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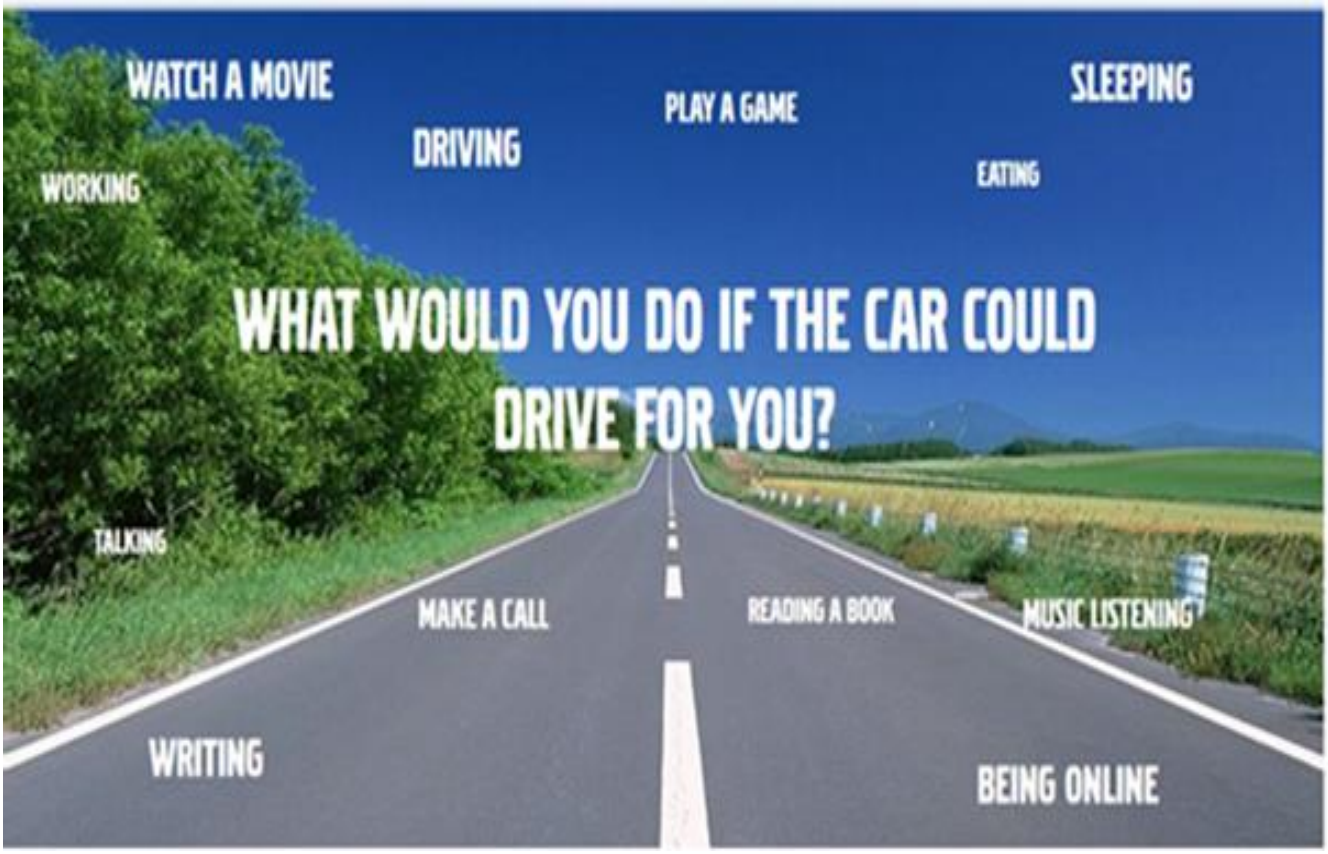

Design of interior for a self-driving car

Propose a conceptual design from a Body & Trim perspective that can be implemented in future self-driving cars

Master's thesis in Product Development

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ISAAC LUBEGA

Department of Product and Production Development
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2015

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Cover:
[A long highway, birthing the need for what people want to do in a self-driving car when travelling far (Wallcoo, 2006)]

Gothenburg, Sweden 2015

ABSTRACT

This master thesis was performed at the Department of Product and Production Development at Chalmers University of Technology in Gothenburg, Sweden. The thesis work was conducted with close collaboration with the department Concept and Strategy at the Body & Trim department at Volvo Car Corporation in Gothenburg, Sweden.

The purpose of this master thesis was to propose a suitable conceptual design from a Body & Trim perspective that can be implemented in future self-driving cars. The reason for this was to create a possibility for humans to utilize the timeslot created in the car when it is self-driven. The proposed concept along with the methodology applied to achieve it will be presented in this report. A scaled prototype will also be built to showcase the result.

In the initial stages of the project a market analysis was conducted. Here interviews both within Volvo Cars and with people outside were held. Observations were made on a self-driving vehicle and the all-new XC90, Volvo Cars latest car model which was released earlier this year. A benchmarking study on fully autonomous cars was conducted as well. Lastly a focus group was conducted with people outside the company. This data was gathered for the development work which helped to form a user requirement specification.

The next step was to generate concepts and later evaluate them with respect to the user requirements. In this phase methods were used that were modified due to the projects futuristic nature.

The final result was a concept named Concept Smart which is an interior that enables the user to utilize the timeslot in the best possible way. A scaled prototype was also showcased in order to see how the solution might look in real life.

Keywords: Volvo Cars, Passenger, Timeslot, Concept, User, Interior, Self-driving, Autonomous

PREFACE

The Master thesis has been performed at Body & Trim at Volvo Car Corporation, which is a unit of the division Research & Development. Collaboration in this thesis was made with the Department of Product and Production Development at Chalmers University of Technology in Gothenburg, Sweden.

We would like to thank many people for the help rendered to us during this thesis. Special thanks to our supervisor at Volvo Cars, Ms Erja Olsson for feedback, insight, inspiration and support during the whole project. We would also like to thank our examiner and supervisor at Chalmers, Dr. Göran Gustafsson for all the feedback, constructive and precise criticism and help during the project.

Other persons to thank are Mr Magnus Lindh who also is our supervisor at Volvo Cars that have helped us with feedback and direction during the project. People at the department of Concept and Strategy have been extremely helpful. Lastly we would like to extend our thanks to the workers at the prototype workshop, who have helped us with the prototype car “Concept Smart”. Special thanks goes to Mr Niklas Hvit.

Finally, thanks to all that have contributed to this thesis in the last 20 weeks.

Gothenburg, June 2015
Paul Filo & Isaac Lubega

Contents

1. INTRODUCTION

This introduction will give a brief description of the background of this thesis. It also includes a short presentation of Volvo Car Corporation (VCC) in Gothenburg, Sweden. The purpose of the project is presented in this chapter along with a description of the delimitations and the problem definition.

1.1 BACKGROUND

The technology within the car industry is today developing with increasing expectations and customer demands. Volvo Cars wants to continue to be pioneers for the next generation of cars emerging on the market. Volvo Cars have the reputation of developing among the safest cars in the world, and since 90 percent of all traffic accidents are caused by human error (alertdriving.com) this opens up the door for development of autonomous vehicles. In this technology you ultimately remove the human's responsibility from driving the car and thus reduces the possibility of crashing. Many consumers might think that the emergence of the autonomous vehicles is going slowly, but yet more and more carmakers are looking into developing autonomous vehicles in today's market. Huge companies such as Mercedes, Audi, BMW and even large tech companies like Google are all eagerly developing and releasing test vehicles. Volvo Cars is in 2017 launching a self-driving autopilot project called *DriveMe*. This is an autonomous drive project in collaboration with Swedish legislators, and is the first large self-driving project conducted on public roads in interaction with everyday traffic. 100 test vehicles are going to be launched. The purpose with the pilot project is to evaluate the societal benefits of self-driving cars as well as pioneering themselves within the self-driving car market.

However, since Volvo Cars motto is; "Designed around you" the question now stands; what will people do in a car when they no longer have the responsibility of maneuvering it? This turns challenges into opportunities as new timeslots are created that can be made use of and hence make life less complicated for the user. Time is a limited currency, which cannot be bought nor kept; therefore the additional timeslot that now arises is very beneficial and thus gives room for new activities and opportunities for the customer. It eventually also affects the customers´ need of space, flexibility and storage.

The thesis work will be conducted at the department Body & Trim at Volvo Cars. This department is responsible for the development of the carriage components. The components involve everything from instrument panels, doors and seats etc. Volvo Cars wants to investigate the use of Body & Trim systems in future autonomous driving.
Volvo Cars is Sweden´s largest car company, that manufactures around 440 000 cars yearly. The company focuses on car manufacturing and is owned by the Chinese firm Geely Holding Group. AB Volvo was established by Assar Gabrielsson and Gustaf Larson in Gothenburg, Sweden with the first car release 14th April 1927. Volvo Cars works towards developing, designing, marketing and manufacturing cars all over the world. Volvo has approximately 20 000 employees. Most of the R&D takes place in Gothenburg, with the main production taking place in both Sweden and Belgium. There are also production sites in China as well as an R&D

office. Volvo consists of several platforms with different models in each, distributed in over 100 countries around the world.

1.2. PURPOSE

This thesis will propose a conceptual design from a Body & Trim perspective that can be implemented in future self-driving cars with focus on functionality. A thorough evaluation has to be made of what the most suitable designs can look like that fulfils the customer needs the most. However this will be with respect to the limited volume space in the car. A small prototype will be built and showcased at Volvo Cars.

1.3. DELIMITATIONS

The solutions will be implemented in the all-new XC90 model; therefore it is limited to its volume space. The software architecture and the function of electrical components won't be considered since the department, where this thesis work is being conducted does not have those implementations as its responsibility. Since the car will use an automatic transmission with a shift-by-wire technology, the gearstick will be integrated in the instrument panel or the steering wheel and the space usually covered by the tunnel console freed up. The actual placements of the engine and powertrain components are not considered in this project. Neither will there be any focus on the components of the suspension system. Considering the depth of this thesis work the solutions will be very approximate, meaning that the physical layout will be of bigger concern rather than the technical details. What is interesting to see in this thesis work is firstly what do people want to do in a car when they are not driving? Secondly how can it be implemented from a packaging perspective?

1.4. PROBLEM DEFINITION

Many large companies are predicting that autonomous drive is going to be the next big thing within the auto industry. Project such as Volvo Car´s "*DriveMe"* and "*The Google Self-Driving" car* project are only to mention a few. Many of these big companies see a benefit with self-driving vehicles from a safety and environmental perspective. However, when this technology is implemented and eventually launched on the market the questions still stands, what do the humans do when not having the responsibility of maneuvering the car? This is a timeslot, which can be spent on working, sleeping, eating or chatting etc. Basically the interior and exterior can be redesigned in order to fit the user and his or her capabilities. This can create new opportunities for space, flexibility and storage since things that is no longer used can be removed. It can also create convenience, comfort and freedom to spend time more efficiently. The CEO of Mercedes Benz, Dieter Zetsche says that true luxury in the future will be quality time and private space (PCMAG, 2015). Thus this is the problem definition in this thesis work: What can people do in a car when they do not have the responsibility of driving? How can such an interior look like? Obviously with respect to the volume space in the all-new XC90 model. These are the questions that will be answered in this thesis work.

2. THEORETICAL BACKGROUND

This chapter will provide a short theoretical framework of the functions of a self-driving car along with its societal implications. The chapter will also describe the Body & Trim components looked at in this thesis work.

2.1 SELF-DRIVING CARS

According to *The Economist* a self-driving car is a logical extension of existing driver aids such as lane keeping systems, adaptive cruise control, auto-parking, emergency braking and satellite navigation systems all tied together using software supplemented with sensors (The Economist, 2013). These sensors read road signs, lane markings and identify pedestrians by using a combination of cameras, radar and lidar. The system today still faces challenges in snow-covered roads and reading of temporary road signs, but technology is still improving.

There are five levels of different vehicle automation degrees according to the federal highway research institute, *BASt-Expert-Group*. These can be seen in the image below;

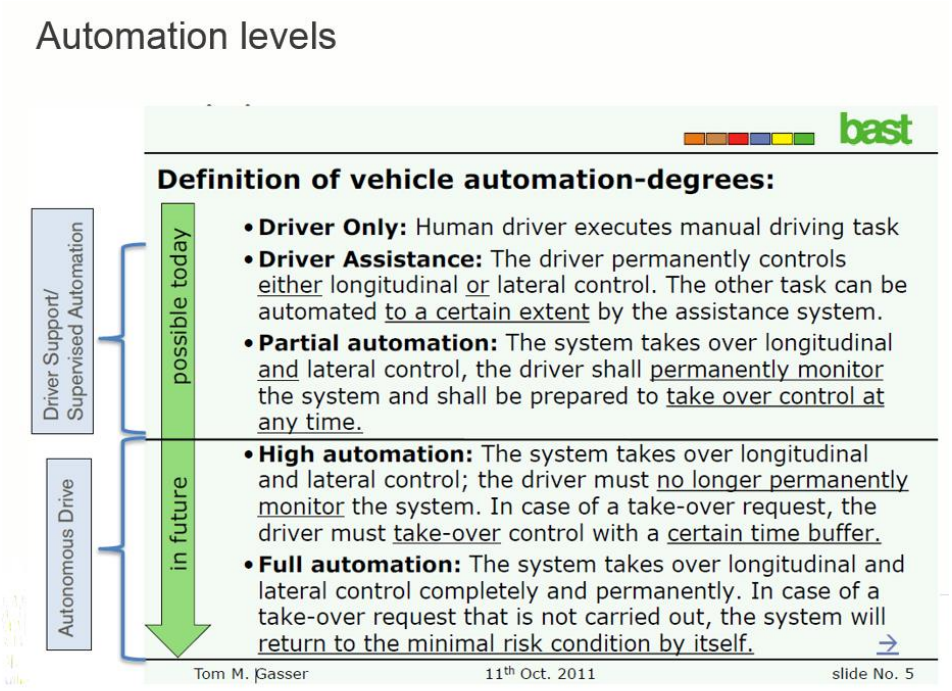

Figure 1: Automation levels (Brännström, 2013)

As you can see in Figure 1 Level 1-2 (not counting driver only) is already existing in cars today, while level 3-4 are for the future. Many companies are already working on developing these

systems for these respective levels. In this project the target is to develop concepts with the prerequisite that it has a level 4 capacity (full automation).

Legally, the self-driving technology is still in its initial stages today, although it has already become legal to test drive in some states in the U.S. namely: California, Nevada, Florida, and Michigan. Even the U.S capital Washington, D.C has approved it. But this only counts for when a human being is sitting behind the wheel as a precaution and ready to step in if necessary. Some car researchers say that if any situation might occur, the driver needs to be able to take control of the car in about 10 seconds (consumerreports.org, 2015). The tech company *Google* has so far been the pioneering company in the world test driving self-driving vehicles on California roads. In Europe, only England has enacted laws for permitting self-driving test vehicles on the road so far (Becker, 2015). Sweden is next country to follow with Volvo Cars launching the DriveMe project in 2017. Another legislative concern is the changes in infrastructure that can be required since these specific cars will initially only be permitted on certain roads. But according to the *Economist,* the technology itself will decide how the law evolves to cope with self-driving vehicles (Hg.org, 2015).

The benefit with self-driving cars is first and foremost safety, since a machine can react faster than a human. It provides better fuel efficiency since speed, distance and energy is controlled. It yields traffic efficiency in terms of a more harmonized flow and usage of roads and provides convenience in terms of time spent on the road (Brännström, 2013). Time is the currency for autonomous driving. In the U.S. the average time of commuting by car to work is 24 minutes (Brännström, 2013). According to *Forbes*, people in the U.S. spend about 157 hours per year, thus autonomous driving can prove to open up possibilities to use this time more conveniently (Ozimek, 2014). Nevertheless fully autonomous cars (level 4) are still a far off from actual commercialization. *IHS Automotive* predicts that these cars will emerge on the market in year 2035 (Tannert, 2014). Many predict as well that the future of the auto industry lies in mobility on demand services and car-sharing, thus neglecting ownership of a vehicle. This will be very beneficial especially in urban areas where congestion can be reduced because of fewer cars on the roads.

2.2 BODY & TRIM COMPONENTS

Body & Trim is a department at Volvo Cars that is responsible for the carriage components of the car. These carriage components consist of Painted Body & Closures, Exterior parts, Interior parts and Climate Control systems. In this project the group only decided to focus on the interior part and the climate control systems, since it is the parts that is in direct contact with the passenger. As mentioned earlier the car model used in this thesis work was the all-new XC90 (see Figure 2) that was launched earlier this year. Down below is an overview picture of the interior and the respective components looked at in this thesis work.

Figure2: B&T components (Jalopnik, 2015)

3. METHODOLOGY

In this chapter you will find a description of the different methods that has been used throughout the thesis project. The sequence of methods used will follow the same order the project progressed. The chapter will include the initial phase followed by the concept- generation- and evaluation phase.

3.1 TIMEPLAN

A Gantt-chart was created in the initial phase to showcase a time plan for the project (see Appendix A). This provided the group with a schedule that would give a clearer overview of the project that would comprehend 20 weeks of full work. The first draft of the Gantt-chart was made after consultation from the supervisor at Volvo Cars, but was updated throughout the course of the project. In the beginning time was spent on gathering data collection for the project, thus interviews with experts and user was conducted as well as a benchmarking study on existing designs. This was followed by concept generation- and evaluation. In the end phase of the project the time was dedicated to design work and writing on the final report.

3.2 MARKET ANALYSIS

A market analysis was made in order to find different competitors and as well elicit customer needs. The information gathered here would set the course for the rest of the project since outcome of this project was poised to be a customer-oriented solution. The market analysis involved benchmarking, interviews and observations.

3.2.1 BENCHMARKING

A benchmarking study was conducted in order to elicit any type of similar or existing solution on the market (Ulrich and Eppinger, 2012). The key was to elicit the specific design layouts and packaging solutions. Focus here would not lie on finding relevant technical data from the competitor since the purpose of this project is not detail construction, but basically to get a glimpse of where the competitors are heading and how far they have reached in terms of design, functionality and packaging. Down below is a list of the companies the group choose to look into.

3.2.1.1 RINSPEED “EXCHANGE CONCEPT”

Rinspeed is a Swiss automobile manufacturer and tuning designer. They have launched a driverless concept car called *ExchangeE* where the interior has been turned into a private room where meetings can be held or where a person can relax. This concept car has luxury business class airline seats that can swivel around in any direction. There is room for four people, which makes it an excellent place to have a meeting in. There is an infotainment system that gives access to extremely fast cloud connection. Steering is optional, whereas the steering wheel is located in the middle of the instrument panel (Figure 3). It functions by the “steer-by-wire” technology. It has hands -on recognition, drive-mode manager display in the rim and transparent multi-function keys with ambiance lighting. It has a movable lightweight steering column with bionic design. The vehicle has four display screens which includes a 1.2 meter display strip in the steering wheel and a gesture controlled 32 inch- 4K monitor in the rear that transforms the car into an on -demand UHD movie theatre. The LTE connectivity links to other data sources tapping into travel-specific Cloud services such as warning messages, recommendations or driver's route (Emirates 24|7, 2014).

Figure3: Steering wheel in the middle (Emirates247, 2014)

3.2.1.2 RINSPEED “Budii” CONCEPT CAR

Rinspeed is continuing on the autonomous track with the “Budii” concept car. It is basically a recreation of the BMW i3 EV but in self-driving format which was unveiled at the 2015 Geneva Show. The car can both be driven manually and autonomously. This is done through a movable steering wheel that is mounted on a seven axis robotic arm. Here either passenger can acts as the designated driver. This works by the steer-by-wire technology. Whenever no one wants to drive, the steering wheel can be placed in the middle to free up space for the passengers. A screen is provided in the centre that works as a central control unit for all gadgets, here the navigation, music and ventilation can be set. The infotainment system is innovative in such that it identifies the habits and preferences of the driver in order to reduce operation steps for him or her. Overall there is an additional screen on each of the two sun shades. To ensure privacy in the cabin, folding fans are provided on the windows, these are decorated with custom graphics. The interior has silver and midnight blue “skai” surfaces and cognac –colored textiles with signal orange highlights. It has instrument panel air outlets with ambient lightning making it look futuristic. The centre console is equipped with cup holders and stowage compartments for cell phones with an inbuilt inductive charging function (see Figure 4). The car has suicide doors that can be opened electronically with a touch function to ease ingress and egress (Caranddriver.com, 2015).

Figure 4: Inductive charging function (BMW Blog, 2015)

3.2.1.3 MERCEDES BENZ “F015 LUXURY IN MOTION”

Mercedes Benz is advancing within the autonomous driving market and has really made an effort into making the interior comfortable for the passengers. With their new concept car *F015-Luxury in motion* they are taking comfort to a whole new level. It is a carriage look alike with the wheels almost out on the edges that measures 5 m in length and only 1.5 m in height. The long windshield morphs into a sunroof as one unit as it swoops over the vehicles roof in the interior there are six high-resolution touch-screens displays situated on the doors that allows the passengers to use touch, gestures or eye movements to browse, navigate or communicate with the outside world (Mercedes-benz.com, 2015). The windows are used as screens. It has four rotating chairs that allows the passengers to sit face-to-face or the “driver” can choose to rotate his chair into a driving position and put on ‘manual drive’ on the steering wheel (Figure 5). The seats belts are directly integrated in the seats. Note also that the seats rotate 30 degrees automatically once the doors open so that it is easy for the passengers to get out. The vehicle can also communicate with its surrounding with the help of LED lights on the front and rear end. For example indicating with a flash or a sound if it's safe to walk for a pedestrian (Santus, 2015).

Figure 5: Rotating chairs (The Car Connection, 2015)

3.2.1.4 THE AKKA “LINK & GO” CONCEPT VEHICLE

AKKA Technologies is a European Engineering and Technology Consultancy Group that offers technical services to major industrial clients.

At the Geneva Motor Show, 2013 they launched a self-driving electric concept car, designed for urban environment called Link & Go. The purpose is to reduce environmental impact of urban transport. The car is small to its stature and has hexagon formed doors that opens laterally for easy access. It has a four seat modular interior that can be transformed into a lounge environment when it’s in self-driving mode. The front seats are rotatable 180 degrees and the rear seats are merged looking like a sofa (see Figure 6). The steering wheel is retractable inside the instrument panel in order to create extra space. In between the two front seats it has a central touch screen that controls driving modes, navigation, social media etc. But to enhance the togetherness between the four passengers a lounge screen has been provided on the upper side panel to provide entertainment. The screen can be controlled by gesture and touch recognitions systems. The plan for the future with the Link & Go vehicle is to use it for car-sharing and car-pooling by the help of social media apps. This will contribute to zero-emissions in the urban cities and create fluidity in the traffic (KGaA, 2015).

Figure 6: Lounge environment interior (Designboom, 2014)

3.2.1.5 VOLKSWAGEN TRIMARAN CONCEPT

In the year of 2012, Volkswagen launched a self-driving concept vehicle called *Trimaran Concept.* The car is set to enter the market 2025 and is seen firmly within the car pooling and sharing business. The exterior design of the car looks like a space capsule with long panoramic glass in the middle and gullwing doors. The car is a three seater and offers two types of layout modes namely: isolation and participation, giving heed to the individualism dilemma in the car interior (beforeitsnews.com, 2012). When in isolation mode it indicates two front passengers and one rear passenger (see Figure 7). A side surface appears as well to shade off the other two occupants. Here the occupants can have their own space if they e.g. want to sleep or make phone calls. This seating structure is very convenient specifically if you sit with people you do not know. The participation mode is when the rear passenger becomes a front passenger making the three passengers sit side by side in the cockpit. Here they can easily chat and converse. What enables this seating transformation is a sliding function on the seats (Carbodydesign.com, 2012).

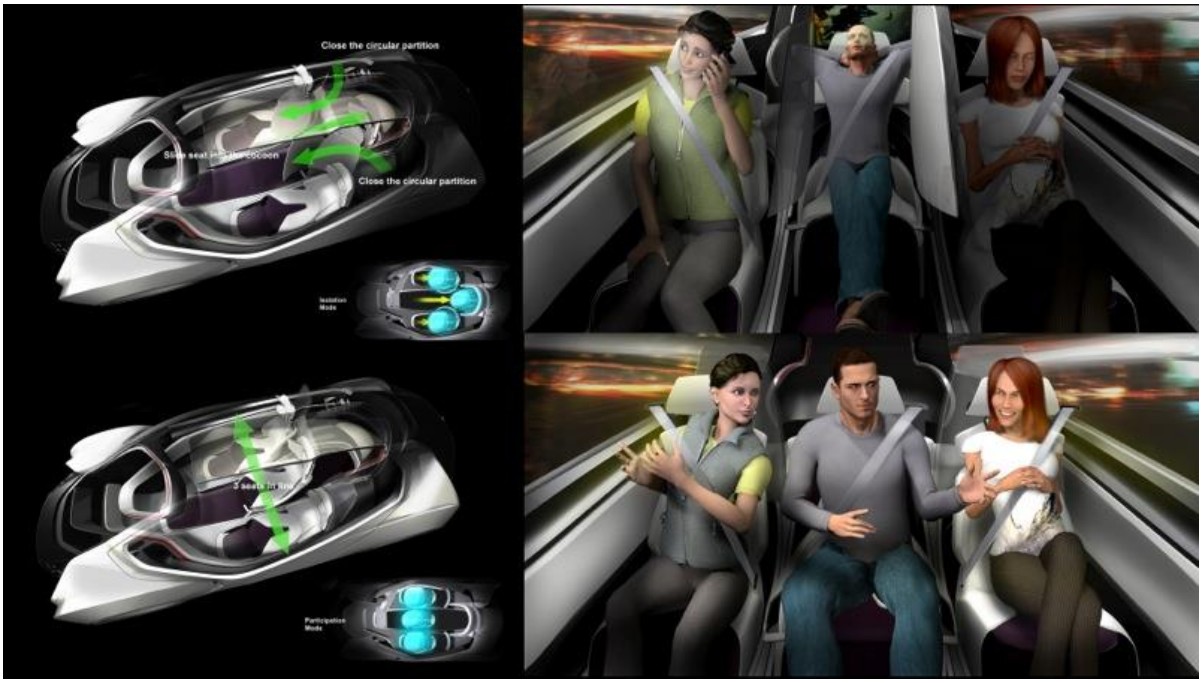

Figure 7: Isolation- and participation mode (About alternative cars, 2012)

3.2.1.6 CHEVROLET-FNR AUTONOMOUS ELECTRIC CONCEPT

General Motors has developed an electric powered concept car called *Chevrolet-FNR*. They launched it on the 2015 Shanghai Motor Show. The car looks very futuristic with its glass capsule design. It has crystal laser headlights and taillights, the doors are dragonfly shaped. The instrument panel is entirely virtual from side to side and the windshield almost being horizontal (Lendino, 2015). The car only starts with eye recognition. It can have a manual mode and an autonomous mode. In manual mode it is manoeuvred by hand gestures control. The seats are rotatable 180 degrees (see Figure 8) so the front occupants can indulge in face-to-face conversations with the rear occupants (Thetorquereport.com, 2015).

Figure 8: Rotating seats (Extremetech, 2015)

Throughout the benchmarking the group realized that many of the large automakers had launched self-driving concept vehicles. Therefore the group chose to only focus on the ones with modified interiors (fully autonomous) and not the ones that have conventional interiors, since focus was on design and functionality. The group discovered a lot of beneficial design layouts and functionalities such as swivelling seats, screen in the windows and retractable steering wheels etc. The main thing that the group discovered was that many of the competitors had their aim on providing spacious interiors where there is possibility to interact with the other passengers, this can be e.g. through a work meeting. Another important thing noticed was the availability of connectivity where the passenger through LED screens could watch movies, play games and communicate on social media etc. All these different ideas enhanced the futuristic state of mind for the group members and this would be vital for the concept generation phase.

3.2.2 INTERVIEW STUDY

Semi-structured Interviews were held with different stakeholders in order to find qualitative data (Ukdataservice.ac.uk, 2015). These stakeholders were both experts within Body & Trim and

people that have busy lifestyles along with being long distance drivers. The purpose with the expert interviews was to gain more knowledge about the development possibilities as well as the different types of constraints for each of the respective Body & Trim components. The group conducted in-depth interviews with long distance drivers with busy lifestyles in order to elicit the underlying needs when driving long distances and getting individual evaluations. The interviews were conducted in a semi-structured manner. The group pondered of the fact to do a quantitative research in the form of a survey for this particular endeavour in order to reach a larger crowd, but the group wanted a subjective response from the consumer, that is very hard to get with a quantitative research method.

3.2.2.1 INTERVIEWS WITH EXPERTS

The group conducted interviews with eleven different experts. Nine of these experts were within the different B&T components regarded in this project, and two experts were within Interior Safety Systems and Active Safety Functions at Volvo Cars.
The purpose with this study was to gain more knowledge from an autonomous drive perspective about each B&T components and their respective constraints, and as well to elicit where Volvo Cars is today in their research regarding autonomous driving. The safety implications were also important to investigate. The group prepared 3-4 questions for each interview. The interview meetings usually started off by the group giving a short presentation of the project and showcasing pictures of the *Mercedes F015- Luxury in* motion and the *Rinspeed ExchangeE* in order to give the interviewee a verbal and graphical insight in what the group wanted to achieve. All the interviews were conducted in Swedish in order to ease the understanding for the interviewee.

One thing the group noticed throughout these interviews was that the experts highlighted how much they were constrained by legal requirements in terms of implementing any major changes in the interior. Thus it was hard for them to give the group constraints in this project since nobody knew what legal requirements there will be 10-15 years from now. This forced the group to make some compromises in what to regard and what not to regard in order to keep the design freedom as large as possible.

However, many of the experts were thrilled by the idea of creating a user-fitted interior for a self-driving car and thus gave the group a lot of inspiration in terms of the latest trends within the automotive industry when it pertains to the B&T components. For example, when speaking to the Glass & Mirror expert she spoke about a technology that enables wider view of the windscreen by projecting a picture of the outside on the A-pillar so that the passengers sees what's behind the pillar. The experts also gave valuable insight to the group in terms of safety. When speaking to the safety systems expert he said that being exposed to a frontal collision when the front seat is rotated 180 degrees is safer than the other way around since the loads is distributed on the surface of the back of the seat which is very large. He also said that the techniques bag-in-belt and bag-in-roof are adequate safety measures if the passenger does not have any airbag in front of him or her.

The knowledge gained from these interviews helped the group in the concept generation phase, both in terms of constraints and inspiration. The interviews can be found in Appendix B.

3.2.2.2 IN-DEPTH INTERVIEWS

In-depth interviews were held with eight different people. The target group involved people in varied ages that have a busy lifestyle and a long way commuting to work. The purpose of these interviews was to see how these people would utilize the timeslot created if the car was fully self-driven (level 4) and their respective underlying needs. This in-depth interview would also give the group a clearer overview picture of how the design layout of the interior might look like. The questions ranged from what they would spend their time doing in the self-driven car to whether they can entrust their life to the technology completely (see Appendix C).

Many of these long distance drivers complained firmly about muscle pain in the back, boredom and problems with being alert when driving very far. If these things were to be vanished due to the self-driven car it would open up a whole world of possibilities for the person to conduct their time more efficiently. Mostly all the interviewees would devote their timeslot to work or entertainment. Work could be things such as answering work related emails, preparing presentations for clients and conducting follow up meetings with co-workers on their way to a destination. In terms of entertainment, people would like to watch movies, play games with other passengers, making phone calls or texting. Many of the interviewees would also love the fact of enjoying a meal or have their morning coffee in the car to add to that. Here they could save a lot of time both in working hours resulting in a person leaving work one hour before in order to avoid the traffic and conducting the last hour work details on the way home. This is also fitting for a person who works late, and now can have their dinner on their way home instead of having to prepare food when they come home. The time saving was highly appreciated. The interviewees also spoke about these self-driven cars being convenient even outside of work commuting, when for example driving to skiing destination with friends or loved ones. Here the interaction between one another, through interactive games like card games and virtual games was something that would be highly appreciated by many of the interviewees. This would for sure eliminate the boredom during an multiple hour drive time. Space and comfortableness was also highly regarded, since today in a car the legroom is very limited. More space would allow many of the interviewees to have a comfortable sleep on their way home for example, this was highly important for the interviewees.

Even though the time slot created by the self-driven car would be very useful, many believed they would have problems with fully relaxing in the initial stages because of lack of trust for the self-driving technology. Some said that they would like to have some form of warning ahead if any situation might occur, e.g. if a sharp turn is approaching the passenger is prepared mentally for it. Similar to the warning signals in airplanes, that indicates tightening of belt. Many for example would still prefer to have some form of steering function, so they are able to feel that they are still in control. This function could not only be limited to a “wheel” but also a joystick for example. People felt that this idea of the self-driving cars would be suited mostly for highways rather than in urban traffic because of traffic complexity with a lot of pedestrians, cyclists and tight intersections. Ensuring safety was definitely the most important factor for the interviewees.

Interesting though was that one person noted that if the passenger is stimulated in the mind with other activities the fear of not having control of the car might be reduced.

Lastly, most of the people would prefer to at times have it quite concealed especially when they are having a business meeting or spending quality time with people. Here many would prefer to have a kind of concealing option more like a “curtain” function, so people can choose whenever they want to be seen or not.

3.2.3 OBSERVATIONAL STUDY

The group conducted an observational study to observe the product in use, this in order to get qualitative data (Strath.ac.uk, 2015). The product in this case was an autonomous Mercedes E-Class and the all-new XC90. An important thing to note was that this was a self-observation, where the group members acted as users of the product. The purpose with this study was to both find out how it feels to be driven in an autonomous vehicle (Mercedes) and to observe the available space and design layout (all-new XC90). With this information the group could find underlying customer needs in terms of driving experience and design layout.

3.2.3.1 OBSERVATION MERCEDES E-CLASS

The group was invited by two fellow thesis workers at Volvo Cars to test drive an autonomous driven Mercedes E- class model. The thesis workers were conducting an observational study on the driver’s perception of the Human Machine Interface (HMI) in the car. So in this study the group members acted as users. The autonomy level of the car was on level 2 (see Figure 1), which basically is when the system takes over longitudinal and lateral control while the driver is prepared to intervene at any time.

At first the car was driven manually out from the Volvo parking lot. When the highway was reached, the user pushed a lever that activated the autonomy function. The velocity was around 70 km/h and the car followed the road path on a straight way without significant problem. During this period it was a thrilling feeling for the user being driven by a self-driven car. It was however during the curves that it started to get uncomfortable, since the car did not follow the road path accurately and thus drove past the road lines. The user had to intervene in order to get the car back on the road again. This caused stress and the user had to sit prepared at all times. The sign which indicates if the car is in autonomy mode was also hard to find as well as the feedback was slow. All these sequences caused uncomfortableness for the user.

The main thing elicited from this study was the lack of ability to trust the vehicle, but when the vehicle did what it was supposed to do the feeling was comfortable. So in a broad sense, as long as the autonomous car does what it’s programmed to do, people will trust and accept the system much faster.

3.2.3.2 OBSERVATION ALL-NEW XC90

An observational study on the all-new XC90 interior was conducted. The group did this in order to elicit existing functions, available space and further design layout.

What the group directly noticed was the limited space that was available, much because of the amount and size of seats and the tunnel console taking up the majority of space. Even if in this project the tunnel console is removed the space is still very limited. The seven seats as well contributes to the space being limited. The seats were covered in leather which enhanced the aesthetics and the premium feeling.

The group noticed that the front passengers wouldn't get a full view from the panoramic roof when they look straight up from their sitting position because the edge is too short. It’s the overhead panels that covered a part of the view. The panoramic roof would also benefit from it being bigger in the longitudinal direction so in case the people in the backseat wanted to relax and lie down they could still get a good view of the sky.

On the instrument panel all the buttons were removed and integrated in a head-up display with touch function in the middle, making the instrument panel look clean. The screen was equipped with smartphone connectivity and navigation, as well as the basic controls like temperature etc.

In the rear middle passenger seat there was a foldable box in the seat where the passengers could place their cups. This is really convenient when wanting to position your drinks. The side panels at the back were equipped with cup holders on each side as well.

3.2.4 REQUIREMENTS SPECIFICATION

After the group had obtained all the information regarding the customer needs, the needs were expressed in the “language of the customer”. Since the solution needed to be designed, a specification of what the product had to deliver needed to be established so the group knew what they were going to deliver (Ulrich and Eppinger, 2012). This had to be done both from a customer perspective (wishes) and from the company’s perspective (demands). The group did these in parallel.

When trying to form a target specification based on the customer needs (wishes) the group intended to follow the four steps that the course literature stated (Ulrich and Eppinger, 2012) which are: *prepare a list of metrics, collect competitive benchmarking information, set ideal and marginally acceptable target values and reflect on the results*. When preparing the list of metrics the group first reformulated all the customer needs into what the system had to deliver (see Appendix D). For example “Provide spacious interior” could be an interpreted customer need. There were many needs that were redundant and thus were removed. The needs that remained were given a degree of importance according to how important it was for the customer. To further prepare the list of metrics one had to construct a so-called Needs-metrics matrix, which is a link between transforming the interpreted needs into metrics, something measurable.

After doing this, the group proceeded with trying to find competitive benchmarking information. The problem here was that the competitors (see chapter 3.1.1) had only released conceptual cars; therefore it was hard to gather any relevant information about these. Since this information could not be found, it was difficult setting the target values. The group therefore attempted to set target values by own means but realized the complexity of the detail level and lack of information. The target specification was then not established in its fullness and therefore discarded. The group opted to instead remain with the interpreted customer needs and its importance levels which is a measure of how important the requirement is for the customer. These importance levels could range from 1 (not important) to 5 (very important). The interpreted customer needs along with the importance levels formed a so called user requirement list (see Appendix F).

After a meeting with our supervisor from Chalmers, the group decided to focus on finding relevant information about the company requirements following three tracks namely: safety, ergonomics and environment. Why particularly these three were chosen was because the product is futuristic and these three things most likely will be at least as strict in the future as they are today.

The group started off with investigating applicable safety requirements first. To do this the group took help from two experts from the Safety Restraints department at Volvo Cars, in order to find some relevant requirements that could be applied. Throughout the meeting the group realized that it was a complex task to attempt. This was based on two reasons. The first was the time

perspective. The interior of a car is designed the way it is because of the legal requirements of today. But since the technology changes with time so will the legal requirements. In 10 -15 years when this product is poised to used there will be other legal requirements. Therefore it was unfeasible for the group to find relevant specifications. The second reason was due to complex detail level. If there were any requirements available that the group could have used the list would have been very long considering that it's a car interior that is being looked at. A car interior has requirements from everything such as strength of the belt attachment to UV-resistance on surface materials on the seats. This is on a detailed level, and the group have had to be qualified engineers in order to redesign a whole interior from scratch with respect to legal requirements. The experts suggested the group to first come up with concepts of different interiors and then study the different collision scenarios on it. For example what happens to the passenger in a frontal collision if the seating structure is formed in this particular way? The concepts that were of most danger to the passenger in a collision is the ones that should be eliminated. How this process went will be described further in chapter 3.4 Concept evaluation.

3.3 CONCEPT GENERATION

This chapter describes what methods the group used when generating concepts. Since the nature of this project was different from traditional product development projects where there is only one product to develop, this project had several products to develop within a car interior thus it was difficult to follow the conventional product development methods. Because of this the group had to consider a whole furnished car interior as a concept and functions within the interior as ideas.

There were modifications made on the methods used in this chapter in order to fit the purpose of the project.

3.3.1 FOCUS GROUPS

A focus group was conducted in the form of an ideation workshop in order to get new ideas and thoughts concerning the interior design from randomly chosen people (Ulrich and Eppinger, 2012). Totally 12 person attended. The workshop incorporated two different exercises. The first exercise involved two individual tasks. The second exercise was a group task. The first task in exercise 1 was called Scenario A, in which the participants on their own wrote down what they would like to do in a self-driven car if they were on the way home after a long day at work. The drive session would last for 25-30 minutes. In the second task the participants were asked what they would like to do in the car if they were traveling in a self-driven car to a skiing destination far away with a group of people. This drive session would last for approximately 6 hours. The last exercise was a group exercise in which each participant was grouped together with one participant, so that the group contained two participants in each group. The assignment was to create an own designed interior of a self-driven car that was user-centred. Also at the same time implement ideas from the first exercise. Their ideas were presented for all the participants on an A3 paper with pictures, note sticks and newspaper material that worked as an illustration for their own interior. This workshop provided more ideas and inspiration that were noted and partially used for the ideation session. See Figure 9.

Figure 9: Workshop

3.3.2 FUNCTION MEANS TREE

Constructing a function means tree was the first step in the concept generation phase. A functions means tree is a graphical representation of what the product needs to do and how it can do it, basically a tree showcasing the entire solution space (Summers, 2014). At the top of this tree, the main function was presented which in this case was; *Utilize timeslot* that is the sole purpose of the self-driving car interior. When writing a solution for this, the group based it on the three main activities humans do in sequence throughout their 24 hours which is; Work, Comfort and Entertainment. These were reformulated into something the car interior had to deliver which is; *Be able to work, Provide Entertainment and Provide Comfort.* These were later expanded where *Provide Comfort* was divided into five subgroups namely; *Visual Comfort, Haptic Comfort, Odor Comfort, Noise Comfort* and *Flexibility.* While the first four subgroups are obvious when looking at *Provide Comfort*, the group also felt that flexibility enhanced comfort as well in the form of a specific function in the interior that makes life easier for the passenger. This can for example be a foldable seat that can be used as a foot rest. Flexibility in itself was divided into the two subgroups; *Positioning* and *Functionality*. *Positioning* is when a certain item is positioned at a location in the car interior that is convenient for the passenger to reach it. A solution to this could be a “fridge in the door panel”. *Functionality* is when a function in a certain item makes the usage convenient for the passenger. An example of this could be an “adjustable table in floor”. One might note that sleep is not mentioned, but the group felt that specifically haptic, noise and some parts of the functionality solutions provide the necessary conditions for sleep.

The second solution in the function means tree was *Provide Entertainment.* This solution could be solved either by *Non-physical activities* and *Physical activities.* A non-physical activity is an activity that does not demand any physical exertion like e.g. playing video games. Physical activities are activities that demands physical exertion like e.g. playing board games.

The third solution was *Be able to work* which was divided into *Individual Work* and *Meeting.* The group wanted to ensure that the passengers both had the possibility to work individually and have group meetings. The function means tree can be seen in Figure 10.

This function means tree worked as a basis for the ideation phase in order to cover the entire solution space. The lowest sub-functions in each branch was the functions that would work as parameters in the morphological “mind map” that will be explained further below.

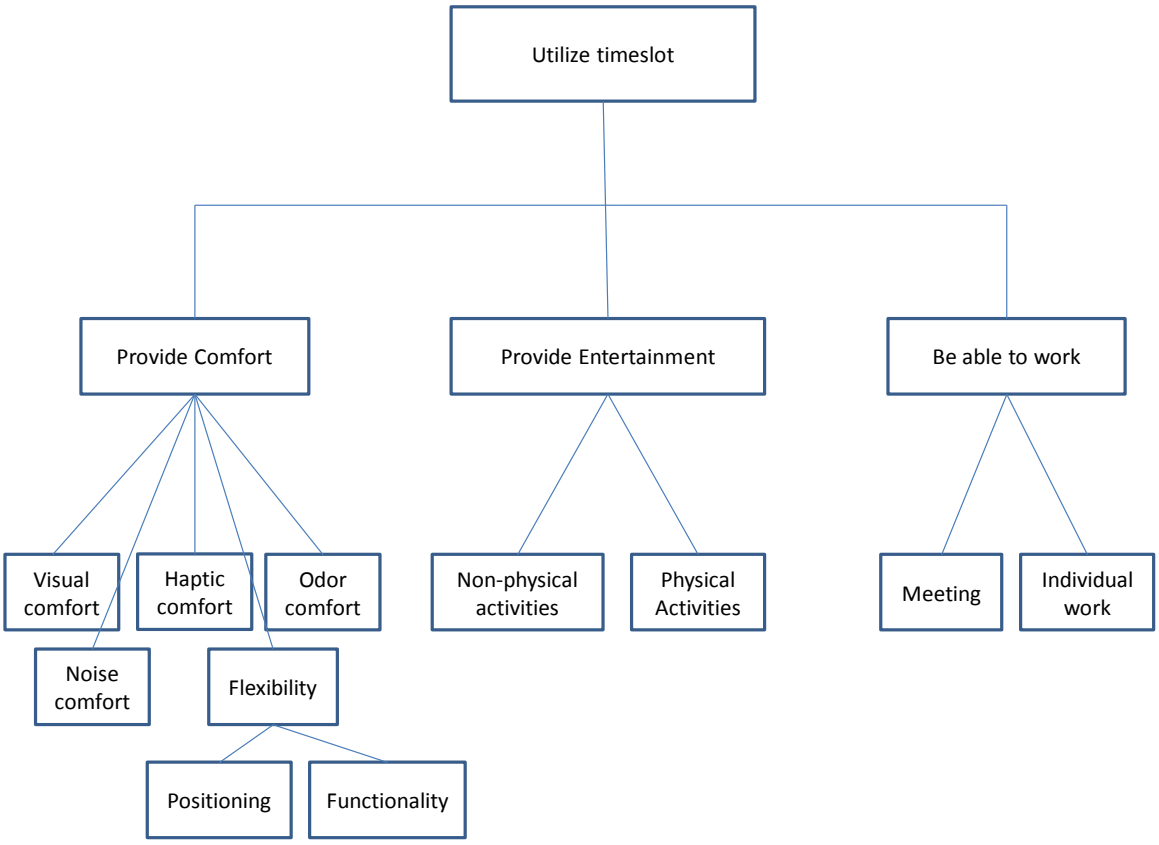

Figure 10: Function means tree

3.3.3 IDEATION

The group first started with an individual ideation session. Each group member had 15 minutes to generate ideas on how to solve all the lowest sub-functions in the function means tree. After the session was over the participants explained each of their own ideas and wrote them down on note-sticks and put them on a corresponding A3 paper. When the individual ideation was done for each component, the group cooperated together and conducted a group ideation. New ideas and solutions were discussed with the help from physical media, the focus group and previously made research to get further information. To gather relevant information the group

looked at truck interiors, airplane seats, train- and yacht interiors. This added a few more ideas on each sub-function. To make it more explicit for the reader each function group had its own colour, however this didn't affect the function of the method. Approximately 135 different ideas were generated by the group. See Figure 11.

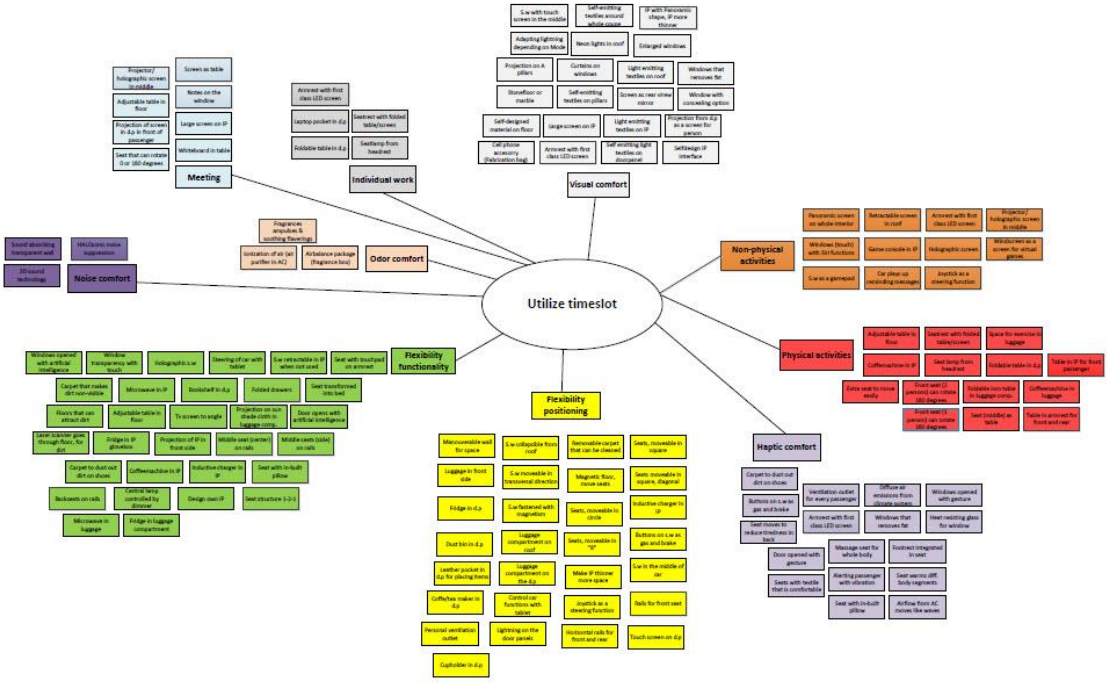

Figure 11: Total Concept Solution

3.3.4 MORPHOLOGICAL "MIND MAP"

All the solutions to the lowest sub functions in the functions means tree needed to be combined in order to form concepts. The group therefore conducted a morphological matrix to combine the different solutions in the car interior that would fit together both from a packaging- and design perspective in order to fulfil every function (see Figure 12). This process did not work as a conventional morphological matrix process would work. In usual product development processes, the solutions to a function is more independent of each other, therefore many solutions cannot be combined with each other that fulfils the same function. In this project, there were many solutions that could be combined with each other that fulfilled the same function. The group therefore relied on synergic design layout and available packaging space in order to combine. The group had three distinctive outlines when combining, each having a certain colour label. One was more technical-oriented with focus on smart technical solutions (red), another one was more focused on solutions that enhanced comfort (blue) and the last one was more focused on solutions enhancing a home feeling (green). All these three were labelled with three different colours in order to see which of the solutions that were combined together. The

solutions that did not get any colour were solutions that were excluded due to impracticality and unfeasibility. All the solutions within the red, blue and green represented parts of a car interior, which could be called concept. In this case a concept could be considered a furnished car interior. One thing to remember though is that all the three concepts (red, blue and green) weren't fully furnished so in order to fill this gap, existing parts from the interior of today remained. For example if the steering wheel was not included in any idea, the group emanated from that the standard steering wheel is there in the standard position. The three furnished interiors were labelled *Concept Smart (red), Concept Relax (blue) and Concept Home (green).* An important thing that the group had to make sure was that all the three concepts consisted of at least one idea on every function so that the concept interior fulfilled the main function which is *Utilize timeslot*. It could happen that some ideas fulfilled more than one function. These three concepts are described in further detail in the next chapter. One thing to note is that a morphological matrix could not be attached in the report due to its large size, therefore the group constructed it as a “mind map" in order to have a better overview (see Appendix G).

Figure 12: Morphological mind map

3.3.5 CONCEPTS

In this chapter each concept generated from the morphological “mind map” is described thoroughly along with its advantages and drawbacks. Each concept as well has a graphical presentation and a summary table of all the ideas included in the concept.

3.3.5.1 CONCEPT SMART

Concept Smart is a four-seater interior focusing on futuristic smart technologies. The seating structure is 2-0-2, where the middle-section has been removed in order to free up space and create a meeting place.

The instrument panel has been made thinner to increase space in the cabin. It has now been transformed into a futuristic panoramic touch screen enabling the front passenger to not only monitor the gauges but also to use it for entertainment, for instance to watch movies. The reason for the panoramic shape is as well to reach synergy with the other screen on the door panel that will be presented further down. The conventional steering wheel has been replaced with a joystick to free up space and enable the driver to use it to play virtual games (synched game console from home in IP) with the windscreen as a screen.

In order to create a wider view of the windscreen without implementing a larger window, there is a technology called *Virtual Urban Windscreen* that projects a picture of the outside on the A-pillars making the A-pillars look transparent and thus enhance a larger view. There have to be researched further if the same technology can be applied on the B and C-pillars, hence the occupants can get a feeling of enlarged windows. The rear view mirror has been changed to a panoramic screen in order to give a wide overview for the passengers of what's happening behind the car and on the sides. This can make the occupants more comfortable especially since the car is self-driven.

To further enhance the futuristic feeling in the car interior, the concept has an integrated screen in the instrument panel that covers the whole sides of the car up to the back. This solution has been called "Screen around the whole car". The sole purpose of this screen is both to enhance connectivity between four passengers by sending images, text messages and playing games but also to act as a lightning source and warning mediator, e.g. if a sharp turn emerges. In order for the passenger to avoid sitting in an uncomfortable posture at all times a holographic screen will be projected from the screen in front of the passenger when e.g. he or she wants to watch a movie, text or play games etc. This screen will increase the togetherness between the passengers in the car.

The windows and doors will not only manually be opened, but can be opened with gesture commands in order to ease the burden of using physical power. Another technology on the forefront is being able to change the transparency on the windows with a transparent touchpad in the window. Just like a person changes the lightning on one's phone. The technology works by varying voltage on electrical polymers that changes colour. This opens up for the passenger to have the transparency of choice whenever he or she wants and not only two modes like it is today.

To enable face-to-face meetings in the interior the front seats were made rotatable and replaced the conventional seats that had two rails with one axis and one rail instead. Here the front passenger in sequence can move longitudinally back and then laterally inwards in the car and thus rotate and revert back the same path. Each seat has a foldable table in the seat rest that

can be used to place items on such as books, accessories and food etc. It can also work as a virtual screen.

There is also a table in the middle section that can be adjust in height and inserted in the floor when not needed. This table can be used for meetings or when playing board games etc.

Every passenger in the car has been equipped with a personal ventilation outlet, similar to the ones in airplanes it is mounted in the roof and every person gets to choose their own ventilation. Since the seating structure in the car is different compared to a conventional car the airflow will be different as well. For example if the front seats are rotated, with the conventional system the air will just flow right at the back of the seat which results in wasted energy. Therefore mounting ventilation outlets in the roof excludes the energy from getting wasted. Beside the ventilation outlet is a personal lamp as well that adapts itself after the mood of the passenger. If the passenger feels tired the light will sense it and thus reduce the lightning.

The climate system still however emits diffuse air in the cabin environment. The interior is also provided with a so called air balance package which is basically a package with four different fragrances of choice, which is integrated with the AC hoses. It is located in the glove box and its purpose is to provide a nice odor in the car cabin. This is good for example when food is being eaten in the interior. The interior also provides sound independency in the form of 3D sound technology where the car is divided into different zones and thus projects the sound in the cabin (alltomcitroen.wordpress.com, 2014); this enables every passenger to have their own privacy. This can for example be convenient when one person wants to listen to music and the other one wants to sleep.

From an autonomous drive perspective this concept opens up the possibility to have face-to-face meetings and for the passengers to conduct shared entertainments such as playing games with each other. The main drawback is the available space there is to rotate the front seats. It may be so that the knees on the passenger sitting in one front seat can collide with the other front seat while rotating.
See Table 1 and Figure 13 for short summary of concept and graphical representation of concept.

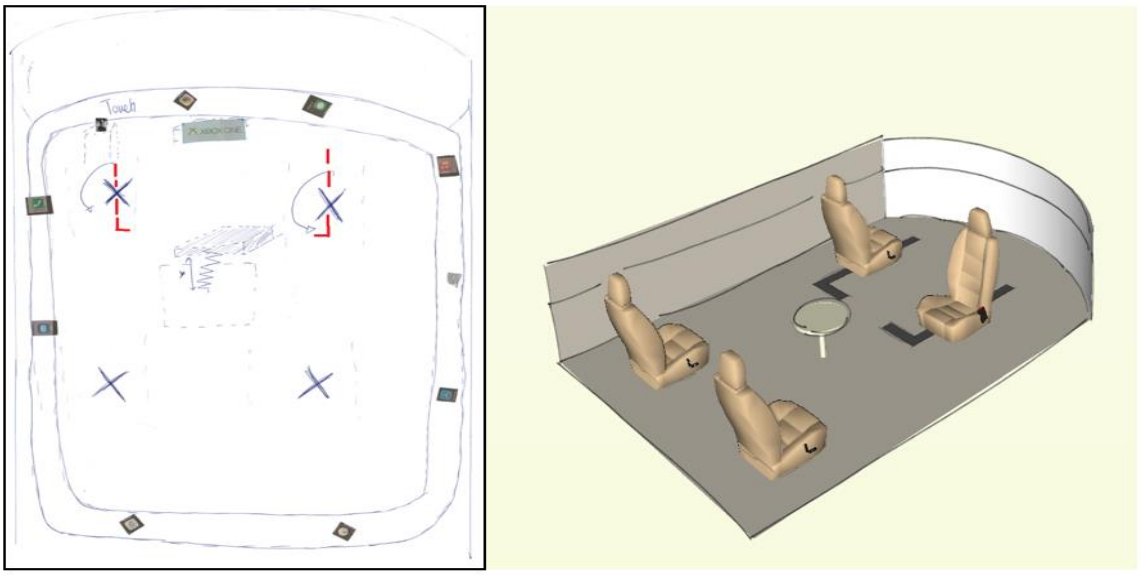

Figure 13: Concept Smart

Table 1: Summary of Concept Smart

Ideas: Concept Smart	Benefit:
Instrument panel has a panoramic shape and has been made thinner.	*Free up space and enhance visual stimulation.*
Rear view mirror on a panoramic screen in the front.	*Provide large overview for what`s happening behind the car in order for the passenger to be comfortable.*
Projection of windscreen on A pillars.	*Enable wider view for front passengers without implementing new windows.*
Light in the interior adapts depending on mode of the passenger.	Relieving the passenger from inserting the setting themselves.
Screen that covers whole inner side of car ("Screen around the car").	*Enhance connectivity sharing between passengers.*
Holographic screen in front of every passenger, projected from "screen around the car".	*Preventing the passenger from sitting in an uncomfortable posture when watching movies etc.*
All side windows opened with gesture command.	*Relieve the passengers from physically opening the side windows.*
Joystick as a steering function.	*Free up space from conventional steering wheel and use it to play virtual games.*
Possibility to open doors with gesture	*Relieving the passengers from*

command.	*physically opening the door themselves.*
Adjustable table in floor.	*Provides possibility for passengers to have joint practical activities e.g. playing board games. Table can easily free up space by being inserted in the floor. It can be used for meetings as well.*
Changing the transparency of the windows with a touchpad.	*Passenger can have the transparency of choice on the windows.*
Game console from home can be synched from IP.	*Enable front passengers to play video games.*
Front seats that can rotate 180 degrees and move in longitudinal and lateral direction.	*Enable face-to-face meetings. Free up space for legroom for front passengers.*
Seat rest with implemented folded table/screen	*Provide placement for food and laptop usage etc. for passengers*
Ventilation outlet for every passenger	*Every passenger can regulate their own AC and get a personal cool environment.*
Windscreen as a screen for virtual games.	*Enables the passengers to have a wider picture.*
Air balance package (fragrance box)	*Provide nice odor in the car cabin.*
3D sound technology	*Provide individualism for every passenger in terms of sound.*

3.3.5.2 CONCEPT RELAX

This concept has its focus on enhancing comfort and relaxation towards the passenger. According to ergonomic studies colour has a big impact on how a person feels in a certain environment and thus enhances relaxation (Shape Magazine, 2011). In this concept self-emitting textiles has been implemented on the door panels, instrument panel and the sides of the panoramic roof. These are the three most visible places in the car for the passenger. The concept is a four-seater with seating structure 1-2-1, middle seats and rear seat being mounted on rails able to move longitudinally. This creates a lot of space for each passenger (See Figure 14). The driver has the steering wheel in the middle and there is a lateral rail that the front and back seat moves on in order to ease the entry level in the car. The front seat is

also rotatable 180 degrees in order for the front passenger to have interaction with the others. Every seat has an integrated reading lamp on the headrest in order to provide a lightning source at a convenient place creating a study room environment. There is a small table on each backdoor panel that can be folded up for laptop usage or when reading books. The front- and back passengers also have access to tables in the armrest. When the passengers wants to take a rest there is an in-built pillow in the head rest that can be folded up and an integrated footrest in the seat.

To provide visual entertainment and enhance the cinema feeling for the passengers a holographic screen is projected in the middle section in the car when the two side passengers are moved back a bit further. The screen is also phase changed for the passenger in the front so he or she also can partake. The holographic screen solution is easily removed when not used thus saving space.

The steering wheel can be electronically folded and pressed in the instrument panel when not used freeing up space for the front passenger.

The windows have an in-built Siri function where each passenger can send messages, place calls or get navigation information. The windows can also be 100% concealed with electronic drawers if the passengers are e.g. going to have a private meeting. The windows have heat resisting properties in order to keep the cabin cool for the passengers in an energy efficient way.

In order to create noise comfort, a so called HAlosonic system can be used which is basically a series of microphones in the cabin that eliminates unwanted sounds from outside. This is very beneficial when sleeping.

To create a nice odor comfort in the car the fragrance CLEAN can be implemented in the Climate System. CLEAN is basically a fragrance that gives a fresh smell to the interior. This can remove the smell of food.

From an autonomous drive perspective the advantages with this concept is that it contributes to a calming effect on the passengers through its different interior functions. This is of great help when the car is autonomous since motion sickness can be reduced (Nhs.uk, 2015). Another advantage is that the steering wheel can be moved away and not take up unnecessary space.

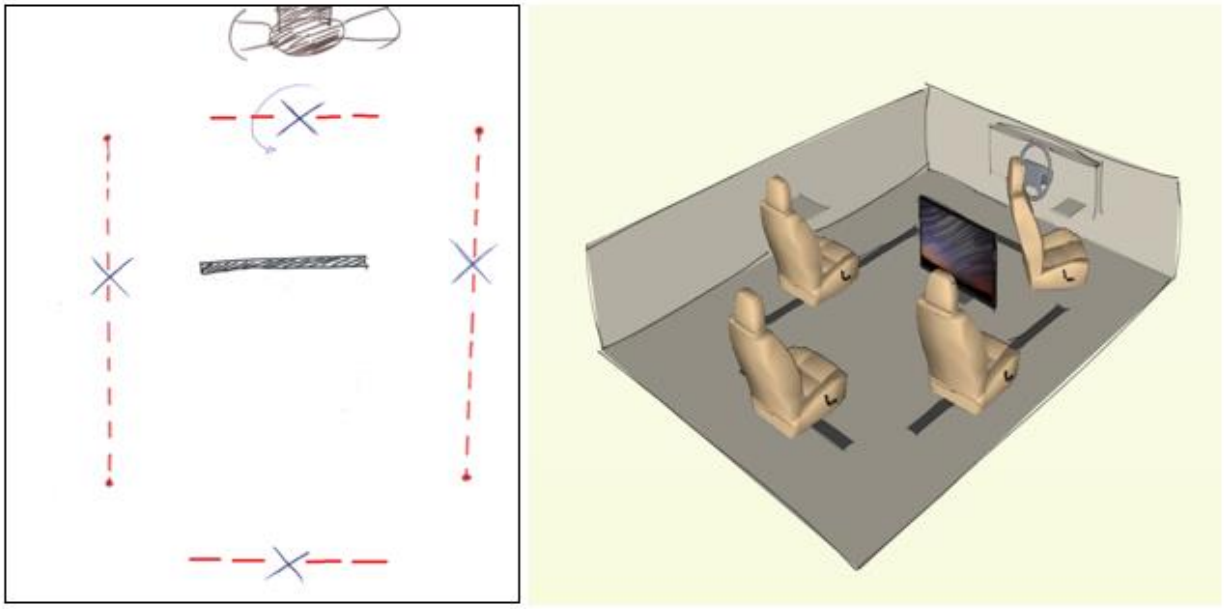

Figure 14: Concept Relax

Table 2: Summary of Concept Relax

Ideas: Concept Relax	Benefit:
Self-emitting light textiles in • *Instrument panel* • *Door panel* • *Sides of panoramic roof*	*Enhance relaxation in visible places.*
Lamp integrated in headrest.	*Enable a light source in a convenient place for the passenger when e.g. reading books.*
Windows with concealing option.	*Provide a concealed environment for passengers when e.g. private meetings needs to be held. As well to enhance premium feeling.*
Windows (touch) with Siri function.	*Every passenger can be provided by both audio and visual information concerning their surroundings. The information is displayed on the*

	window.
Windows glass with heat resisting glass.	*Provide a cool environment for the passengers in an energy efficient way.*
Seat with in-built pillow in head rest	*Provide comfortable place for head when sleeping.*
Seat structure 1-2-1 with rails on middle seats and back seats.	*Create space for all passengers.*
Front seat rotatable	*Enhance community between the front passenger and the back passengers.*
Projector/holographic screen in the middle section.	*Provide visual entertainment for the passengers at a convenient place. Can be used to have virtual meetings as well.*
S.W retractable in IP when not used.	*Create space in the front section for front passenger/driver.*
Foldable table in door panel (backdoors) for passengers on the sides.	*Provide placement for food and laptop usage etc. for passengers on the side.*
Footrest integrated in all seats	*Provide comfort for legs*
Table in armrest for front and rear passengers.	*Provide placement for food and laptop usage etc. for passenger in the front and rear.*
HALOsonic noise suppresion	*Create a comfortable noise level in the interior.*
Integrate Clean fragrance in Climate system.	*Provide a nice odor in the interior.*
Lateral rails for front and rear	*Ease entry level in car*

3.3.5.3 CONCEPT HOME

This concept focuses on creating a “home” feeling for the passengers. A place where the things a person has in the kitchen and living room is available within a close range. The concept is a five-seater (2-1-2). See Figure 15.

The interior is equipped with dustbin, cup holder, inductive charger (no cable) and fridge in each door panel providing independence for each passenger. There is a coffee machine integrated in the instrument panel. Two coffee cups is mounted on a stool that goes on rails. The stool comes out of the machine when coffee has been loaded, where the two front passengers have access to. This is convenient for a person that did not have time to make the coffee at home before

work. The instrument panel also has two tables for the front passenger's. Here they can for example place their food etc.

The middle seat has rails in order to create space for the passenger sitting in it. It can both move longitudinally and laterally. Lateral movement is beneficial for easing the entry level for the passenger, whereas the person does not have to walk in the car and have a risk of stumbling but can meet the seat at the door. The seat is also angled approximately 30 degrees so that the passenger easily can get seated. The middle seat can be transformed into a table when being folded, providing the back passengers with placement for food for example. It is also height-adjustable. The table as well has an integrated LED-screen in the back enabling entertainment for the back passengers.

Each seat is also equipped with a LED touch screen that can be folded from the seat rest. This can be seen in the first class seats in airplanes.

In order for the passengers to have individualism in terms of sound, a wall that is sound absorbing and transparent can be implemented. This can enable that one passenger can listen to loud music while the other is sleeping quietly. This solution has to be investigated further whether it is applicable to use since it has not been established on the market yet.

To provide nice air quality in the cabin an air purifier ionizer can be used. This machine filters the air in the cabin.

The advantage with this concept from an autonomous drive perspective is that a passenger is easily provided with home appliances close by, this is perfect when driving very far distances and not having time to stop. The drawback can be that the front passengers have no interaction with the rear passengers.

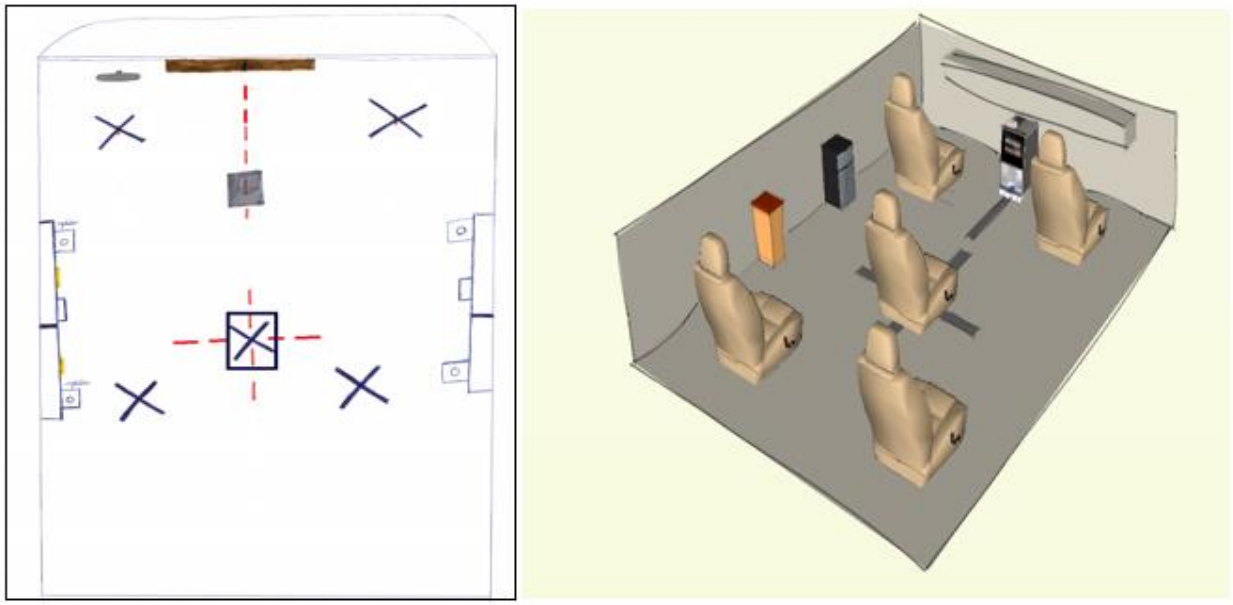

Figure 15: Concept Home

Table 3: Summary of Concept Home

Ideas: Concept Home	Benefit:
Rails for middle back seat (longitudinal and lateral)	*Create space for the passenger sitting in it. Ease the entry level for the middle passenger.*
Dust bin in every door panel	*Provide place close to the passenger for removal of junk.*
Cup holder in door panel	*Every passenger has his or her own cup holder.*
Inductive charger in door panel	*Every passenger has his or her own charging place.*
Armrest with first class LED screen for every seat.	*Every passenger has access to his or her own screen.*
Fridge in door panel	*Every passenger has access to a fridge close by.*
Coffee machine in instrument panel/ Coffee on rails.	*Front passengers have access to coffee.*
Middle seat can be used as a	*Flexible usage, can be used for*

table/screen.	*placing food and for entertainment for the rear passengers.*
Table in instrument panel for front passenger.	*Food placement for front passengers.*
Sound absorbing transparent wall	*Provide a quiet interior for the passengers needing it.*
Air purifier ionization	*Create nice odor in cabin.*

3.4 CONCEPT EVALUATION

In this chapter the different concepts were evaluated towards the customer needs. During this phase however, the group met with a safety expert and evaluated each concept from a collision scenario in order to see if any concept could be eliminated, but no concept was eliminated since there were always modifications that could be made in order for the concept to provide better safety. These modifications could for example be using plastic instead of glass in order to prevent glass fragments during crash. These things worked more as safety recommendations rather than evaluations.
So the group only focused on selecting the concept that fulfilled the customer needs the best. This was conducted by using a Kesselring matrix which is described further down below.

3.4.1 KESSELRING MATRIX

A Kesselring matrix was used to evaluate the three different concepts towards a specification criteria and thus determine its ranking (Ulrich and Eppinger, 2012). The selection criteria in this case were the user requirements. This method provided a great way for choosing the best concept by opting out those concepts that satisfied the requests from the customer the least.

All the needs were arranged with their respective importance on the left hand side. The importance numbers in this case is the same importance numbers from the user requirements list. Each concept was horizontally listed at the top with its weight (w) which is a measure of how well the concept fulfils the customer need. It can range from 1 (worst) up to 5 (best), in which all of these scales are linear. The points (t) are a result of the multiplication between the importance number (Imp) and the weight (w).

During the evaluation each concept were rated against every customer need. The importance for every customer need was multiplied with the selected weight and it got a total point. The total points for every concept were summed up into a total. Concept Smart proved to be the concept that got most points, scoring **259** points and thus fulfilled the customer needs the best, therefore it was chosen as the final concept. See Figure 16. Note that it was far above much better the than the other two since it fulfilled many of the high importance user requirements.

Nevertheless, since Concept Relax and Concept Home fulfilled some of the customer needs that had high importance (Imp = 5) better than or as good as Concept Smart at six occasions, the group did not want to leave out the solutions that contributed to this. Therefore this Kesselring matrix was slightly modified. This was done in order to get a final concept that fulfilled the customer needs in the best possible way but yet excluding subjective assessments. The customer needs with highest importance that was fulfilled best by either Concept Relax or Concept Home were marked with red. The solutions in the concept that contributed to this directly replaced or was added to the previous solutions in Concept Smart. This happened on two occasions.

The first occasion dealt with the user requirement; *enable every passenger to have a comfortable sleeping position,* where Concept Relax was better than Concept Smart. The

“footstool integrated in seats solution” (see Table 2) in Concept Relax contributed to this therefore it was added to Concept Smart. The second occasion dealt with the user requirement; *provide placement for drink and food for every* passenger, Concept Smart did not provide any accurate placement for drinks, while Concept Home did. Here the “cup holder in door panel” solution from Concept Home was added (see Table 3). The “coffee machine in the instrument panel” solution (See Table 3) and “fridge in door panel” solution (See Table 3) was also added in order to further enhance the customer value. Why particularly these two was because the group saw a greater benefit with just being able to store drinks, but now also be able to make warm drinks and contain cold drinks.

The customer needs that was fulfilled by the other concepts as good as Concept Smart was marked with orange. For the ones marked with orange the group decided by consensus which of the solutions that should be added. Motives for discarding one solution could be based on how practical it is in relation to the other solution. This happened on four occasions. When it came to the user requirement; *“provide space for relax able seating position”,* the group decided to remain with the “longitudinal aligned rails” solution (See Table 1) since it was a bit shorter than the one in Concept Relax. There was no need for the rail being long in Concept Smart.

The user requirement; *Every passenger should be able to watch their own movies/programs*, also needed to be discussed. Both Concept Smart and Concept Home provided a screen for every passenger so that they can watch their own movies/programs (See Tables 1&3). The benefit here with Concept Smart was that the screen was multifunctional and could act as a table as well. Therefore the group decided to remain with that solution.

When it came to the user requirement; *provide table for interaction activities*, the group decided to remove the “adjustable table in floor” solution (See Table 1) and add the “seat as table/screen” solution (See Table 3) from Concept Home. This because the group wanted to utilize the option of having five passengers instead of four, since the car originally is a seven seater and four would have been too much of a drastically change. Along with the benefit of still being able to use it as a table and screen as well, that’s why it was chosen. The last user requirement that the group discussed was; *Car has a steering function, pedals and parking function.* As noticed in the Kesselring matrix is that all of the concepts have equal points on this requirement. Here the group then evaluated which of the solution for a steering function (assuming pedals & parking function won’t be changed) would be appropriate. The joystick from Concept Smart (See Table 1) was removed and replaced by the “retractable steering wheel” solution from Concept Relax (See Table 2). This was because of the retract ability function that it provided compared to the joystick. This steering function created space when it was not used, this is very important when the car now is autonomous, why have a steering function in the way at all times?

The group felt that they needed to modify the Kesselring matrix and conduct it in this way since it’s an interior filled with many products rather than only looking at one product therefore it is easy to miss solutions that are better than others. After all this was done the group felt now that they had the concept that fulfilled the customer needs in the best possible way.

	Concepts						
		Smart		Relax		Home	
User requirements	Imp	w	t	w	t	w	t
Warn/alert the passenger ahead of time if any situation might occur	5	5	25	3	15	3	15
Enable every passenger to have a comfortable sleeping position	5	3	15	5	25	4	20
Provide space for relaxable seating position	4	5	20	5	20	4	16
Provide placement for food and drink for every passenger.	4	1	4	1	4	5	20
Enable face-to face interaction between front and rear passengers.	5	5	25	1	5	1	5
Enable to control transparency on windows	4	5	20	1	4	1	4
Every passenger should be able to watch their own movies/programs	5	5	25	1	5	5	25
Provide table for interaction activities	5	5	25	1	5	5	25
Provide spacious interior	4	5	20	2	8	3	12
Things that is not used should be non-visible	5	3	15	3	15	3	15
Provide place for storage of goods	3	4	12	2	6	1	3
Car has a steering function, pedals and parking function.	5	5	25	5	25	5	25
Enable wide view for every passenger	4	4	16	3	12	2	8
Is easy to clean	3	4	12	2	6	2	6
Sum ∑=			259		155		199

Figure 16: Kesselring Matrix

4. RESULTS

In this chapter, the final concept will be described thoroughly along with images from its CATIA V5 presentation. Safety recommendations will also be given.

4.1 DESCRIPTION OF FINAL CONCEPT

As mentioned in the previous chapter *Concept Smart* was awarded as the final concept along with some solutions from *Concept Relax* and *Concept Home* that fulfilled the user requirements the best. Here is a graphical representation of the final concept. The parts that were not part of the idea generation were taken from Volvo Cars virtual database software called Teamcenter, and all the different ideas generated were modelled using CATIA V5. The Teamcenter parts were loaded into CATIA V5.
It should be noted that the Figures in this chapter are functional sketches of the concept and not detailed design.

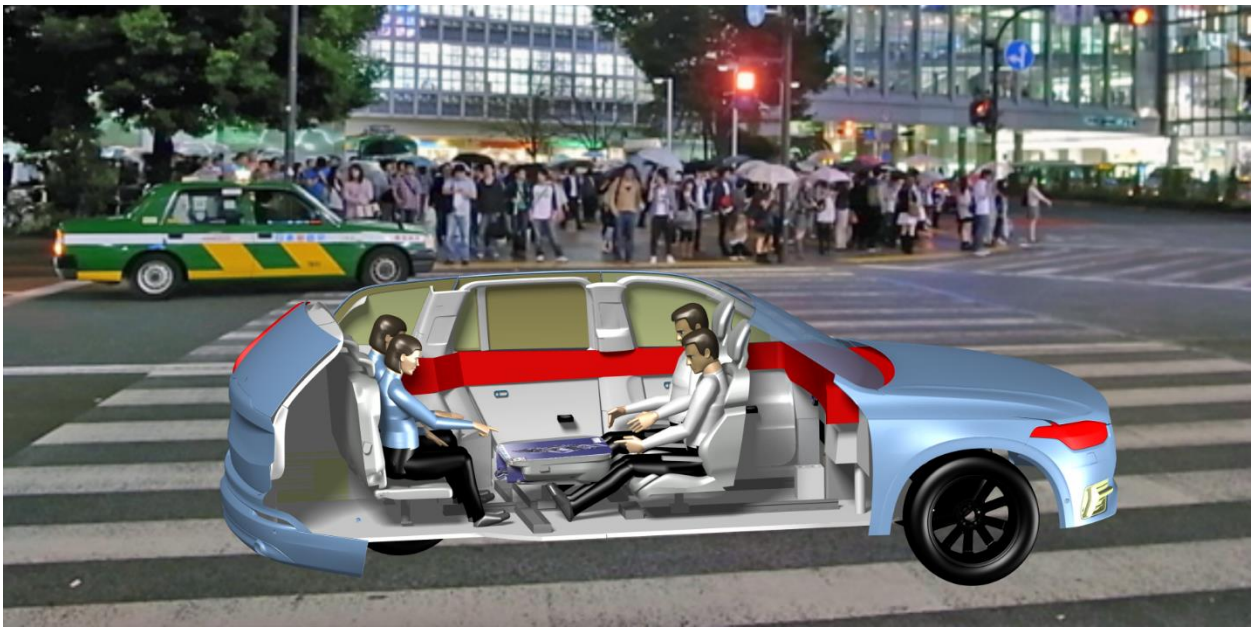

Figure 17: Side view

4.1.1 SEATS

The seat structure is a 2-1-2. The front and middle seats are mounted on rails through an axis and they can be moved longitudinal in order to create more legroom for the passengers (see Figure 18). The seats are standard Volvo Cars seats from the all-new XC90.

The middle seat can be moved laterally as well. The two front seats are rotatable in order to enhance face-to face contact between the passengers. In order for this to happen, the middle seat in the car needs to be moved on its rail laterally and folded (see Figure 19) in order to

create maximum space. The rotation goes as follows; one of the front seats moves backwards until the mid-section and then moves inwardly towards the centre of the car and then rotates (see Figure 19). The same procedure is done with the other seat, when the rotated seat already has moved backwards to create space (see Figure 20). This enables face-to-face interactions between the four passengers and thus makes the timeslot more enjoyable. The rotation is conducted electronically. The rotation is also beneficial when entering and exiting the vehicle. Now instead of having an uncomfortable posture when entering and exiting the car, the seats will now rotate 30 degrees upon entering and exiting making it easier for the front and middle seat passengers to enter. Note that the two front seat has their seatbelts integrated in the seat rather than the B-pillars, so the person still is fastened while the rotation occurs.

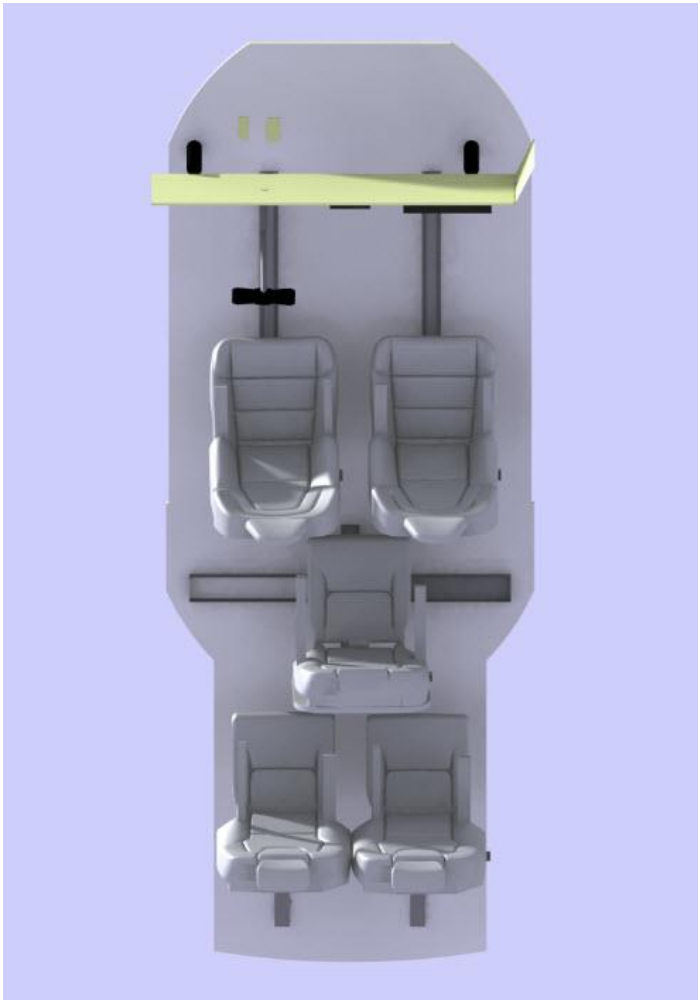

Figure 18: Seat structure

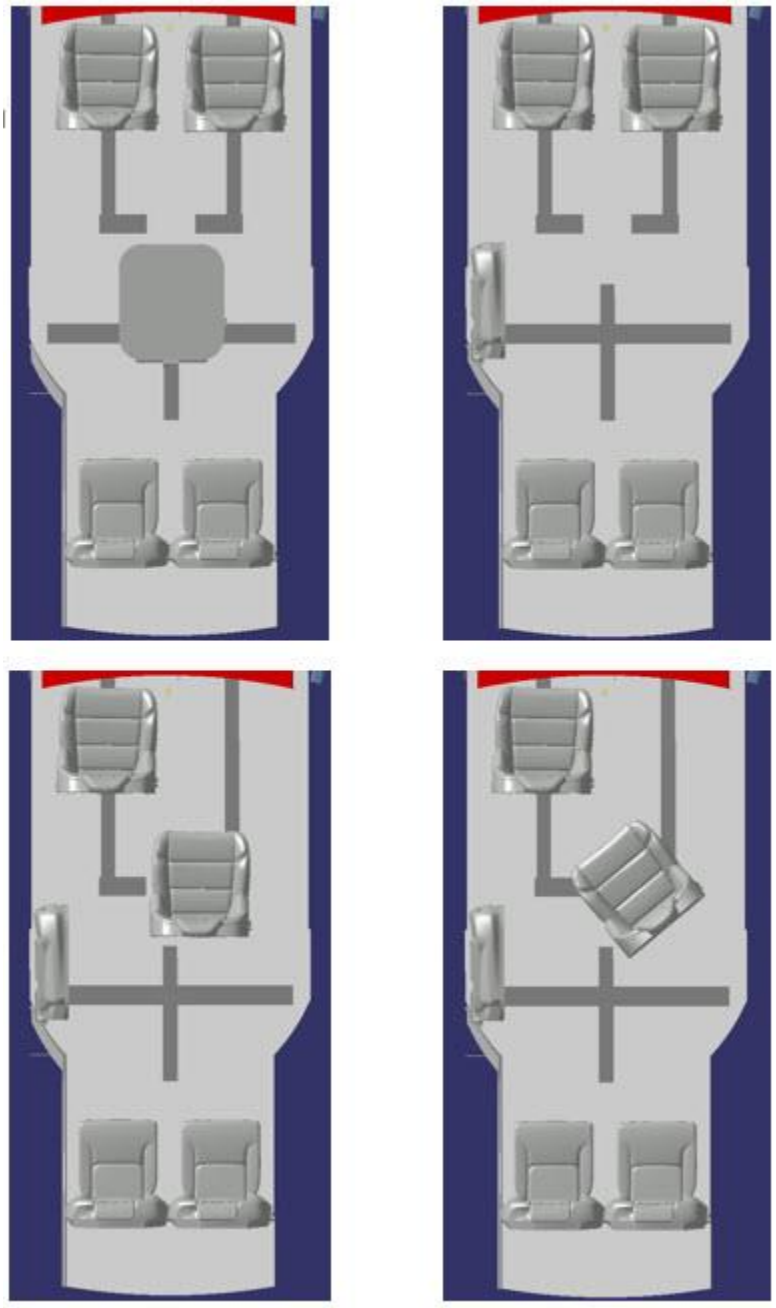

Figure 19: Rotation, Step 1-4

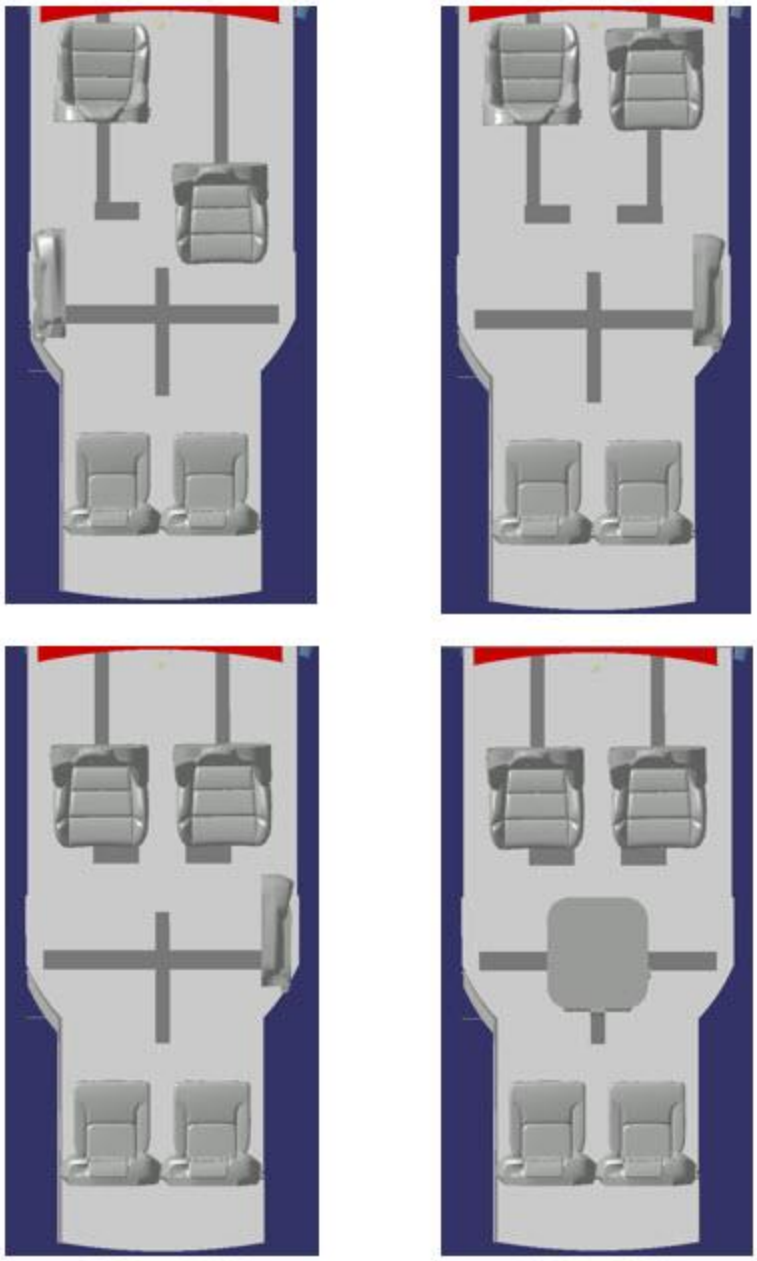

Figure 20: Rotation, Step 5-8

The middle seat stands for flexibility in this concept. It can be folded into a table where the passengers can place items such as documents etc. (see Figure 21). The table has a quadratic form and is adjustable in height in order to fit the user .The table is also equipped with a virtual touch screen that can act as an interactive office desk, a board to play games on or a movie screen. The table has an anti-spill function and is waterproof. Every seat has a table mounted on the armrest through an arm similar to the first class tables in airplane seats, where the passenger can place their belongings such as food etc. This table as well has a mini virtual touch screen on its surface for each of the passengers to use privately like writing emails, playing games and watching movies etc. The front seats and back seats also have an

integrated foot stool in order to increase the comfort for the four passengers. As mentioned before the middle seat can both be moved longitudinally and laterally, this makes its positioning very flexible. If the middle passenger wants to easily exit or enter the car, the seat can move on its lateral rails and rotate 30 degrees. This is a convenient packaging solution or else it can be very difficult for the middle passenger to enter and exit the car without an uncomfortable posture.

Figure 21: Middle seat

4.1.2 INSTRUMENT PANEL

The instrument panel has been transformed from an instrument panel with air vents and a small touch display to a large touch display with a curved and elliptic form that covers the whole panel (see Figure 23). This will give the customer a feeling of being enclosed by the whole screen. The benefit with this new design is that it makes the instrument panel look non-cluttered and clean hence simplifying the interaction between machine and user, it also adds a futuristic look to it with the curved form. All the functions such as gauges, indicators, navigation and entertainment is all integrated in the screen and can be showcased when desired by the driver. The screen can be manoeuvred both by touch, mind-melds gesture and voice commands. While driving alone it could work out as a robot that the driver can talk to. The instrument panel screen can also be synched to the windscreen enabling wider view. This can for example be very beneficial when watching a movie or when conducting virtual meetings.

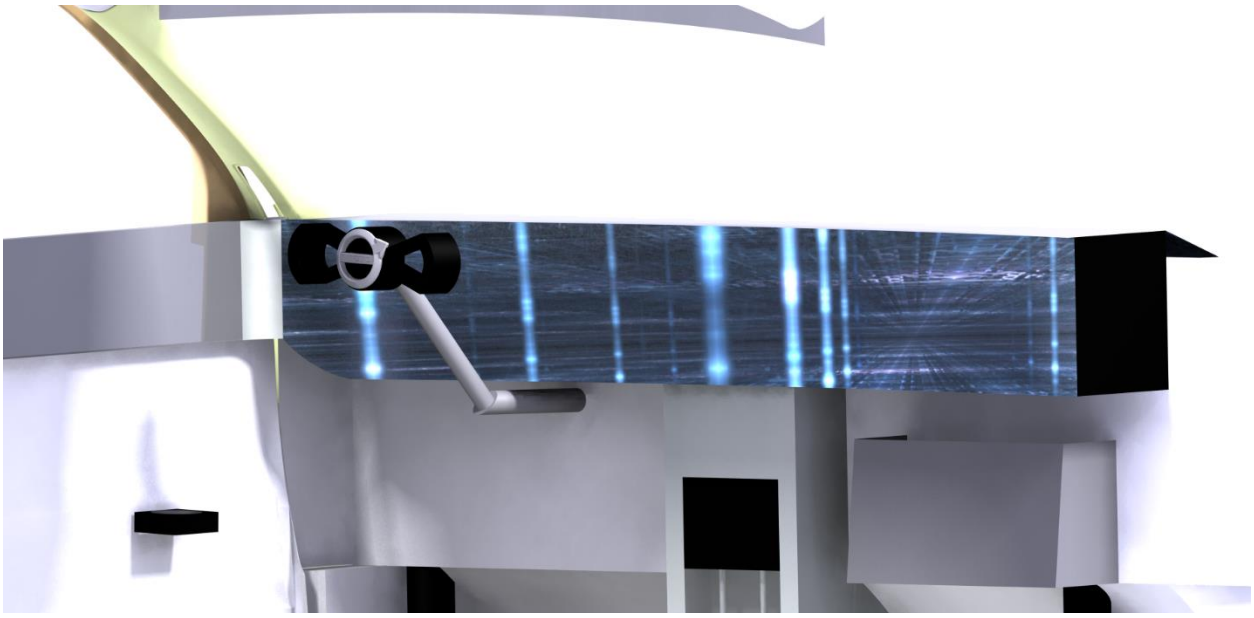

Figure 23: Instrument panel

The instrument panel also has an integrated coffee machine. There are two cups that are placed on a platform that moves on a rail and distributes the coffee to the two front passengers (see Figure 24). If the other passengers want coffee the front passengers can distribute it to the others by handing over the cups**.** The reason why inbuilt coffee machines have had a slow development in the automotive industry is because it was considered as something that distracted the driver. But now since the driver does not have the main responsibility of manoeuvring this is no longer a problem. Coffee is today usually used during social engagements and being able to have a cup of warm coffee in your car whenever you feel like it without having to stop is a luxury in itself. Last of all, the instrument panel is an entertainment centre as well where the passengers can sync to their game consoles at home and play it in the car using the steering function of the car and external controls or gestures and thus display the game virtually on the windscreen.

Figure 24: Coffee machine on rails

The instrument panel is also integrated with a panoramic screen which covers both sides of the cabin (see Figure 25). The purpose is both to enhance the connectivity sharing between passengers by sending pictures or video clips by an easy swipe function and information sharing like navigation and controls of the car. In order for the driver to avoid sitting in an uncomfortable posture, when handling the screen a holographic display can be projected in front of the passenger as an option in order to ease manoeuvring (see Figure 26). This panoramic screen in the interior will bring a sense of togetherness among the passengers sharing information easily between each other and making the utilized timeslot a fun and thrilling experience. It as well adds a futuristic look to the car interior. The instrument panel as well has speakers that project 3D sounds in different zones of the interior. This is beneficial when each passenger wants to conduct different activities and does want to have their own privacy.

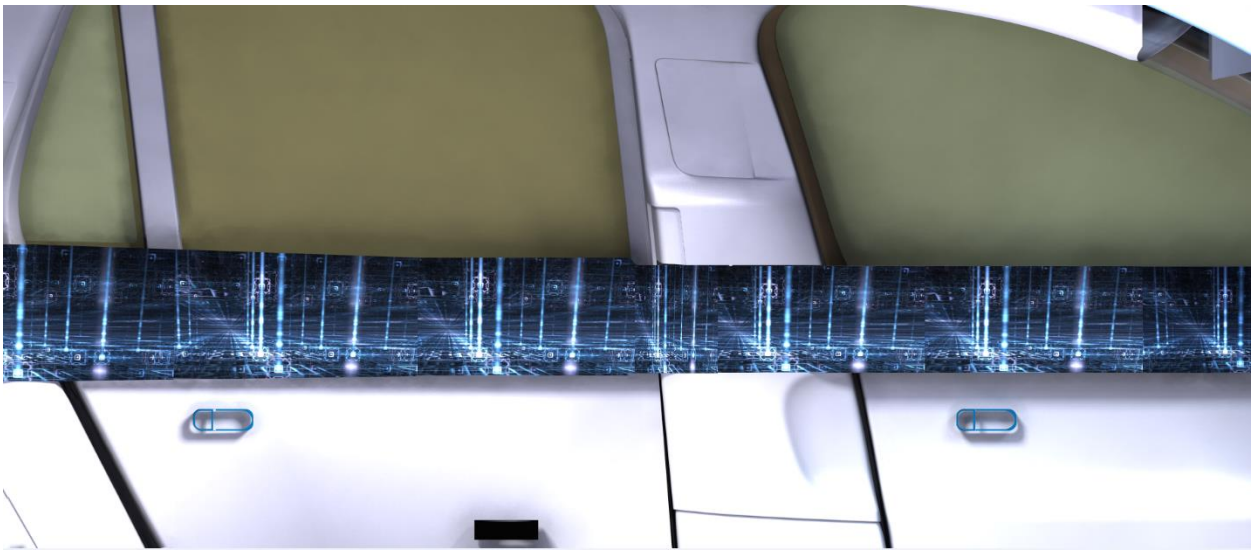

Figure 25: Panoramic screen

Figure 26: Holographic display

4.1.3 GLASS & MIRRORS

A demand from the user study was to enable a wider view of the windows. Instead of reconstructing the windows this could be done by projecting the environment behind the A-pillar on its surface making it transparent (see Figure 27). This is a very efficient method and less costly than manually changing the shape of the windows. However it has to be investigated of whether this method can be applied on the B and C pillars in order to enable a wide view for the passengers at the back.

The rear view mirror has been replaced by a panoramic screen that covers the whole upper part of the windscreen (see Figure 27). This enables all the passengers to get a wide view of what's happening behind the car and on the sides. This function can be activated manually by the user, but if it's not activated the passenger uses the conventional rear mirror that lies behind it. According to our user study, having a wide view of the outside is beneficial from an autonomous drive perspective. The passenger will psychologically feel more comfortable when the car is driving itself, rather than if it was concealed. Another reason why this concept is called *Smart* is that the passenger no longer has to open the window manually by pressing a button. The window can now be opened by simple gesture commands that is recognized by a sensor in the window. This brings a form of haptic comfort, since the passenger can in any posture close or open the window whenever he or she wants. This can be convenient when a person is sleeping or sitting in a meeting and is far away from the window. When it comes to the window

transparency, it is not any longer limited to only two modes. In this concept the transparency will be able to be manually changed through touching in the window, similarly hand movement when zooming on your smartphone. This offers the passengers to decide themselves whenever they want to have privacy or when to be seen.

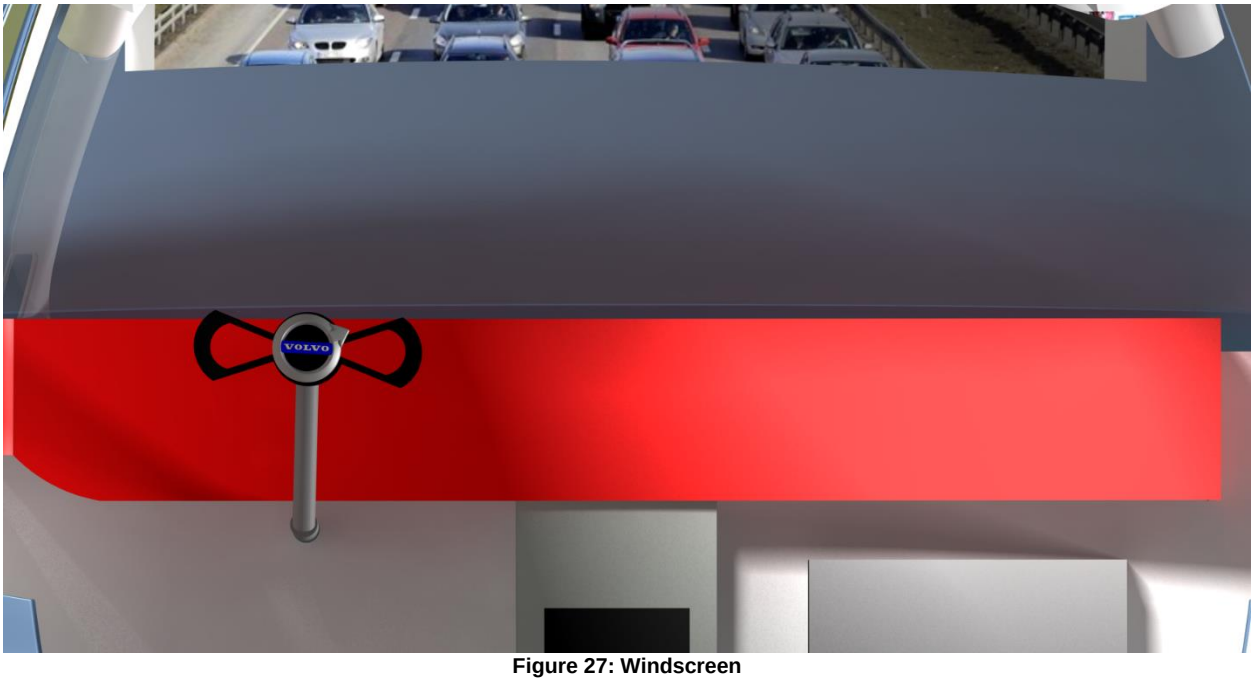

Figure 27: Windscreen

4.1.4 DOOR PANEL

The highlight item on the door panel is the panoramic screen that is connected with the instrument panel screen. The screen covers the upper part of the door panel making it levelled with the front and middle passenger's shoulders replacing the interior panel along with the speakers. For the rear passengers the screen is a bit curved because of the wheels. All the door panels is further equipped with a cup holder in the middle and a fridge on its lower right (see Figure 28). The rear passengers also have access to a fridge and cup holder (conventional). These items enables personalization, each passenger can individually fetch their drink or sandwich whenever he or she wants to without asking anybody for help.

The manual door handle for opening and closing is still available; however the door can as well be maneuvered with the help of hand gestures making the passenger not having to use force when closing.

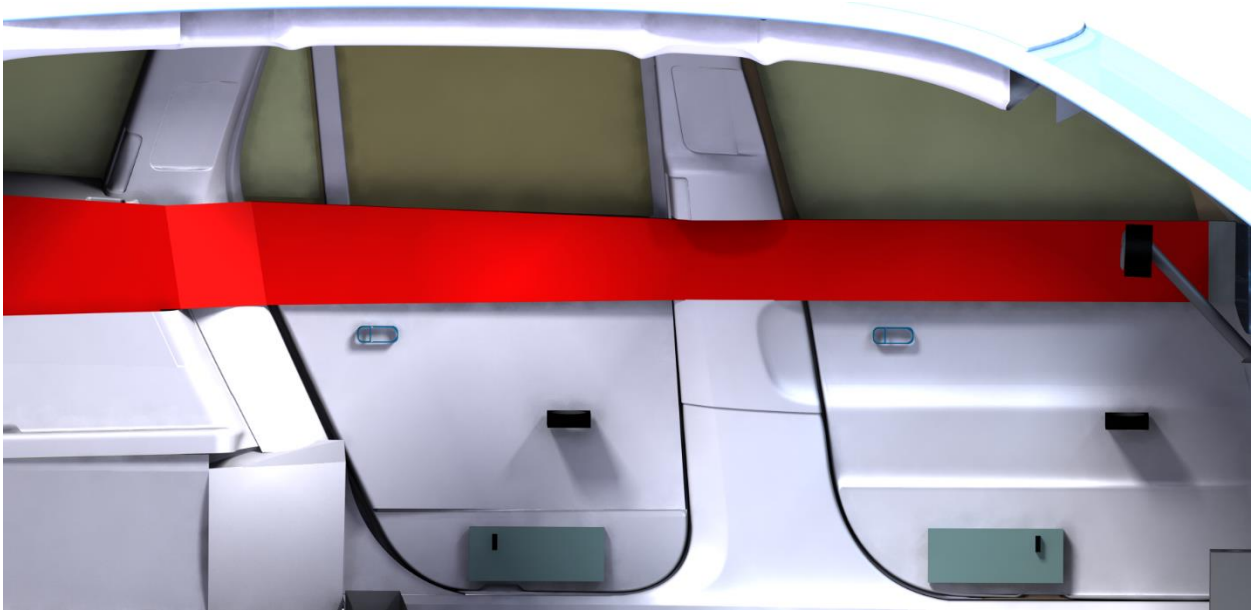

Figure 28: Door panel

4.1.5 STEERING-WHEEL

The steering wheel in this case has been transformed from a traditional wheel to a butterfly shape remote (see Figure 29). The purpose was to reduce the size since it takes up a lot of space today. The steering-wheel will not be used at all occasions considering the car now being self-driven, so therefore in order to free up the space, the two handles can be pressed in and the wheel can be pressed inside the steering column (see Figure 30). It is done automatically. The positive with this is that the system is flexible and the driver does not have to worry about being clamped in a big rotating wheel. This also permits the driver to use the touch screen on the instrument panel without disturbance and free up space to fold back the seat when facing the back against the driving direction.

Figure 29: Steering wheel

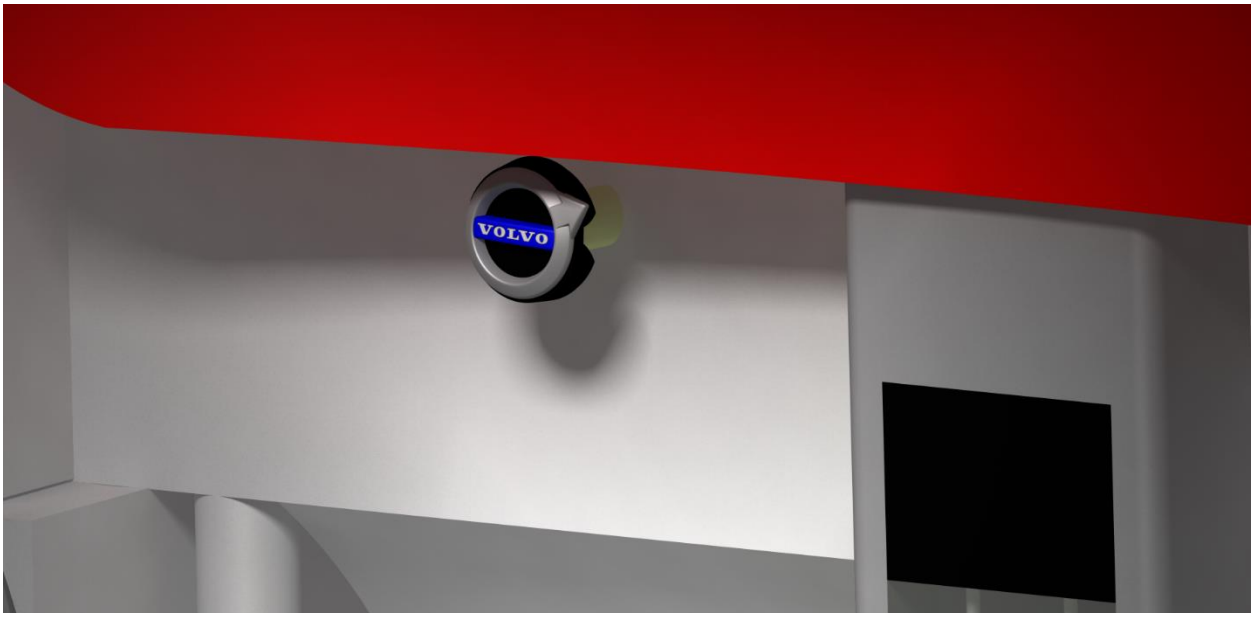

Figure 30: Steering wheel retractable

4.1.6 CLIMATE SYSTEM

The airflow in this cabin will be quite different considering the seating structure not being conventional. The traditional air vents on the face of the instrument panel has been removed and placed on the top of the instrument panel. They are letting out air diffusively cooling or heating the cabin environment and not focusing on cooling the passenger directly. Six ventilation outlets have been integrated in the headlining, one for each of the front and back passengers and one on each side for the middle section (see Figure 31). The passengers can themselves regulate the airflow from their respective touch screens or manually. The ventilation was positioned in this way because of the seating structure e.g. if the front passenger is sitting with their backs faced to the air vents, the energy will be wasted. This enables a better use of air flow within the cabin and is much likened to personal ventilation on airplanes. It is also beneficial for the passenger since he or she can themselves choose what ventilation they want and not be dependent on any other person. This creates a comfort for the individual. The AC hoses in the front is also integrated with an *AIR-BALANCE* package, which is a small glass box that contains four fragrances of the passenger's choice. It is positioned inside the glove box. This adds to the comfort and will thus result in the passengers being calmer when being driven by a self-driving car. This also helps when there is food being eaten in the interior and the passengers still want it to smell nice.

Figure 31: ventilation outlets

4.1.7 INTERIOR LIGHTNING

Having the light on in the car today while driving is considered a distraction for the driver since he or she does not see clearly outside, especially when it's dark and for oncoming traffic. But when self-driving cars becomes more of a common thing in society the drivers will no longer have the need for always seeing out which enables the light inside to be on. The group thought of an idea of having a light that senses the passenger's mood and thus adapts itself after it. This can for example be when the time is 7.30 AM and a person is about to head to work but still wants to sleep in, the car can sense that this person is tired and thus wants subdued lighting and automatically sets it. The same can be said for if a meeting is going to be conducted then the light needs to be strong.

4.1.8 OTHER COMPONENTS

These areas were not developed further due to the existing solutions being sufficient. Applying any solution to Carpets & Headlining would be too much detail, since functionality was the most prominent thing. When it comes to changes in Ornamentation & Roof System will result in exterior changes that are not part of the project scope. The group did not want make any major changes to the luggage compartment because large storage volume was something important for the customers (see Appendix B).

4.2 SCENARIOS

In this chapter the group will showcase three different scenarios in order to provide an overall picture of how certain activities can look like in this interior. The group has used the software

CATIA V5 with the workbench called Environmental Design. This workbench allows the designer to create human manikins. Five different manikins were created in order to showcase humans in interaction within a certain environment. Down below is a short description of the scenarios with a describing picture.

Scenario 1: *“After a hard day of work at Volvo Cars, John is taking a small nap while being stuck in traffic for an hour”*

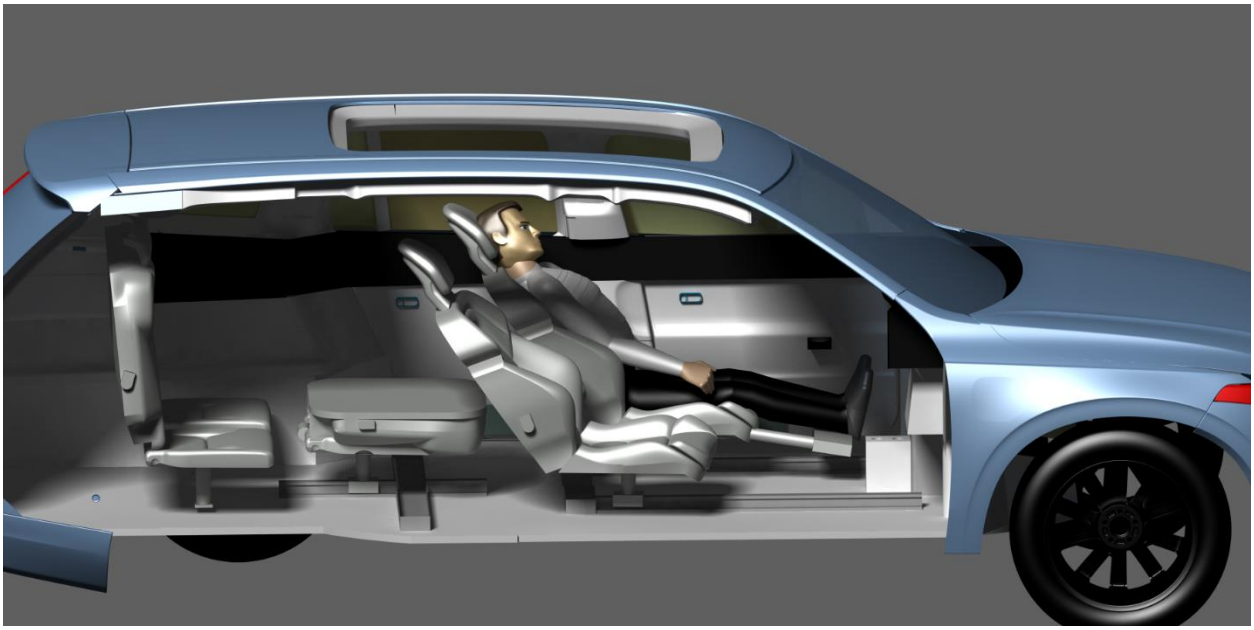

Figure 32: Scenario 1

Scenario 2: *“Four executives had to meet up for a quick update meeting while heading out for lunch”*

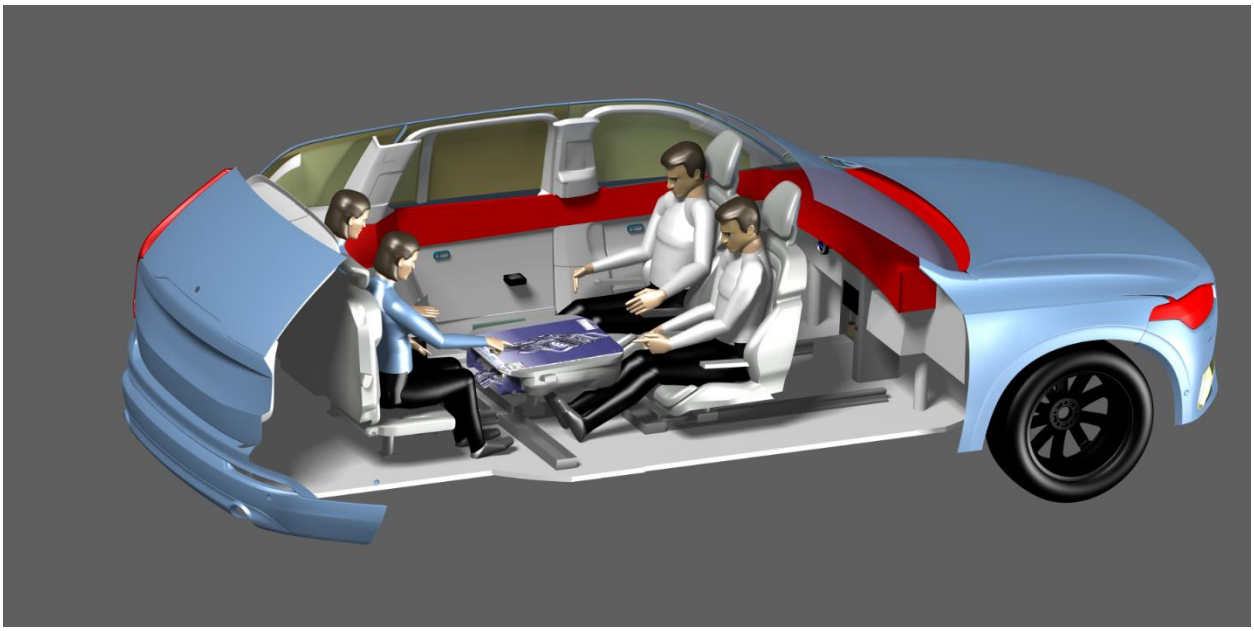

Figure 33: Scenario 2

Scenario 3: *“Five Chalmers students are heading up to a skiing destination which takes six hours. On their way some are playing internet games with each other, while others are watching movies on their screens.”*

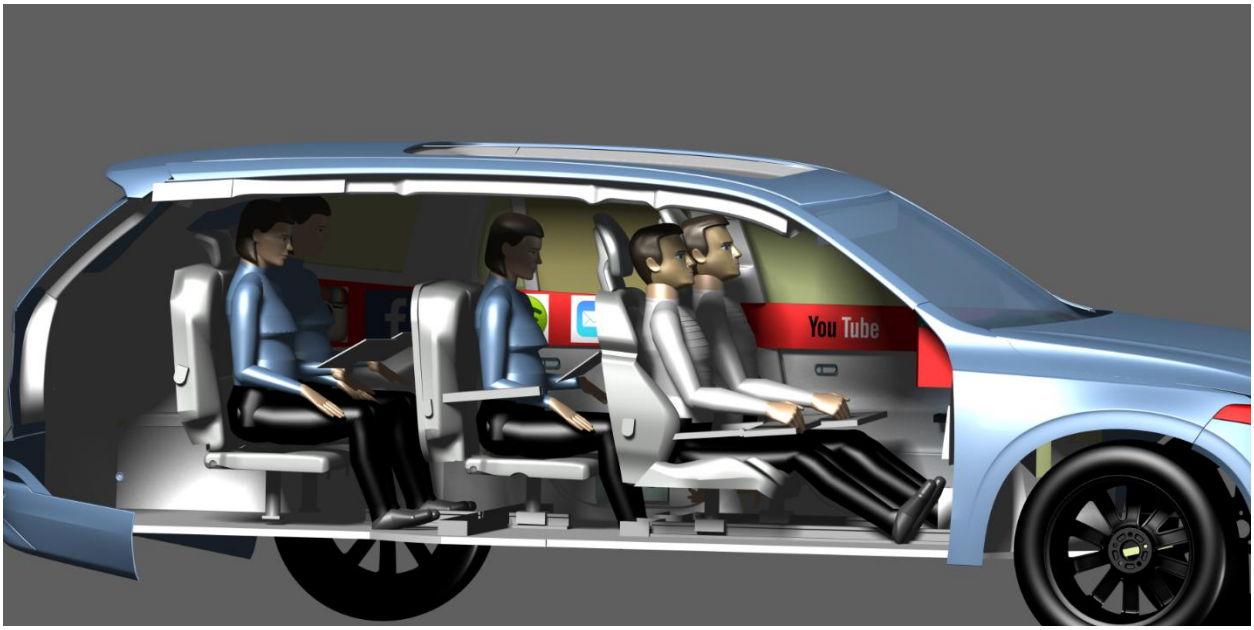

Figure 34: Scenario 3

4.3 SAFETY RECOMMENDATIONS

In this chapter applicable safety recommendations are going to be discussed. Safety cannot be overlooked since the safety demands might be stricter when self-driving cars emerges. Since this concept will be launched in a marketplace where there are still manual driven cars on the road, safety has to be taken into consideration. As mentioned earlier the group met with a safety expert from *Safety Restraints* at Volvo Cars that evaluated the different concepts from a safety perspective. Some of the things that were mentioned in that meeting will be discussed here. The group even applied knowledge from the safety systems expert interview that was conducted in the initial stages of the project.

Since the instrument panel has been covered with a screen all along, the traditional airbag had to be removed from the front passenger's side. The airbag in the steering wheel is still intact. Nevertheless, a frontal collision in this stage is dangerous since the instrument panel is covered with a screen and the shape of the instrument panel being thinner. A company called *TRW Automotive*, a supplier of automotive systems, modules and components are designing a so called *Bag-In-Roof* concept (TRW Automotive, 2015). This is an airbag in the roof mounted on the roof rail close to the windshield. One thing to note is that the front passengers might not always be in a position which is convenient for the bag-in-roof because of the rails neither is the middle seat passenger´s positioning convenient. *Autoliv*, a supplier of automotive safety systems have launched a safety system called *Bag-In-Belt* which already indicated in the name, an airbag in the belt that inflates when sensing a crash. The purpose is to reduce the load on the passenger's ribcage in a frontal collision (Autoliv.com, 2015). This can also be an applicable solution that can be used together with the Bag-In-Roof.

If the front passengers are sitting with their backs against the driving direction, it's the best way to face a frontal collision according to the safety expert since the load is distributed over a larger surface. The drawback however is that the seat needs to be strong which will result in it being heavy and expensive. For the rear seat passengers it's dangerous when facing a frontal collision since they have no protection in front of them available. A company by name *Dainese* that specializes in protective wear for sports such as motorcycling and other similar sports have launched a product on the market called D-Air, which is basically a wireless airbag for motorcycle riders that inflate when the driver falls of the bike. The same technology has already been implemented in seats today. This is very convenient for all passengers since the person is protected regardless if it's a frontal, rear or side collision.

A critical scenario is as well when any of the front passengers want to sleep. This entails that the seat needs to be angled to a certain extent in order to reach a comfortable posture. But the passenger is not protected if a rear or frontal collision occurs because of risk of belt slippage. According to the safety systems expert (see Appendix B) there are two ways to solve this, either to have a very steep airbag in the belt that can hinder belt slippage or for the seat to revert back to its normal position and be protected by a conventional airbag (bag-in-belt/bag-in-roof).

The Safety Restraints expert lastly highlighted that the screen should have plastic as material in order to prevent cuts on glass fragments. Another important thing he stressed was that the passenger should avoid having things in front of him or her like folded tables etc. Here an airbag in the seat, just as mentioned above should be applicable to solve this.

5. PROTOTYPING

Before the project started there was an agreement between the group and the supervisor from Volvo Cars that a prototype would be created with 3D printing technique to showcase the final design of the interior of the car. This would be created in CATIA V5 and the file would be sent through Teamcenter to the prototype workshop at Volvo Cars before being printed out. The prototype model was initially planned to be created in a scale of 1:4 from the original all-new XC90 size, but after some discussion with the workshop the group agreed to create a 1:5 scale instead. This was due to cost and size but also the later scale were more suitable for the project. Both the exterior and the interior of the car would be 3D printed.

The 3D models were initially when loaded still “Surfaces”. During the project it was found that the CAD models needed to be “Solids” in order to be 3D printed. This caused problems for the group. Since the all-new XC90 is a car released just recently, the design model of this car had not been worked with so much compared to previous Volvo car models. So the group needed to convert the CAD models from “Surface” designs into “Solid” design.

The group started with choosing the parts from Teamcenter that needed to be 3D printed. The chosen parts were saved in Teamcenter and loaded into CATIA V5. Totally the parts that had been chosen counted up to 71 different parts. Just when starting to load the first parts into CATIA problems occurred such as to large part sizes. The group therefore decided to approach simplify the models by removing unnecessary parts so that it became a basic structures. After this, thickness was applied so each part could become a solid. This was however a very complex task, since an error message occurred when models were scaled down to 1:5. Another main problem were that the curves on the different parts had a very small radius after it had been scaled down, and when applying the thickness it was proved that thickness got a larger value than the radius of the curve in which resulted in an error coming up.

Due to this problem the workshop was consulted and it was concluded that it would be too complex to 3D print the whole exterior. However there were possibilities for some of the interior parts of the car to still be 3D printed. Concerning the exterior the group looked at alternative methods in manufacturing techniques. Free forming with vacuum forming was the next option to look into after discussing with the supervisor. It was found that the cue for this technique was too long which did not fit the time frame of the project, hence this method was discarded. The next technique to opt for was milling, but proved to be unfeasible since the aesthetics of the prototype would not end up being appealing.

The group therefore choose to 3D print the interior parts. These parts were divided into seven different parts. When completed, each part were saved as a SLS-file which is the format that is required by the 3D print machine. Later on it was sent to the workshop responsible for printing. For the exterior parts the group used a transparent polycarbonate exterior covering the front and one side of the car. The group also used a screen image of the door panel that was glued on the polycarbonate wall. On top of this were pictures of different “apps” glued on the wall as well to symbolise the “screen around the car” function.

The following techniques were used for creating the prototype. The front-, middle seats and rails were created with a 3D printing machine. The back seats, bottom plate and instrument panel were created with the FFF (Field Flow Fractionation) machine and had the material polyamide. The walls of the interior were made with the material called polycarbonate as mentioned earlier. Down below are pictures of the prototype from different angles (see Figure 35 & 36).

Figure 35: Prototype

Figure 36: Prototype

6. CUSTOMER VALUE MODEL

Now when the final results and its functions have been showcased, the question still stands; why does a customer specifically want to buy this product when it enters the market? What customer value does it offer compared to its competitors? This can be answered using customer value models such as a Business model Canvas, Buyer utility maps, Porters Value Chain Analysis Model and the Value Proposition Canvas, according to the Project assignment; *How to obtain and describe customer value (to convince others for investments)*. These methods provide a systematic approach of evaluating customer value of a product business. Many of these methods require a significant amount of data such as distribution channels, revenue streams, logistics and disposal etc. Since the product is not poised to enter the market until 10-15 years from now this information is irrelevant now since no one know what the future holds. However the questions can still be answered using the *Value Proposition Canvas.* This canvas makes explicit how you are creating value for your customers (businessmodelgeneration, 2015).

The canvas is divided into two parts namely; *value proposition* and *customer segments.* The value proposition is in itself divided into three parts which is *Product & Services, Gain Creators* and *Pain Relievers*. The Product & Services is a description of which products & services that a company offers that fulfil the customer needs. The gain creators is a description of how the company's product & services create benefits, the customer expects, desires or would be surprised by (Osterwalder, 2012). Lastly, the pain relievers is a description of how the company's products & services alleviates the customer pains (Osterwalder, 2012).

The second part of the canvas (customer segments) is also divided into three parts namely; *Customer jobs, Gains* and *Pains.* The customer jobs can be the tasks the customers is trying to get done, the problems they are trying to solve or the needs they are trying to satisfy (Osterwalder, 2012). The gains are the benefits the customer expects, desires or would be surprised by (Osterwalder, 2012). Last of all is the Pains which is the negative aspects the customer experience when before, when or after conducting a certain type of task. The purpose is to reach a perfect fit between these two parts (value proposition and customer segment) where the value proposition match the characteristic of the customer segments profile and the customer segment accepts it.

The group conducted a value proposition canvas (see Appendix E) and this tool was very useful in trying to match the customer needs with the product and services thus reach a fit.

6.1 RESULTS OF CUSTOMER VALUE MODEL

Concept Smart reaches a perfect fit with the customer segment characteristics and thus offers maximum customer value (see Appendix E). The two main advantages that Concept smart offers in terms of customer value is utilized time on the road, more legroom and connectivity sharing between passengers. A worker can now maximize his or her work efficiency and thus get x hours of more work done every day depending on commuting time back and forth from the office. This is very convenient for people that works more than 40 hours a week. It's also convenient for busy parents with young children. It is not many hours during the day where they get time to relax since almost the whole day is devoted to work and children. More legroom is

very convenient when traveling far since it increases comfort and enhances better blood circulation. The last thing that brings about the customer value is the connectivity sharing. Today there are many apps that provide these services. Why not utilize this in the car during drive? This will make the drive session fun and get rid of the isolation. This could also change the purpose of the driving experience. The purpose have always been to maneuver the car from place A to B, now there are possibilities for the customers to always enjoy the drive by using these applications and alter the lifestyle of people.

This is what a customer will get when buying this product. It was unfeasible in this stage to gather information regarding pricing since the product is not being launched anytime soon, and many things would have changed by the time it is launched in terms of material and production cost etc.

7. DISCUSSION

One thing we noticed when conducting the market analysis was that competitors only had products in the concept phase which made it hard to conduct a thorough benchmarking analysis. The results may have been different if we had access to data and customer reviews. With this it could have been easier to localize the weaknesses of the product and thus focus our development where the competitor's weaknesses are concerned. It was also hard to delimit our research from the competitor's conventional car interiors. There is a lot of interesting design layouts and infotainment systems that are available even in conventional cars but we found this area too vast to enter into and therefore only focused on self-driving vehicles. The results might have been different if the time and resource had been available to make a diligent research within this area of conventional car interiors.

We contemplated in the beginning by also conducting a quantitative research to add on to the qualitative research. This would be in form of a survey in order to make sure we had covered a large amount of crowd. This might have made the results different considering the small amount of people we chose to interview. However the purpose was to find the underlying needs of the user and this is very hard to elicit when only conducting a quantitative research. We are therefore satisfied with the chosen method but the research could have been better with more people involved. The questions asked during the interview could have had a subjective approach to them, so whether other type of questions had been asked the result of these findings might have been different. The observational study was done during a very short time frame and only one focus group was conducted. With more time invested in the observation study and another focus group with other members the results might had been altered.

Forming the requirement specification was one of the most demanding tasks of the project, where we searched tirelessly to try to find relevant requirements that could be appropriate for this type of concept interior. We wanted to narrow down the design freedom since the solution space was too open. We have at no time previously in product development projects in school worked without adequate requirements. But if it was to be found it would have been too complex since it's a car interior that is being looked at. We therefore choose to focus solemnly on the

user requirements which was the only way. If this was the right or wrong method to use is still indefinite.

When we generated concepts individually, many of the ideas were based upon own knowledge and less from the internet. By this we generated multitudes of ideas since there was no real restriction of imagination. Together with input from internet, experts and the data collection it resulted in many good ideas. If we would have done vice versa, there might have been restrictions in terms of imagination, but since this problem was very futuristic, we had to base the ideas on own knowledge since the market findings are restricted, but not human imagination. It was also difficult to always regard every concept as a room filled with products rather than only looking at only one product. This made us construct modified methods. Individual opinions and subjective assessments may have affected the outcome of the results.

We were used to eliminate concepts on the basis of set requirements from previous projects and courses but since there were no requirements available we had to use the listed user requirements as the evaluation criteria in the Kesselring matrix and thus modify the matrix. The fact that some of the solutions in other concepts were integrated into the final concept might judge the credibility of the final result but since we are looking at a room filled with products we as developers wants to ensure that we give the customer a room with products that fulfils all the customer needs in the best way. Therefore we felt this method was applicable to use. The reason for not using a Pugh matrix was due to the fact that the amounts of concepts generated were too few and therefore we deemed it unnecessary to screen the concepts. If we had gone through both a screening- and scoring matrix, it would have been wasteful in our case. So the group went directly into conducting a Kesselring matrix.

Although we are satisfied with the final results, what's important not to forget is that we wanted to showcase functionality rather than aesthetics and detailed design. If these two aspects would have been considered however, this project would have taken much longer than six months and the complexity level would have increased significantly. What`s important also to note is that the final result was showcased in an all-new XC90 model. This car is designed after the requirements and laws of today and not of the future. Therefore the packaging solutions may not be hundred percent adequate but the importance was to stress the functionality of the solution.

In the early stages we made a clear plan concerning the prototype and 3D printing which seemed to be easy to follow. What caused trouble for us was the fact that the all-new XC90 is a new car that just had been released to the market. There were no design models of the car available that were of solid design, which was a requirement for it to be printable with the 3D printing technique. This led to that we needed to find new ways for the prototype which took much time. The final call was to only create the interior parts with 3D printing, while creating the exterior with a polycarbonate structure and pictures of the door panel and screens to visualize the interior. The prototype would visualize functionality of the interior and not the design aesthetics.

Necessary data about revenue, pricing and logistics etc. were not available considering the final concept being futuristic, we therefore deemed it necessary to showcase customer value in another way namely an: *Value Proposition Canvas.* Had the necessary data been available we could have conducted a thorough *Business Model Canvas* which showcases the business proposition throughout the product's whole life chain. This would have increased the concepts validity in a consumer’s eye.

The project`s nature was very idea fixated and therefore very sensitive to subjective approaches and opinions and thus the result would have definitely been different if it was other people conducting the same project. The difficulty we faced mostly during the project was the task to stay objective and apply the methodology taught from school. This made it hard initially for us since there were so many ways we could choose, but with time and knowledge increasing we felt satisfied with the methods chosen and modifications made. Another difficult thing was deviation from the original purpose which is to design a user-centred interior for a self-driving car. The key word here is user. But being an engineering student is very tempting to fall into the technology trap and forget the intended user the product is being designed for. This was a lesson for both of us.

8. CONCLUSIONS

The purpose with the thesis project was to propose a conceptual design of a user-centred interior for a self-driving car. After thorough evaluation and screening *Concept Smart* became the winning concept, the name *Smart* indicating its functionality that makes life easier for the passenger. The group is confident that *Concept Smart* is the interior solution that enables the passenger to best utilize the timeslot created when the car drives by itself.

When conducting product development projects of futuristic nature like this one it is important to have in mind how the customer needs might look like when the actual product is poised to be launched which is a difficult step to accomplish. However the needs of today, that were found during the user study that were of importance was that customers wanted to utilize timeslot by sleeping, interaction with others and watching movies. The need for feeling safe was also important; this could be provided by alerting/warning the passenger ahead of time if any situation might occur. As well as providing a steering function. Some kind of placement support was also highly appreciated. This could be in the form of a table. People wanted to use things that easily could be removed out of the way, in this way reluctant against things that took unnecessary space.

Throughout this project product development processes has been modified and assumptions made that is described in the discussion, this is very important to take into account when reviewing the final result. What has to be taken into account as well is that the ideas the group generated were implemented in a conventional car interior which is designed for the conditions of today. The car interior can be completely different designed if not being restricted by the laws and regulations of today. The available space in the interior is for instance constrained by certain components such as the size of the instrument panel. A decreasing size of the instrument panel would create more freedom for the front seats. Also the space in the middle is today limited due to the fact that there are three seats in the middle of the car, which restrains the activities in the car such as having a meeting. In order to have this meeting a rotation needs to be done. One thing to note is that the size of the seats cannot be of conventional sizes as today for the rotation to occur.

As mentioned earlier in the project, the group stated that *Provide Comfort, Provide Entertainment and Being able to work* were the solutions for utilizing the timeslot created. In terms of providing comfort, the way to solve this the best way was by enabling enhanced legroom for the front passengers. This was done through the application of rails and removed rear seats so that the front seat could be folded. An applied footrest made it even more convenient for the passenger. This was an important user requirement since the group aimed at

people that live busy lifestyles and would like to relax fully on their commuting time from or to work. Visual comfort was provided by enabling a large overview of the outside for the passengers. This was done by the projection on the A-pillars.

The other solution for utilizing the timeslot was to provide entertainment for the user. A solution containing a “Screen around the whole car” provides entertainment and interaction between passengers. This screen is firmly used for interaction activities between passengers. But can be problematic to use during long sections when watching a movie since it requires an uncomfortable posture. Therefore it could be projected as a holographic screen in front of the passenger, enabling a more comfortable posture. Every passenger have their own touch screen in the armrest that also can be used as a keyboard in cooperation with the holographic screen.

Being able to work was important for utilizing the timeslot. One of the ways to work could be by having group meetings between passengers. In order to have this, the passenger needed to face each other. This was solved by rotating the front seats with 180 degrees. Some conditions were needed to able to do this. The instrument panel size needed to be reduced and the middle section space freed up. This was done by removing the outer seats in the middle section, with one remaining middle seat needed to be pushed to the side. The solution for enabling individual work was solved by a table/screen in the armrest. Here the person could use either the screen for work, or place the laptop on the table.

9. RECOMMENDATIONS

A more vast market analysis has to be conducted, both more within the conventional car interior market and other segments i.e. furniture and trucks in order to increase the solution space. There are many good car interior solutions that are emerging within these different auto shows all over the world. Even other segments such as the furniture market where a lot of convenient design can be an inspiration. Truck interiors is designed to accommodate long distance drivers, here different packaging solutions can be investigated further. Further investigation of viable data from the competitors within the self-driving car segment needs to be conducted in order to get an edge over the competitors.

A quantitative research method should be added to the data collection; this would increase the credibility of the data collection and thus reach the needs of a greater population. Another thing that can be considered is an observation study on a consumer sitting in a self-driving vehicle. Here the underlying needs of a user in this type of environment can be elicited easier than just purely interviewing them.

A recommendation would be to investigate adequate concept screening and scoring methodologies for concepts that have many different products within them. Methodologies that excludes subjective assessments. This might be hard to achieve since design work most of the time relies on synergy. A good start would be to look at the methodology that was applied in this project and develop it further.

A design recommendation should be to evaluate the process when entering/exiting the vehicle. It was only touched upon slightly in this project since the main focus was on the interior, but it is a very important factor for the user to be able to enter and exit the car comfortably. Here the possibility of removing the B-pillar can be looked upon. How does it affect the structure of the car? The door structure can be looked upon as well e.g. hydraulic doors as they have in buses. How does the person open the door? Touch, facial recognition or invisible keys? Another thing to investigate could be packaging space. Where does a passenger put his or her jackets and bags so they aren’t in the way?

For future work a more in-depth safety analysis can be made, since it wasn´t sufficient in this project due to the complexity level. Safety aspects involve the airbag placements. The panoramic roof will create trouble for a bag-in-roof concept, especially for the middle seat passenger that is located right under the roof window. Another aspect to consider for future investigation is when items is placed in front of the passenger and a collision occurs. As mentioned earlier the Dainese airbag can shield the passenger from any type of collision, but what happens if it inflates and the passenger got items in front of them? The space between the

passenger seats during a face to face meeting is important, because if a crash occurs there are always risks for clashes between passengers.

A detailed ergonomic analysis needs to be made. Things to investigate could regard usage of “Screen around the whole car” while swiping. When passengers are doing different activities, for instance if one would like to play video-games and the other would like to sleep. How is an independent environment regarding noise level between those two created? It was only slightly touched upon in this project, but it needs more research within it.

The virtual model showcased in CATIA V5, used in this thesis work was an approximation of the all-new XC90 with respect to seat sizes that had been minimized. This was due to the computer not handling large files, so reducing of such parts had to be done. Rotation has to be tested in a real car interior with reduced size of the seats to see if it works, since the space is limited.

The 3D printing technique is emerging fast and after usage of it by the group it is recommended since the results was explicit and exact compared to the design models created in CATIA V5. The workshop at Volvo Cars gave good directions and advices on how to design the models with perfect results. This technique will be further developed in the future and Volvo Cars could take advantage of this by having future prototype cars designed by 3D printing technique.

As soon as viable data gets available a thorough business case needs to be conducted, preferably a *Business Model Canvas* that displays the products business proposition across its whole life chain. How much more will this car cost with this type of an interior compared to a conventional interior? What are the distribution channels?

Overall recommendations could be to look at a broader scale than just the vehicle in itself. How might the infrastructure look like 10-15 years from now? Will these cars drive on independent roads from conventional cars? What will the expectations be on self-driving vehicles from a law perspective? Who takes the blame if an accident occurs? Will a person have to own a car or will mobility on demand be a better option for a consumer? How does these car communicate with each other? Answers to these questions will ease the development work significantly.

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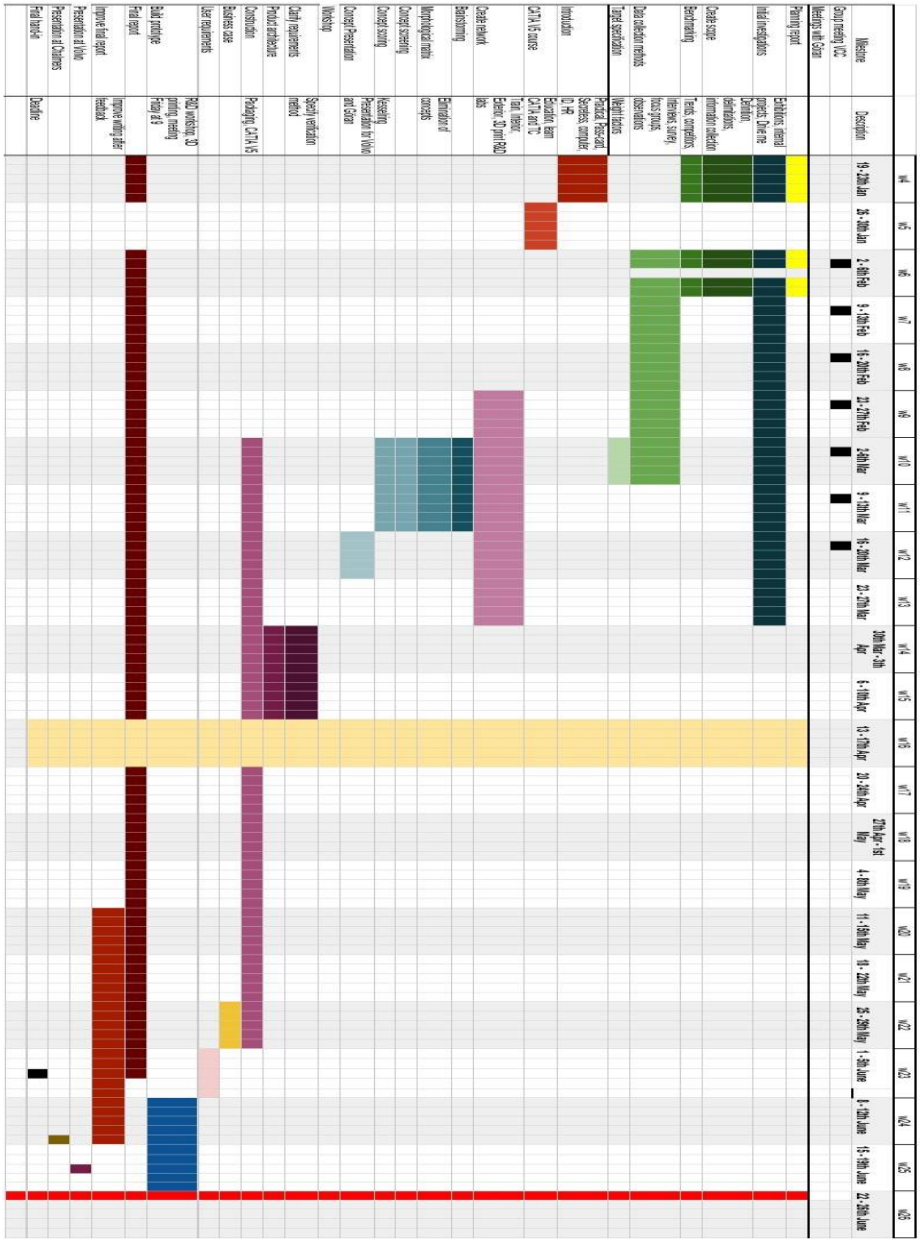
11. APPENDICES

Appendix A: Time plan



Appendix B: Expert Interview guide and summary

Questions to experts in these areas:

- **Instrument Panel**
  - What are our limitations in terms of redesign? Can we apply a screen across the whole instrument panel for example?
  - Is there a possibility to clothe the whole instrument panel in carbon fiber? What is the limitation in this case?
  - Is it possible to apply self-emitting light textiles on the instrument panel?

- **Steering wheel**
  - Are there any limitations regarding the positioning of the steering wheel?
  - How do you think the legal requirements will evolve in the future regarding the steering wheel when it pertains to autonomous driving? Do you think there will be a possibility to remove the steering wheel completely?
  - Do you think there is a possibility to maneuver the car with a virtual steering wheel? What are the hindrances here in terms of safety?

- **Seats**
  - Are there any restrictions in terms of positioning of the seats?
  - Is it possible from a safety perspective to implement rotating seats?
  - What are the constraints in terms of design freedom on the seats when it comes to safety?
  - Is there a possibility to replace the surface material on the seats today for something more comfortable for the passengers?
  - Is it safe to have the belt strapped in the seats instead of the B-pillar?

- **Carpets & Headlining**
  - What textile are you using today for your carpets? Why particularly that textile?
  - Is there a possibility to replace this textile or is it a certain standard that must be followed here regarding textiles?
  - Can self-emitting light textiles be implemented on the Carpets & Headlining?
  - Do you see any benefit from a customer's perspective regarding implementation of self-emitting light textiles?

- **Glass & Mirrors**
  - Is there any possibility to implement Heat reflective glass without exceeding the demands for safety?
  - Are there any restrictions with changing the size of the windows?
  - Does glass have to be the only material used on the windows? Cannot for example polycarbonate be used instead? This in order to achieve a much lighter vehicle and better aerodynamics.
  - Can the side- and windscreen functions act as touch screens?
  - Can the windows functions as "curtains"? We assume that passengers in a self-driving car want to at times have it quite concealed.
  - Can the rear view mirror be removed or are there any legal demands that states that it has to be available even for a self-driving car?

- **Climate System**
  - Can a surface material with time replace the function of the climate system? Like for example finding a surface material that both heats and cools.
  - Are there restrictions regarding placement of the climate system?
  - Is it possible to implement personal ventilation outlets for every passenger in the headliners? Such as they have in airplanes.
  - Is it possible for the airflow, to inject the air in the cabin diffusively?

- **Luggage**
  - Are there any limitations in implementing seats in the luggage compartment? Is there a possibility to have folded seats mounted on the walls?
  - Is there a possibility to mount objects on the headliner in the luggage compartment such as a TV screen or a projector?
  - Is there a certain maximum volume that cannot be exceeded in the luggage compartment?

- **Door panel**
  - Are there any restrictions when it comes to design freedom of the door panels?
  - Is it possible to implement a sound absorbing material in the door panels?
  - Can LED lights be implemented in the door panels?

- **Interior Safety Systems**
  - Are there limitations on where to place the airbag?
  - Are bag-in-belt and seat belt retractor sufficient safety methods to protect a passenger if he or she is seated in a rotated position towards another passenger?
  - Would a bag-in-roof method work in this case?

- **Active Safety Functions**
  - What is the aim for Volvo Cars when it comes to autonomous driving? How far do you want to reach?
  - How do you think the laws for fully autonomous driving will look like ten years from now?
  - What are the constraints that we have to be aware of regarding the interior design?
  - How autonomous is a fully autonomous car? Can it transport a person from Gothenburg to Stockholm without problems?

- **Ornamentation & Roof system**
  - Do you consider a panoramic roof being appreciated by customer in a self-driving car or do you think he or she will feel too exposed?
  - Does the glass on the panoramic roof have some form of heat-reflecting properties?
  - Is there a possibility to extend the panoramic roof in the longitudinal direction? What are the consequences?
  - Can an infrared-reflective film be applied or does it already exist today?

Interview with Luggage expert

The volume space in the luggage compartment is important from a customer's point of view. He said that in Germany, Mercedes is aiming at having the biggest volume segment in their luggage compartments. Luggage compartment volume is very important for car companies today. So whichever solution that is applied, as long as the passenger can easily return to the original volume space this would be highly appreciated by the customers. When it comes to hanging objects on the ceiling such as projectors or TV screens that is the responsibility of the carpets & headlining group. Today the ceiling is quite soft, since it's made out of glass fibre, foam and textiles. The only way to mount heavy items is to apply fasteners in the car body roof.

The TV screens and projectors have been visible in some cars in the US, so there is a possibility for it but there are extra productions steps required which is costly But one thing that speaks for such an implementation is that the self-driving car will not be the high volume product when it is launched, so it can afford to be expensive. Primary SUV`s will be applicable to use as self-driving cars because of their large coupes.

To be able to get a surface to display the projection, one can use the sunblind in the luggage area for Volvo Cars, if another material is applied. The positive with this you use something already existing, the negative is that the surface is not that big.

Interview with Seats expert

The important thing when deciding placement of seats is to locate which area the seats is supposed to move within. Today the seats only move in the x-direction which is the driving direction but there is a possibility for it to move in the y-direction which is the transverse direction. However it is forbidden to sit sideways i.e. the back against the doors or vice versa in Europe because of safety regulations. But sitting with the back against the driving direction is not a problem when it comes to safety. Rotating seats can work as long as the seat is not rotating when driving.

The design freedom on a seat is very limited today due to the large amount of legal requirements on seats today. The headrest, which is the strictest feature on the seat in terms of legal requirements, has limitations in height and width. Today in the automotive market there are requirements from associations such as Euro NCAP, which rates different car models against one another in order to make it easier for consumers to choose.

On the all-new XC90, the seats will contain interesting features i.e. massage function, cooling function (seat heating already exist).

If a sofa would be implemented there are restrictions on where the belt configuration has to sit. The expert did not see any hindrances in folding the seats and using it as a foot rest, it is actually already on the market.

Having the seat belt strapped only in the seat and not in the B-pillar puts a lot of requirements on the seats, floor and car body structure in terms of strength and durability.

Interview with Instrument panel expert

The expert said that there is a possibility to enlarge the already existing screen. However safety during a collision is essential when implementing a screen. The screen cannot block the view of the driver in any direction. Another important factor when implementing a screen is still making sure all the different controls in the instrument panel still is accessible.

Applying carbon fibre on the instrument panel is an option, but there must be a balance between weight and cost when implementing this material. The most vital aspect is that the materials energy absorption can handle a collision so that the material does not splinter or the body hits sharp edges. One important function of the instrument panel is that it works as an “up fetching” system during the collision. There exists laws in the U.S. in were a collision without belt should be handled; in this case the instrument panel is vital during collisions. Therefore any changes on the instrument panel should not compromise its safety capability.

Self-emitting light textiles is applicable. Ambient lighting is currently used as light strips in the all-new XC90 in order to highlight aesthetics. It should not however distract the driver during the drive.

Interview with Door panel expert

There is room for applying a conductive charger in the door panels of the car, but it is important that the device being charged is held flat onto the inductive surface it charges against since it is very sensitive.

There is currently a R&D project being conducted regarding opening the door with a button instead of the traditional door handle. An important factor here to not forget is that it still exists a manual opener and not only an electrical one. This is important in case if the battery would dies after a collision. An easy and smart solution would be to have a button that when being pushed the first time opens the door electronically, and in case this does not work, the door can be opened manually by further pushing the button. Theoretically there is a chance to implement finger touch for opening the door, but it is a question about price.

There is not a necessity to have two opening doors on each side, since it today already exists three-doors. If designing a car with one door, an important thing to consider is that the passenger can safely evacuate the car without being constricted.

Interview with Glass & Mirrors

Today there exists solutions that keep heat away from the car compartment such as IR-glass and window tint film that can be implemented in a car without exceeding Volvo Cars requirements. A company called *Saint-Gobain Sekurit,* one of the largest manufacturers of car windows to the auto industry is a supplier to Volvo Cars and other car companies. There are requirements today such as the glass being laminated and UV-resistant. As long as the eventual solution keeps these requirements any solution that keeps away heat can be applied.

Changing the size of the windows is a possibility if it is done with respect to law requirements, collision-safety and production of glass. However there are smarter solutions that can be applied in order to get a larger view of the window. Today Jaguar Land Rover is developing a system called *360 Virtual Urban Windscreen* which makes the A-pillars invisible and thus gives the driver an unhindered view of the road. This might even be applicable for the B and C pillars.

Technology exists to implement OLED-screens into the windows so they work as screens. In order to change transparency on the windows a technology named electro chromic can be applied. This technique is used in the air-plane Boeing Dreamliner´s cabin windows. However there are also requirements regarding the modre permeable that needs to be considered if implementing this technology. There are no requirements pertaining laws of having the inner mirror installed, if the exterior mirrors are approved, it can be removed.

Interview with Steering wheel expert

According to the expert, the steering column is what constrains the positioning of the steering wheel. Wherever the steering column moves, that's where the steering wheel will be also. Today it cannot move in the lateral direction since it's a mechanical part connected to the gearshift and wheels. This could only work if the same technology that is applied in video games existed where there is a potentiometer that connects it.

Another constraint is the legal requirements that states that if the steering wheel is going to be positioned in a certain way then the driver must still be perfectly aligned with the airbag incase of a collision.

When it comes to the size of the steering wheel, the size is restricted to the size of the airbag. But if the airbag placement would be changed to some other location like the roof for example, then the steering wheel could be completely redesigned to a joystick or something more convenient for the younger generation.

The group elicited the prospect of applying a snap-and-fit function on the steering wheel, just like they used in the Formula One cars in order for their drivers to easily get out of the car. The expert said that it could be liability in case the consumer mounts in wrongly it can lead to functions not working such as airbag, controls and honk for example. All these things are controlled by law requirements today.

Another thing to consider when it comes to the steering wheel in relation to autonomous driving; the steering wheel today is used for many more things that just steering. Controls such as phone, sound, cruise control, and audio play etc. If the car is to be autonomous, maybe the passenger would want to still have access to these controls even their sitting with their back against the driving direction.

Interview with Carpets/Headlining expert

Today they use tufted textile carpets in the Volvo Cars as base carpet. Tufted is a technology of making small straws that makes it easier to remove dirt. On top of this, post rubber carpets are used close to the feet in order to easily remove water. If it wasn't used, then the seats and the tunnel console would have to be removed in order to get hold of the base carpet. Today the styling group is looking at implementing vinyl carpets as base carpets. They are plain and tight and can be likened to a bathroom plastic, it's used in trucks and pickups and has an aesthetic appeal. The problem is that it does not look nice when it coincides with the plastic panels because of its hardness compared to a soft textile carpet.

One problem with implementing self-emitting light textiles is that the passenger might not see what's happening on the road, which can create a form of inferiority. Also an important thing to note is to avoid to put these textiles close to the feet so that the dirt becomes visible. Today they have problems with the lighter carpets getting very dirty. It should be placed from the knee height and upwards.

Achieving very high sound-absorption is hard, but there are different ways of making it better than what it is. Volvo Cars has now in the all-new XC90 implemented something called ANC (Active Noise Control) which is a small microphone that sends out a suppressing sound in order to counteract noise. However the expert did not know whether these microphones where effective or not. Airplanes use the same procedure in their first class cabinet in order to take away engine noise.

Interview with Active Safety Functions expert

An interview was held with an expert within Active Safety Functions. This person is part of the team that is working on the development of the future self-driving cars. He said that Volvo Cars would take one step at the time towards full self-driving automatization in cars. The "*Drive Me*" project in 2017 will work as a start of it and later expand in terms of the car handling higher velocities, different environments and more demanding traffic situations. The long-term goal for the cars is to be fully autonomous in the urban areas.

Volvo Monitoring & Concept Center (VMCC) has done studies of where the self-driving systems will be of most value. Their conclusion was that the time between home and work that usually comprises around 26 minutes is the target timeslot. People usually spend this time on the highway. Time saving and comfort is important factors when driving long distances. So initially the car being most of the part autonomous on highways is the initial target, and that is where they believe the highest customer value lies for now.

The expert believes that the autonomous car interior will look identical with a conventional car interior even in the future. This is because there are some road conditions that the autonomous car still cannot handle; therefore the driver must be able to quickly intervene. To have a concept likened to the Mercedes F015 – Luxury in motion might work better in future taxi cars that drives in the urban areas or car pools that can be rented.

The self-driven cars will be customized so that they have a primary system, and if that system crashes the car will stop at a safe place if the driver cannot take over. If the driver can take over, the car will be driven manually.

Interview with Airbag expert

Today in vehicles the seatbelts is the most important safety system, since it takes up the most energy. Secondary is the airbag. The airbag fulfils two purposes; it protects the driver/passenger from hitting themselves on the instrument panel and provides protection against neck rotation. If these two cases are solved, there is no need for an airbag.

The expert says that an airbag is not needed for passengers sitting with their back against the driving direction in case of a frontal collision. This is the best way to be seated when a frontal collision occurs since the load is distributed over a larger surface. But this demands a seat that is strong enough to handle the load. There is though a problem with making the seats stronger, they get heavier and more expensive. So another option would be to implement a form of airbag in the instrument panel that supports the seat during crash. You make the seat weak so that it is supposed to take up the energy until it gets the support from the instrument panel. This scenario is only applicable for the people sitting with their backs against the driving direction. But for the sitting towards the driving direction a bag-in-belt and a bag-in-roof is enough to protect them. The only problem here can be that the passengers can collide in each other.

One scenario however to think through when contemplating to use this type of layout (*Mercedes f015*) is what can happen to the person sitting on the opposite side to a side crash and evaluate what risks there are. One thing to consider is if a bag-in-roof is to be used there have to be a great distance between the passenger and the roof as well.

The expert mentioned a company by name Dainese D-Air that develops airbags in motorcycle clothing. Today there are people who have applied the same concept in the seats today. This concept would be very applicable for a rotating seat since it does not matter what angle the seat has it can protect the passenger in any case.

Another aspect to consider is what happens in a collision when the passenger is lying down sleeping? Since the person has a very steep spine angle he or she can easily fall out of the seat

during a crash. Two ways to solve this is either to have a very steep airbag in the belt that can hinder the body from slipping through the belt or if the seat can revert back to its normal positioning in order for the bag-in-belt/bag-in-roof to protect the body. The expert believes this will be among the biggest demands from customers, to be able to sleep in the car safely.

Interview with Ornamentation & Roof system expert

The expert started off by saying that it is a wish from the consumers that the panoramic roof should be extended more to the front, so that the front passengers also can have benefit of the view. The constraint is the implementation of the bag- in-roof in the front.

There are however thoughts of extending the panoramic roof opening so far that it even goes under the sunshades in the V40 model. This will enhance the cabriolet feeling.

There is a R&D project currently going on about electronically controlling the transparency of the windows. There are law restrictions on the front windows but the panoramic roof has no restrictions if the transparency were to be changed.

The technique comes from varying the voltage of electrical polymers that changes darkening depending on voltage. The plan is to apply this technique on a fixed panoramic roof in 2019. This could be controlled with a touch function. Today mechanical curtains are used. When this method is an applied, the windows will have more design freedom. A further idea for the future according to the expert could be to implement an OLED display on the roof which is the next stage for the panoramic roof.

The expert concluded by saying that the first step is to implement electrical transparency. The second step is to use the same type of technology to create a “digital” curtain that can be dragged down instead of the mechanical sun-visor.

Interview with Climate System expert

The expert said that the much of the energy generated from the climate system today is used to cool the battery. Therefore there is not so much left to cool the passengers in the cabin. The system would therefore benefit with other cooling functions to provide assist for the system.

Today they have fans in the bottom of the seat to cool the passenger, yet they are still striving to get more cooling for the backside. The problem with cooling in the bottom part is particularly an issue for women with short skirts. The back is as well more convenient because of its sensitivity to temperatures. The e-textiles they use only provide heating and not cooling.

Today on the SPA platform, all the new cars will be equipped with an Air-Conditioning system both in the instrument panel and in the back seat as well. This system is applicable for the seat

structure that exists today. However, if the seat structure would look more like a form of living room area the airflow in the cabin would move differently. For example if the front seats would be directed with the back against the driving direction, the airflow coming from the instrument panel would be wasted energy, because it is being blown in the back of the seat.

A solution to this problem could be to implement four “air knobs” on the four different corners in the car combined with an AC outlet in the instrument panel that releases air diffusively. So if the car is a four-seater every person has their own mini-AC just like in the airplanes. The “air knobs” should also release air diffusively in order for it to be pleasant for the passenger.

One thing to make it even more luxurious considering the environment being very confined is to implement an Air balance item in the cabin. This is a form of fragrance glass box with five different flavours of your choice that is mounted on the door panel. This box diffusively sprays out the fragrance in order to get better air-quality in the cabin, as well as it being the perfume of your choice. Today the Mercedes S-Class currently has this system implemented.

Appendix C: In-depth interview question guide

Q1
What is for you the most difficult thing when driving very far?

Q2
What would you like to do in the car if it would be self-driven? Example, work, sleep or watch movies.

Q3
Do you believe that you can fully relax during the drive without worrying about the safety aspect? Why?

Q4
Would you consider to have a steering wheel or not even it is not needed?

Q5
For privacy sake, would you prefer concealed windows or have like a “curtain” function where you can choose?

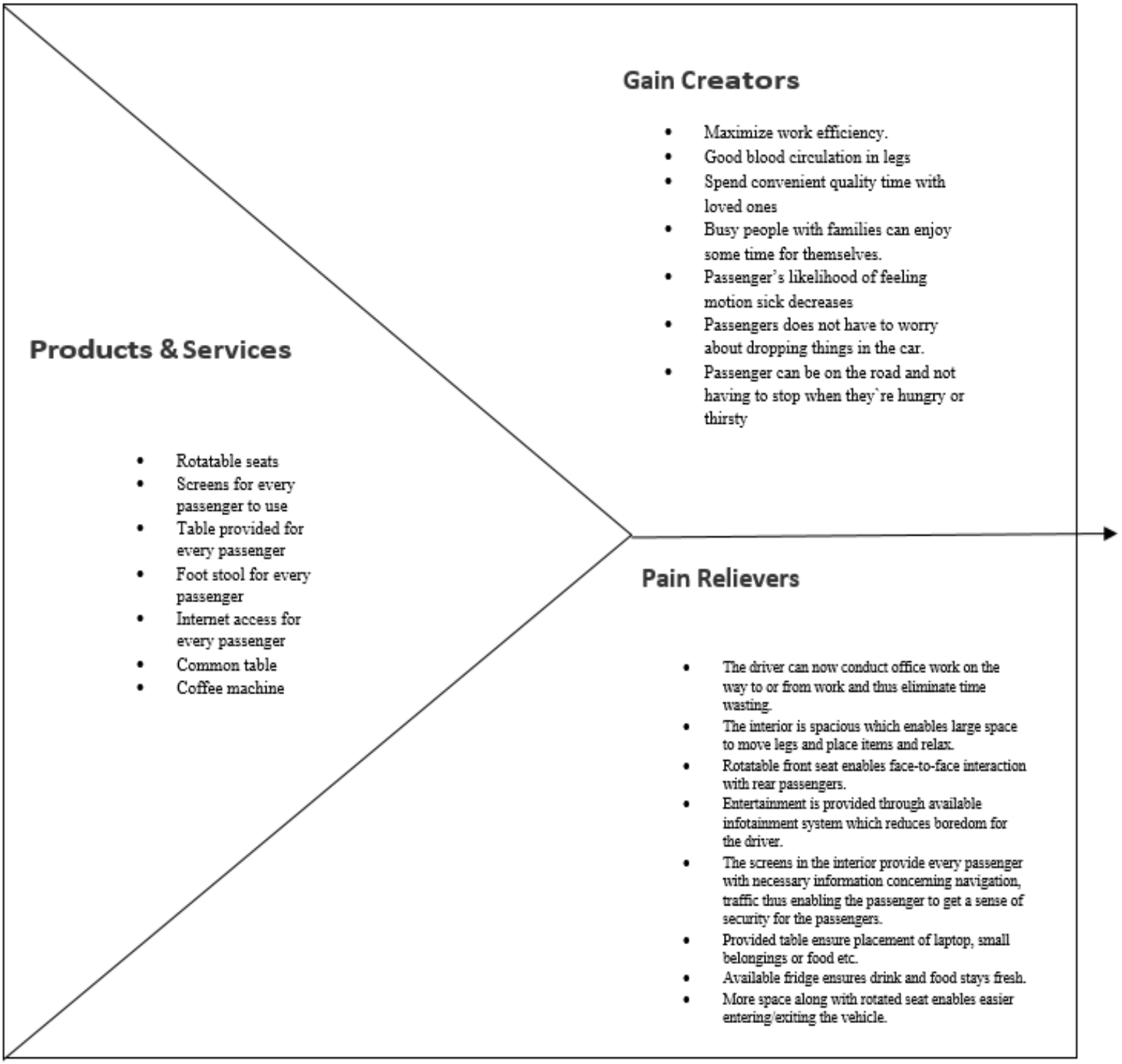
Appendix D: Needs conversion table

Question /Prompt:	**Typical customer statement(s):**	**What the system should deliver:**
What is for you the most difficult thing when driving very far?	• I get uncomfortable in my back. • I have problems with being alert long distances. • I get very bored • I feel pain in my muscles	• **Provide space for comfortable seating position**
What would you like to do in the car if it would be self-driven?	• I would work with my laptop. • Have a meeting with co-workers. • I would definitely watch movies. • Have a cup of coffee • Eat my dinner on the way home from work • Interact and play games with others. • Definitely, sleep! • I would like to paint my nails and do my makeup. • I would pay my bills, text message friends, check my emails and make calls. • I would want to have my own space and as well be able to have wide view so I do not feel isolated. • Read my favourite book • I would love to have a place where I can store my jacket and bags and stuff.	• **Every passenger should be able to watch their own movies/programs.** • **Provide placement for food and drink for every passenger.** • **Enable every passenger to have comfortable sleeping position** • **Enable face-to face meetings between front and rear passengers.** • **Provide table interaction activities.** • **Enable wide view for every passenger.** • **Provide spacious interior** • **Things that is not used should be non-visible** • **Provide place for storage of goods in the interior.** • **Is easy to clean**

Do you believe that you can fully relax during the drive without worrying about the safety aspect? Why?	• In the initial stage, no! I would like some form of warning. Before e.g. sharp turns. • I won't be able to entrust technology with my life! I want to be able to take control in case of anything. A camera overview of the outside would be good. • No, can be exposed to cyber-attacks, however trust will come with time. • On motorways yes, but in urban traffic, No! Something else needs to catch my interest so I can relax.	• **Warn/alert the passenger ahead of time if any situation might occur.**
Would you consider to have a steering wheel or not even if is not needed?	• Yes, definitely. It could be cool if it was movable • Yes, like a joystick or something. • Yes, to control and take over in case of anything. • Initially, it is important but with time we might do without.	• **Car has a steering function, pedals and parking function.**
For privacy sake, would you prefer concealed windows or have like a "curtain" function where you can choose?	• When I have a meeting or when I am watching movies I would prefer concealed but not at all times, so a curtain function should be good. • I want to choose myself. This would be cool with some type of transparency change.	• **Enable to control transparency on windows**

	• Definitely a curtain function. It is good to have privacy of course but it is also good to be seen by people. Seeing people is a sign of life. This is very important when driving for a long time on highways.	

Appendix E: Value proposition



Appendix E: Customer segment

Appendix F: User requirements specification

User requirements	Importance
Warn/alert the passenger ahead of time if any situation might occur	5
Enable every passenger to have a comfortable sleeping position	5
Provide space for relaxable seating position	4
Provide placement for food and drink for every passenger.	4
Enable face-to face interaction between front and rear passengers.	5
Enable to control transparency on windows	4
Every passenger should be able to watch their own movies/programs	5
Provide table for interaction activities	5
Provide spacious interior	4
Things that is not used should be non-visible	5
Provide place for storage of goods	3
Car has a steering function, pedals and parking function.	5
Enable wide view for every passenger	4
Is easy to clean	3

Appendix G: Morphological mind map