the control movement also resembling the corresponding movement of the seat. The rearmost control is controlling the tilt of the backrest by moving it back and forth, and the headrest height is adjusted by pushing the control up and down. The horizontal control is used to control the seat cushion, being able to adjust the seat cushion back and forth, adjusting the height and the front, as well as the rear position of the seat by tilting the button.

**Figure 4.3:** An image of the seat adjustment controls in an Audi Q7, located on the outer side of the seat.

The rotary knob located at the front of the module has six different modes. By rotating the knob the current mode is selected, with a number of functions related to each mode. Thereafter changes to a specific control is adjusted by pushing the four buttons on the control, which is notable because of distinct cut-outs at the control locations. The adjustments controllable by this control are massage, seat belt height, upper part of backrest tilt, lumbar support, side bolsters and seat extension.

A memory function with the possibility to store two seat settings, is located at the door. In the center console panel two buttons are controlling the seat heating and ventilation. A visualization of the functionality of the controls are shown in Figure 4.4. The screen in the center console panel provides feedback of what control is adjusted, and in which direction it is controlled. The positive and negative aspects of the HMI is presented in Table 4.2.

**Table 4.2:** Positives and negatives of the HMI in an Audi Q7.

| **Positive** ⊕ | **Negative** ⊖ |
|---|---|
| Traditional placement of controls simplifies localization. | No indents on the buttons used to control the basic functions. |
| Feedback of what is controlled and in which direction from touchscreen. | Controls for bolsters and lumbar support is somewhat difficult to use. |
| Shiny back plate create premium feeling. | Some functions do the same thing, which creates confusion. |
| It is easy to reach the control. | Hard to understand and use all functions intuitively. |
| | Difficult to know when seat is correctly adjusted. |
| | Controls not visible from a seated position. |

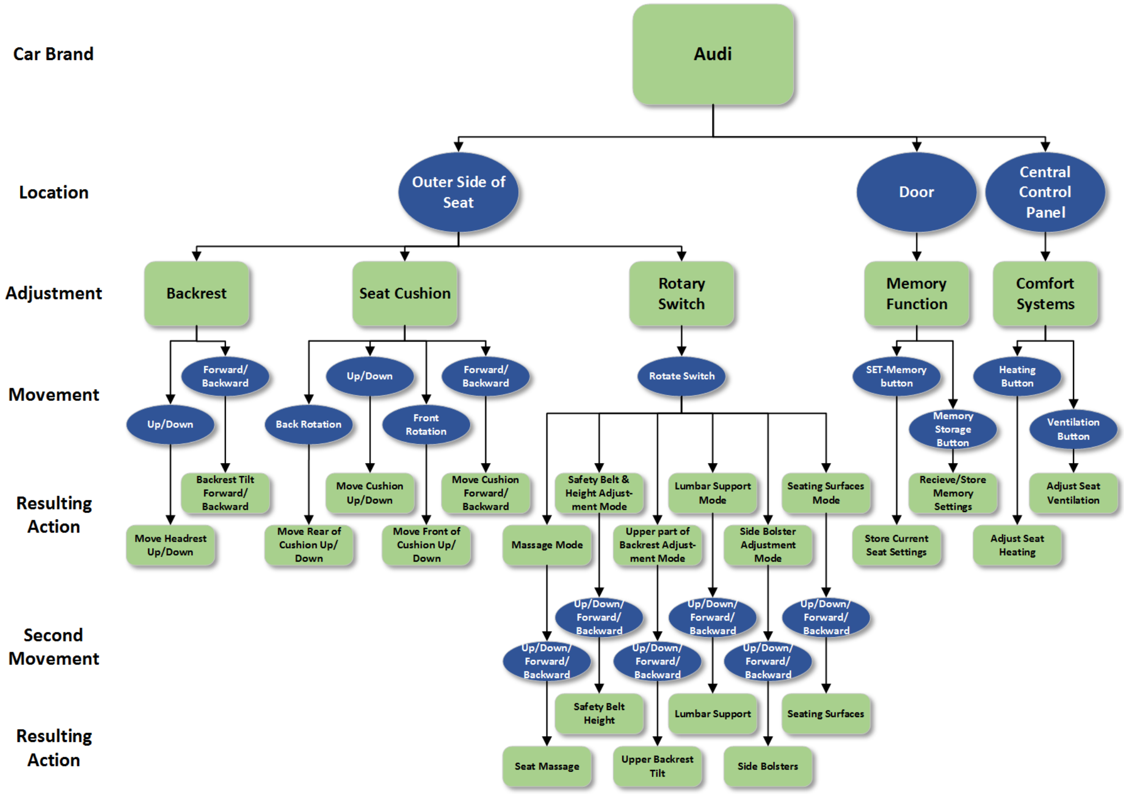



**Figure 4.4:** A Function-Means model of the HMI of Audi Q7.

### *BMW*

In a BMW X5, the majority of the seat adjustment controls are located on the outer side of the seat, with controls for the seat heating and ventilation being positioned in the center console.

The controls located at the outer side of the seat are presented in Figure 4.5, being easily reachable with a good clearance space between the door and the controls. The controls of the backrest, seat cushion and leg extensions are located to correspond to their positioning in the seat. The leg extensions are controlled to be extended or retracted, pushing the control at the left -hand side of the image forward or backwards. The cushion control have three functions, moving it back and forth to move the seat back and forward, moving it up and down changes the height/depth of the cushion and rotating it changes the tilt of the cushion. Being logical, but somewhat troublesome to use since the rotation and vertical control movement are performed by similar physical actions.


**Figure 4.5:** An image of the seat adjustment controls in a BMW X5, located on the outer side of the seat.

The control of the backrest contain three functions, firstly by rotating the control the backrest is tilted. By moving the control vertically the vertical position of the headrest is adjusted. In the middle of the control there are a switch which can be pressed forwards and backwards horizontally, by using this control the upper part of the backrest is tilted, adjusting the seat curvature. The round button at the rear is controlling the lumbar support, controlling the vertical placement as well as the firmness of the support. The control at the top right corner is the control for the backrest bolsters, both adjusting the width of the side support of the seat. The seat heating and ventilation is controlled in the center console panel. In some models it is adjusted on the touch screen and for some models it is adjusted by switches in the center console console. Also, the massage function is controlled by the touchscreen.

A logical explanation of the adjustment controls are presented in Figure 4.6. Linking the seat adjustment controls location, to the physical control, further to the movement used to operate the controls and the resulting seat action. A list of some of the positive and negative aspects of this implementation is presented in Table 4.3.

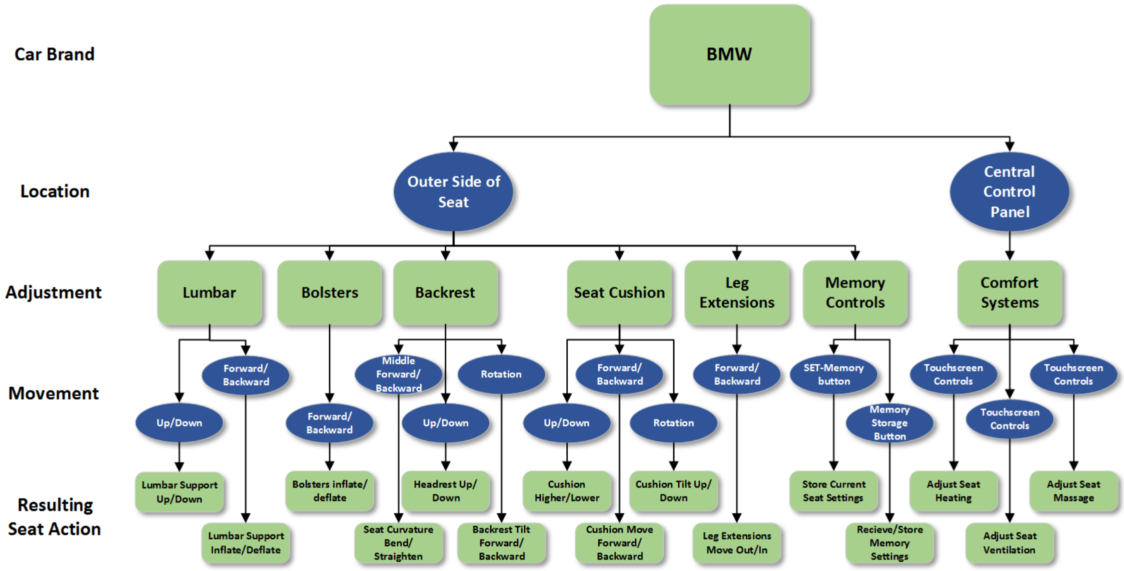



**Figure 4.6:** A Function-Means model of the HMI of BMW X5.

**Table 4.3:** Positives and negatives of the HMI in a BMW X5.

| **Positive** ⊕ | **Negative** ⊖ |
|---|---|
| Grouping of controls on the traditional placement at the left side of the seat. | Easy to confound one to adjust the wrong control. |
| Logical controls and control placement make it easy to reach and control. | Controls for bolsters and lumbar support is somewhat difficult to locate. |
| Buttons have a suitable amount of functions. | Difficult to know when the seat is correctly adjusted. |
| Intuitively divided mapping of the seat. | Controls not visible from seated position. |
| Traditional placement of controls simplifies localization. | |

***Mercedes-Benz***

Mercedes-Benz E-class 220i seat HMI is located partly in the door console and partly at the center console unit. The controls located at the door are shaped to resemble the appearance of a seat, with each control action corresponding to an alike change of the seat. The implemented controls are shown in Figure 4.7. The memory function, seat heat, seat ventilation and the button used to adjust the passenger seat is also located close to the other controls. Being an area focusing on seat controls, the controls located in this area are the seating posture adjustment, seat memory, seat heating and seat ventilation.


**Figure 4.7:** An image of the seat adjustment controls in a Mercedes-Benz E-class Sedan, located at the door console.

As mentioned, the shape of the controls are resembling a seat, and the contours around the seating controls reinforce that feeling. The location at the door makes the controls easy to localize, since it is visible from the drivers normal sitting posture. The movements of the controls resemble the corresponding movement of the seat. However, sometimes they are hard to use since it is not enough clearance for the fingers, resulting in obstructing objects. In addition, it is not evident that you can use some of the controls because of their appearance. The location of the control makes it somewhat unpleasant to reach them, because you need to turn your arm and hand in unpleasant angles in order to use them. The controls also affect the appearance of the door, making the door look a bit cluttered. The seat heating, ventilation, memory and passenger seat controls are located close to the seat adjustment, making it easy to find them. However, it is not evident what the function of the passenger seat control do, (making it possible to adjust the passenger seat with the driver's seat controls), by looking at the control.

**Figure 4.8:** Image of the center console of a Mercedes-Benz E-class Sedan.

The controls of the side bolsters, massage function and lumbar support of the seat is located in the center console panel, shown in Figure 4.8. There are no clues that the controls are located at the center screen, but when that is localized the seat controls are easily located at the screen. The controlling is conducted either with a touch pad steering control or a rotary knob. By pressing the controls you move forward into a mode, and there are a separate return control for each of the controls. The lumbar support is changed by moving a cursor on the screen, within it is possible to move the cursor vertically and horizontally, as shown in the top of Figure 4.8. When using the touch pad the control was instinctive, but it was harder to achieve by the rotary knob. The feature made it easy to understand how the lumbar support was changed. The objects controlled was also shown on the screen, visualizing what is moved but not which direction it is moved in.

A logical explanation of the adjustment controls are presented in Figure 4.9. Linking the seat adjustment controls location, to the physical control, further to the movement used to operate the controls and the resulting seat action. A list of some of the positive and negative aspects of this implementation is presented in Table 4.4.

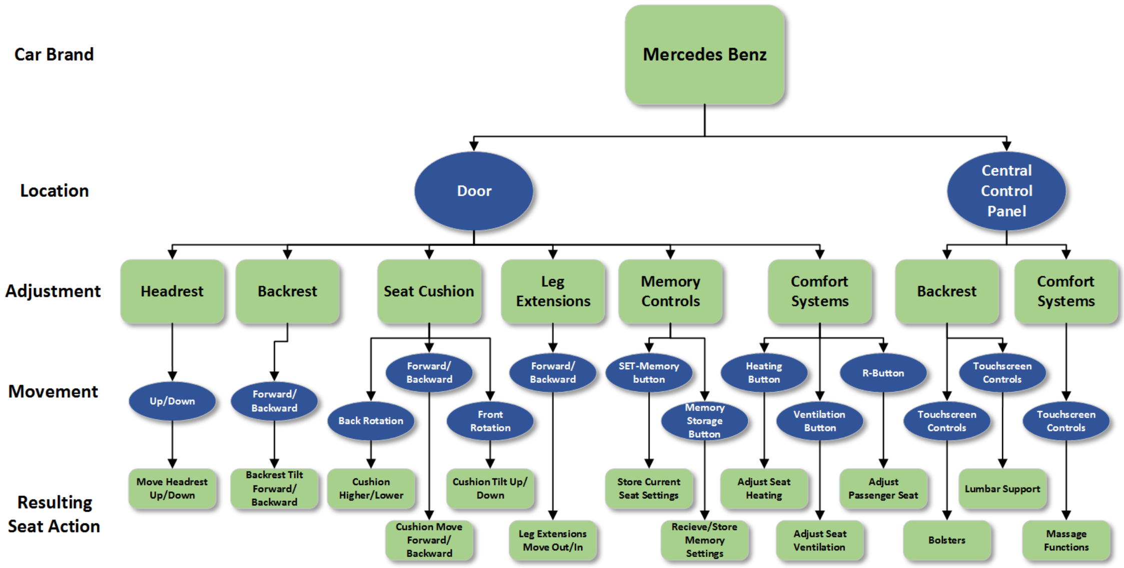



**Figure 4.9:** A Function-Means model of the HMI of a Mercedes-Benz E-class Sedan.

**Table 4.4:** Positives and negatives of the HMI in a Mercedes-Benz E-class Sedan.

| **Positive** ⊕ | **Negative** ⊖ |
|---|---|
| Visibility of the controls when seated. | Adjustability while driving. |
| Logical correspondence between maneuver and corresponding event. | Small clearance for the controls, hard to access some controls. |
| Grouping of controls in the door. | Reachability, ergonomically difficult to control from seated position. |
| Visual beauty of controls. | Tricky to find controls for bolsters, massage and lumbar support. |
| Feedback from touchscreen. | Interupts the smoothness of the door design. |
| Easily understandable lumbar support controls with quick feedback. | Difficult to know when seat is correctly adjusted. |

### 4.3.2 Alternative Implementations

Some other adjustment controls which are particularly interesting, providing additional information for the project are presented in this section.

***Aston Martin***

For the Aston Martin DB11, most of the seat adjustment controls are located on the outer side of the center console, facing toward the seat. These controls are shown in Figure 4.10. The controls consist of two controls resembling a car seat in an L-shaped pattern, including a 2-way adjustable backrest as well as a 6-way adjustable seat cushion. Above those controls are buttons for the memory functions, having three memory storage slots. The seat also has seat heating and ventilation, side bolsters etc.. However, the placement of the controls is what stand out compared to competing car brands.

**Figure 4.10:** Seat adjustment controls located on the seat of an Aston Martin DB11 Coupe 2016.

***Cadillac***

The primary location of the seat adjustment controls of the seats in a Cadillac CT6 are located at the door, with only the seat ventilation and heating located at the center console. The controls located at the door are shown in Figure 4.11. The controls consist of two controls having a resembling appearance to a seat, a round button controlling the massage, a round control controllable in four directions, with a pin controllable up and down located in the middle, and memory controls located below the other controls.

**Figure 4.11:** Seat adjustment controls located on the seat of a Cadillac CT6.

The bottom one of the controls resembling a seat is controlling the seat cushion. The control movement is resembling to the seat movement. Moving the control forward or backward adjust the seat cushion back and forth, moving the rear of the control up and down raise and lower the cushion, and moving the front of the control up and down tilt the front of the seat up and down. The other control adjust the tilt of the seat back, moving the control back and forth.

The round control marked by arrows control multiple functions. The functions are toggled between by pressing the pin up and down, controlling the functions thigh support, lumbar support, bolster and upper back support. Each function is controlled by the four buttons, with different buttons used dependent on the number of ways the function could be adjusted. By pressing the massage button the massage mode is entered. Then the pin and the arrows are used to change the massage function and the intensity of the massage. By pressing the massage button again the massage mode is exited. The screen in the center console is providing feedback of the operations.

The memory function, also located on the door, enables one to store and recall two sets of seat settings. In the touchscreen of the center console panel the seat heating and ventilation are adjustable.

***Land Rover***

**Figure 4.12:** Seat adjustment controls located at the seat of a Range Rover.

The majority of the controls of the Range Rover are located on the outer side of the seat, and the controls are shown in Figure 4.12. These are the controls adjusting the positioning of the seat. The small foremost control is controlling the leg extension supports. The bottom control is adjusting the seat cushion in three direction, horizontally back and forward, vertically up and down, and the tilt of the cushion. The rearmost control is adjusting the tilt of the backrest as well as the vertical position of the headrest. By rotating the rotary know the bolsters are adjusted. By pressing the knob forwards or backwards the firmness of the lumbar support is adjusted, and by pressing it up and down the positioning of the support is adjusted. The buttons for the memory function of the car is located in the door, just next to the door handle. Seat ventilation, heating and massage features are available, and they are controlled in the touch screen in the center panel.

***Lincoln***

**Figure 4.13:** Seat adjustment controls of Lincolns, 30-way adjustable seat concept.

Lincoln have presented a concept of a 30-way adjustable seat, yet not in production, with the majority of the controls located on the door. The controls located at the door are designed to resemble a car seat, shown in Figure 4.13, with a 4-way adjustable headrest, a backrest with adjustable tilt and individually adjustable top half tilt, a 6-way adjustable seat cushion and individually adjustable leg extensions. The door adjustment console also contain three memory buttons numbered one, two and three and controls for the massage functions. Containing a button to start the massage, buttons to adjust the intensity of the massage and to navigate the location of the massage.

Some controls can be controlled by the touch screen in the center console of the vehicle. The lumbar support is adjustable in 4-ways, controlling the stiffness and vertical positioning. The bolster support is controllable in 4-ways, controlling the bolsters of the upper part of the back as well as the lower part. Lastly, there are a control which is not adjusted by the user and that is a 4-way thigh extension, which can be adjusted both vertically and horizontally.

***Porsche***

The seat adjustment controls of the Porsche Panamera are split up into three different locations, the door, left-hand side of the seat and the middle console. With the memory package being the only part of the seat controls which is located at the front of the door. Adjustments of the seat shape is made on the side of the seat, with the controls shown in Figure 4.14. While features such as heat, ventilation and massage is positioned on the middle console.

**Figure 4.14:** Seat adjustment controls located at the seat of a Porsche Panamera.

The design and composition of the buttons on the side are neatly done and creates a premium feeling. The actual buttons have stand out as one of the brands with the most elaborated designs, with nice cut-ins which facilitate the understanding and makes it natural to realize what functions are available. However, the button for lumbar support is quite bad being rounded outwards making it unnecessary complicated to press a button and not slipping of. Also, there are an extra button for leg extension which is easy to understand and use.

***Renault***

In Figure 4.15 the HMI of Renault is shown. The controls contain two buttons placed to resemble a seat, the backrest button is used to adjust the tilt of the backrest and the seat cushion button is used to adjust the height and length of the actual seat. However, it is not possible to adjust the tilt of the seat cushion, something most other car brands allow. There is a separate button for adjusting the lumbar support which is quite oblong, hence it creates the impression of only having adjustments back and forth and not also up and down, which it has. The metallic button to the left in the figure starts the massage mode when pressed. The massage mode is shown on the touch panel, see Figure 4.16, were the different settings can be changed. The touch panel works good but creates small irritation as an ON-button also have to be pressed to start the massage. A seat heat button also exist, located as a button in the center console unit.

**Figure 4.15:** Seat adjustment controls located at the seat of a Renault.

The design of the controls feel intuitive to a great extent, however the metallic button for the massage is not, but it is probably something that is easy to learn after some use. The other buttons feel obvious to understand, even more as the seat cushion button only has two functions. Also, there are enough space to reach and adjust while the car door is closed. The touch panel is very good. It is easy to use and have good explanatory pictures and bars.


**Figure 4.16:** The center touch panel of a Renault while using the massage feature.

### 4.3.3 Other similar implementations

Reviews of multiple seat adjustment controls are conduced. The reviews provided in this section has many similarities to the brand evaluated more thoroughly in the sections before.

***Alfa Romeo***

The controls for adjusting the seat are located on the side of the seat and the heat function is located on the central console panel in the Alfa Romeo Giulia. The controls' placement feels intuitive on the seat and have a rough shape of a seat and what looks like a rotating knob with buttons, as shown in Figure 4.17. But the knob don't rotate, it contains four buttons in which the lumbar support are adjusted. The seat-like buttons to the left of it are used to change the rotation of the backrest and the length and height of the entire seat. The controls also include three memory buttons, their function is hard to figure out without prior knowledge of what they are controlling and how to use them. The design of the buttons are clear, it looks roughly as a seat. However the lumbar adjustment are impossible to understand prior to use, the functions are few and the controls looks bulky and don't instill a premium feeling.


**Figure 4.17:** Seat adjustment controls located on the seat of an Alfa Romeo.

***Ford***

The HMI of a Ford Edge is mainly placed on the side of the seat, except for the heat function which is located in the center console. The controls are made of the buttons placed to resemble a seat with corresponding functions and a round two-way button used for increasing and decreasing the lumbar support, see Figure 4.18. The buttons except the round one have a high degree of understandability due to the seat form and together with less functions than the premium brands, also a good discoverability. The design of the HMI is okay, it possess a feeling of quality but at the same time, not all functions of the controls can easily be found by looking or feeling, and it don't have as many functions as some other brands. There is also no feedback from the car whatsoever, which decreases the discoverability a little.

**Figure 4.18:** Seat adjustment controls located on the seat of a Ford.

***Honda***

The adjustment controls on Honda are located on the side of the seat towards the door which feel intuitive and accessible. Memory buttons also exist, located on the door. The usability and discoverability of the controls are good, the control is understandable by looking at the controls to see the symbols, see Figure 4.19. The question is how many that actually look at the symbols as they are located low in the car. Despite that the controls are straight forward to use and they don't have too many functions on the same buttons. However, the design is quite boring, with a bad emotional design, with shapes that don't create a premium feeling, and giving a plastic feeling. Meanwhile the seat doesn't have as many functions as the premium cars, which ease the discoverability and understanding.

**Figure 4.19:** Seat adjustment controls located on the seat of a Honda.

***Hyundai***

In Figure 4.20 a picture of the HMI in a Hyundai is shown. The controls are exactly the same as in the Honda described above with no apparent difference. They are easily accessible with enough clearance towards the door to be reachable with ease.

**Figure 4.20:** Seat adjustment controls located on the seat of a Hyundai.

***Jaguar***

In the HMI of a Jaguar type F seat, the controls of the seat is located on the inside of the door. The controls are presented in Figure 4.21, with cutout lines connecting the three controls of the seat backrest and the two controls of the seat cushion, which indicates which seat part is adjusted. The cushion is controlled by the bottom button controlling the height, horizontal position and tilt of the cushion. The additional button on front of that control is adjusting the length of the cushion. The controls at the back is adjusting the backrest, with the long diagonal control controlling the tilt. The side bolsters are inflated/deflated by rotating the small round button and the lumbar support is adjusted with the small squared control. Above these controls the buttons of the memory settings are positioned.


**Figure 4.21:** Seat adjustment controls of a Jaguar F-type seat.

***Jeep***

The adjustment controls shown in Figure 4.22 is the seat adjustments of a Jeep Cherokee is on the side of the seat with two buttons mapped as a seat and one round button in front of them. The round button is to adjust the lumbar support and the two other are for basic functions such as height, length and backrest tilt. The design of the buttons are basic, quite rectangular with rounded corners but with no indents to show were to press. However, the lumbar support have good and clear indents on were to press which make that function understandable and discoverable.

**Figure 4.22:** Seat adjustment controls on the seat of a Jeep.

***KIA***

The seat adjustments of KIA is similar to other brands with two buttons mapped to look like a seat, see Figure 4.23. The seat cushion allows three different adjustments and the backrest allow one adjustment. A 2-way horizontal lumbar support button behind the other two buttons also exist. There is enough clearance to reach the controls with the door closed and the design that looks metallic gives a more premium feeling than most other brands with the same number of functions, but not as much as the premium brands. Only the lumbar support button have indents to show where it is possible to press the buttons, hence functions on the other two buttons might be missed.

**Figure 4.23:** Seat adjustment controls on the seat of a KIA.

***Lexus***

The seat adjustment controls of a Lexus NX are very basic for being a brand reaching for the premium segment. The controls are shown in Figure 4.24 with three buttons, two with basic functions such as height, length and tilt mapped as a seat, and one button for a 2-way lumbar support. The lumbar support is the only button with indents to show a possibility to be pressed but the indents are small and could easily be missed. The overall impression of the design of the buttons are bad, the buttons are very rectangular and plastic and you get a feeling that no time or commitment have been put to create it. The good parts are that the controls are easily reached and enough room are given to adjust the seat when the door is closed.

**Figure 4.24:** Seat adjustment controls on the seat of a Lexus NX.

***Mitsubishi***

The seat controls of Mitsubishi are located on the side of the seat with one 2-way button for the lumbar support and two buttons for backrest tilt, seat cushion tilt, seat height and seat length, shown in Figure 4.25. Unlike most other brands, the two buttons are not mapped to look like a seat. The benefit is that you more easily understand that you can press the seat cushion button both in the front and in the back to perform different functions, which may not be as obvious in other cars. The drawback is that it might be hard to realize the relation between button and wanted movement which is obvious in other cars. Also, the buttons doesn't provide a high-end premium feeling.

**Figure 4.25:** Seat adjustment controls located at the seat of a Mitsubishi.

***Nissan***

The HMI of Nissan GT-R differ much from Nissans usual adjustment control design, however it was an interesting concept which is interesting to compare to the other premium cars. The adjustment controls are shown in Figure 4.26, apart from many other brands Nissan GT-R have its' heating function on the side of the seat (top left in Figure 4.26). On the side there is a 2-way button and a rotary knob, mapped far apart from each other. The button is used for tilting the front of the seat cushion. Whilst the rotary knob is used to tilt the back of the seat cushion by pushing the knob up or down, which is not very intuitive. By pushing the knob horizontally the seat is moved back and forth and by rotating the control, the tilt of the backrest is adjusted.

**Figure 4.26:** Seat adjustment controls located at the seat of a Nissan GT-R.

At first glance the controls feel innovating, compared to other brands which are quite similar but that changes fast. The only way of understanding how to adjust the seat is to try the different controls until the right one is found, which is really bad. There is also quite few functions in total so it should not be that complicated or unintuitive to adjust the seat.

***Tesla***

The design of the Tesla Model S tested is very basic for a premium brand and the seat doesn't have close to as much functions as other brands. It don't have massage, no adjustments for side bolsters, no seat extension, no ventilation and no memory buttons, it may be in the key but that was not tested. However, the existing buttons shown in Figure 4.27 are easy to understand. There are two buttons shaped as a seat to control the tilt of the backrest and cushion and the motion length-wise and height-wise. A round knob with four buttons also exist. The buttons have a shallow cut-out to facilitate discoverability in the same way as Audi and are used for a 4-way lumbar adjustment.

**Figure 4.27:** Seat adjustment controls located at the seat of a Tesla Model S.

The controls are easy to reach but the space between the side of the seat and a closed door is quite narrow, which complicates adjusting the seat. Also there are some delay in the buttons which decreases the understandability.

***Volkswagen***

The controls of a Volkswagen Passat are located at two locations, with some controls located at the left-hand side of the seat and some controls located at the center console of the car. The seating adjustment controls are shown in Figure 4.28, located at the left-hand side of the seat and are shaped to resemble the car seat, with one control for the backrest and one for the seat cushion. In front of these buttons there are a pushable non-rotary knob to adjust the lumbar support. The controls are positioned at the outer side of the seat cushion according to the traditional placement of seat adjustment controls, but they are not visible from a seated position in the seat. The controls are located in a close proximity to the door trim, and thereby the space for the controls are limited. Also, the controls locations entails a need of squeezing your arm between the backrest of the seat and the covers of the door, especially when the seat is in its rearmost position.

The controls are controllable logically, an alike movement of the controls make a corresponding movement of the seat. But it might take some time to understand that the seating cushion is controllable in three aspects. These controls have markings, notable by touch, which shows the end of the controls. The knob controlling the lumbar support has clear cutouts at the front and back, making it possible to understand how it can be controlled by touching it, but there are no cutouts showing that it is controllable up and down as well. These features are logically placed to the corre-

**Figure 4.28:** Seat adjustment controls of a Volkswagen Passat.

sponding action, but it takes some time to get feedback of what you are controlling, especially for the vertical placement of the support. The sound of the controls is making it clear when a control is pressed by a distinct clicking sounds when pushing a button. The memory controls are located above the seating adjustment controls, using push-down buttons facing upwards.

In the central console panel the seat heating and ventilation is controlled. They are controlled by a push-down button, opening the controls at the touch display. At the touch display the settings of both of the controls can be adjusted.

### 4.3.4 Data Compilation & Analysis

When compiling all the information gathered from the benchmarking some commonalities, a lot of differences and a few innovative sub-solutions can be seen. A comparison in different aspects between Volvo and nine of the brands, chosen to be the most relevant, has been made and can be seen in Table 4.5.

**Table 4.5:** A comparison of the HMI:s used by a number of car brands.

| | Volvo (ref) | Aston Martin | Audi | BMW | Cadillac | Jaguar | Land Rover | Lincoln | Mercedes-Benz | Porsche |
|---|---|---|---|---|---|---|---|---|---|---|
| **Ease of Use** | | | | | | | | | | |
| Control direction correspond to intended movement | 0 | 0 | 0 | ✓ | 0 | ✓ | 0 | ✓ | ✓ | ✓ |
| Intuitiveness of controls | 0 | 0 | 0 | 0 | 0 | ✗ | 0 | ✗ | 0 | ✓ |
| Amount of functions | 0 | ■ | ✓ | 0 | 0 | ✗ | ✓ | ✓ | ✓ | ✗ |
| **Accessability of controls** | | | | | | | | | | |
| Visibility of controls | 0 | ✓ | 0 | 0 | ✓ | ✓ | 0 | ✓ | 0 | 0 |
| Reachability | 0 | ✗ | 0 | 0 | ✗ | ✗ | 0 | ✗ | ✗ | 0 |
| **Feedback of actions performed** | | | | | | | | | | |
| Visual feedback (e.g. display) | 0 | ■ | ✓ | ✗ | ■ | ✗ | ✗ | ■ | ✓ | ✗ |
| Physical feedback (e.g. buttons or touch) | 0 | ■ | 0 | 0 | 0 | 0 | 0 | ■ | 0 | 0 |
| **Design** | | | | | | | | | | |
| Pleasurability of the Design | 0 | ✓ | ✓ | ✗ | ✗ | ✗ | ✗ | ✓ | ✓ | 0 |
| Feel of buttons | 0 | ■ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ✓ |
| Mapping | 0 | 0 | 0 | ✓ | 0 | ✗ | 0 | 0 | 0 | ✓ |
| **Focus** | | | | | | | | | | |
| Focus needed operating the controls | 0 | ■ | 0 | ✓ | ✗ | ✗ | ✓ | ✗ | ✗ | ✓ |

■ = Not evaluated
✓ = Better than reference
0 = Same as reference
✗ = Worse than reference

Clarification of the 'Amount of functions' category is that Mercedes, Land Rover and Audi have adjustments for the headrest, while Audi also has controls for the height of the seat belt adjustment as well. For visibility of controls Mercedes do have better visibility than Volvo but one of their negatives are the difficulties in finding bolster, massage and lumbar adjustments which levels the score to a zero. The last clarification is for the visual feedback. A minus is given when there is none, a zero when a static display is used and a plus for a display giving further feedback of what is happening. All car brands can not be evaluated out of all aspects but since they are interesting for the comparison out of other aspects, they are still included in the comparison. Some of the key findings of the studies involve subjects such as the placement of the controls, the design of the controls and the feedback of the system. The most important findings are presented in the list below.

1. The shape of the controls of most car brands are designed to resemble a car seat, in some cases with the additional controls for some additional features.
2. The most common location of the controls is the traditional placement at the outer side of the seat, however some car brands have tried new placements on the inside of the door.
3. For the most common locations of the seat adjustment controls, reachability and viewability are two aspects which seem to be correlated.
4. Premium brands tend to use materials making the controls differentiate from the seat, whilst other brands often use a similar material for the controls as for the seats.
5. There is a trade-off between using many buttons making them easier to use but harder to localize, and using fewer buttons with more functions making the buttons harder to use but easier to localize.
6. How the controls movement correspond to the movement of the seat influence the initial perception of the control greatly.
7. The number of seat adjustment functions are increasing, meaning there is an increased need of automatic seat adjustment such as seat memory functions.

The most striking commonality of the HMI:s tested is the seat shape placement of buttons which exist in every brand except of two (Mitsubishi and Nissan). The shape is perceived positively for some models, providing an indication of how to use the controls. However, when adding many additional buttons in close proximity that advantage is easily lost. The lumbar support control is most commonly implemented as a round button and in some cases as a square button. Indents, showing how to use the controls are common on the lumbar support control but not on the other buttons.

Most controls are located on the side of the seat, a few are on the door and one are on the side of the center console. The current trend seem to be that some car manufacturers try to move the controls away from the traditional placement of the controls at side of the seat, most commonly trying to place the controls at the inside of the car door. Mercedes and Lincoln are two car manufacturers having their seat HMI in the door, which facilitate the understanding of the seat shaped buttons. However, the placement of the controls make them hard to reach and the hand sometimes need to be bent in an awkward and unpleasant angle in order to reach them. This indicates that there are a correlation between reachability and viewability of these two placements, the placement of the controls at the outer side of the seat seem to be advantageous for the reachability, whilst the placement in the door seem to favor viewability. Another difference is the location of the lumbar support button. In around half of the times is it mapped in front of the other buttons, and the other times behind them. Lumbar support is often not interacting with the other controls and seem to be positioned to be out of the way of the other controls. A difference between the good premium solutions and the other brands is that premium brands use different materials and finishes to create differences between the seat, the controls area and buttons while the other brands often use the same material and finish for controls and the panel on the side of the seat. Another difference between the good premium brands is the finish of the back plates of the adjustment controls, using shiny or may finishes. Audi and Aston Martin uses shiny back plates while BMW, Lincoln, Porsche and Mercedes have other types of back plates.

Apart from the seat shaped buttons, Audi uses a round knob as an universal control to adjust different modes, BMW, Land Rover and Porsche have a lot of buttons quite widely spread out, whilst Lincoln and Mercedes have many buttons more closely grouped together. BMW have a lot of buttons which can make it messy, but still, if you understand the idea of the seat shape and examine the location of each button the mapping is understandable. The HMI of Audi looks very clean and fresh but having one control to adjust in several modes have its' drawbacks too. Longer adjustment time and the risk of getting lost in different modes. The advantage is if you understand how to use the button you will most certainly adjust all available adjustments, something which due to complexity and lack of understanding might not be sure for the other brands. There are a bigger risk of the user skipping some adjustment possibilities. These two examples provides a trade-off, using many buttons makes the buttons easy to use but harder to localize. Whilst using few buttons result in the opposite, meaning there is a big need of getting feedback of what is controlled in order to understand what is changed. Locating buttons visible for the operator makes it possible to use more controls without making it hard for the user to localize the controls.

Another design issue of the buttons are how the movement of the controls correspond to the movement of the seat. Most buttons adjusting two inherent functions are easily understandable. The problem usually appear when more functions are implemented in the same button. The optimal implementation when having three functions in a button is perceived to have the functions correspond to moving the control vertically, horizontally and by rotation. This should mostly be an initial problem when using a car seat you have not used much before.

The growing number of controls which needs to be adjusted have resulted in an increase of the time it takes to adjust the seat into the optimal position. Hence, memory functions are commonly implemented in the vehicles. This in order to make it possible for users to change the seat into their optimal position quickly, without having to control the controls themselves. The memory function is usually controlled by buttons, most commonly located on the inside of the door.

There are some things that are really good and stand out from the crowd. For example Audi and Mercedes provides feedback on their displays when pressing a control which facilitates the understanding of what is happening. Providing feedback of what is controlled is important in order for the user to understand what is happening, which otherwise might be tricky with more complex functions such as massage and leg supporting extensions, or from functions providing a small amount of haptic feedback while controlled. Another important subject is the design of the buttons. For example, the buttons on Porsche are smoothly and nicely designed and the design also facilitate one to understand that how they are adjustable, and how one can press the button both in the front and in the back to achieve different results, with indents on the sides of the buttons. Having a design which feels premium is also very important, something Lincoln, Audi and Mercedes have succeeded in. Some subjects that is perceived negatively, giving a feeling of lower quality are for example the rectangular buttons of Lexus and Honda that gives a none qualitative impression, and the plastic appearance of some HMI:s providing a non-premium feeling.

There are also some solutions that are new and not adopted by other brands. Nissan have a single wheel which adjust almost all of their adjustments, Aston Martin have their HMI on the side of the center console as mentioned before and Cadillac have another design for their lumbar support than other brands. Mercedes have the controls of their extra functions such as side bolsters and massage on a touch button on the center console, and Renault have a button on the side of the seat which activates the massage function, which thereafter is controlled on the touchscreen.

## 4.4 User Study

For preparation of the user study a fixed set of questions and tasks were created based on the areas and questions stated in Chapter 4.1. A total of 25 test persons were gathered to participate in the study, both at Chalmers and at VCC. The aim of the study was to find movement patterns when adjusting the seat as well as understanding how the controls were perceived. Initially in this chapter the execution of the study is presented. The results are categorized by the prerequisites of the participants, the positive and negative comments about the different controls and the number of comments arranged into different subjects.

### 4.4.1 Conducting the study

During each study two roles were divided between the project members. One of the team members acted as an interviewer, leading the interview and asking questions to the interviewee. The other member kept track of audio and video recordings of the interview, and took notes of what was happening along the interview.

The study was conducted in a process were the user initially got some questions about their prerequisites and some formality questions. Thereafter the participants were asked to adjust specific settings of the seat, initially they were not given any guidance of how to do it but if needed some additional guidance were provided in order for them to understand how to use the controls. While the participants were given tasks of adjusting the seat, the participants hand movements were recorded by video. The audio were also recorded and the participant were asked to comment what they were doing and add their thoughts along the procedure, and additional questions about the task where added by the interviewer.

Thereafter the user were interviewed further about their thoughts of the design using a semi-structured interview, according to the methodology presented in Section 3.2.1. While being questioned the participants were still allowed to keep using the control in order to get a deeper understanding of the controls, and providing knowledge continuously for the participants related to the specific questions. Thereafter, a selection of the participants were allowed to drive the car for a short lap. Providing the participants with some further tasks to conduct while operating the vehicle and asking some further questions related to operating the seat adjustment controls while driving. Thereafter, the study was rounded up by adding some summarizing questions after the drive.

Notable is that during the test two different versions of the adjustment controls were used, for 16 of the participants a fully equipped SPA-seat was used. Whilst for 9 of the participants a SPA-seat with somewhat simpler controls were used, and thereby these participants could not evaluate the feedback from the screen and all the functions such as massage, bolster support, leg extension support and seat ventilation. This difference did probably affect the results from the study to a small extent, but it was an unavoidable problem.

### 4.4.2 Prerequisites

Some prerequisites and basic facts of the participants was gathered in order to support conclusions made from the study, this information is presented in Table 4.6. Theses stats show that the participants are heavily concentrated in the age span between 21 and 30 years old. A few of the participants are employees at Volvo, however many additional participants has worked with projects in the car industry, meaning they have an inherent knowledge of cars and car design.

**Table 4.6:** Prerequisites of the participants in the user study.

| | Range | Amount | Percentage |
|---|---|---|---|
| Age: | <20 | 1 | 4% |
| | 21-25 | 13 | 52% |
| | 26-30 | 7 | 28% |
| | 31-40 | 2 | 8% |
| | 41-50 | 1 | 4% |
| | 51-60 | 1 | 4% |
| VCC Employee: | Yes | 6 | 24% |
| | No | 19 | 76% |
| Driver license: | Yes | 23 | 92% |
| | No | 2 | 8% |
| Type of controls on own car: | Electric | 9 | 36% |
| | Semi-electric | 3 | 12% |
| | Mechanic | 10 | 40% |
| | No car | 3 | 12% |
| Frequency of adjusting the seat: | Often | 11 | 44% |
| | Pretty often | 3 | 12% |
| | Seldom | 6 | 24% |
| | Once | 2 | 8% |
| | No Opinion | 3 | 12% |
| Looked at controls before entering car: | Yes | 4 | 16% |
| | No | 21 | 84% |
| Total | | 25 | |

### 4.4.3 Comments Regarding the Different Controls

The tasks were conducted by the study participants according to the instructions of the interviewer. After reviewing both the participants movement and the recordings of the participants thoughts of the tasks a number of positive and negative comments and notes were categorized and compiled into the graph shown in Figure 4.29. Since the study was conducted with two different HMI:s the side bolsters and massage functions could not be tested by all of the participants.

The categories in Figure 4.29 are further explained in Table 4.7. Presenting the positive and negative comments made on the controls, and presenting some additional comments of the participants thoughts of the controls.

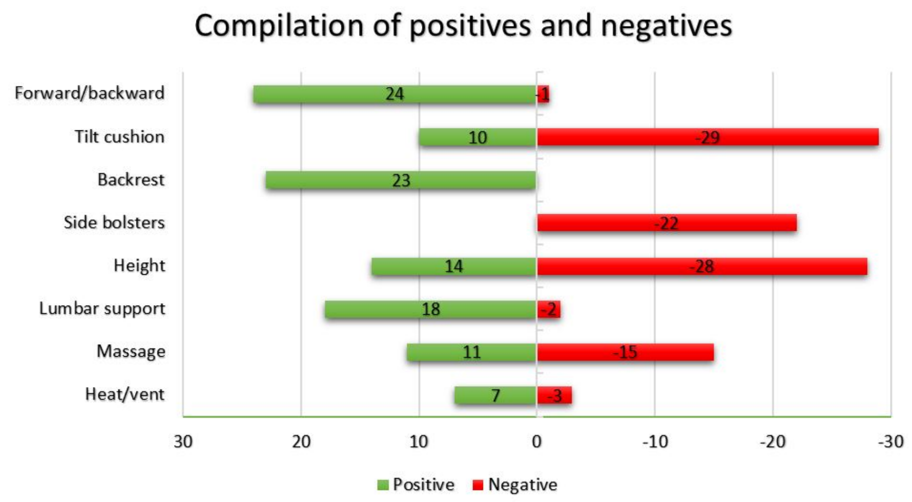



**Figure 4.29:** A compilation of noticed difficulties and simplicities when adjusting the seat. Note that since the study was conducted with two different HMI:s, the side bolsters and massage functions could not be tested on all participants.

**Table 4.7:** An explanation of the positives and negatives for each task.

| Tasks | Positive | Negative |
|---|---|---|
| Forward/backward: | Easy **x24** | A bit hard to find the button **x1** |
| Tilt seat cushion: | Works fine (used to button) **x5** | Trying to rotate whole button **x15** |
| | Works fine **x5** | Hard to find **x9** |
| | | Trying to push whole button upwards **x5** |
| Backrest: | Easy **x23** | |
| Side bolsters: | | Hard to understand if something happens **x16** |
| | | Hard to find **x6** |
| Height: | Works pretty well **x14** | Trying to push whole button upwards **x17** |
| | | A bit hard to find the button **x9** |
| | | Changes the tilt before height **x2** |
| Lumbar support: | Easy to understand(knowledge from bolsters) **x18** | Hard to find, searching among the two "seat buttons" **x2** |
| Massage: | Easy to find **x11** | Tricky how to move in the sub-meny **x8** |
| | | Hard to turn on **x5** |
| | | A bit hard to find **x2** |
| Heat/vent: | Pretty easy **x7** | Hard to find due to bad picture on display **x3** |
| Reason not adjusting everything: | The others were already good **x1** | Not used to this many functions **x7** |
| | | Forgot functions **x1** |
| | | Not so important **x1** |

It is quite easy to see from Figure 4.29 and Table 4.7 that adjusting the seat forward/backward and the backrest are easiest. From the comments made these adjustments are placed in a way that they feel natural to change, they are changed in the same way the user want to change the seat. The lumbar support is also quite easy to understand, mainly as all four buttons on the knob can be used and prior knowledge from trying to understand the side bolsters could be used.

However, tilting the cushion, adjusting the side bolsters and height were a real struggle, with some users even giving up and needed help to proceed. The difficulties many users encountered with tilting the seat was not understanding how the horizontal oblong button worked. Many tried to rotate the button thinking in the same way as adjusting the backrest and simply rejected the button and moved on when it didn't work. They didn't understand which and how many functions each button had. Another big trouble area was the height of the seat cushion, many users tried to push the whole button upwards instead of the back of the button. Opposite from the two other cases, many users eventually found the right way of pushing it, by mistake or after thinking, and eventually thought it was quite okay.

On the other hand, the main problem using the side bolster was not finding the function, which went quite smooth, but adjusting it. As only two of the four buttons on the knob change the bolsters, users had troubles understanding which two to press. They also had huge troubles understanding if something happened or not and often tried other controls instead of continuing with the same buttons. A reason to the dramatically lower number of problems which occurred while adjusting the lumbar support compared to the side bolster is partly the haptic feedback from the adjustment. But, mainly the difference is thought to be that the users could use the knowledge gained by adjusting the side bolster, which was conducted previously. This was often mentioned by the users multiple times, and it could also be part of the reason to the difference between other controls, as the seat height was perceived better than the seat cushion tilt.

When asked to adjust the seat into their favorable driving position no one adjusted every function. When asked about this many said they weren't used to this many functions and would have adjusted them later on if they owned the car. But, in the moment when facing them they simply didn't know which position to adjust them to.

### 4.4.4 Amount of Comments Divided into Subjects

During the interviews a lot of comments, both positive and negative were made in different areas. Below, in Figure 4.30, the number of comments are compiled into different subjects.

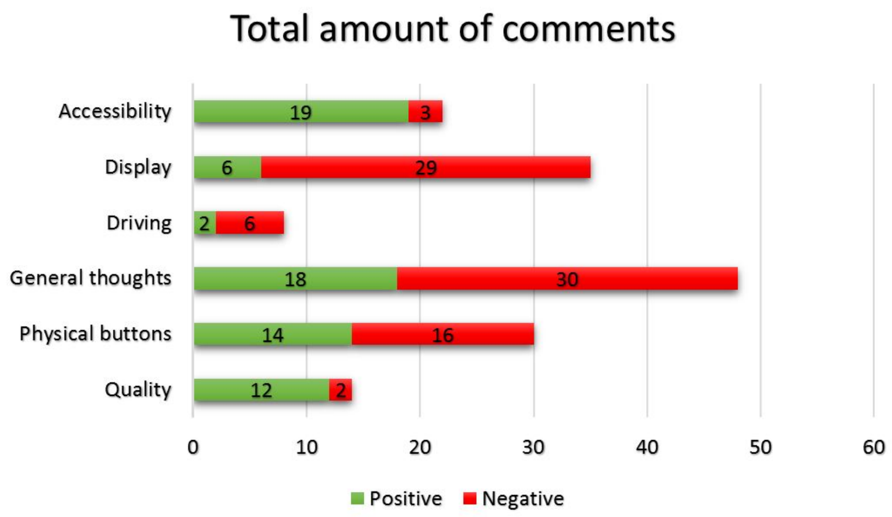



**Figure 4.30:** A compilation of the amount of comments compiled into different subjects.

From the figure it can be seen that the areas which brought most comments are general thoughts about the controls and the display. Thoughts about adjusting something while driving is much less than the other areas.

In order to understand Figure 4.30 better the most frequent positive and negative comments, and some chosen less frequent comments in each area have been compiled below.

**Accessibility**

- Enough room **x12**
- A bit tricky but enough room **x7**
- Very little room **x3**

**Display**

- Not enough feedback **x15**
- No help which buttons to use **x8**
- Intuitive display **x3**
- Display disappears too fast if idle **x2**
- Display don't show current action of every function, just some **x2**
- Is no intro film on the display **x1**

**Driving**

- Want information right in front (head-up display, dashboard) **x2**
- Want to adjust massage by voice while driving **x1**
- Too many buttons to turn off massage **x1**

**General thoughts**

- Easy and logical backrest and seat cushion (forward/backward) **x17**
- The knob is tricky **x11**
- The seat cushion button is illogical **x8**
- Hard to know how to sit, many options **x8**

**Physical buttons**

- Good size **x12**

- Don't understand the functions of the buttons purely by feel **x8**
- Good with haptic feedback **x1**
- The semantic of the controls are bad **x1**

**Quality**

- Good quality **x7**
- A bit plastic but still good quality **x5**
- Neither good quality nor plastic **x4**
- Plastic **x2**

Most of the users thought the controls were easy to use and they though they had enough room to reach them. It was also perceived that the buttons have a good size. However, many commented that the help received from the display was lacking. The display did show when some functions were activated but it did not help to show which buttons to press or if something happened. Many also thought the seat shape of the two buttons was good but the buttons themselves did not tell much about their functions. Whilst driving comments about losing focus on driving while adjusting the seat and using the touchscreen was mentioned. Suggestions of displaying the functions beside the speedometer or on the head-up display were mentioned. The general thoughts tend to go into the extremes, mentioning the good aspects are great or very good,and the bad aspects as very bad. Lastly, many participants also had troubles knowing how to sit properly, both mentioning it as problem and not using the optimal procedure to adjust the seat into the optimal position.

## 4.5 Concluding remarks

From the three different sections of this pre-study a few things are part of all of them. Every time a seat is adjusted there is a question if the current seating position is the best. Neither Volvo nor any other brand tested gave the user any easily accessible help or tips of how to adjust the seat. Help from the car was in general lacking and incomplete. Something almost every brand had instead was the seat shape of two or more buttons which facilitated the understanding a lot. The control movement was connected with the anticipated seat movement for new users. The lumbar function was never a part of the seat shape but in the user study many users' first instinct was to try to control it by moving the lower part of the backrest button horizontally.

The brands having side bolster and/or cushion tilt struggled. The struggle was between having a separate button which facilitated that function but complicated the mapping and simplicity of the whole control with more buttons, or incorporate the functions into fewer controls, and increase the complexity and struggle with understandability. Another trade-off discovered was between reachability and visibility. The controls on the side of the seat have good reachability but almost no visibility, while controls on the door have great visibility but worse reachability.

# 5

# Concept Generation and Evaluation

This section cover the process of concept generation and the evaluation of generated concepts. Included are the process used to obtain and eliminate concepts, the different ideas, the screening as well as possible features to enhance the overall experience independent from the different concepts.

## 5.1 Initial Concept Generation and Screening - Phase 1

The initial concept generation was based on an internal search, to bring out the team members own ideas, ideas which had been accumulated along the project and ideas from the results of the preparatory study. The idea generation was carried out by doing brainstorming, brainwriting and a morphological matrix, presented in Table 5.1, and was used in order to combine sub-solutions. The outcome of the idea generation was 30 concepts. Not all concepts were unique, many features were shared between different concept ideas, but some differences of the design or placement existed.

**Table 5.1:** Morphological matrix used to generate concept ideas.

| | | Sub-solutions | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sub-functions | Placement | Outer Side of seat | Door panel | Armrest of door | Top of center console | Side of center console | Armrest of door | Steering wheel | Center touchscreen | Roof | Outer side of backrest | Front panel |
| | | Front panel | Floor | Downside of the front panel | Phone | Voice | Gestures | | | | | |
| | Design | Seat shaped with few controls | Touchscreen | Touchpad | 1 control | Seat shaped with many controls | Buttons | 2-way switches | Round switch staying when rotated | Round switch which return when rotated | Joystick | Pedals / Levers |
| | | Pedals / Levers | Tiltable switch | Phone | Voice | Gestures | | | | | | |
| | Understanding the controls | Protrusions & indentations | Button for info/help | Logical seat-like mapping | Signs / symbols | Automatic features | Sound feedback | | | | | |

The generation process was divided into two parts. One part with ideas on different positioning, and secondly the designs of the adjustment controls. Many additional functionalities which are possible to integrate with the ideas were also developed. The idea is that these functionalities can be used together with most of the concepts in order to improve them, hence being independent. However, these features are kept out of the initial screening process and will be integrated into the concepts and evaluated later along the development process. These functionalities which could be integrated into most of the ideas are presented below:

- Seat settings are adjustable from the center touch screen as a complement to the adjustment controls.
- Dynamic visual feedback on the touch screen.
- Feedback for all functions.
- Memory function, could be integrated in touchscreen meaning you can add more slots and have individual names for the slots.
- Help-function providing information of how to adjust the seat if you do not understand it.
- Integrate the seat adjustment into phone application, with memory function also connected to the phone application.
- Help to reach an optimal seating position based on your body measurements.
- Adjustments by voice commands.
- Fully automatic adjustment of the seat.
- Improve the HMI of the touch screen.
- Increase the time the application is shown on the display after a button is pressed.

In the initial screening process the 30 ideas' feasibility were evaluated to see if they met the basic requirements of the final product and VCC's demands. If an idea didn't fulfill a requirement it was eliminated from further development. The Elimination matrix is presented in Table 5.2, and the requirements to fulfill the aspect 'Fulfills Demands' is presented in Table 5.3. The demands are retrieved from an early version of the requirement specification developed alongside the project process. In the Elimination matrix the ideas that fulfill an aspect are marked with a '+', ideas not fulfilling an aspect are marked with a '-' and aspects not evaluated are marked with an 'X'.

**Table 5.2:** Elimination matrix used for the initial idea screening.

| | Solves main problem | Compatible /realizable | Reasonable cost | Safe | Fits portfolio | Fulfils demands | Enough information | Decision |
|---|---|---|---|---|---|---|---|---|
| ~~Wireless control~~ | + | + | + | + | - | X | + | - |
| ~~Augmented reality~~ | + | + | - | + | + | X | + | - |
| Clump functions | + | + | + | + | + | + | + | Pass |
| Seat shape on seat | + | + | + | + | + | + | + | Pass |
| Seat shape on door | + | + | + | + | + | + | + | Pass |
| Seat shape center console | + | + | + | + | + | + | + | Pass |
| ~~Seat shape side of center console~~ | + | + | + | + | + | - | + | - |
| Individual buttons | + | + | + | + | + | + | + | Pass |
| Touch on seat | + | + | + | + | + | + | + | Pass |
| Only touch screen | + | + | + | + | + | + | + | Pass |
| Buttons steering wheel | + | + | + | + | + | + | + | Pass |
| Touch screen steering wheel | + | + | + | + | + | + | + | Pass |
| ~~Levers steering wheel~~ | + | + | + | + | + | - | + | - |
| ~~Fully automatic~~ | - | + | + | + | + | + | + | - |
| Single button on seat | + | + | + | + | + | + | + | Pass |
| ~~Voice control~~ | + | + | + | + | + | - | + | - |
| ~~Basic button & Voice control~~ | + | + | + | + | + | - | + | - |
| Touch center console | + | + | + | + | + | + | + | Pass |
| Single button center console | + | + | + | + | + | + | + | Pass |
| Movable touch screen | + | + | + | + | + | + | + | Pass |
| ~~Semi-automatic~~ | + | + | + | + | + | - | + | - |
| ~~Gestures~~ | + | + | + | + | + | - | + | - |
| Four buttons + ok button | + | + | + | + | + | + | + | Pass |
| Some form of buttons | + | + | + | + | + | + | + | Pass |
| ~~Seat model from ceiling~~ | + | - | + | + | - | X | + | - |
| Touch on armrest | + | + | + | + | + | + | + | Pass |
| Single control on armrest | + | + | + | + | + | + | + | Pass |
| Seat shape side of armrest | + | + | + | + | + | + | + | Pass |
| ~~App on phone~~ | + | + | + | + | + | - | + | - |
| ~~3D holograms~~ | + | - | - | + | + | X | + | - |

**Table 5.3:** The subjects evaluated in the requirement 'Fulfills Demands' in the Elimination matrix.

| Demands to Elimination matrix | Verification | Target Value |
|---|---|---|
| Response time | Assessment | 0.2 [s] |
| Attention needed | Assessment | yes/no |
| Life span | Assessment | 10 years |
| Control visible with torso lean | Assessment | yes/no |
| Control reachable with torso lean | Assessment | yes/no |
| Estimated material cost | Cost estimation | 30 [SEK] |
| Provide a premium feeling | Assessment | yes/no |
| Controllable for all drivers | Assessment | yes/no |
| A control should not be possible to be mistaken as another fundamental control | Assessment | yes/no |
| Fast assembly | Assessment | yes/no |
| Bear impacts naturally occurring in its environment | Assessment | yes/no |
| The design guide the user to use the controls correctly | Assessment | yes/no |
| Maximum attention needed for control | Assessment | |
| The control should not be easily accessible by accident | Assessment | yes/no |
| Controls does not intrude with interaction of other important controls | Assessment | yes/no |
| Time needed to adjust | Assessment | too long/enough |

## 5.2 Concept Evaluation and Screening - Phase 2

The remaining ideas were developed further in order to have enough information to undergo a second screening, the evaluation was based on a Pugh matrix, see Figure 5.4 and **??**. Some new ideas were generated based on the results from the Elimination matrix. In this process stage the ideas were evaluated regarding their performance based on the 30 question formulated earlier in the theory. The ideas are evaluated against a reference, an idea resembling one of the adjustment controls implemented in VCC today. The ideas which are assessed to be better than the reference regarding an aspect are marked with a '+', ideas assessed to be equally good as the reference are marked with a '0' and ideas being worse than the reference are marked with a '-'.

The criterion of the Pugh matrix are not evaluated towards strict values, instead the project group do an assessment of them. This makes it possible to evaluate the concepts with a low amount of data available, making the evaluation process quick and easy to perform. Also, manufacturing and cost aspects are intentionally kept out of this part of the process in order to generate as good concepts as possible, not concerning cost which is handled by the Elimination and Kesselring matrices. The criterion of the matrix are clarified below:

**Visibility**: Assessing how visible the controls are when entering a car and when seated in the car. Also assessing how far a driver need to move their eyes from the road in order to see the controls whilst driving.

**Reachability**: Assessing how hard is it to reach the controls while seated in the car. Evaluating if there is a need of changing the sitting posture, or if there is a need of twisting or bending of arms, wrists or hands in order to reach the controls.

**Intuitiveness**: Assessing how easy it is to understand the controls the first time encountered. Are the initial thoughts when encountering the controls correct and are the right control found directly.

**Design Beauty**: Assessing how beautiful the design of the controls are, and how it contribute to the beauty of the interior of the vehicle.

**Ease of Interaction**: Assessing how easy it is to interact with the controls. How does the controls design and layout affect the interaction of the controls.

**Risk of Unintentional Interaction**: How big are the risk of interacting with the controls unintentionally, changing the settings of the seat by accident.

**Risk of Handling Errors**: How big are the risk of handling the controls incorrectly, leading to incorrect commands to the system.

**Learning Time**: How long time does it take to learn the controls, and understand how all controls are controlled correctly.

**Accuracy**: Assessing how accurately the controls enables the operator to adjust the seat.

**Table 5.4:** Pugh matrix used for the initial idea screening.

| Main concepts | Additional Detailed explaination | Visibility | Reachability | Intuitiveness | Design beauty | Ease of interaction | Risk of unintentional interaction | Risk of handling errors | Learning time | Accuracy | Sum + | Sum 0 | Sum - | Net score | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Seat shaped on seat** | Seat like controls + extra control **(Reference)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 7 |
| | Only seat like controls | 0 | 0 | + | 0 | 0 | 0 | + | - | 0 | 2 | 6 | 1 | 1 | 1 |
| | Seat like controls + central touch display | 0 | - | 0 | + | - | 0 | 0 | 0 | 0 | 1 | 6 | 2 | -1 | 16 |
| **Clump functions** | Outer side of seat | 0 | 0 | - | 0 | 0 | 0 | 0 | + | - | 1 | 6 | 2 | -1 | 16 |
| | Armrest of door | + | 0 | - | 0 | 0 | - | 0 | + | - | 2 | 4 | 3 | -1 | 16 |
| | Center Console | + | 0 | - | - | 0 | - | 0 | + | - | 2 | 3 | 4 | -2 | 24 |
| **Seat shape on door** | Only seat like controls | + | - | + | - | 0 | - | + | + | 0 | 4 | 2 | 3 | 1 | 1 |
| | Seat like controls + extra control | + | - | 0 | 0 | 0 | - | 0 | 0 | 0 | 1 | 6 | 2 | -1 | 16 |
| | Seat like controls + central touch display | + | - | 0 | 0 | - | - | 0 | 0 | 0 | 1 | 5 | 3 | -2 | 24 |
| **Touch display on door** | Inside of door panel | + | - | 0 | - | - | - | + | 0 | 0 | 2 | 3 | 4 | -2 | 24 |
| | Armrest at door panel | + | 0 | 0 | - | 0 | - | + | 0 | 0 | 2 | 5 | 2 | 0 | 7 |
| **Seat shape on center console** | | + | - | 0 | - | 0 | - | 0 | 0 | 0 | 1 | 5 | 3 | -2 | 24 |
| **Individual buttons** | | 0 | 0 | + | - | + | 0 | + | - | 0 | 3 | 4 | 2 | 1 | 1 |
| **Touch on Seat** | | 0 | 0 | - | + | + | - | + | 0 | 0 | 3 | 4 | 2 | 1 | 1 |
| **Only touch screen** | | 0 | - | 0 | + | - | 0 | 0 | 0 | 0 | 1 | 6 | 2 | -1 | 16 |
| **Buttons steering wheel** | | + | + | - | + | 0 | | | | | | | | | |
| **Touch screen steering wheel** | | + | 0 | - | + | - | | | | | | | | | |
| **Single button on seat** | | 0 | + | - | 0 | + | | | | | | | | | |
| **Touch center console** | | + | - | 0 | 0 | 0 | | | | | | | | | |
| **Single button center console** | | + | - | - | - | + | | | | | | | | | |
| **Movable touch screen** | At the door | + | + | 0 | - | 0 | | | | | | | | | |
| | At the center console | + | + | 0 | 0 | 0 | | | | | | | | | |
| **Four buttons + ok button** | Outer side of seat | 0 | 0 | - | 0 | 0 | | | | | | | | | |
| | Door panel | + | - | - | 0 | 0 | | | | | | | | | |
| | Armrest at door | + | 0 | - | 0 | 0 | | | | | | | | | |
| | Center console | + | - | - | - | 0 | | | | | | | | | |
| **Touchpad on armrest** | | + | 0 | - | + | 0 | | | | | | | | | |
| **Single control on armrest** | | + | 0 | 0 | 0 | + | | | | | | | | | |
| **Seat shape on side of armrest** | | + | - | 0 | - | 0 | | | | | | | | | |
| **Some form of buttons** | Outer side of seat | 0 | 0 | 0 | 0 | 0 | | | | | | | | | |
| | Door panel | + | - | 0 | 0 | - | | | | | | | | | |
| | Armrest at door | + | 0 | 0 | - | + | | | | | | | | | |
| | Center console | + | - | 0 | 0 | - | | | | | | | | | |

## 5.3 Concept Screening - Phase 3

The concept ideas which were rated as good or better than the reference of the Pugh matrix were taken further in the development process, the remaining ideas are presented in Appendix A. The ideas were then clarified more detailed and alternative solutions of these ideas were generated in an iterative manner. The remaining ideas were evaluated in a Kesselring matrix, see Figure 5.5 and **??**. Based on the matrix, seven concepts were chosen for further development and evaluation. The elimination after the screening was primary based on two aspects, concepts which either had low ratings in the matrix or had a superior resembling solutions which was preferred.

For the Kesselring matrix the evaluation criterion from the Pugh matrix were reused and their importance for the final solution was evaluated between 1-5. The accuracy criteria was not evaluated again since it was already achieved equally good for all of the concepts in the Pugh matrix. In addition to these criterion some additional criterion were added into the evaluation and are presented below:

**Estimated Cost**: Assessing the total cost of the concept in production.

**Ease of Localizing the Control**: Assessing how hard it is to localize the control of a specific function.

**Premium Feeling**: Does the control design provide a premium feeling to the interior design of the vehicle.

**Adjustment Time**: Estimating how long time it takes to adjust the seat settings with the control.

**Modularity**: How modular are the controls to be used for seats with different amount of functions and for different seats.

**Durability**: How durable is the control and how does the placement of the control affect the risk of outer impacts.

**Table 5.5:** Kesselring matrix used for the idea screening.

| | | Visibility | Reachability | Intuitiveness | Design beauty | Ease of interaction | Estimated Cost | Ease of localizing the control | Premium feeling | Risk of unintetntional interaction | Risk of handling errors | Adjustment time | Modularability | Durability | Learning time | T =Sum(t) | T/T_max | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | w | 3 | 5 | 5 | 3 | 5 | 4 | 4 | 3 | 4 | 3 | 5 | 4 | 4 | 3 | | | |
| **Ideal** | v | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | | | |
| | t | 15 | 25 | 25 | 15 | 25 | 20 | 20 | 15 | 20 | 15 | 25 | 20 | 20 | 15 | **275** | **100%** | |
| **Seat shape stuck together** | v | 2 | 5 | 3 | 3 | 4 | 3 | 5 | 3 | 5 | 4 | 5 | 3 | 4 | 3 | | | |
| | t | 6 | 25 | 15 | 9 | 20 | 12 | 20 | 9 | 20 | 12 | 25 | 12 | 16 | 9 | **210** | **76%** | **2** |
| **Seat shape twofolded backrest** | v | 2 | 5 | 3 | 3 | 3 | 3 | 5 | 3 | 5 | 3 | 5 | 3 | 4 | 4 | | | |
| | t | 6 | 25 | 15 | 9 | 15 | 12 | 20 | 9 | 20 | 9 | 25 | 12 | 16 | 12 | **205** | **75%** | **6** |
| **Seat shape & Round with four buttons** | v | 2 | 5 | 3 | 3 | 3 | 3 | 5 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | | | |
| | t | 6 | 25 | 15 | 9 | 15 | 12 | 20 | 12 | 20 | 12 | 20 | 16 | 16 | 12 | **210** | **76%** | **2** |
| **Seat shape & Round knob** | v | 2 | 5 | 3 | 3 | 4 | 3 | 5 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | | | |
| | t | 6 | 25 | 15 | 9 | 20 | 12 | 20 | 12 | 20 | 12 | 20 | 16 | 16 | 12 | **215** | **78%** | **1** |
| **Seat shape & Rotation + Button** | v | 2 | 5 | 2 | 3 | 4 | 3 | 5 | 4 | 5 | 3 | 3 | 4 | 4 | 4 | | | |
| | t | 6 | 25 | 10 | 9 | 20 | 12 | 20 | 12 | 20 | 9 | 15 | 16 | 16 | 12 | **202** | **73%** | **7** |
| **Seat shape & Joystick** | v | 2 | 5 | 3 | 3 | 4 | 3 | 5 | 3 | 5 | 4 | 4 | 4 | 1 | 4 | | | |
| | t | 6 | 25 | 15 | 9 | 20 | 12 | 20 | 9 | 20 | 12 | 20 | 16 | 4 | 12 | **200** | **73%** | **9** |
| **Round knob on seat** | v | 2 | 5 | 2 | 3 | 4 | 4 | 5 | 3 | 5 | 3 | 3 | 5 | 4 | 4 | | | |
| | t | 6 | 25 | 10 | 9 | 20 | 16 | 20 | 9 | 20 | 9 | 15 | 20 | 16 | 12 | **207** | **75%** | **5** |
| **Round four buttons on seat** | v | 2 | 5 | 2 | 3 | 3 | 4 | 5 | 3 | 5 | 3 | 3 | 5 | 4 | 4 | | | |
| | t | 6 | 25 | 10 | 9 | 15 | 16 | 20 | 9 | 20 | 9 | 15 | 20 | 16 | 12 | **202** | **73%** | **7** |
| **Two buttons in one control on seat** | v | 2 | 5 | 1 | 2 | 3 | 4 | 5 | 2 | 5 | 3 | 3 | 5 | 4 | 3 | | | |
| | t | 6 | 25 | 5 | 6 | 15 | 16 | 20 | 6 | 20 | 9 | 15 | 20 | 16 | 9 | **188** | **68%** | **12** |
| **Double rotational button on seat** | v | 2 | 5 | 1 | 2 | 2 | 4 | 5 | 3 | 5 | 3 | 3 | 5 | 4 | 3 | | | |
| | t | 6 | 25 | 5 | 6 | 10 | 16 | 20 | 9 | 20 | 9 | 15 | 20 | 16 | 9 | **186** | **68%** | **15** |
| **Individual buttons** | v | 2 | 4 | 2 | 1 | 4 | 3 | 5 | 2 | 5 | 4 | 5 | 3 | 4 | 2 | | | |
| | t | 6 | 20 | 10 | 3 | 20 | 12 | 20 | 6 | 20 | 12 | 25 | 12 | 16 | 6 | **188** | **68%** | **12** |
| **Touch on seat** | v | 1 | 5 | 2 | 5 | 3 | 2 | 4 | 5 | 5 | 2 | 4 | 3 | 3 | 3 | | | |
| | t | 3 | 25 | 10 | 15 | 15 | 8 | 16 | 15 | 20 | 6 | 20 | 12 | 12 | 9 | **186** | **68%** | **15** |
| **Button on steering wheel** | v | 5 | 5 | 2 | 5 | 5 | 5 | 2 | 3 | 4 | 3 | 1 | 5 | 5 | 4 | | | |
| | t | 15 | 25 | 10 | 15 | 25 | 20 | 8 | 9 | 16 | 9 | 5 | 20 | 20 | 12 | **209** | **76%** | **4** |
| **Round on steering wheel** | v | 5 | 5 | 1 | 2 | 5 | 4 | 2 | 2 | 3 | 3 | 1 | 5 | 5 | 4 | | | |
| | t | 15 | 25 | 5 | 6 | 25 | 16 | 8 | 6 | 12 | 9 | 5 | 20 | 20 | 12 | **184** | **67%** | **19** |
| **Joystick on steering wheel** | v | 5 | 5 | 1 | 1 | 5 | 4 | 2 | 2 | 3 | 3 | 1 | 5 | 2 | 4 | | | |
| | t | 15 | 25 | 5 | 3 | 25 | 16 | 8 | 6 | 12 | 9 | 5 | 20 | 8 | 12 | **169** | **61%** | **21** |
| **Touchscreen on steering wheel** | v | 5 | 5 | 4 | 3 | 4 | 1 | 1 | 3 | 3 | 5 | 2 | 3 | 4 | 5 | | | |
| | t | 15 | 25 | 20 | 9 | 20 | 4 | 4 | 9 | 12 | 15 | 10 | 12 | 16 | 15 | **186** | **68%** | **15** |
| **Movable touchscreen at the door** | v | 4 | 2 | 4 | 1 | 4 | 1 | 1 | 2 | 1 | 5 | 2 | 3 | 2 | 5 | | | |
| | t | 12 | 10 | 20 | 3 | 20 | 4 | 4 | 6 | 4 | 15 | 10 | 12 | 8 | 15 | **143** | **52%** | **24** |
| **Movable touch screen at left front panel** | v | 4 | 1 | 4 | 1 | 4 | 1 | 1 | 2 | 1 | 5 | 2 | 3 | 2 | 5 | | | |
| | t | 12 | 5 | 20 | 3 | 20 | 4 | 4 | 6 | 4 | 15 | 10 | 12 | 8 | 15 | **138** | **50%** | **26** |
| **Movable touch screen at right front panel** | v | 4 | 1 | 4 | 1 | 4 | 1 | 1 | 2 | 1 | 5 | 2 | 3 | 3 | 5 | | | |
| | t | 12 | 5 | 20 | 3 | 20 | 4 | 4 | 6 | 4 | 15 | 10 | 12 | 12 | 15 | **142** | **52%** | **25** |
| **Movable touch screen at center console** | v | 4 | 3 | 4 | 5 | 4 | 1 | 1 | 5 | 3 | 5 | 2 | 3 | 4 | 5 | | | |
| | t | 12 | 15 | 20 | 15 | 20 | 4 | 4 | 15 | 12 | 15 | 10 | 12 | 16 | 15 | **185** | **67%** | **18** |
| **Seat shape on door** | v | 3 | 3 | 4 | 2 | 2 | 3 | 4 | 3 | 4 | 4 | 5 | 3 | 4 | 4 | | | |
| | t | 9 | 15 | 20 | 6 | 10 | 12 | 16 | 9 | 16 | 12 | 25 | 12 | 16 | 12 | **190** | **69%** | **11** |
| **Touch display on door armrest** | v | 3 | 4 | 4 | 2 | 3 | 1 | 1 | 3 | 1 | 4 | 2 | 3 | 2 | 5 | | | |
| | t | 9 | 20 | 20 | 6 | 15 | 4 | 4 | 9 | 4 | 12 | 10 | 12 | 8 | 15 | **148** | **54%** | **22** |
| **Touchpad on armrest** | v | 3 | 4 | 3 | 2 | 3 | 2 | 1 | 3 | 1 | 3 | 2 | 3 | 4 | 3 | | | |
| | t | 9 | 20 | 15 | 6 | 15 | 8 | 4 | 9 | 4 | 9 | 10 | 12 | 16 | 9 | **146** | **53%** | **23** |
| **Round knob at armrest** | v | 3 | 4 | 2 | 4 | 3 | 5 | 2 | 3 | 3 | 3 | 3 | 5 | 5 | 4 | | | |
| | t | 9 | 20 | 10 | 12 | 15 | 20 | 8 | 9 | 12 | 9 | 15 | 20 | 20 | 12 | **191** | **69%** | **10** |
| **Round four button at armrest** | v | 3 | 4 | 2 | 4 | 3 | 4 | 2 | 3 | 3 | 3 | 3 | 5 | 5 | 4 | | | |
| | t | 9 | 20 | 10 | 12 | 15 | 16 | 8 | 9 | 12 | 9 | 15 | 20 | 20 | 12 | **187** | **68%** | **14** |
| **Joystick on armrest** | v | 3 | 4 | 2 | 4 | 3 | 4 | 2 | 3 | 3 | 3 | 3 | 5 | 2 | 4 | | | |
| | t | 9 | 20 | 10 | 12 | 15 | 16 | 8 | 9 | 12 | 9 | 15 | 20 | 8 | 12 | **175** | **64%** | **20** |

## 5.4 Concept Idea Descriptions - Phase 4

The seven concepts which were evaluated to be the most promising in the previous phase were developed further. Both describing the ideas, establishing an initial design sketch and listing the advantages and disadvantages of the designs. An internal discussion as well as a discussion with experts in the field of seats were held on the basis of all gathered information during the project to evaluate and compare the concepts. The seven concepts are presented below.

***Seat shape, Stuck together***

The seat shape using two buttons is the basis of the concept, controlling length, height, cushion tilt with the lower button. The left upper button control the backrest tilt for the whole seat, the tilt for the upper part of the backrest and bolster support. Leg extension is a button just above the lower seat shape button. The lumbar support is an individual button placed in close proximity to its real location at the seat-like control. Massage is not integrated into the controls, instead individual buttons located in close proximity to the other seat controls control the massage functions. The controls are marked with a massage symbol to ease identification and controls to toggle between modes increasing with '+' and decreasing with '-'. According to the literature, buttons with few functions are preferable.

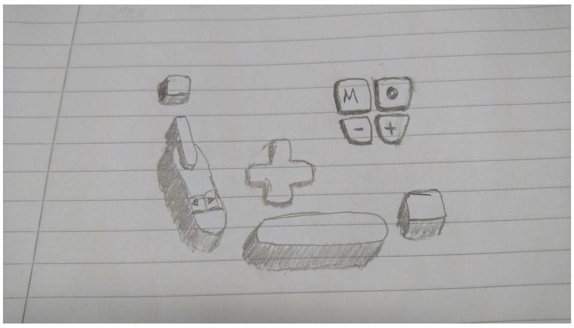



**Figure 5.1:** Sketch of the concept idea 'Seat shape, Stuck together'.

Advantages

- Possible to mirror to passenger side but some changes of the controls are needed.
- Using the control with a lower specified car with fewer function makes the control logical and easy to use.
- Using seat shaped controls makes is logical since the controls resemble the seat so the user will easily relate the control to the seat.
- The control can be accessed from the outside of the car.

Disadvantages

- Many controls makes it hard to localize the individual controls.
- Might appear as quite messy when there are many buttons on a small area, this might reduce the seat resemblance of the controls and make it hard to find some controls.
- It might be hard to integrate more functions into the same set-up without making the controls harder to use.

***Seat Shape & Round switch with four buttons***

There are two controls located at the side of the seat having a design resembling the form of a car seat controlling some basic functions. In addition there are an additional round control used to control some additional functions. By rotating the additional control the user toggles between different modes, which each is containing some functions. On top of the round control there are four buttons used to adjust the functions in each mode.

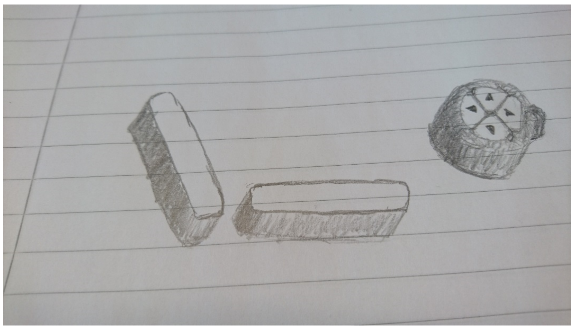


**Figure 5.2:** Sketch of the concept idea 'Seat Shape & Round switch with four buttons'.

Advantages

- Possible to mirror to passenger side.
- Using the control for a seat with fewer functions makes the control logical and easy to use.
- Intuitive to search for the controls at the outer side of the seat since it is the traditional placement of the controls.
- Using seat shaped controls makes sense logically since the controls resemble the seat the user will easily relate the control to the seat.
- The controls can be accessed from the outside of the car.

Disadvantages

- Having the seat control between the seat and door panel makes the space for the hands while adjusting the seat limited, especially when you push the buttons on top of the control.
- Integrating a seat shape with a control not shaped as a seat is confusing and might restrict the positive aspects of the seat shape.
- There are no logical design of the round control in order to resemble the functions it is adjusting.

***Seat shape & Round knob***

There are two controls located at the side of the seat, having a design resembling the form of a car seat, controlling some basic functions. In addition to this control, there are an additional round control used to control some additional functions. The additional control is used to toggle between different modes by pressing a button on top of the control. When inside a mode both rotational, longitudinal and elevational motions are used to adjust the seat.

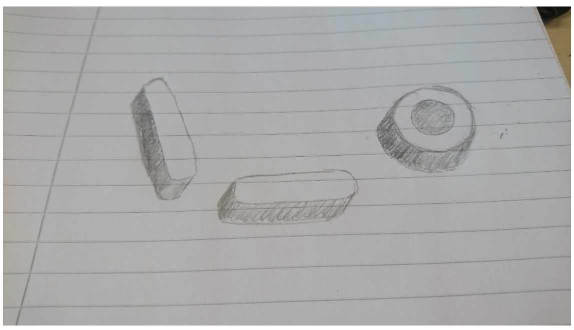


**Figure 5.3:** Sketch of the concept idea 'Seat shape & Round knob'.

Advantages

- Possible to mirror to passenger side.
- Using it with fewer function makes the control logical and easy to use.
- Intuitive to search for the controls at the outer side of the seat since it is the traditional placement of the controls.
- Using seat shaped controls makes sense logically since the controls resemble the seat the user will easily relate the control to the seat.
- The same motions are used to control all controls.
- Can be used outside the car.

Disadvantages

- Having the seat control between the seat and door panel makes the space for the hands while adjusting the seat limited.
- Integrating a seat shape with a control not shaped as a seat is confusing and might restrict the positive aspects of the seat shape.
- There are no logical design of the rotary control in order to resemble the functions it is adjusting.

***Round knob on seat***

One single round button is used to control all the functions, located at the outer side of the seat. Another button on top of the button is used to toggle between different modes. Longitudinal, elevational and rotating motions are used to adjust the functions of the seat in each mode.

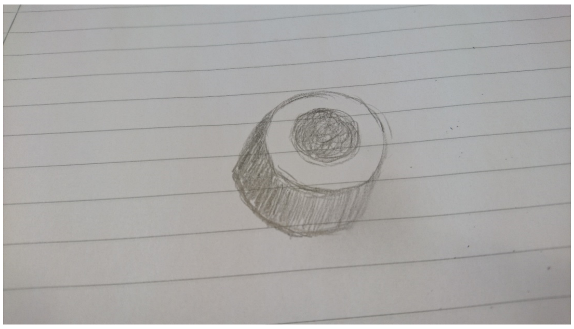


**Figure 5.4:** Sketch of the concept idea 'Round knob on seat'.

Advantages

- The solution is possible to mirror the passenger side without any changes to the control design.
- Traditional placement makes it possible for most users to find the controls easily.
- Easily adaptable for seats with fewer functions.
- All functions are changed in the same way.
- Can be accessed from the outside of the car.
- The control is located between torso and hand, no strange hand rotation is needed to access the control.

Disadvantages

- The big number of functions means that there is a need of using many modes, which makes it harder for the user to navigate in the system.
- Might be a risk of controlling one of the basic seat functions by accident, when unintentionally being in the wrong mode.
- When toggling between modes with the button on top of the control there is a need of using wraparound and no possibility of stepping back, meaning it might be somewhat hard to navigate when there are many modes.
- Take long time to adjust.

***Round with four buttons on seat***

One single round button is used to control all the functions, located at the outer side of the seat. The control is rotated in order to toggle between different modes, containing some functions. Thereafter, four directional buttons on top of the control is used in order to adjust the functions inside of each mode.

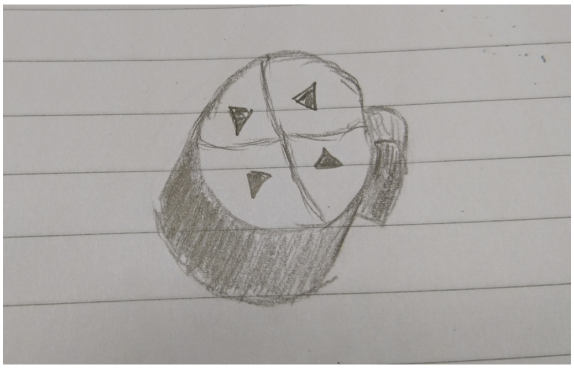


**Figure 5.5:** Sketch of the concept idea 'Round with four buttons on seat'.

Advantages

- Traditional placement means it is the first point most people turn in order to access the controls.
- Easily adaptable for seats with fewer functions.
- Possible to mirror the control to the passenger side.
- All functions are changed in the same way.
- Can be used outside the car.
- The control is located between torso and hand, no strange hand rotation.

Disadvantages

- For some user the space between the door and the seat might be narrow and thereby there might not be so much space for their hands while adjusting the controls.
- There is a need of many modes when only having four controls used to adjust the seat settings.
- Not logical to integrate controls for adjusting the steering wheel into the same control.
- Might be a risk of controlling one of the basic seat functions by accident, when unintentionally being in the wrong mode.
- Take long time to adjust.

***Button on steering wheel***

Adding an extra button on the steering wheel, used to start the seat controls. Thereafter, controlling the seat with the four control-arrows at the right-hand side of the steering wheel, which is usually used to control audio. Feedback is provided by the HUD/dashboard/-touchscreen.

Advantages

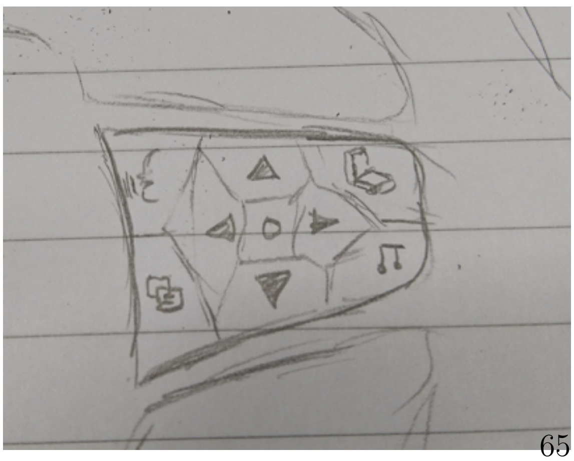


**Figure 5.6:** Sketch of the concept idea 'Button on steering wheel'.

- Easy to reach from a standard seated position.
- The control is visible right in front of the driver.
- Having the controls at the steering wheel makes it easy to use and toggle between modes.
- Easily adaptable for seats with fewer functions.
- It is logical to integrate other adjustment controls involved with the seat into the control as well (such as steering wheel and massage).
- Clean design.

Disadvantages

- Having an untraditional placement of the control might make it harder for users to find it when using the controls for the first time.
- It is not possible to mirror the control to the passenger side.
- A small number of controls (4) mean that there are a need of having many modes for the seat adjustment controls.
- Not that easily accessed from the outside of the vehicle.
- Might be a risk of controlling one of the basic seat functions by accident, when unintentionally being in the wrong mode.
- Having controls mapped in another direction than the seat is usually controlled in makes the control direction illogical.
- Take a long time to adjust.

***Round knob at armrest***

A round control located at the armrest of the door. The control uses modes to adjust functions, enabling movements in a longitudinal, elevational and rotating direction together with a button on top. The control is positioned between the controls of the car windows and the controls for the side mirrors. The design of the control has a rotating outer shell with an inward bend at the bottom of the controls to show that they are also controllable sideways. On top of the button there is a picture of a seat in order to show that the control is used to adjust the seat controls.

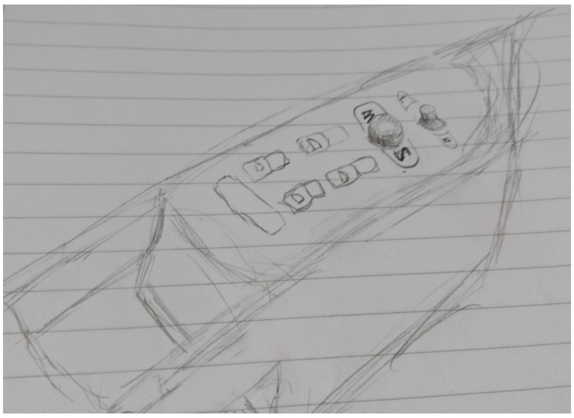


**Figure 5.7:** Sketch of the concept idea 'Round knob at armrest'.

Advantages

- The positioning in the armrest enable both visibility and easily accessibility in the same control. The visibility means you can give indications of how the control is controllable in the design of the control.
- The control is easy to reach for drivers driving with the right hand meaning you usually would have the possibility to comfortably having your arm at the

armrest in the door.
- The control in itself should be easily controlled without any need of big forces, meaning it is also simple to change a control movement instantaneously when feedback is perceived.
- It is logical to integrate other adjustment controls involved with the seat into the control as well (such as steering wheel and massage).

Disadvantages

- There is a risk of accessing the control by accident while having your arm at the armrest.
- Moving the control to an untraditional placement might result in that the user does not understand where to look for the controls.
- Take long time to adjust.
- There is a risk of losing track of which mode/function is active.
- The operator need to have focus on both sides of the steering wheel while adjusting the seat, (armrest and display).
- Having controls mapped in another direction than the seat is usually controlled in makes the control direction illogical.
- Mapping increases difficulty for headrest, lumbar and height.

## 5.5 Final evaluation and screening

In order to find the optimal solution the seven final concept ideas were evaluated both internally and with help from experts in the field of car seats. The evaluation was based on the entire knowledge gained along the project this far. Each of the concepts have been discussed individually and been compared to each other. Based on these evaluations, the best solution was 'Seat shape & Round knob', which both had the best score in the Kesselring matrix and was evaluated to be the best solution.

The reason why it was seen as the best solution was that it seem to be the most intuitive. The seat shape has during every step of the pre-study as well as the theory shown to be the easiest to understand, the movement the user expect to happen happens. But including too many functions into the seat shape creates complexity and looks messy and the good aspects of the seat shape disappears as the seat shape becomes more fuzzy. That is why this concept include seat shape buttons and an extra button called round knob. When having multiple connected controls it is preferable that the controls have a similar design language and use similar control movements. And as the seat shaped controls can be pushed horizontally, vertically and rotated, the round knob can as well, decreasing the active thinking of the user. Rotating the round knob entails a change of function and by using several other buttons, the seat shape, the number of needed modes in the round knob are decreased, reducing the risk of mode errors. The round knob don't have a logical form but a trade-off had to be made and this disadvantaged is thought to be overcome by a good display with feedback. Lastly the pre-study indicated that the placement of controls at the side of the seat is preferable, as this placement is not used by any other controls to be confused with, and that it is a good placement to connect the mapping of the controls to the wanted seat motions.

# 6
# Concept Development

After eliminating all inferior concepts only 'Seat shape & Round knob' was left. This concept is thereby the final solution and is further developed to close the remaining knowledge gaps and improving the concept further. Presented in this chapter is firstly the idea of the overall concept. Thereafter the development of the physical adjustment controls and the touchscreen as well as some auxiliary value adding functionalities which can be added to enhance the performance of the concept.

## 6.1 Overall Concept Idea

The basic overall concept exist of four buttons located on the side of the seat. Three having a design which together resemble a car seat and are controlling some basic functions. Just beside these controls are a round control used to control the other functions not controlled by the seat shaped controls. The idea of how to include all remaining functions into the round control is to use modes enabling several functions to be adjusted by the same control. The initial idea has also been to use a button on top of the control to switch between modes. However, by the development work it was noticed that most of the functions which initially was controlled by the round control could be integrated into other controls. Thereby, the best implementation of this control was to use the rotational movement in order to switch between modes and horizontal and vertical movement to adjust the functions. Thereby, the button on top of the control is considered as superfluous, and is removed from the concept.

The development work was conducted to create a concept which achieves the demands and requirements set up in the requirement specification, see Appendix B, and also evaluating them towards the 30 questions phrased in Section 4.1. In order to develop an optimal system of the adjustment controls the connection between the control design, touchscreen interface and feedback perceived is crucial in order to reach an optimal performance. In addition to this the concept has been evaluated with the FMEA presented in Appendix C. A patent search was conducted in order to get knowledge of restraints on the design by obstructive patents.

## 6.2 Physical Controls

The final design of the adjustment controls can be seen in Figure 6.1. The design is decided based on the results from the literature and preparatory study, hence it incorporates different angles on the buttons, indentations to show the possible functions and how to use them as well as the general idiom.

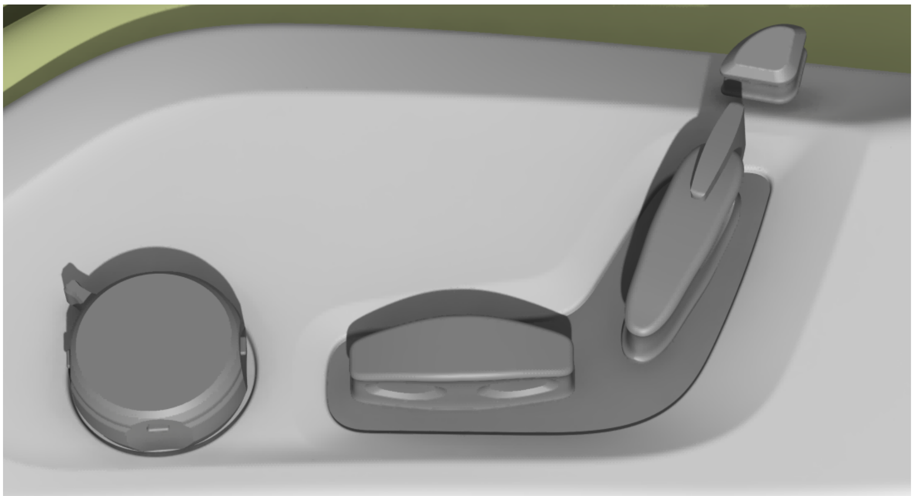


**Figure 6.1:** The physical buttons of the concept.

The functions that should be integrated into the adjustment controls are listed below:

- Length adjustments (2-way)
- Height adjustments (2-way)
- Cushion tilt (2-way)
- Leg extension (2-way)
- Lumbar support (4-way)
- Backrest tilt (2-way)
- Top backrest tilt (2-way)
- Side bolsters (2-way)
- Headrest support (4-way)
- Massage

The placement and mapping of the these functions are done by incorporating as many functions as possible into the seat shape design in order for the seat to behave in the way the user expect, without incorporating too many functions to create confusion. The top right button contains a 4-way headrest function, see Figure 6.2, designed to resemble the headrest, something also the mapping is supposed to show. The alternative was to include it in the round button but then the adjustment time and the risk for handling errors would have increased.

**Figure 6.2:** The headrest button from the concept.

Below the headrest is a large button resembling the backrest with a smaller button on top, see Figure 6.3. The big button can be rotated to tilt the backrest and the smaller button on top of the control is used for tilting the top part of the backrest. The two functions are located on the same spot as they are closely linked together and separating them would only create confusion as the user would not understand the difference between the functions.

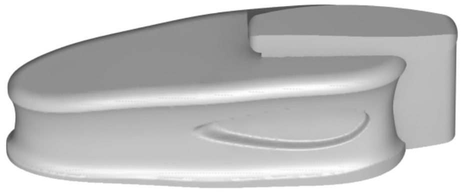


**Figure 6.3:** The backrest buttons from the concept.

The horizontal button to the left is resembling the seat cushion, see Figure 6.4. The functions using this control is the length changed by pushing the control forward or backward, the height changed by pushing the whole button up or down, and the tilt of the cushion changed by tilting the entire button. The functions are the same as on the current control but how to adjust them has been modified to facilitate use and remove handling errors. This new button also have indents and flat short sides to show were to push the button.

**Figure 6.4:** The seat cushion button from the concept.

The three remaining functions lumbar support, leg extension and side bolsters are included in the round knob, see Figure 6.5. The knob has four flat sides, to show that it can be used by pushing it vertically and horizontally. The sides are flat instead of indents to enable both one and two fingers and different finger sizes to be used when changing, something the round design also facilitates. It is also equipped with a tip to change between the functions.The functions adjusted by the round knob is arranged into different modes each containing a number of the functions. Changing the modes are done by rotating the button to toggle between different modes. When the control is released the control return to its original position. An alternative way of implementing this is to use a button staying at each mode, as a stove knob, however this solution was deemed inferior to this solution and is analyzed further in the discussion. There are two modes in the knob, one with a lumbar 4-way function and a second with leg extension and side bolsters as they both are 2-way functions reducing the risk of handling errors.

**Figure 6.5:** The knob button from the concept.

The massage function was considered to be more closely connected to the seat comfort functions as seat heating, seat ventilation and steering wheel heating, than the seat adjustments, and hence it was moved to their placement on the touch-screen. Also, the massage function does have several massage modes which needs to be controlled, and they doesn't correspond to the appearance of the adjustment buttons.

The controls mounted on a seat can be seen in Figure 6.6 and in Figure 6.7.

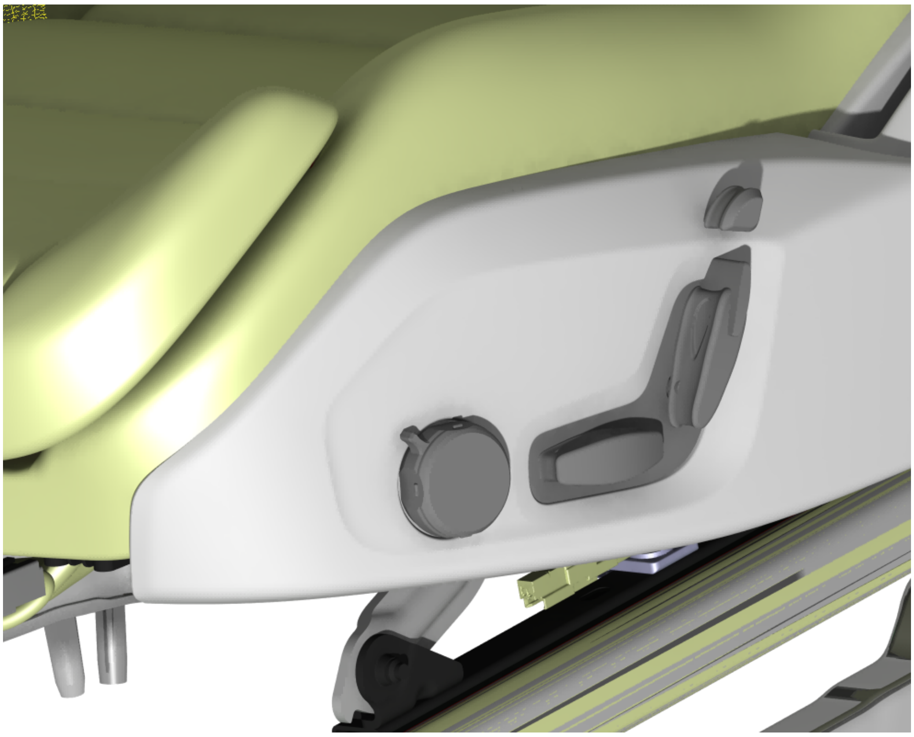


**Figure 6.6:** The controls mounted on a seat zoomed in.

**Figure 6.7:** The controls mounted on a seat.

The exact geometries and relations between the controls have not been decided. Instead the current relations were used as not enough knowledge of this existed and the previous work done by Volvo was seemed to be sufficient. The questions not answered are listed below:

- What angle should it be between the seat cushion button and the backrest?
- Where should the round control be placed?
- What should the distance between the seat cushion button and the backrest be?
- What should the distance between the backrest button and the headrest be?
- What size of the controls is the most optimal?

## 6.3 Touchscreen Layout

The touchscreen interface developed is based on an interface used by VCC today. Thereby, the design of most of the interfaces backgrounds and symbols have not been handled in the development work, only minor adjustments to the symbols has been made. Also, the interface developed in this project is not a functional interface but only a setup of static images showing the screens, with text explaining how the interfaces are connected.

The results from the literature study indicates that a screen is read from the top-left corner down towards the bottom-right corner. Thereby, the most urgent information should be presented in the top left corner indicating what is happening in the current screen, and adding more information while the user move their attention down-right. The study also shows that it is important to keep the user updated with feedback of the system and presenting the information the user needs, avoiding mode errors, but keeping the information presented at a suitable level not to take to much of the drivers attention.

The interfaces developed differ somewhat between when a single user is adjusting the seat and when multiple operators are using the control simultaneously. When a single user is adjusting the seat more information is presented. A visualization of the touch screen when a single user is using an adjustment control is shown in Figure 6.8 and 6.9. At the top-left corner of the screen the user has knowledge of that a seat function is operated. Beneath, information of what mode is open is presented, as well as information if there are more modes available for the same control. At the right hand side an image of the seat is presented, highlighting what parts of the seat can be controlled in that mode, how it can be controlled and providing dynamic feedback of how it is currently controlled. Below, an image of the adjustment control is presented, showing how the control is currently used and what other ways the control is controllable in that mode. The controls currently not used are faded out to show their positioning compared to the currently controlled button. The display will also show when the functions in the seat shaped controls are used, highlighting that control in the same way and fading out the modes and other buttons. When the seat is adjusted until its maximum in one direction the arrow in that direction is faded away, as shown in Figure 6.10.

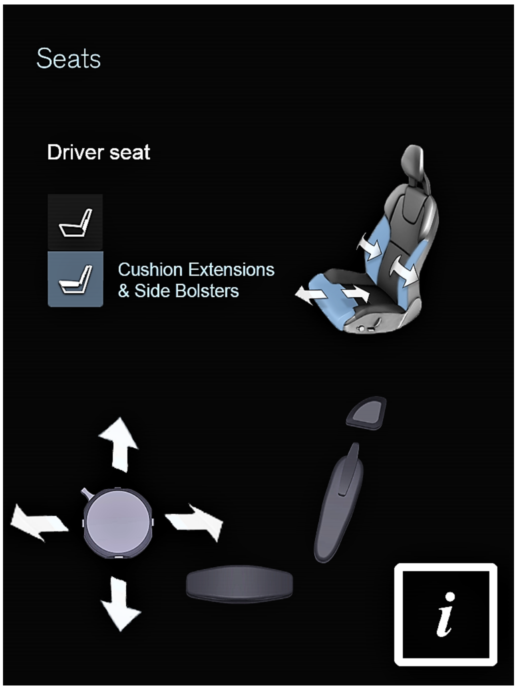



**Figure 6.8:** The appearance of the touch display in mode 2 while not currently moving the round knob.

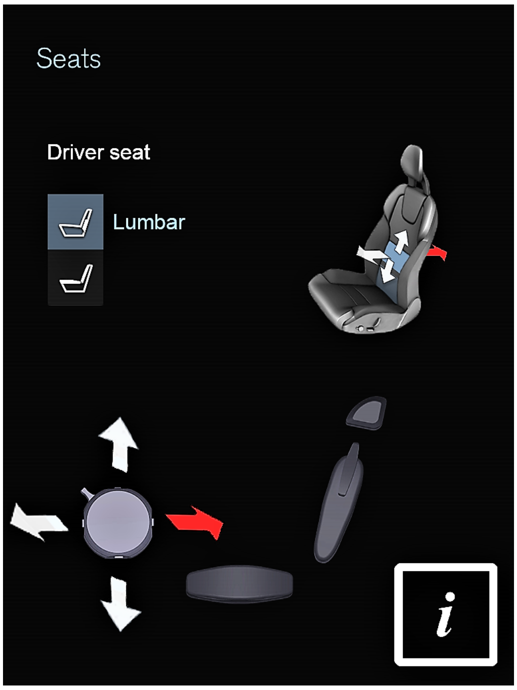



**Figure 6.9:** The appearance of the touch display in mode 1 while adjusting the round knob backward.

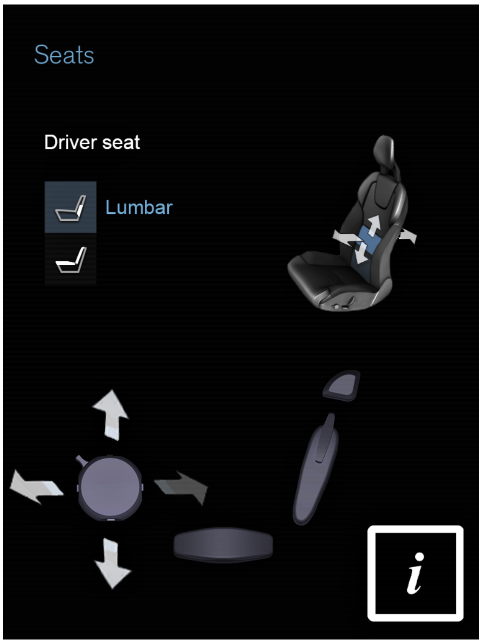



**Figure 6.10:** The appearance of the touch display when the seat is fully adjusted backwards.

When two users use the controls simultaneously the majority of the screen is implemented in the same way as for the screen when a single user is adjusting the seat. The information is presented with the driver at the top of the screen and the passenger below. The visualization of the adjustment controls are not shown for the duo-screen.

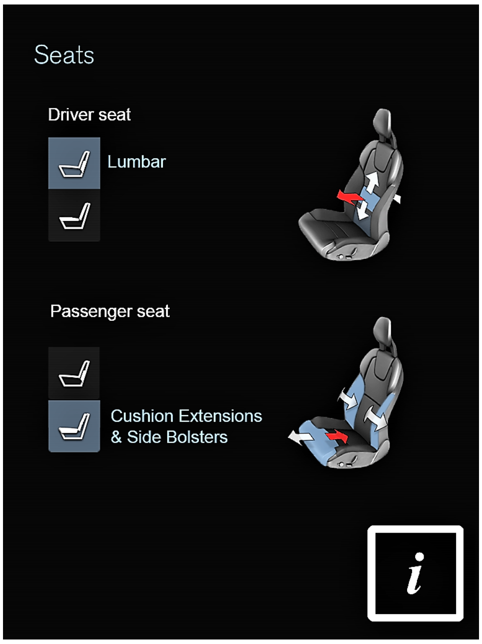



**Figure 6.11:** The appearance of the touch display when the driver and passenger seats are adjusted simultaneously.

At the bottom-right of the screen is there an information button. This button can be used in order to get additional information about the seat adjustment. The screen is shown in Figure 6.12, more information about how to control other seat settings can be accessed by scrolling up or down. The interface provide the user with a video guide showing how the entire seat can be adjusted into an optimal positioning, showing which order the adjustment controls should be used and how to know when seated in a good position. Also, it is providing the user with a written guide of how each of the buttons are used, which is understandable without watching the video guide. This will provide the user with enough information to be able to control the seat into an optimal seating position without the need of any further information.


**Figure 6.12:** The appearance of the top of the help display, by scrolling down more information is provided in the same menu.

The seat comfort systems of the vehicle are all arranged together in the center console panel. This is a logical mapping, connecting the similar functions. Simultaneously, it reduces the amount of functions which needs to be adjusted by the physical adjustment controls positioned at the outer side of the seat, making these controls easier to use. The controls are arranged as shown in Figure 6.13 and 6.14. The seat heating, ventilation, steering wheel heating and massage are arranged in a pop up menu at the center console unit. The massage function is activated there with three different intensities available, and when the massage button is used an additional control is opened, making it possible to choose what massage program to use, see Figure 6.15. This mean that both the speed and intensity of the massage are arranged into three modes, making them easy to adjust even if it reduces the flexibility of the control somewhat, compared to if intensity and speed would be adjusted separately.

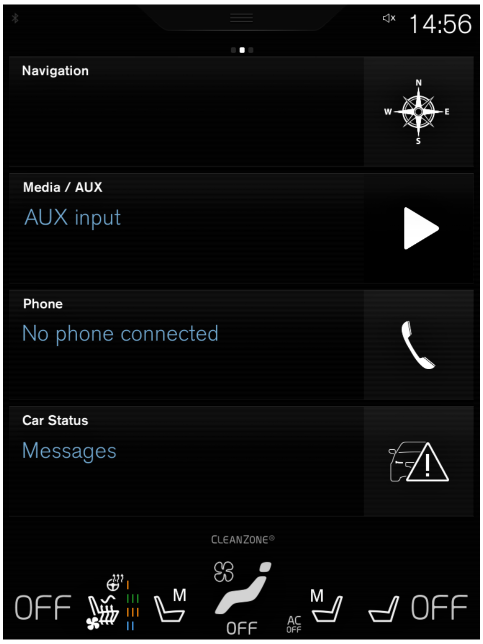



**Figure 6.13:** The appearance of the main menu of the center console display, with massage turned on at maximum intensity.

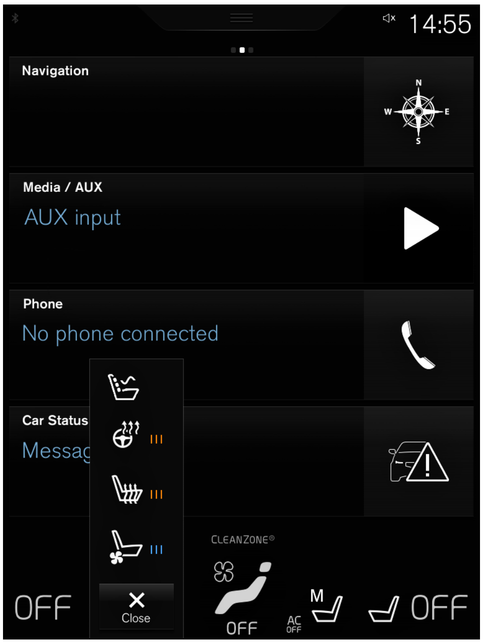



**Figure 6.14:** The pop-up menu for the comfort systems, with massage turned off.

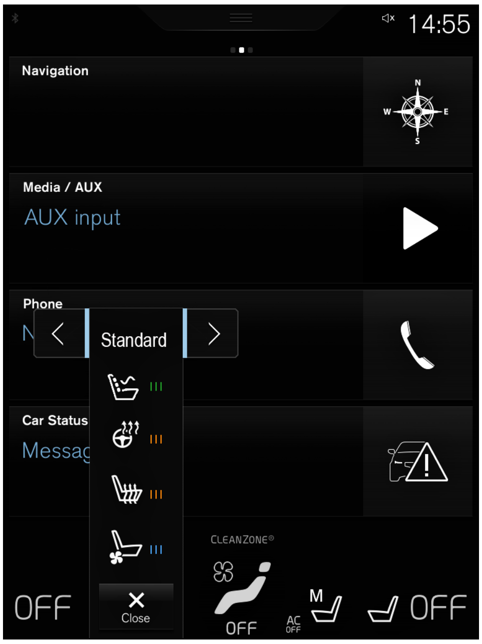



**Figure 6.15:** The pop-up menu for the comfort systems, with massage turned on.

Instead of having individual memory buttons located in the door the memory functions could be handled with an individual button in the central touch display. This enables one to name the different positions saved as well as storing more than two alternative seat settings. As an extra bonus it would also remove the physical buttons from the door which would look nice visually and save some production costs. The button for the seat memory is located at the inner side of the button seat comfort system, shown in Figure 6.13. When pressed the pop up menu shown in Figure 6.16 is shown. The menu shows the seat settings stored for different users, also making it possible to store the current seat settings in a new or existing storing location. The memory menu is not accessible when the car is moving but only when the car is standing still, when moving the memory button is tinted in order to make user understand that it is not controllable, see Figure 6.17.

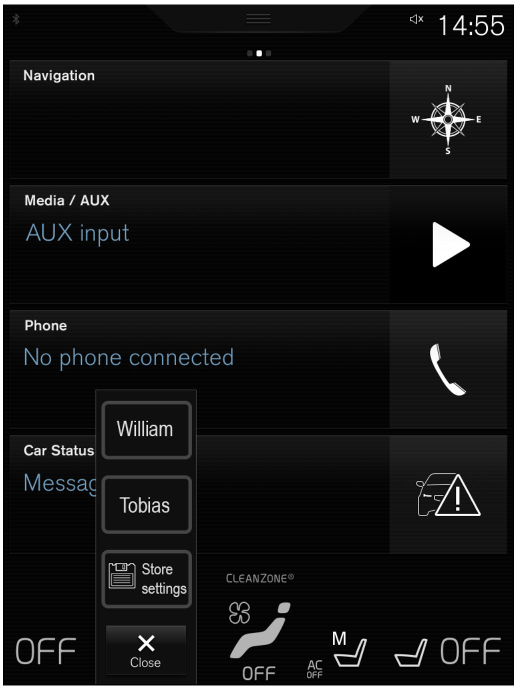



**Figure 6.16:** The appearance of the pop-up menu of the seat memory function.

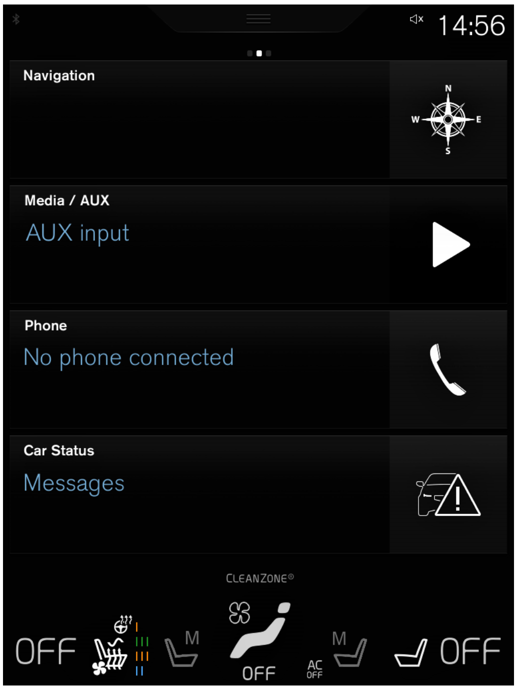



**Figure 6.17:** The appearance of the main menu of the center console display while driving, with the seat memory not controllable.

In order to enable the user to understand the touchscreen before it is shut down it is important that the screen stays open long enough for the operator to comprehend all of the information in the screen. This is important because even if the operator is not using the controls at a specific moment, the operator might still be thinking about the control and trying to understand it by looking at the touchscreen. In many of the tested car brands, as for example Volvo, this time has been considered to be too short and all of the information presented in the touchscreen could not be read before the screen was closed. If some adjustments of the seats are executed while driving it would be helpful if some information about what is adjusted would be presented in the dashboard, especially when the controls has multiple modes connected to them. This would enable the user to comprehend what is adjusted, only looking away with an angle of a couple degrees from the road, meaning the user has more help from their peripheral vision to notice events up ahead on the road.

## 6.4 Auxiliary Improvements

Today, many manufacturers have seat memory functions implemented into their vehicle in some kind of way. Sometimes, the seat memory is connected to memory functions activated by pushing a button in the vehicle, and for some vehicles it is connected to the keys to the vehicle. As the vehicles get more seating functions which needs adjustment, adjusting the seat gets harder, and more sharing of cars are used by car-pools etc. the need of memory functions increase. A good way of storing the seating memory would be by the users mobile-phone. This would enable individual seat settings being available for each user of a vehicle, even if it is a family using the same vehicle or if they are using vehicles from a car-pool. It could also be integrated into the 'Volvo On Call' phone-application. However, an issue of this solution is that this would entail a need of knowing which telephone is currently connected to which seat.

# 7
# Implementation

Before implementing this concept there are still some areas beyond the design and layout that need to be investigated such as which materials to use, the manufacturing and the commercial assessment. These are all presented in this chapter, followed by an assessment of how future development of the car industry might affect seat adjustments.

## 7.1 Material selection & Manufacturing

Since the placement of the controls are the market standard, and currently used by VCC, the wear, fatigue and outer impacts of the controls can be assumed to be the same as for Volvo today. Thereby, the material currently used for the controls should be suitable for these aspects. Also, the user study shows that the materials currently used by VCC, a smooth and shiny plastic, is perceived to have a high quality and providing a premium feeling for the user. Thereby, a material with a similar appearance which can bear the impacts of a kick, wear and of water should be used. The material should be recyclable and not consist and the environmental impact of the materials should be kept to a minimum.

Another important aspect when evaluating the material is the manufacturing process. Both what manufacturing processes can be used when designing components of that material and the environmental impacts of that production method. Also, the evaluation of the manufacturing should include how the control are attached to the other components. The attachment should allow for easy disassembling as well as accessibility for maintenance and reparations. Not enough information about this have been gathered during this project and need to be further investigated.

## 7.2 Commercial assessment

The following section will treat the current market, how the concept will help the customers, behave against the competitors and for future and current implementations. A Business Idea Identification what the concept will offer VCC is also presented.

### 7.2.1 Business Idea Identification

To describe the benefits and business idea for 'Seat shape & Round knob', a Business Idea Identification was done, see Figure 7.1. This clarifies the properties the concept is providing, to whom it is provided, the advantages of having it, and the benefits it consequently will provide.

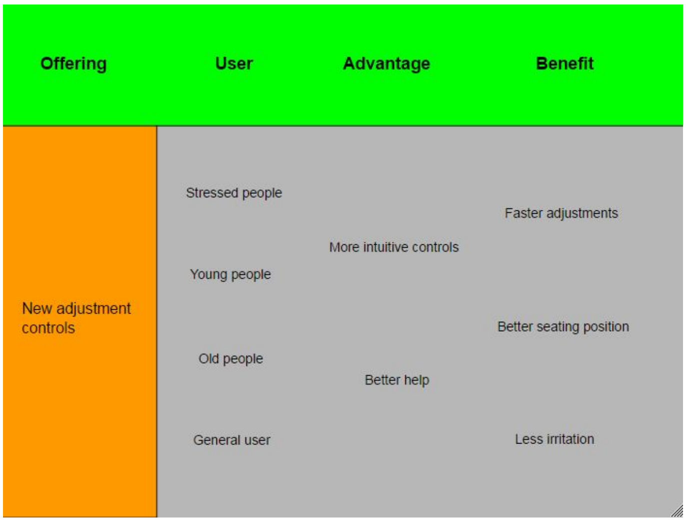



**Figure 7.1:** Business Idea Identification for the concept.

### 7.2.2 Customers

Sitting comfortable is crucial for customers to enjoy a car ride, and understanding how to adjust the seat is important to facilitate that. By having easy understandable adjustments enable the user to sit better by improving the existing seats, hence not having to invest huge amount of resources on developing new seats to improve comfort. Simultaneously, it is in line with Volvo's strategy 'Design around you' were the car should be designed around every user. If the controls are easy to use and the user are using every function, which they do not do now according to the pre-study, the seat will be in line with the strategy as the seat is positioned individually. Customers also expect distractions and the attention needed to operate the controls to be minimal while driving and having intuitive controls could decrease the irritation users feel when not understanding a control, and thereby increase their attention on the road.

### 7.2.3 Competitors

There are a lot of competitors on the market but not too many different solutions as shown in the pre-study. Therefore only Audi, BMW and Mercedes will be compared here as they are the main premium competitors as well as including the main differences on the market together.

The 'Seat shape & Round knob' concept is in many ways similar to Audi but differs in some aspects. The buttons on this concept have a clear design to ease understanding of possible functions and to give the user a more comfortable hold. It has less functions in the round knob than Audi to decrease the risk of handling errors and distraction time. This concept is more intuitive than BMW as it has less buttons so the user do not have to remember which button have which function. There are minimal risk of the user not understanding the seat shape idea, as there are not many other buttons interfering with the understanding. The concept also enables all buttons to be clustered together and not scattered over the whole side of the seat, consequently improving the reachability and the ergonomics. Compared to Mercedes this concept provides better ergonomic aspects as no twisting of hands are needed. Also, there are no negative impact on the door design. Mercedes do have better visibility but the idea is that by having better mapped functions the controls can be used without looking. There will also exist support in the display to guide in a better way. The main expectation is that this concept has collected the best from every aspect to a solution, which in the end will provide a better way of adjusting the seat into a better sitting posture than most competing solutions.

### 7.2.4 Resources to implement new functions

One big advantage of the 'Seat shape & Round knob' concept is the possibility to easy implement new functions due to the round button. This means that it will not require that much resources to implement possible new functions in the future. The current modes are few, meaning new functions can be added without a big increase of the risk of mode errors or losing track of what is currently controlled in the menu.

### 7.2.5 Adaptability for different models

The concept is modular and can easily be adapted for different specifications without any trouble. The controls could be included in the whole range of Volvo's car models. However, having electric controls instead of mechanical on smaller cheaper cars increase the cost and could therefore be a reason not including all models, even though it is possible.

## 7.3 The Future

The adjustment controls on the market today are all quite similar. The technology used have a high degree of maturity and the market have merged towards a standard. That is the reason not so many new concepts emerge but the placement change instead. The technology is on the top of its' s-curve were innovative solutions are rare. This have meant that this project's solution is not revolutionary as the room for improvement on the curve is limited, but instead is an optimization and modification of the solutions currently on the market. Instead there is a real opportunity to implement an entire new solution for adjustment controls, beginning a new s-curve with more potential. A possible solution, that also goes well together with autonomous drive, is automatic seat adjustments. When autonomous drive emerge users will most likely also expect the seats to be automatic. Starting the development of automatic seat settings early would give an edge on competitors, and could be used as a sales advantage. Meaning the cars would not only be the safest but also the most pleasant and comfortable to drive. Automatic adjustments will also solve the problematics noticed during the preparatory study were user do not know how to sit properly by adjusting the functions for comfort and safety. With the introduction of autonomous cars the use of car pools and unmanned taxis will most certainly increase. A need from the users would then emerge to have a seat and car that is specifically adjusted to them even if they do not own it. By having their own profile of their preferred settings on the Volvo app and using automatic adjustments, every car would be adapted for the users best liking, following the Volvo way of "Designed around you".

Automatic adjustments were one of the concepts during the initial screenings and was clearly the superior concept in many aspects. It was removed as a concept because it was not a complete solution, since it needed to be complemented with extra controls. The reason was that users need the possibility to fine-tune after their own preference as everyone likes to sit a bit differently. It was thereby decided that the concept of automatic adjustment could not stand as its own concept. Also, it was decided that it is not realizable at this very moment. Hence, this concept's opportunities and possible solutions are presented in this section as a very promising solution for the future.

First the question of how the seat should be adjusted arises. One way of doing it is to use cameras. Cameras which are used whilst driving and parking could be used to scan the user from outside of the vehicle to receive different body measurements. There already exist camera solutions inside of the car, looking at the eyes of the driver to recognize if the driver falls asleep for an example. That camera could be used to calculate the height of the eyes compared to the height of the seat and thereby calculate the upper body measurements as well. Knowing this could help adjust almost every adjustment except for the side-bolsters.

Using statistics could be an alternative way of solving it. By enabling the user to put in their height, in their phone or car, and use existing statistics on standard length of peoples' different body parts, something called Golden Ratio the seat could be adjusted. By knowing one measurement of a body part Golden Ratio enables to know the normal probability length of every body part. A knowledge gap is if Golden Ratio is applicable for the whole world population or if it differs between persons with different origins.

A third way is to use pressure sensors to read weight and pressure points. By using sensors you could know when the bolsters for example would start to squeeze the driver and thereby find the right position. It could also be used to know how much pressure there is on different parts of the seat cushion, hence changing the tilt to spread out the pressure on the whole cushion to increase comfort. The disadvantage is that not all functions can be adjusted based on only pressure sensors.

Before implementing automatic adjustment some knowledge gaps and decisions need to be made. Knowledge of the best ergonomic seating posture need to be obtained, for an example what angles between the backrest and seat cushion are preferable. Also, how will the introduction of autonomous cars affect the preferred driving postures of the drivers, should different seating modes be available for the user depending on their activity. The solutions mentioned above could also be combined, which would be preferable to reach an optimal position. For example combining a camera read of the upper body with statistics about golden ratio or using pressure sensors together with cameras. The manufacturing cost would probably not increase, sensors on the seat's placement already exist and a possible cost increase by using more senors would be faired by removing physical adjustment controls. Nevertheless the main question which needs to be answered first is which approach is the right, should you try to find as many measurements as possible or find one good to originate from and use statistics to calculate the other body measurements?

# 8
# Discussion

The purpose of the project has focused on where seat controls should be placed and how to design the buttons to facilitate use. Throughout the evaluation process it has been found the preferred placement to be on the side of the seat. The final design has incorporated all the knowledge gathered from the preperatory study and during the evaluation phase to provide easy to use controls that will facilitate the use.

An aspect which has a big impact on the results of the project is what attributes are considered most important for the HMI. In this project the perspective has been that the most important aspect is how to design the controls to make them easy to understand and to minimize the risks when adjusting the seat. This entails that some other aspects has been considered as less important, and prioritizing other aspects higher could have drastically changed the results of the project. A similar aspect occur at the screening phases when all the work has been conducted at subjective evaluations, not using any strict values to compare the results.

Since it is a subjective area it is almost impossible to please all stakeholders, and how the result is perceived always depend on who is the receiver. Since this study is conducted in Sweden, with Swedish participants in the user study the result will mostly reflect on the Scandinavian view of how the design should be implemented in order to achieve a good result.

The literature used in the study has been gathered from well known sources and well known scientists in their specific fields. However, even with well known scientists, their perceptions of how to develop a HMI differ somewhat, and thereby a different set of sources could have changed the result of the study. Connecting the study conducted with the literature studied, the results from the preparatory study and other research in the project implies high correlation to this project's results.

Some of the aspects considered as the key aspects by the project group when designing interfaces based on the study and literature are four things. Firstly one aspect is that the entire HMI needs to be designed coherently, designing controls, feedback and functions to work together to reach an optimal solution. Hence, the design of the touchscreen interface can be considered as an extension of the adjustment controls, designed with the focus to maximize the functionality of the adjustment controls. The design of the supporting systems is very important for a control design, and the configuration of the supporting systems could even enhance the perception of an inferior control considerably. The touchscreen has thereby incorporated pictures of the physical controls and how they may be changed into its HMI to ease the interaction.

Much literature present a design guideline to design controls and implement the mapping of controls to correspond to the object which is controlled. Even as the user study shows that there are considerable positive effects on controls resembling the seat there are a risk of mapping too intensively on a small area, or adding too many functions to a control. Doing this might instead decrease the resemblance between the control and the controlled object and create unnecessary complexity. In that case it would be better to use an alternative control and supporting functions to give better understanding of how to use the control/controls. Therefore, this concept has included a round control to facilitate the interaction and decrease the complexity. However, a problem with the currently implemented controls is that many functions are included, making that round control complicated to use. Therefore, in this concept a trade-off between decreasing the complexity of both the seat-alike controls and the round control have been made to reach an as good solution as possible.

Also and specifically for vehicle design, controls should be designed to minimize the focus and eye distraction of the operator. The optimal solution is to give the operator feedback of what is happening with an alternative media to visual content, however this is not always applicable. When designing visual feedback for vehicles, it should be presented as close to the drivers line of sight while driving as possible, and the attention needed to understand the feedback should be minimal. Therefore, the screen is using dynamic feedback to make the user aware of the most important part of the screen and quickly making the user aware of what is currently being controlled, minimizing the distraction time. Lastly, with an increased use of car pools and car sharing the controls should be as intuitive as possible, making it easy for a new user to learn and understand the controls. Using that aspect as a foundation when designing the physical controls created the indentations, new angles, new movement patterns and additional buttons.

The seat comfort systems (seat heat, massage, etc.) implemented in the touchscreen are some of the controls most regularly controlled while driving. In order to reduce the distractions while driving these buttons could be implemented as physical buttons rather than in the touchscreen. This might make it easier to remember the positioning of the controls intuitively and thereby reduce the need of looking away from the road when controlling these functions, using muscle memory to remember which button control which function. This might result in a more functional implementation, but also might affect the design aspects negatively. This project did not find a better positioning of these buttons than in the touchscreen, but more investigations could be done about this subject.

The results of this study has not been confirmed with any user tests. The only method which has been used to evaluate the results are internal testing and evaluation by the project group. Thereby, there is a need to evaluate the results further in order to know that the results are perceived well in practice as well. This is particularly important in the case of the touch display were many implementations have some positive aspects and the results would need to be tested in a functional system to get deeper knowledge of what is the best solution.

# 9 Conclusions

The objective of this thesis has been to create a concept of seat adjustment controls that support the interaction with the user while providing a good user experience by having great intuitiveness. With the created concept, the physical controls together with the touchscreen, the intuitiveness together with many more aspects such as adjustment time and distraction have been improved and areas previously lacking have been enhanced. The focus has throughout the whole process been on functionality, trying to minimize the risk of errors while maximizing the ease of use. The final concept have not yet been verified but compared to the gathered data from the literature and preparatory study this concept is more in line with that than any other compared adjustment controls on the market today.

While developing new adjustment controls many different aspects have an impact as it is a wide area which entailed many different trade-offs during the development phase. Some trade-offs needed to be made in the early phase with limited information and others later on, with almost no facts as many aspects are subjective, and as every user experience things differently. Nevertheless, some aspects have been proven to be very one-sided and a maximization of these giving overwhelming good results, for an example feedback, without creating any particular trade-offs. The physical controls and the touchscreen have not been optimized separately but together as the main importance is how they work together to create the user experience. Overall the key findings are use of dynamic feedback, indents on buttons, having a movement pattern on the controls similar to the movement of the seats and moving the massage function to a more suitable place.

The era of cars are soon entering a new phase with autonomous drive and how the seats are adjusted needs to keep up with the changes. As stated in the report these types of adjustment controls are mature with less and less room for improvement and the next step with automatic adjustment is the natural way. Shifting to automatic adjustments in the near future will be the way to comply with the noticed increasing demands.

Overall this project have given new insights on which aspects are most important and how to weigh them against each other. A new concept has been developed, optimized to be easier to use for more people, than controls on the market today. It also provides some inspiration of how the market seem to change in the future and what needs to be done to keep up with the development. Following the guidelines and trade-offs made in the project is a good way of creating a good Human-Machine Interaction, not only for the seat but for the whole car.

# 10 Recommendations

In this chapter some final recommendations of what further improvements are most crucial to optimize the design and complement the information gathered in this project. The most important issue is to conduct user tests, to evaluate that the results from the study correspond well to real-life situations, and in order to find out what is the best implementation of the concept. The different sizes of the physical buttons and their distances and angles between each other also need to be further investigated in order to find the optimal solution.

There are some aspects which needs to be further developed and evaluated about the touchscreen interface. Firstly the design aspects of the symbols in the interface has not been developed in this project, and many of the symbols could be designed more nicely and giving a better representation of their meaning. For example, the small seat representations which appear when the seat adjustment controls are used and the symbols for the massage functions could be refined, and the interfaces which appear when using the basic seat adjustment functions needs to be developed. Also, the concept interface has not been evaluated yet and this is needed to confirm the results of the project, simultaneously this could give specific guidelines and figures of some design aspects, as of how long the touchscreen needs to show to enable the user to read all the information presented.

This project has concluded that some information of what is adjusted should be presented in the dashboard. The development of the dashboard interface as well as studies about how the dashboard should be designed needs to be conducted in order to comply to this idea.

# References


Almefelt, L. (2016a, January 20). *Requirements management with product innovation in mind.* Gothenburg. (Lecture at Chalmers University of Technology, course MPP126 Product Development Project)

Almefelt, L. (2016b, January 18). *Systematic design - overview.* Gothenburg. (Lecture at Chalmers University of Technology, course MPP126 Product Development Project)

The automotive hmi report 2013. (2013, November). *Telematic Update.*

Bhise, V. D. (2012). *Ergonomics in the automotive design process.* 6000 Broken Sound Parkway NW, Suite 300: CRC Press. (ISBN 978-1-4398-4210-2)

Brud, A. (2016, March 2). *Entrepreneurship & immaterial rights: Transforming knowledge to products and business.* Gothenburg. (Lecture at Chalmers University of Technology, course MPP126 Product Development Project)

Epstein, S. (1994). Integration of the cognitive and the psychodynamic unconscious. *American Psychologist*, *49*, 709.

François, M., Osiurak, F., Fort, A., Crave, P., & Navarro, J. (2016, May 30). Automotive hmi design and participatory user involvement: review and perspectives. *Ergonomics.* (DOI: 10.1080/00140139.2016.1188218)

Ghazinoory, S., Abdi, M., & Azadegan-Mehr, M. (2011). Swot methodology: A state-of-the-art review for the past, a framework for the future. *Journal of Business Economics and Management*, *12*(1), 24–48. (DOI: 10.3846/16111699.2011.555358)

Gillham, B. (2017). *Research interviewing.* McGraw-Hill Education. (ISBN 9780335215867)

Gkouskos, D., & Chen, F. (2012). The use of affective interaction design in a car user interfaces. *Department of Interaction Design, Chalmers University of Technology*(41), 1–5.

Gruhn, P. (2011, January). Human machine interface (hmi) design: The good, the bad, and the ugly (and what makes them so). *66th Annual Instrumentation Symposium for the Process Industries*, 27–29.

Jordan, P. W. (2006). *Designing pleasurable products: an introduction to the new human factors.* 11 New Fetter Lane, London EC4P 4EE: Taylor & Francis. (ISBN 0-748-40844-4)

Kerzner, H. (2013). *Project management: A systems approach to planning, scheduling, and controlling* (11th ed.). Hoboken, Hew Jersey.: John Wiley & sons Inc. (ISBN: 978-1-118-02227-6)

Larossi, G. (2006). *Power of survey design.* World Bank Publications. (ISBN–9780821363928)

Litcanua, M., Prosteana, O., Orosa, C., & Mnerieb, A. V. (2015). Brain-writing vs. brainstorming: Case study for power engineering education. *JProcedia - Social and Behavioral Sciences*, *191*, 387 – 390.

Monö, R. (2004). *Design for product understanding.* Liber.

Nielsen, J., & Mack, R. L. (1994). *Usability inspection methods.* New York: John Wiley & Sons. (NY ISBN: 0-471-01877-5)

Norman, D. A. (2013). *The design of everyday things.* Basic Books. (ISBN: 9780465050659, Chapter 2)

Norman, D. A., & Eucher, J. (2016). Design for use - an interview with don norman. *Conversations*, 15–19.

Osvalder, A.-L., & Ulfvengren, P. (2010). Arbete och teknik på människans villkor. In M. Bohgard (Ed.), (pp. 353–438). Prevent. (ISBN: 978-91-7365-110-3)

Quality-One. (2017). *Failure mode and effects analysis (fmea).* Available from `http://quality-one.com/fmea/`

Smart cars need smart seats. (2016, July 5). *Automotive World*.

Stapenhurst, T. (2009). *The benchmarking book: A how-to-guide to best practice for managers and practitioners.* Linacre House, Jordan Hill, Oxford OX2 8DP, UK: Elsevier. (ISBN–978-0-7506-8905-2)

Thimbleby, H. (1990). *User interface design.* ACM Press. (ISBN 0-201-41618-2)

Tidwell, J. (2010). *Designing interfaces: 2nd edition.* O'Reilly. (ISBN: 978-1-449-37970-4)

Ulrich, K. T., & Eppinger, S. D. (2011). *Product design and development* (5th ed.). Hoboken, Hew Jersey.: McGraw-Hill. (ISBN: 978-0-07-340477-6)

Ulrich, K. T., & Eppinger, S. D. (2012). *Product design and development.* 2 Penn Plaza, New York, NY 10121: McGraw-Hill Education. (ISBN 978-007-108695-0)

Vasantharaj, G. (2014, January 4). State of the art technologies in automotive hmi. *SAE technical paper*. (DOI: 10.4271/2014-01-0258)

Wickens, C. D. (1992). *Engineering psychology and human performance: Second edition.* 10 East 53rd Street, New York NY 10022: HarperCollins Publisher Inc. (ISBN 0-673-46161-0)

Williams, M. A., Attridge, A., & Pitts, M. (2011). User-centred design and evaluation of automotive seat adjustment controls. *Int. J. Vehicle Design*, *55*(2–4), 119–138. (ISSN 0143-3369)

# Appendices

# A

# Concept Ideas before Kesselring matrix

**Seat shape stuck together**: The seat shape by two buttons is the basis of the concept, controlling length, height, cushion tilt, backrest tilt and maybe lumbar or having lumbar as an add-on button on top of the button. Leg extension is a button just above, but with contact surfaces, of the seat cushion button. The top part of the backrest is located on top of the backrest button, sticking out a little bit on the top. The headrest is a separate button located above the backrest button. The massage function is not included in this concept.

**Seat shape twofolded backrest**: The controls are having a design resembling the form of a car seat, with all functions compressed into seat alike controls. The backrest is divided into two parts, one controlling the angle of the entire backrest and one the upper part of the backrest. Otherwise is the concept similar to "Stuck together". The massage function is not included in this concept.

**Seat shape & Rotary with four buttons**: There are two controls located at the side of the seat having a design resembling the form of a car seat controlling some basic functions. In addition to this control are there an additional rotary control used to control some additional functions. The additional control is used to toggle between different functions, and the functions are changed by rotating the control in an upward or downward motion. On top of the control are there four buttons used to adjust each function.

**Seat shape & Rotary knob**: There are two controls located at the side of the seat having a design resembling the form of a car seat controlling some basic functions. In addition to this control, there are an additional rotary control used to control some additional functions. The additional control is used to toggle between different modes. When inside a mode both rotation, longitudinal and elevational motions are used to adjust the seat.

**Seat shape & Rotation + Button**: There are two controls located at the side of the seat having a design resembling the form of a car seat controlling some basic functions. In addition to this control, there are an additional rotary control used to control some additional functions. The additional control is used to toggle between the remaining functions, and the functions are changed by pushing a button on top of the control. Thereafter, each function is adjusted by rotating the control. The rotary button may only be rotated or pressed on top of the button.

**Seat shape & Joystick**: There are two controls located at the side of the seat having a design resembling the form of a car seat controlling some basic functions.

In addition to this control, there are an additional joystick used to control some additional functions. The joystick has a button on top used to toggle between different modes. The seat settings are adjusted by tilting the joystick in a longitudinal and elevational motion.

**Rotary knob on seat**: One single rotary button is used to control all the functions, located at the outer side of the seat. The control enables modes to be changed. A button on top of the button is also used. Longitudinal, elevational and rotating motions are used to adjust the seat.

**Rotary four buttons on seat**: One single rotary button is used to control all the functions, located at the outer side of the seat. The control is rotated in order to toggle between different functions. Thereafter, four directional buttons on top of the control is used in order to adjust the seat settings.

**Two buttons in one control on seat**: One single rotary button is used to control all the functions. A horizontal button on top of the control is used to enable one extra function in every mode. The rotary button can also be moved in longitudinal and elevational direction as well as by rotation.

**Double rotational button on seat**: One single rotary button but instead of having a solid panel on the button, the center part can be rotated independent of the outer part.

**Individual buttons**: Having many buttons with maximum of two functions allocated to each button, located at the outer side of the seat. A mapping resembling a seat is used in order to keep a logical mapping for the user.

**Touch on seat**: Using a touch panel to enable swiping on the side of the seat. Thereby, the seat is divided into areas used to control different functionalities of the seat. The areas may have indentations to show where and how to move them.

**Button on steering wheel**: Extra button on the steering wheel, used to start the seat controls. Thereafter controlling the seat with the four control-arrows at the steering wheel. Feedback is provided by the HUD/dashboard/touchscreen.

**Rotary on steering wheel**: There are a rotary control at the steering wheel. The control is rotated in order to change between different modes. On top of the control are there four buttons used to adjust the seat.

**Joystick on steering wheel**: There are a small joystick alike control at the steering wheel. The control has a button on top used to toggle between different modes and the functions in each mode are adjusted by tilting the control in a longitudinal or elevational motion.

**Touchscreen on steering wheel**: A touchscreen located at the center of the steering wheel which is used both to control the adjustments and to provide feedback for the user.

**Movable touchscreen at the door**: All seat adjustments are controlled by a movable touchscreen that is positioned in the front side of the door that is foldable to the left-beneath the steering wheel (about 8 o'clock). The movement can be automatic and/or manual.

**Movable touch screen at front panel**: All seat adjustments are controlled by a movable touchscreen that is, positioned at the front panel at the left, beneath the steering wheel ( 8 o'clock). The movement can be automatic and/or manual.

**Movable touch screen at center panel**: All seat adjustments are controlled by a movable touchscreen that is position at right beneath the steering wheel and below the central control system. Locating it behind the steering wheel will hinder it from being in the way of the gear lever. The movement can be automatic and/or manual.

**Movable touch screen at armrest**: All seat adjustments are controlled by a movable touchscreen in the armrest in the middle console where the screen follow the user and is possible to bend to face towards the driver in order to ease interaction.

**Seat shape on door**: Seat shaped controls located at the inside of the door. With all functions compressed into the seat like controls.

**Touch display on door armrest**: A touch display located at the armrest of the door panel is used to control the seat. The touch display is angled toward the user to be visible while still reachable by the hand at the armrest.

**Touchpad on armrest**: A touchpad located at the front of the armrest in the door. The touchpad is used to adjust the seat settings with feedback provided from the HUD/dashboard/central touchscreen.

**Rotary knob at armrest**: A rotary control located at the armrest of the door. The control uses modes to adjust functions, enabling movements in a longitudinal, elevational and rotating direction together with a button on top.

**Rotary four button at armrest**: A rotary control located at the armrest of the door. By rotating the control, different modes are selected. By using four directional buttons, the seat is adjusted. Joystick on armrest: A small joystick located at the armrest of the door is used to toggle between different modes. Thereafter, the seat is adjusted by using four directional buttons.

# B

# Requirement Specification

**Table B.1:** Part 1 of the Requirement Specification.

**Requirement Specification - Human-Machine Seat Interface**

*Created: 2017-01-31*
*Modified: 2017-05-08*

| | | Criteria | Justification | Target Group / Reference | Evaluation / Verification | Fulfilled | Comment |
|---|---|---|---|---|---|---|---|
| **1. Performance** | | | | | | | |
| 1.1 | R | Follow the correct control movements according to the Logic of operation | VCC TM 0438 | User | Confirm with Guidelines & Evaluate | | |
| 1.2 | D | Haptic feedback, perceived from the seat about what control is adjustment | | Volvo | Internal evaluation | | |
| 1.4 | D | It is possible to use the control with small attention put toward the adjustment task | | User | Evaluation & Testing | | |
| 1.5 | R | Adjustment of the base functions (seat height, length, backrest tilt) is understandable intuitively | | User | Evaluation & Testing | | |
| 1.6 | D | After some usage the adjustment of the base functions is conducted without moving the eyes from the road | | User | Evaluation | | |
| 1.7 | D | The additional functions are easily understood with help from the touchscreen | | User | Evaluation | | |
| 1.8 | D | Massage should be easily stopped, started and restarted | HMI req. | User | Evaluation | | |
| 1.9 | D | Timeout time of the touchscreen should be long enough that the user have time to read and understand the information presented | | User | Evaluation | | |
| **2. Environment** | | | | | | | |
| 2.1 | D | Recyclable material | | Volvo | Evaluation | | |
| 2.2 | D | Easy dissembling for recycling | | Volvo | Evaluation | | |
| **3. Design** | | | | | | | |
| 3.1 | R | The clearance between controls makes it possible to use the controls without hinders | VCC Ergo Req. | User | Confirm with Guidelines & Evaluate | | |
| 3.2 | D | The design should be perceived as equally beautiful or better than the current design | | User | Assessment | | |
| 3.3 | D | Modularization for different car models and amount of functions | | Volvo | Evaluation | | |
| 3.4 | D | Modularity in order to be used for seat with different amount of functions | | Volvo | Evaluation | | |
| 3.5 | R | Follow size guidelines from ergonomics aspects | VCC Ergo Req. | User | Confirm with Guidelines & Evaluate | | |
| 3.6 | D | The design and tactile feedback guide the user to do the correct action intuitively | | User | Evaluation | | |
| 3.7 | R | The design should not confuse user | | User | Evaluation | | |
| 3.8 | D | The design guide the user to use the controls correctly | | User | Evaluation | | |
| 3.9 | D | The controls are identified by touch | | User | Evaluation | | |
| **4. Maintenance** | | | | | | | |
| 4.1 | D | Access during maintenance/repair | | Volvo | Assessment | | |
| 4.2 | D | If broken the control or part of a control should be easily replaced | | Volvo | Assessment | | |
| **5. Life Span** | | | | | | | |
| 5.1 | R | Design for Exhaustion over the lifetime of a vehicle | | Volvo & User | Evaluation | | |
| 5.2 | R | Bear the physical impacts from kicks which would be expected at the location of the control | | Volvo & User | Evaluation | | |
| 5.3 | R | Bear the impacts from weather and water | | Volvo & User | Evaluation | | |

**Table B.2:** Part 2 of the Requirement Specification.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 6. | **Positioning** | | | | | | |
| 6.1 | R | Control visible with torso lean | | User | Evaluation | | |
| 6.2 | D | Control visible without torso lean | | User | Evaluation | | |
| 6.3 | D | Controls located away from the angle cone | | User | Evaluation | | |
| 6.4 | D | Head movement needed to see feedback | | User | Evaluation | | |
| 6.5 | D | Controls should be reachable without torso lean | | User | Evaluation & Testing | | |
| 6.6 | D | Placed to be reachable without leaning | Formula SAE Rule A1.2.2 | User | Evaluation & Testing | | |
| 6.7 | D | Controls are reachable without uncomfortable twisting & bending of wrist | | User | Physical testing | | |
| 6.8 | D | Similar controls should positioned together | | USer | Evaluation | | |
| 6.9 | R | The seat is adjustable form outside of the car, before ingress | | User | Evaluation | | |
| 7. | **Costs** | | | | | | |
| 7.1 | D | Target material cost | | Volvo | Evaluation | | |
| 7.2 | D | Target production cost | | Volvo | Evaluation | | |
| 8. | **Material** | | | | | | |
| 8.1 | D | Provide a premium feeling | | User | Evaluation | | |
| 9. | **Ergonomics** | | | | | | |
| 9.1 | R | Controllable for all drivers | | User | Evaluation | | |
| 10. | **Safety** | | | | | | |
| 10.1 | R | Using the control doesn't take too much attention from driving | | User | Evaluation | | |
| 10.2 | D | Design should allow for testing things without risk | | User | Evaluation | | |
| 10.3 | R | Design should allow for making changes of one's procedure midstream | | User | Evaluation | | |
| 10.4 | R | A control should not be possible to be mistaken as another fundamental control | SAE standard J1139 | User | Evaluation | | |
| 10.5 | R | Controls does not intrude with interaction of other important controls | | User | Evaluation & Testing | | |
| 10.6 | R | The control should not be easily accessible by accident | | User | Evaluation | | |
| 10.7 | D | Controls should automatically stop when not being actively used | | User | Evaluation | | |
| 10.8 | D | If something is jammed (input force higher than threshold value) while the control is used it stops automatically | | User | Evaluation | | |
| 10.9 | D | The feedback from the system doesn't disturb the users attention from driving | | User | Evaluation | | |
| 11 | **Production** | | | | | | |
| 11.1 | R | Same production methods as used today should be possible to use for production | | Volvo | Evaluation | | |
| 11.2 | D | Allows for fast assembly | | Volvo | Evaluation | | |

# C

# FMEA - Failure Mode and Effects Analysis

**FMEA (Failure Mode and Effects Analysis)**

| Main system | Date | Part name | Issued By |
|---|---|---|---|
| **Adjustment controls** | **2017-05-10** | **Seat shape & Round knob** | **Tobias Darrell & Wiliam Norrblom** |

| Part | | Characteristics of Failure | | | | Rating | | | | Action status | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nr. | Function | Failure Mode | Cause of Failure | Effects of failure on part/syst. | Testing | Po | s | Pd | RPN | Recomendations | Decisions taken | Po | s | Pd | RPN | Resp. Dept/Sign |
| 1 | Usage | Fracture in locking section | Misdirected or overload of the forces used | Reduced performance or failure | FEM simulations | 3 | 7 | 3 | 63 | | | | | | 0 | |
| 2 | Usage | Fracture in locking section | Fatigue or corrosion | Reduced performance or failure | Life-time testing | 4 | 6 | 5 | 120 | More testing | | | | | | |
| 3 | Usage | Failure in "connection pins" | Misdirected or overload of the forces used | Reduced performance or failure | FEM simulations | 3 | 7 | 3 | 63 | | | | | | 0 | |
| 4 | Usage | Failure in "connection pins" | Due to fatigue or corrosion | Reduced performance or failure | Life-time testing | 4 | 6 | 5 | 120 | More testing | | | | | | |
| 5 | Usage | Cracks in controls | Impacts from outer forces | Less premium feeling | FEM simulations | 3 | 3 | 4 | 36 | | | | | | 0 | |
| 6 | Usage | Cracks in mechnics cover | Impacts from outer forces | Less premium feeling | FEM simulations | 2 | 3 | 3 | 18 | | | | | | 0 | |
| 7 | Usage | Jamming of controls | Impurities in mechanics | No or exessive movement of seat | Physical testing | 1 | 10 | 5 | 50 | | | | | | 0 | |
| 8 | Usage | Increased mechanical inertia | Impurities in mechanics | Reduced performance | Physical testing | 2 | 3 | 10 | 60 | | | | | | 0 | |
| 9 | Usage | Loose Connection | Misuse or much usage | Lag in mechanism | Life-time testing | 5 | 4 | 5 | 100 | Tolerance modification | | | | | | |
| 10 | Manufacturing | Inncorrcet mounting | Assemby | Reduced lifetime | Simulations | 4 | 7 | 3 | 84 | | | | | | 0 | |
| 11 | Manufacturing | Dimension error | Part manufacturing | Less premium feeling or impossible assembly | Changing tolerances | 2 | 6 | 2 | 24 | | | | | | 0 | |

**Figure C.1:** An FMEA of the adjustment controls.