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Second Row Comfort and Safety in Level 3-4 Autonomous Vehicles

A User Centered Conceptualizing Process

Bachelors Thesis in Design and Product Development Engineering

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Department of Product Development
CHALMERS UNIVERSITY OF TECHNOLOGY
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PREFACE

This thesis has been performed on behalf of Autoliv Sverige AB in Vårgårda. It covers 15 university credits and was carried out during part-time under the period January to June 2018 by Caroline Falk and Ida Geschwind, Design and Product Development Engineer students at Chalmers University of Technology, Gothenburg.

The thesis has been carried out together with Anna-Lisa Osvalder as supervisor and examiner at Chalmers University, Design for Human Factors, Department of Industrial and Materials Sciences and together with Fredrik Kjell and Hanna Karlsson, Autoliv. We would like to thank you for your support and assistance during the process. A further thanks to Lennart Simonsson, who took care of us at the company and to all experts at Autoliv, who contributed to the work with the aid of their knowledge. We would also like to thank all those who participated in our interviews.

Caroline Falk

Ida Geschwind

ABSTRACT

As much of the focus in this industry are today on the automated vehicle, the demand for more suited safety systems are increased. These new systems will have to protect the occupants, in both autonomous and human dependent vehicles - in a traffic consisting of both kinds. Since 94 percent of severe accidents are caused by the human error, the goal of an automated car is to prevent collisions from even occurring.

With the autonomous technologies progressing, leading to less human drivers and more passengers, the rear seat is getting more attention. The purpose of this thesis is to identify the rear seat travelers in a level three to four automated car, the user needs and how to protect the occupants in the event of a collision.

Using methods as observation, interviews and open questioned surveys - both hard and soft values were discovered. The conceptualizing consisted of workshops with brainwriting, idea analyzing method, sketches and CAD sketches. The evaluation methods were PNI, weighting of demands and a disassembly analysis.

The rear seat is presumed to have three seats, be as adaptive and luxurious as the front seats. Including variation of backrest angle, seating angle and length of seat cushion - all in order to maximize body support and thereby comfort.

The result of a user focused airbag conceptualizing, based on a developed product specification, was a frontal protective airbag. The frontal airbag - Inflatable Frontal Curtain gave the best results in all of the concept evaluation methods and was considered as the best.

The Inflatable Frontal Curtain, IFC, is an airbag installed in in the ceiling, behind the first-row chairs. It covers the whole area across the B-pillars in order to give full protection for all rear seat occupants. Furthermore, the IFC contributes to an enhanced safety for the first row, as it protects the occupants from projectile loose objects or unrestrained rear seat occupants.

The thesis work has concluded a suggestion for an enhanced comfort and improved safety in the rear seat of an autonomous vehicle, level 3-4.

TABLE OF CONTENTS

1. INTRODUCTION

Autoliv was founded in 1953 by Lennart Lindblad and has since 1968, provided safety solutions to the automobile industry. The first successful solution came to be the two-point seat belt, which later developed to the lifesaving three-point seat belt (Autoliv, 2018). Autoliv are world-leading in the automobile safety industry, and has been responsible for the majority of the technology breakthroughs for more than 60 years.

Autoliv develop passive safety products such as seat belts and a variety of airbags (Autoliv, 2018). Their vision is "*Saving More Lives*" whilst their mission is "*to be the leading supplier of safety systems for the future car, well integrated with autonomous driving*".

1.1 BACKGROUND

As the focus in the automobile industry are rapidly increasing in the autonomous "self-driving" vehicle, the demand for a more suited safety system is increasing. Though, before every vehicle on the road are entirely autonomous and can predict accidents, there will still be human dependent vehicles that cannot. This contributes to the situation where the collisions caused by human error still is possible, whilst the autonomous vehicle theoretically breaks and hopefully decreases the impact energy. By the time of the impact, the passenger of the autonomous vehicle is in another position, due to the predictive breaking, than the passenger of the non-autonomous vehicle. Therefore, there is a demand for a passive safety system that manage to keep the passenger safe during this new kind of accident.

The vehicles of today are equipped with frontal airbags. The frontal airbags are mounted in the steering wheel and in the dashboard. Further the first row are equipped with side-, knee- and far side airbags. To cover the driver and passenger at a side collision, the vehicles are supplied with curtain and side airbags mounted in the seat. The curtain airbags are mounted in the ceiling, on both sides, starting at the A-pillar in the front and continues all the way back to the C-pillar. This ensures that both front and rear seat passenger are protected in these types of collisions.

The focal point of automobile safety systems during the past years has been regarding the driver, or the front seat passenger. However, with the autonomous vehicles in reach, leading to less human drivers and more passenger who chose to travel in the rear seat are getting more attention.

1.2 PURPOSE

The purpose is to identify the passenger of the rear seat and their needs, where the main focus will be on road safety. Furthermore, the implementation of an airbag will be analyzed.

1.3 AIM

The aim of this project is to develop a safe rear seat concept, including an airbag concept, for the second row in an autonomous car. The identified user and their needs will be relevant to these concepts.

1.4 LIMITATIONS

The prospective autonomous car, is at level 3-4 and cannot be controlled from the rear seat today, and is therefore a limitation in this project. The vehicle in aforementioned grade must at least have a driver who is supervising the transit.

Based on the user needs, limitations about the seat position in the rear seat has been made, due to the lack of existing rear seat in the future autonomous cars. The project has therefore determined possible travel positions, in the second row of the vehicle. A design concept for an airbag have been developed, fitting this particular rear seat concept, presuming the occupant wearing a seatbelt. These concepts have focused on meeting the user needs, rather than the technical specifications.

An overall picture of the world's automobile industry has been made, but due to limited time, it has been decided to only focus on the users in Europe and the United States.

The time limit for this project is determined to be 200 hours per project member, the projects' total time schedule is therefore 400 hours distributed over 20 weeks.

1.5 RESEARCH QUESTIONS

- Who travels in the rear seat?
- Who will travel in the rear seat in the future?
- Which are the user needs of the rear seat?
    - How are people positioned in the rear seat today?
    - How would people like to be positioned?
- How could these needs be implemented in a rear seat in a future autonomous vehicle?
- What are the demands on collision safety/airbag systems?

2. THEORETICAL FRAMEWORK

Following chapter describes the theoretical researches, relevant for the further conceptualizing process.

2.1 GLOSSARY

This glossary contains descriptions of words used throughout the thesis.

2.1.1 Comfort

“A pleasant feeling of being relaxed and free from pain” (Cambridge dictionary, 2018).

2.1.2 Seating Rows

The different seats in a car are often being separated by mentioning them based on their location in the interior of the car. Where the front seats are to be the first row, whilst the rear seat the second row and so forth.

2.1.3 Deformation Zone

A deformation zone, also known as crush or crumple zone, is areas of a vehicle that are designed to increase the occupants’ safety (Volkswagen, 2018). These zones are located in the front and rear of the body shell and absorb impact energy and the impact of a crash.

In the event of a collision, the deformation zones slow down the impact and divide the energy across the deformation zones by crumpling in a controlled way (Autoportal, 2018). This cause more damage to the vehicle, because it is designed to collapse, but is safer for the occupants. (Fereiro, 2017).

2.1.4 Thorax

Chest - the part of the body, containing the head organs of circulation and respiration. It is located between the neck and the gut, consisting of the ribs, breastbone (Oxford living dictionaries, 2018) and the upper half of the spine.

2.1.5 Far-side Impact

A far side impact is a collision that affect the occupant, who is placed in the opposite, non-struck side of the vehicle (Autoliv, 2018). For example, this can be the driver hitting the head towards the front seat passengers head.

2.1.6 Human Error

The mishandling of a human, as the cause of an accident (Nationalencyklopedin, 2018). These human errors are trivial mistakes made by people, and a part of being human (Dictionary, 2018).

2.1.7 Euro NCAP

Euro NCAP is an organization carrying out vehicle tests in which each vehicle receives a safety rating, in a five-star classification (Euro NCAP, 2018). It is a safety rating system where the costumer can compare the safety in different vehicles. The stars show how well the vehicle performed in the test and available safety equipment.

2.1.8 Load Case

Test procedures are testing the car and its safety, in different types of collisions often called load cases. These various load cases are performed with different barriers, velocity and crash dummies. An example of a requirement is one test procedure for the frontal load case, UN R94. In this procedure, the car hits a frontal barrier at 56 km/h, with 50-percentile dummies in the driver and front passenger seat (ECE 94-03). Several parameters are included in this requirement, such as occupant injury values and other impact values.

2.1.9 Legal and Rating Requirements

Legal requirements are such of what the car must meet in order to be put on the market. These requirements differ from country to country, depending on that country's vehicle safety policy.

Rating requirements on the other hand, is requirements that measures the vehicles safety performance in different load cases (NHTSA, 2018). These are not out of legal proportions, but do have a great impact on the market.

2.1.10 Out of Position

The safety systems used in a vehicle are measure by how effective the protection for the occupant is. It is of great importance to test different positions, so called *Out of Position* positions, in order to make sure that the safety system is not harmful for the occupant (F. Kjell, personal communication, April 24, 2018).

Out of Position refers to all positions except the recommended, upright and belted position 10 inches from the airbag cover (NHTSA, 2018). All the *Out of Position* tests are performed with unbelted crash dummies. Furthermore, in frontal impact procedures only the first row is *Out of Position* tested (FMVSS 208), while both first and second row are tested in a side impact procedure (Lund, 2003). This is due to the lack of frontal airbag in the rear seat.

2.2 AUTONOMOUS VEHICLE

Collision avoidance systems are already being used in the vehicles of today. These systems are able to assist the driver, in the case of a situation where the attention of the driver is elsewhere. The systems are a combination of warning-, adaptive- and active systems. The warning systems are those of example lane- and roadway departures, whilst the adaptive systems are such of headlights and cruise control. The active systems are among the most developed, such as electronic stability control and brake distribution. All these systems are constantly being developed to fit an autonomous vehicle.

Based on the fact; that 94 percent of severe accidents are caused by human error (NHTSA, 2018), aforementioned collision avoidance systems, used in combine, gives the autonomous vehicle the potential of saving lives. In case of an accident, the vehicle is able to notice the collision before it happens. The sensor tells the vehicle to, for example, activate the emergency breaks which increases the break pressure (Ford, 2018). This can either prevent the collision from happening, or at least reduce the impact energy, leading to a less testing impact on the passenger.

To sort the different capabilities, the vehicles are placed in a 0-5 level stage, which is more a guideline, than a correct definition. As figure 1 shows, the category 0 is a completely non-automated vehicle, whilst 5 is all around automated and independent of the human driver (National Highway Traffic Safety, 2018).

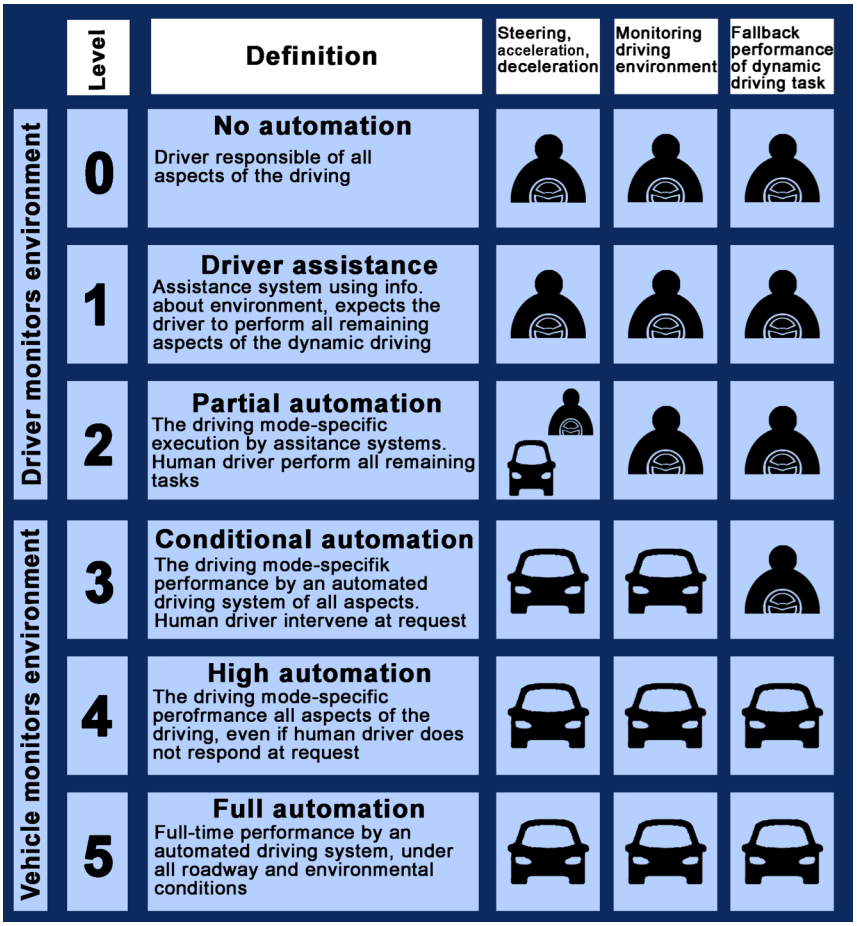

Figure 1. Level of automation, based on SAE Standard J3016. Author's own copyright.

In an autonomous vehicle of stage 3, the vehicle is still dependent on the human driver but are taking advantage of the collision avoidance systems in such a way that the driver only has to intervene in certain situations. Whilst the vehicle of stage 4 allows the human driver to skip the interference during transit.

2.3 SEAT ERGONOMICS

Ergonomics is about the human and machine interaction and how to use theories, data and methods to design for human well-being (Bohgard, 2015).

A good ergonomic seating position is to preserve the lower back in a natural position (Bohgard, 2015), a position that maintains the same profile for the lower back while standing up. To enhance the comfortable, ergonomic, seating position, the distribution of pressure on the human body is of great relevance. This can be achieved by providing a seat that distribute the pressure of the occupant, where the pressure culminates at the area around the ischial tuberosity. Due to that both of the ischial tuberosity's takes up 18% of the human body weight while seated (Kolich & Taboun, 2004). The pressure should then decrease gradually towards the front and side of the legs.

Regarding the pressure distributed in the backrest, a pressure that culminates in the lumbar area is perceived as more comfortable. However, a backrest with an increased lumbar support can be uncomfortable in the long-term. Except the enhanced lumber pressure, there should not be any other distinct pressure points in the backrest due to the amount of soft tissue (Kolich & Taboun, 2004).

To achieve a good ergonomic seating position, the angle α between the seat and the backrest (figure 2) should be 100-110 degrees (Pheasant, 2006). Furthermore, the backrest should follow the contour of the spine and the chair should allow variation while seated (Bohgard, 2015). In order to maintain a good lower back support, the depth of the seat should not exceed the buttock-popliteal length (figure 3). A seat that exceeds this buttock-popliteal length could bring discomfortable pressures on the back of the knee, as the knee grip locks the knee and creates a static load (Malmstolen, 2018). By tilting the seat angle β (figure 2), 5-10 degrees, towards the backrest the pressure contact with the backrest is increased, as well as minimizing the risk of gliding underneath the seatbelt in the event of a collision. Additionally, to create the best possible support, the seat should have a width of at least 500 mm.

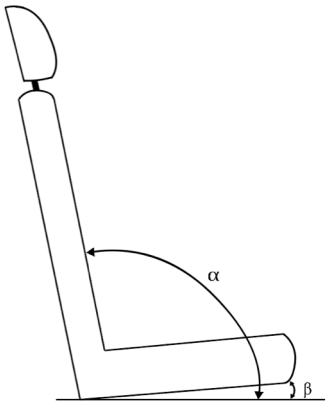

Figure 2. Defining seat angles.
α - backrest reclining. β - seat tilting.
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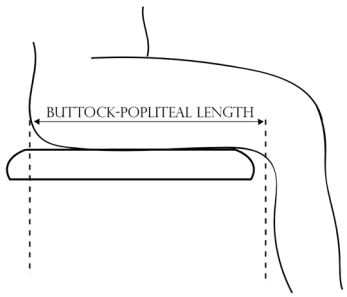

Figure 3. Defining buttock-popliteal length.
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2.3.1 Comfort

Seat comfort implicate occupants to feel fit when travelling by car for a few hours, without experiencing discomfort. Comfort is associated with feelings, well-being and by impressions of a product or environment. Discomfort is about feelings of pain, stiffness and numbness - caused by physical constraints in the design (Hiemstra-van Mastrigt, Groenesteijn, Vink & Kuijt-Evers, 2017). To accomplish a high level of comfort, discomfort needs to be low. Once the comfort is achieved, it can attract occupants.

When remaining seated for a long period of time, almost every seat turns uncomfortable. Depending on different factors such as seat-, user-, and task characteristics, some seats are more fit for long term traveling than others. Wherefore a seat is uncomfortable is determined by how the body is properly supported. If this does not occur the posture is only provided by muscle effort which, in combination to lack of a seat profile match, creates discomfort (Pheasant, 2006).

To avoid discomfort, it is of great importance to allow different seating positions, in which the body is correct supported. A seat that is comfortable for a longer period of time, is also physiological satisfying (Pheasant, 2006).

2.3.2 Feeling Safe

The fear of losing control is related to the experience of feeling safe, rather than to be unable to change the surrounding circumstances. The response of feeling uncertain in situations, is the body creating stress hormones released in the blood system. These hormones target the spots where the body decides whether to fight or flight the issue (Folk, 2018).

The feeling of safe and in control, is dependent on rituals and routines (Eckoldt, Hassenzahl, Laschke, Knobel, 2013). These rituals are incorporated in the everyday usage of the car. The car itself creates a familiar and safe construction surrounding the users. When changing these familiar routines, as of making the car automated, the user can experience a sense of losing control.

Another element contributing to the sense of feeling safe, involves claustrophobia. By being in an enclosed space, as in an in-spacious car, can trigger fears of being restricted (Paddock, 2017), or not in control.

By taking these elements into consideration while forming the interior of the car, both the psychological satisfaction and the feeling of being safe can be increased.

2.5 CAR SAFETY

The vehicle safety systems are one of the most flourishing sectors in the car industry (Nayak, 2013), in which the airbags and seat belts undoubtedly have increased the safety. As the Swedish population travels 390 kilometers per day, and as much as 77 percent of these are by car (Trafikverket, 2018), the need of effective safety systems is obvious.

2.5.1 Seatbelt

A seat belt is an arrangement of straps designed to secure the occupant in the car seat. When a collision occurs, the seatbelt reduces the risk of serious injuries by 60-70 percent and fatalities by 45 percent (Autoliv, 2018). Since the seat belt was introduced in the vehicles, it has saved more than million peoples' life.

Two- and Three Point Seatbelts

The two-point seat belt (figure 4) was the first patent seat belt to protect its occupants. It was introduced in 1885, but did not get common in cars until the beginning of 1950s (All om vetenskap, 2005). The two-point seat belt was either diagonally across the body or across the hips (figure 5).

Figure 4. Two-point seatbelt (Autoliv, 2018). Used with permission.

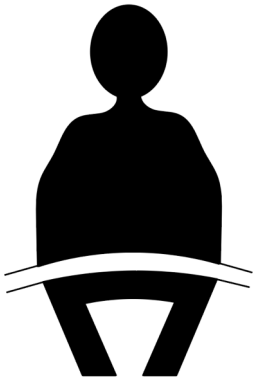

Figure 5. Demonstration of two-point seatbelt usage. Author's own copyright.

The Swedish engineer Nils Bohlin was hired by Volvo Car Corporation in 1958, to be their first safety engineer (History, 2018). Bohlins job was to develop a new, safer seatbelt and in 1959 he introduced the three-point seat belt (figure 6). This belt secure both upper and lower body. The seatbelt contributes to a properly seat position, in which the airbag is maximized, and protect the occupants in several types of collisions.

Figure 6. Demonstration of three-point seatbelt usage. (Karlsson & Tullock, 2017). Used with permission.

Pretensioner and Load Limiter

A seatbelt system in today's vehicle have components such as a pretensioner and a load limiter. The pretensioner restrains the seat belt during a collision and pull the passenger tighter to the seat, which prevents the body from moving forward. To prevent injuries by the seatbelt, the load limiter decreases the pressure on the thorax and grant a controlled forward motion (MAZDA, 2018). Autoliv has developed an adaptive seat belt that adjusts the load limiter after different individuals. This can reduce the risk of injuries from the seatbelt even further, by knowing how fast the belt is pulled during a collision or severe decelerating (Wedberg, 2013).

Legal Requirement for Seat Belt Usage

The legalization for using seatbelts in Sweden was introduced in 1975, for front seats occupants. Eleven years later, 1986, it became a legal requirement for rear seat occupants above 15 years and in 1988, the requirement was implemented for children as well (NTF, 2018). A. Bud, who is working with seatbelts at Autoliv, explains during an interview (April 20, 2018) that he believes the delay of the legalization, for the rear seat, was due to lack of knowledge.

Bud explains that all countries in EU has a law on wearing seatbelt, but only 34 states in the United States has a primary law for front seats occupants, where only 18 of these has a legalization for the rear seat (Governors Highway Safety Association, GHSA, 2017).

2.5.2 Airbag Systems

Airbags is a safety system which, implemented in vehicles, reduces the risk of fatalities and serious injuries by spreading the forces of a collision over a larger area of the body (Autoliv, 2010). The airbags consist of different types of gas-inflated nylon cushions, mounted in the steering wheel, dashboard, door, roof, or seat (Autoliv, 2018).

The vehicles are equipped with crash sensors that sends information to inflate the cushion when the sensor detects a collision (Lakshmana Rao, Narayanamurthy & Simha, 2016). If the system determines that an airbag is necessary, it sends a signal to the inflators which causes a chemical reaction, emitting gas and entails the airbag to expand (Autoliv, 2018). Once the airbag has been deployed it must be replaced with a new one (NHTSA, 2018).

Frontal and side-impact airbags are two types of airbags that exist on the market, where the side-impact airbag consist of various types. The purpose of these airbags is to prevent the occupant from getting serious injuries from the deformation zones, if a crash occurs from the front, side or behind.

Following are the existing airbags described, placed inside the car, that save people's lives every day.

Frontal Airbag

Frontal airbags are folded up in both the steering wheel (figure 7) and in the dashboard, protecting the driver respective the front seat passenger. It has been a standard equipment since 1998-1999 (NHTSA, 2018) when it had been proven that it protects more than doing harm (History, 2018). The airbag is filled with air in less than 50 milliseconds. The bags are deflated immediately, through ventilation holes in the fabric, after deployment in order to create a softer impact (Autoliv, 2018).

Figure 7. Deployed steering wheel airbag. (Autoliv, 2018). Used with permission.

In order for an airbag to be as effective as possible, it must be combined with a seatbelt and a correct seating position (NHTSA, 2018). This combination decreases the risk of hitting the interior of the car when a collision occurs. Additionally, the frontal airbag reduces the number of head injuries by 60 percent and fatalities by 20-25 percent (Autoliv, 2018).

Knee Airbag

The knee airbag was first introduced in 1996, to improve occupant safety (Bustos, Ramos, Peyre and Le Norcy, 2012). It is located below the steering column on the driver's side, as seen in figure 8, and below the glove box on the passenger's side. The knee airbag decreases the chest deflection and reduces the risk of injuries to the knee, thigh and hip. It secures the occupant in a proper position, in which the protection from the frontal airbag is maximized and radically decreases the injuries (Autoliv, 2018).

Figure 8. Knee airbag placed beneath the steering column (Autoliv, 2018). Used with permission.

Inflatable Curtain

Together with the other airbags, the curtain airbag contributes to a more secure vehicle when a collision occurs. The first inflatable curtain for two rows was introduced by Autoliv in 1998 (Autoliv, 2013). Curtain airbags consists of a cushion between the window and the occupant and are often mounted along the sides of the ceiling (figure 9). When a sufficiently strong collision occurs, the sensor reacts and cause the curtain to blow up (Volvo cars, 2016).

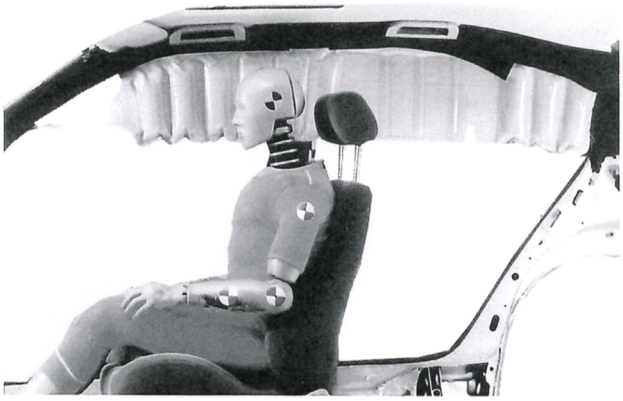

Figure 9. Deployed inflatable curtain (Nilsson, 2003). Used with permission.

In comparison with other airbags, some of the curtain airbags are inflated for several seconds (Folksam, 2018). The longer duration of inflation is to protect the occupants head and stability if a rollover happens, as well as preventing the occupants from launching out of the vehicle. While other have a shorter stand up time, protecting from first impact. The curtain airbag reduces the risk of life-threatening head injuries by 50 percent, for the passengers that are seated on the outer sides of the vehicle (Autoliv, 2018).

Since there are no legal requirements for a curtain airbag in Europe, it is not a standard component in all vehicles. However, in the United States it is a legalization and therefore standard in all vehicles.

Side Airbag

World's first side airbag was introduced by Autoliv 1994, and was implemented in a Volvo 850 (Nilsson, 2003). The airbag is mounted in the backrest of the front seats (figure 10), and expands between the door and the occupant when a collision occurs. It takes 20-30 milliseconds for the airbag to be fully inflated and consumed.

Figure 10. Deployed side airbag.
(Autoliv, 2018). Used with permission.

This type of airbag forces the passenger to a safer distance from the impact zone, and reduces serious chest injuries by 25 % (Autoliv, 2018). There are different types of side airbags that exists on the market. These are thorax-side airbags, head-thorax side airbags and pelvis-thorax side airbags.

Thorax-Side Airbag

The thorax-side airbag is the more basic one of the three versions. This airbag has a volume of 8-12 liters and provide the right protection, in the smallest volume possible (Autoliv, 2018).

Head-Thorax Side Airbag

This airbag protects both head and thorax and is used in vehicles where a curtain airbag is un mountable (Autoliv, 2018). These airbags are most suited when the passenger is properly positioned in the car (F. Kjell, personal communication, April 24 2018).

Pelvis-Thorax Airbag

The pelvis-thorax airbag (figure 11) is an extended version of the thorax-side airbag. This extra cell, which gets a higher pressure during the inflation, makes a better protection to the pelvis and thorax area.

Figure 11. Deployed Pelvis -Thorax airbag.
(Autoliv, 2018).
Used with permission.

Almost all manufactures install side airbags in the first row, even though it is not a legal requirement (Insurance Institute for Highway Safety, 2018). This in order to meet side protection requirements and get a higher score in Euro NCAP, and through this increase the customer range.

Front Center Airbag

To protect drivers and front passengers in a far-side impact, a front center airbag is placed in the inboard side of the driver's seat (figure 12). This airbag prevents serious injuries as excessive neck/spine bending and reduces the risk of passenger and driver to collide during a crash (Autoliv, 2018).

Front center airbag is a relative new product, and was introduced to the market in 2013 by General Motors (Dunn, 2018).

Figure 12. Deployed front center airbag. (Autoliv, 2018). Used with permission.

Life Cell Airbag

The Life Cell Airbag was developed by Autoliv, and are mounted directly in the chair. This creates the opportunity for the airbag to be protective regardless of the chairs comfort settings. The shape provides protection for both far-side, near side and for impact from unsecured objects. Together with the frontal airbag in the steering wheel, this airbag creates a protective cocoon as seen in figure 13 (Autoliv, 2018).

Figure 13. Deployed Life Cell Airbag. (Autoliv, 2018). Used with permission.

2.5.3 Rear Seat Safety

From the above described safety devices only seat belts with pretensioners and load limiters are frequently used, this is however not a legal requirement. Despite this, the pretensioner and load limiters exist in most cars, as it provides a safer vehicle and creates higher ratings in, for example, EuroNCAP (N. Schaerer, personal communication, April 24, 2018). However, these are not a common equipment for the middle seat, due to packaging constraints.

As in the front seat, the side airbag and curtain airbag is an option for the rear seat. The side airbag is more unusual than in the first row and if there is a curtain airbag in the vehicle, it protects the rear seat as well.

The rear seat has previously been known to be a safer place to sit in, compared to sitting in the front seat. This has recently been proved to be incorrect, due to increased effectiveness and advanced restrictions in the front seat, in newer vehicles (Wiacek, Rudd & Collins, 2011). As the customers have higher demands, the rear seat now gets more focus.

2.6 CHILDREN IN VEHICLE

Children shorter than 135 centimeters need special safety devices, such as carrycots and a variation of child restraints (Transportstyrelsen, 2018).

Children have different body proportions than fully grown adults, as well as other strengths and weaknesses, which changes rapidly at the speed of their growth. One major difference between children and adults are that a smaller part of the children's abdomen is protected by the pelvis and rib cage. Furthermore, the children's rib cage is more ductile and bends rather than breaks, which transmits the energy from the collision to the child's heart and lungs (Toryan & Peden, 2007).

Further, a child's proportions differ from an adult by having a large and heavy head, relative to the rest of the body and especially the neck. This causes the head to launch forward in the event of a collision (Transportstyrelsen, 2018) or by a heavy break.

To prevent this head launch in the most critical ages, all children under 4 years are recommended to travel backwards. The rearward facing child restraint absorbs the energy of the impact and protects the child's head and neck. If the child travels facing forward, the risk of dying or getting serious injuries are five times higher (Transportstyrelsen, 2018).

Since all children under age of 4 are supposed to travel in rear-facing child restraints, the *International Organization of Standardization,* ISO, has introduced a standardization, isofix, (ISO 13216) which fixes the child restraint in a quick and simple way. Isofix consists of two metal anchorage (Besafe, 2018), located between the backrest and seat (figure 14), which minimizes the risk of misassemble.

Figure 14. ISOFIX, a simple way to fixate the child restraint. Author's own copyright.

2.7 ELDERLY IN VEHICLE

Today's society shows that there are increasingly older people who have driving licenses and cars, compared with previous years (Trafikverket, 2014). An increasing age leads to a fragile body which can result in an increased morbidity. Furthermore, the safety of the car must be adapted to the elderly in order to reduce the risk of serious injuries. A comparison between an 75 year old driver with a person between 30-70 year shows that the risk to be injured or killed in traffic is 2.5 higher for the older person (Transportstyrelsen, 2018).

This increased risk for elderly of getting seriously injured may have many reasons. At the age of 40 years, people start to decrease in length, as well as a decrease in body weight. The weight loss does not mean fat loss, but a decay of muscles (Pheasant, 2006). Even though the body fat does not decrease, it rearranges to other parts of the body - making the proportions of elderly slightly different.

Due to the differences in proportions, and the decreasing muscles, it is of great importance to include the elderly while developing car safety systems. Which is why NHTSA launched a five-year plan in 2013 to enhance road safety for elderly people. This plan aims to that the safety systems should be reviewed in order to be adapted to the elderly, as the older population increases (NHTSA, 2013). The plan describes what should be done in the near term, short term and long term in order to enable a better safety system. For example, the plan describes that they need to get more data about the injury risk and the relationship between an older person’s anatomy and the tolerance of injuries.

2.8 COLLISIONS AND INJURIES

Each year over 1,2 million people die in traffic all over the world, and over 50 million obtain severe injuries (World Health Organization, 2015). The death rate is higher in low-income countries, as they have not managed to maintain the infrastructure, when vehicle use increases. In India, for example, 20,000 people die each year in traffic (Autoliv, 2013), whilst there are only 300, and below, deaths in Sweden per year (European Commission, 2018).

Severe accidents that occur in traffic are mainly due to the human error (NHTSA, 2018). These collisions occur due to, for example, speeding, driving while drunk or that the driver is distracted and not aware of the situation (World Health Organization, 2015). The *Global Status Report on Safety* (2015) describes that speed limit laws, the use of seat belts and child restraints as well as the legislation for not driving drunk have had positive effects in which collisions, injuries and fatalities have been reduced.

2.8.1 The Most Common and Deadliest Types of Collisions

The most common collision is when you get hit in the rear from the car behind (NHTSA, 2015). This type of accident does not usually cause any death or serious injury. However, long-term damage such as whiplash has a high possibility to occur, usually at low speed (Carlsson & Svensson, 2014).

48 percent of fatal accidents are caused by side collisions and rollovers (Autoliv, 2010). However, the most common type of collision with a fatal outcome is a frontal collision (The Automobile Association, 2015). Another type of accidents is those in cross sections, both between vehicles and pedestrians. However, the amount of fatalities in these types of collisions are fairly low as the speed are reduced.

In multiple impact collisions, in which there are two or more impacts during the accident, the risk of getting severe injuries is three times higher, and fatal injuries four times higher than in a one impact collision (Sander, Mroz, Boström & Fredriksson, 2009).

2.8.2 Common Injuries

Even though the vehicle safety systems such as airbags and seatbelt may prevent a head impact, the most typical cause of injuries causing death or severe disability are head injuries (Schmitt, 2004).

The most common injuries in car accidents are traumas to the head, neck and pelvis (European Commission, 2017). Where the soft tissue injuries in the neck are one of the most typical occurring, as the loading on the head transfers as neck loading, but near all injured are fully recovered (Schmitt, 2004).

Injuries to the thorax are frequently occurring due to frontal and side collisions, as well as a multiple impact collision. These occur when the occupant gets a direct contact with the vehicle interior or a direct impact from the side (Schmitt, 2004).

2.8.3 Future Accidents

The accidents and collisions of the future will look different from the ones today. Looking at the collisions that will take place in the next 5 years, it will be the same as today. However, more cars are becoming autonomous, which will create a change in how the collisions occur (N. Lubbe, personal communication, April 12, 2018). During the transition period, where there are both regular and autonomous cars, the human error will still play its part.

When all vehicles are autonomous, rear-end collisions will completely disappear (N. Lubbe, personal communication, April 12, 2018). This as the vehicles will be equipped with a system that are able to know the distance to the vehicle ahead, and know when to decelerate to keep a safe distance, familiar to an adaptive cruise control system (Magdici & Althoff, 2017). Further, introducing a driver warning system can reduce intersection collisions up to 50%, and with an autonomous emergency braking system up to 70%. These reductions require that the systems are faultless (Sander & Lubbe, 2018) and that every vehicle in traffic are provided with these.

3. METHODS

This chapter define the methods, and how the usage throughout the project.

3.1 ONLINE QUESTIONNAIRE

By using an internet based questionnaire, an indirect questioning method, a large amount of answers is enabled (Karlsson, 2007). This survey was shaped to retrieve an image of who the users are and how the rear seat and an autonomous car is perceived. The questions in the survey are both multiple choices and shorts text answers, where only the multiple-choice ones were mandatory. This to prevent that those without text answers not submitting the survey at all. The multiple-choice questions resulted in quantitative results, whilst the short text answers resulted in qualitative results (Karlsson, 2007).

The questions were opening with who the user is, the user's family situation and how the rear seats are used today. These are easy to answer, and will give the submitter a warm up. The questions were then formed more about how the user feel about the automated cars of tomorrow, and how the automation will affect the car interior. The lack of description, regarding the automated cars, in the introduction is a deliberately made choice to prevent giving the submitters any boundaries. The questions in full can be reviewed in appendix 1.

The survey was compiled and the written responses analyzed using the following KJ-method.

3.2 OBSERVATION

An observation is a method where the product and/or the user is observed in an ordinary situation. The method is used both in the beginning of a project to develop a deeper understanding for the product, but also in the end to determine how well the concept fulfils its use (Karlsson, 2007). In this project different rear seat solutions, seating solutions in other vehicles and the usage of these has been observed.

3.2.1 The Rear Seat Over Time

In order to see how the rear seat has changed over time, an observation was made at a brand specific car museum in Gothenburg. The cars that was shown were from the 1920s to the 21st century, which resulted in a wide variety of cars.

3.2.2 Rear Seats in Different Car Markets

To create an overview of the existing rear seat market, brief observations of different car brands were made. This took place both in designated brand stores, and those with a variety of brands. During these observations, the rear seat was tested, photographed and evaluated. Each observation ended with a short interview, with the automobile salesmen. These interview questions can be viewed in appendix 2.

3.2.3 Observation of Suitable Solutions

The fact that the automated car, in grade five, not yet have penetrated the market, make the interior undefined. To evaluate different interior concepts, some functions were tested outside of the car industry. Observations regarding the rotatable and foldable front seat were made inside motorhomes, which was tested and documented by photographs.

A different function for reclining the backrest was observed in a high-speed train, which was both tested, measured and documented by photographs.

3.2.4 Participant Observations at the Vårgårda Fair

To determine how users with different sizes take place in the rear seat, open observations during Vårgårda fair was made. A total of 21, both women and men, participated in the observation. These attendants were selected with a statistically representative selection, a random selection in order to represent the target group (Karlsson, 2007) - a group of all ages with different sizes.

During this observation, the participants was placed in the driver seat at first, to interact with the vehicle. Then the participant moved to the rear seat, in which the comfort experience, in both front and rear seat was evaluated with the help of a scale as seen in figure 15.

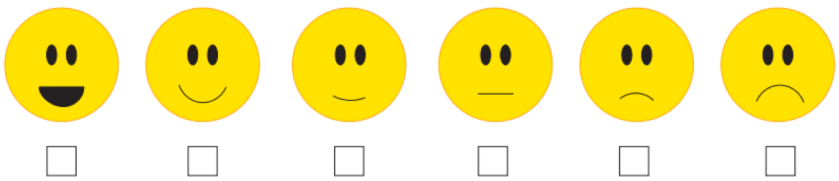

Figure 15. Evaluation scale of perceived comfort. Author's own copyright.

After the comfort evaluation, the participant got to answer a few questions regarding the experience. These questions were:

- Are you comfortable? Why?
- What would you like to change?
- Was it more comfortable in the front seat? Why?

The participants actions and answers was written down and documented by photographs, so analyzes could be implemented and generate important results about the rear seat. To enable comparison, regarding the size, the participants seat height was measured.

The KJ- Method, described in the section *3.4 KJ-Method*, was used to analyze the participants answers. This to be able to make conclusions and go forward in the process to developing a new rear seat.

3.3 INTERVIEW

An interview is where a number of question is being asked and the answers are recorded. This method is the most basic one to sample information of the user (Karlsson, 2007). The advantage with interviews is that it can lead to more qualitative responses, in which soft product values can be noted (Johannesson, 2013). The interviews have been carried out with people well informed with the automotive safety industry.

To get a deeper knowledge about car safety and how it works, several semi-structured interviews with specialized people was fulfilled. Semi-structured interviews are interviews with predetermined questions, this in order to have questions to start with but can lead to follow-up questions developed during the interview (Academic Work, 2018).

The interviews started with a short introduction where the participants got informed what the aim of the thesis was, to give a brief understanding what was needed. General questions preamble the interview to get an overview about today's situation in the vehicles. These questions were thereafter more directed against the participants area, which can be viewed in full in appendix 3-7, and the meeting ended up asking for ideas and which direction the thesis should indicate. The consultations were recorded to not lose important information and draw overhasty conclusions, this was accepted by all respondents.

Furthermore, an interview with a person living in Pakistan, whom have had private drivers, was performed to learn more about the rear seat usage in that part of the world. These questions revolved around how the rear seat was perceived, how it was used and how and where the vehicle safety culture appeared in Pakistan. The interviewed Pakistani have traveling experiences from both Sweden and other parts of the west hemisphere, which enabled comparison type of questions. The interview questions can be reviewed in full in appendix 8.

3.4 KJ-METHOD

The KJ-analysis method is a way to enable a structure out of verbal questionnaire answers. This method does also provide a way to create an overview, and to communicate these answers (Karlsson, 2007). This was carried out by writing all answers on separate notes, and group them together until every note had been used, as seen in figure 16. Notes of groups and the amount of same answers was made to summarize the survey.

Figure 16. Example of an KJ-analysis. Author's own copyright.

3.5 ANTHROPOMETRY

Anthropometry is the study of human body measurements and includes human dimensions and proportions, body positions, ranges and movement space (Bohgard, 2015). The data is used when designing product and environments according to human conditions, to produce the right product to the right presumption.

To form a concept with the right proportions, anthropometry has been used.

The anthropometric data was collected from the book *Bodyspace: Anthropometry, Ergonomics and the Design of Work* where the design has been adapted to the 95th percentile. Use of the 95th percentile will ensure that the majority of the population will fit. This is because the 95th percentile means that only 5 percent of the population is larger and 95 percent is smaller (Pheasant, 2006), and will result that 95 percent will get enough space. The dimensions will be adapted for both adults, elderly and children, to accommodate as large population as possible.

The table below (table 1) shows the dimensions that is required, for Swedish Adults, for the study and is captured from the aforementioned book *Bodyspace*. It shows the 5th to 95th percentile for women and men and shows the divergence.

To accommodate dimensions that suits everyone, the 95 percentiles of men is used. This because men are larger.

3.5.1 Structural Data

Structural data is used to find out the dimensions and distances in standardized body positions (Bohgard, 2015). The data is utilized to find the right dimensions and proportions to a seat position, to lead to a well-adjusted rear seat. The most important structural dimensions for the study is the seat width and seat length.

To use the correct seat width and length parameters, the table shown below (table 1) is used. The seat width is described as hip breadth and seat length as buttock-popliteal length.

3.5.2 Functional Data

Functional data describes how much space and range is required in different situations. This data is used to obtain the dimensions that is needed for motion space and range in the rear seat to produce the right proportions (Bohgard, 2015).

For the passenger to experience a satisfactory seating position, the legroom needs to be adequate. To be able to get enough space the equation (equation 1) is used. By inserting the values from table 1 the result, for a 95-percentile man, is a length, *d,* of 752 millimeters.

$$d = b + \sqrt{p^2 - H^2} + f$$

Equation 1. To calculate *d*, the distance between buttocks and toes. Where *b* is buttock-popliteal length, *p* popliteal length, *f* foot length and *H* is the seat of height. Author's own copyright.

Table 1. Percentile dimensions, relevant to rear seat chair.
Numbers used from Pheasant, 2006. Author's own copyright.

	Men			Women		
Percentile:	5th	50th	95th	5th	50th	95th
Dimension						
Sitting height	830	900	970	805	860	915
Shoulder breadth	420	465	510	355	390	425
Hip breadth	310	360	410	315	365	415
Buttock-popliteal lenght	430	480	530	430	485	540
popliteal height	385	430	475	350	400	450
Knee height	480	530	580	455	500	545
Head lenght	185	195	205	170	180	190
Head breadth	145	155	165	135	145	155
foot length	240	265	290	225	245	265

3.6 SPECIFICATION OF FUNCTION

To evaluate why the product exists, there must be a specification of functions. In this specification, the functions are expressed by a verb and a noun phrase. It is of great importance to not have the phrases too precise, in order to prevent narrowing down the ideas (Österlin, 2011). The function phrases are prioritized based on how essential they are for the main function of the product, which are divided into groups of; main function, *MF*, part function, *PF*, support function, *SF,* and desirable, *D*. This enables a wider solution approach.

The main function, *MF,* is the main purpose of the product and the part functions, *PF,* are the functions needed to fulfill the main function. Support functions in the other hand are the functions that is extra for the product and are not needed for the purpose (J. Tuveson, personal communication, September 10, 2015).

The function specification is made on both the rear seat, and on an overall airbag. This is to enable an understanding of which are the most important features on both of the products.

3.7 PRODUCT SPECIFICATION

A product specification is made to define the requirements of a product and to achieve the customer needs (Österlin, 2011). A theoretical framework will result in a specification of requirement, defined with the functional requirements (Johannesson, Persson and Pettersson, 2013) and can be used in the design phase for guidelines. When evaluating the concepts, a product specification can be used to analyze the products and lead to a final conceptual selection.

3.8 BRAINWRITING

As a part of the idea generation, the project used a method called brainwriting. This method is formed to prevent the project members to immerse on the same ideas (Österlin, 2011). The aforementioned method is performed by doing the brainstorming individually, writing down multiple ideas, complete solutions or a small attribute, on pieces of paper during a set time of five minutes. Afterword the project members deliberate all ideas, gaining new inspiration in order to perform the exercise one more time. All the generated ideas are then sorted into groups, to create an overview of the solutions.

The first brainwriting session was carried out by the two authors alone. This was done before having a lot of knowledge about how airbags work, to create a wider range of ideas. The session was ten minutes, in which every idea and thought was put down on paper notes. To enhance the idea range, balloons was used as inspiration. After the session was done, the ideas were discussed to create a greater understanding.

3.8.1 Cooperative Brainwriting

As the ideas from the first brainwriting were pretty wide, a decision was made to have a brainwriting session together with people working with or around the subject. To get together a group of people with shared experiences in the subject, a theoretically representative selection of participants was used. This to get out a wide range of good and suitable ideas. A theoretically representative selection is meant that participants are selected based on representative criteria, that is to say, have the same experiential characteristics (Karlsson, 2007). Fifteen people were invited, eight of these could come.

The workshop started with a presentation of the thesis writers and what the purpose of the thesis were. Furthermore, the expected rear seat and interior in an autonomous car was presented and discussed - to give the workshop participants an understanding for what type of rear seat the airbag could be placed. Followed by that, the participants got to introduce themselves including the occupation.

In front of the participants, the table was filled with printed pictures of both rear seats and other inspirational objects as seen in figure 17. This was to prevent any absence of ideas.

Figure 17. Inspirational figures at the cooperative brainwriting session. Author's own copyright.

The first cooperative brainwriting session was signed to evolve around frontal collisions, were the participants was given seven minutes to form and write ideas. After the seven minutes, the ideas were discussed and rated within the group.

The second session evolved around side collisions and how to protect the occupants in that type of impacts. Again, the participants got seven minutes of idea writing and then discussing and rating the ideas without a time frame.

The third session was thought to evolve around multiple collisions, but as the subject was presented - a lively discussion emerged. To avoid missing out on any thoughts and ideas, the discussion was continued and the last brainwriting session was withdrawn.

3.9 PNI: POSITIVE, NEGATIVE, INTERESTING

By creating a chart, listing all the attributes of the ideas, it creates a visible way of discussing the interesting parts of the ideas. The attributes have been evaluated and sorted into; positive (P), negative (N) and interesting (I). The most important part of this method is the discussions leading to the result, not the result itself (Österlin, 2011). By creating this easily overlooked chart, the disadvantages of the ideas can either be deserted or remade.

The PNI matrix was conducted on the ideas developed in the different brainwriting sessions, and can be viewed in chapter *6.4.1 PNI Analysis*.

3.10 DISASSEMBLY ANALYSIS

Design for disassembly is about making the product as simple as possible by designing for disassembly - it means that the product should include few components and simple assemblies. This makes it easier for the manufacturer to replace, upgrade or facilitate recycling and reuse the product (Autodesk, 2017).

To enhance the durability of this safety system, it is of great importance to simplify the disassembly and the replacement of the airbag. By using four elements as an evaluation of the sustainability in the two highest scored concepts - another dimension is being noted. The focus during this sustainability analysis is the design for disassembly, which entails a simplified assembly as well. To enhance the disassembly, there are certain elements that influences this. Some of these are accessibility, standardization, interchangeability, replaceability and repairability (Shetty, 2016). The four most relevant elements in this study, and those used in the evaluation, are:

- Accessibility
- Standardization
- Interchangeability
- Replaceability

3.11 VISUALIZATION

Virtual prototyping is when modeling a product in computer programs. It can be used to give an early perception of the product and expose it in different perspective (Johannesson et. al. 2013), before creating a physical prototype. A prototype can be used in different stages of the design process where different prototypes are used on different occasions to illustrate the intended product (Österlin, 2011).

Computer-aided design program and prototypes

In order to be able to show the product more clearly and to demonstrated it at different angles, the winning concept -Inflatable Frontal Curtain was created in computer-aided design program (CAD), in the Autodesk Alias program. It is structured in an easy way to quickly display its intended form in different perspectives. It is visualized alongside the rear seats to provide insight into the size of the airbag and its location to the seats.

4. RESULTS OF REAR SEAT USAGE

This chapter presents the user in different parts of the world and how the rear seat is used. The rear seat usage depends on various factors and differ around the world.

During the years that the automobile industry has been producing different car models, a variety of solutions regarding problem solving in the rear seat has been introduced. Many of them did not have the coveted effect and was only placed in a small scale of models.

The seats in the first and second row started off as identical. Both were wide, bench like seats stretching from one side of the car to the other as seen in figure 18. By the time the safety aspects of traveling started to take place, so did the evolution of the driver and front passenger seat start as the rear seat remained close to unchanged.

Figure 18. A bench like rear seat, in an early car model. Author's own copyright.

Automated cars in level 3-4 are still in the need of a designated driver, which implies that the influence on the front seat will be next to nothing. In an interview M. Svensson (20 March, 2018) believes; that private car rear seat usage, probably will remain unchanged in the upcoming 10-15 years. Following are the compiled results, regarding the user of the rear seat and the user needs. The user needs resulted in a rear seat concept.

4.1 THE USER

The people who uses the rear seat differs around the world. This due to elements such as culture, wealth and safety regulations. Therefore, the challenge lies in having the rear seat fitting a wider range of users - children to elderly.

4.1.1 Different Users Around the Globe

Different parts of the world travels in their vehicles in different ways. This was emerged through interviews and studies. When limitations had to be imposed, Europe and the United States were chosen as countries and continents to focus on. Nevertheless, worldwide surveys were made to find out the overall differences that exist.

Europe and the U.S.

Interviews with several automobile salesmen, public surveys and observations, indicate children as the primary passenger in the rear seat. This due to a belief that it holds a higher personal safety, but also due to the rear being less spacious.

In the western hemisphere, rear seats tend to be used by travelers with a “lower priority, or those with shorter legs - due to a shortage of legroom. Lower priority referring to a sort of family hierarchy, where survey answers and observations implies that children and younger siblings have the lowest. The same data suggests that children, even though they have grown up, still travel in the rear seat - mostly out of habit.

Parents, and other adults, choose to travel in the front passenger seat to be able to have a conversation with the driver, but mostly because of the superior comfort. This was confirmed by the automobile salesmen; the car owner travels in the most luxurious and most comfortable seat in the vehicle - the first row. However, the collected data suggests that a majority of the adults prefer to be the driver than a passenger.

Asia

On the other end, in Asia, it is more common for a wealthy car owner to travel in the rear seat, with a personal driver. In this part of the world, the rear seat is more used by adults than in the west hemisphere (A. Haider, personal communication, March 26, 2018). Due to this phenomenon, numerous of car manufactures have special Asian editions, which are about 20-30 cm longer. This is to enable greater leg space. Nowadays; these longer vehicles, are mostly driven by the owner, the length aspect is more of a status symbol, which M. Svensson (personal communication, March 20, 2018) points out.

4.1.2 User Results of Online Questionnaire

The respondents of the online questionnaire were a total of 168 persons when the answers started to reach the point of giving less new information. Out of which 69% were female. 83% of the respondents had a driver's license. The ages were spread as seen in figure 19, the major age group was however 21-25 years.

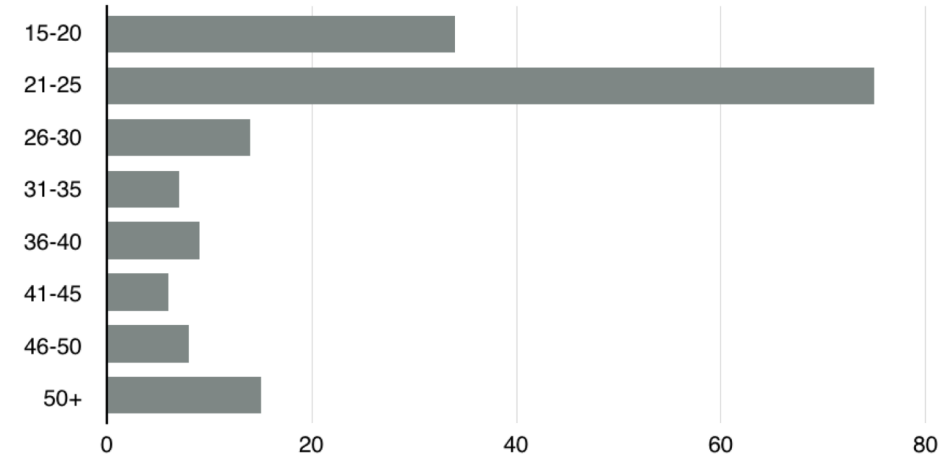

Figure 19. Questionnaire; age distribution. Author's own copyright.

The participants were given a multiple-choice question, which asked for the most likely placement in the rear seat. As figure 20 tells, close to everyone preferred travelling in an upright, correct position. Half of the participants also like to lean against the window.

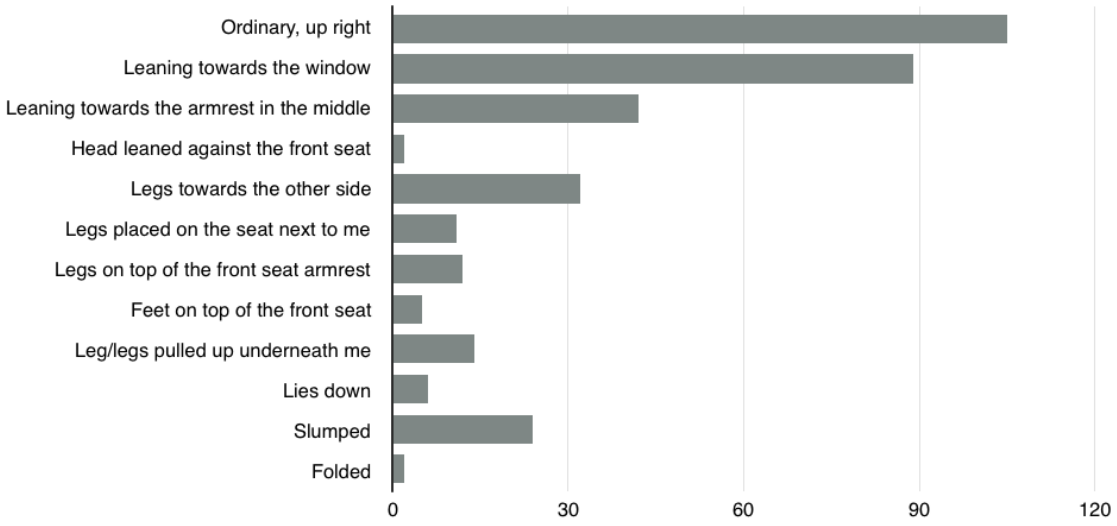

Figure 20. Questionnaire; most likely placement in rear seat. Author's own copyright.

Habits and Family Hierarchy

The online questionnaire resulted in an understanding for how the rear seat is perceived and used by the masses. The major result was regarding how the car is “filled from the front”, which translates to how it is less attractive to travel in the rear seat. The families often consist of somewhat like a family hierarchy, where youngest in the family travels in the rear seat, for example the youngest siblings.

Preferring the First Row

When the survey asked where the respondents preferred to travel, astonishing 94% preferred travelling in the front seat (figure 21). The majority of those was due to the lust of driving, or to be able to have a conversation with the driver. Another big part of the respondents felt like having a greater overview of the driving situation and the overall view.

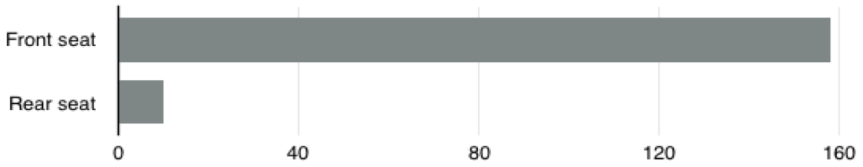

Figure 21. Questionnaire; preferring front or rear seat. Author's own copyright.

Other elements that made the respondents prefer traveling in the front passenger seat was regarding the travel comfort. The ability to change seating posture by many different adjustments that were not abled in the rear seat, such as backrest recline and seat heat. Feeling more spacious and having more leg room was also of great importance.

Preferring the Second Row

The few people who preferred to travel in the rear seat, did so because of the “private” atmosphere. This made it easier for the passenger to sleep, or to listen to their own music in headphones. If there were no one else in the rear seat, the possibility of using more space, to spread out, was also mentioned.

The summary of this section, *the user,* is that most children are placed in the second row in the U.S and Europe while in Asia there are many adult rear seat occupants as well. This indicates that the rear seat must be adaptive to fit a wide range of passengers- children and adults.

4.2 THE USER NEEDS

The user needs were an important part of the project to find out about, because the project would in the end result in a rear seat concept- based on these needs. The user needs emerged from the online questionnaire, observations and from the interviews with automotive salesmen.

4.2.1 The User Needs - Told by the Online Questionnaire

In the online questionnaire, the participants were asked which activities the rear seat should provide. Most important while traveling in the rear seat, as seen in figure 22, was to have a conversation with the first-row occupants.

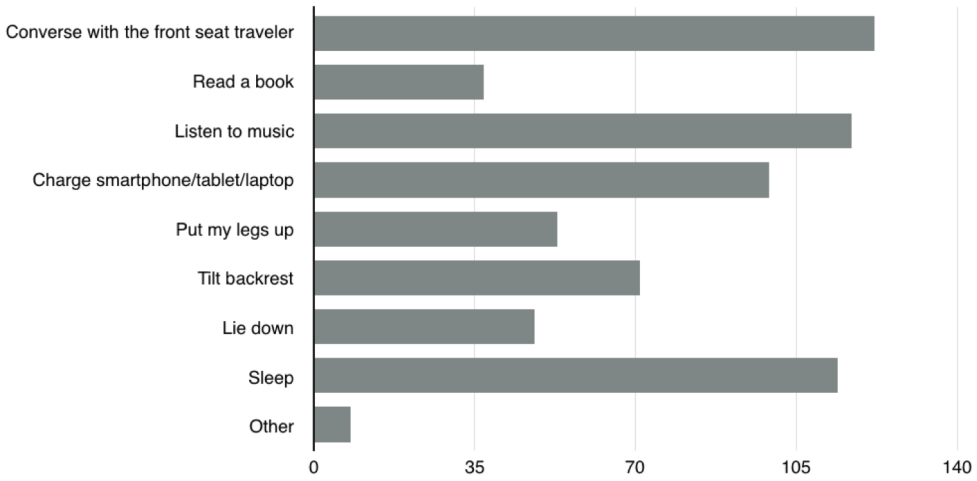

Figure 22. Questionnaire; preferred rear seat activities. Author's own copyright.

The participants were then asked which rear seat factors was important during the purchase of the car. The major rear seat factors while choosing and purchasing a car, appears to be the leg space and comfortable seats (figure 23).

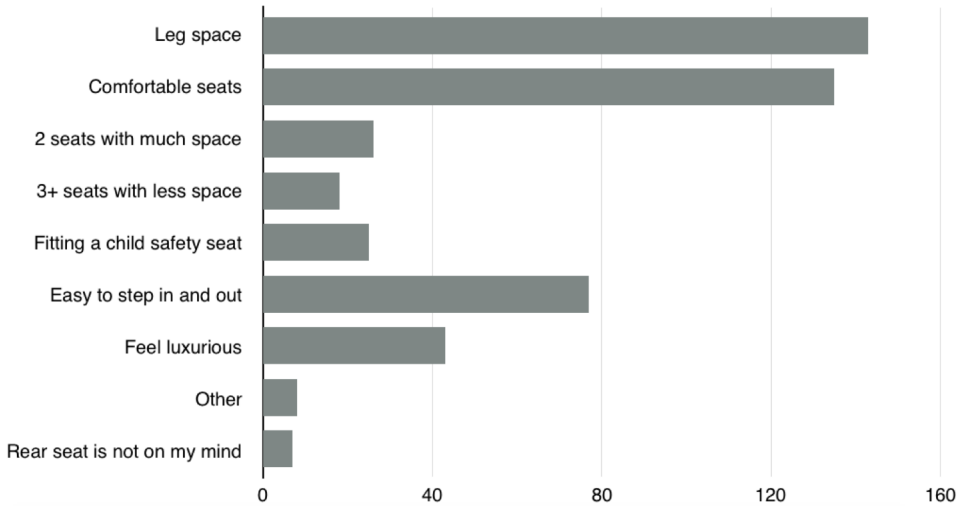

Figure 23. Questionnaire; important rear seat factors at car purchase. Author's own

User Needs – Compiled From the KJ-analysis

The rest of the questions regarding the rear seat needs of the survey respondents were qualitative short text answers. The responses have been analyzed using the KJ-method, where the analysis concluded into following elements.

Motion Sickness

Many answers regarding why the user prefer to sit in the first row was when the passenger was suffering from motion sickness. If someone in the company were suffering from motion sickness, the aforementioned family hierarchy seemed to be discontinued and the troubled family member were prioritized for traveling in the front passenger seat.

Lack of Space

When the passengers are not family members, the ones with the shortest legs are placed in the rear seat. This because of the same reason for placing the youngest children in the back - lack of space and legroom.

Believed Future Car Interior

The questionnaire did also examine how the masses expected, and wished, that the rear seat in the autonomous cars would be. Some answers supposed that the front seats would be rotatable, to enable conversations between all of the passengers. Others thought that it would look like it does in the vehicles of today, but more spacious.

Other thoughts and wishes were that rear seat should be more like the front seats, regarding possible adjustments and comfort. Some even wished for fully reclined seats, almost like beds, with included feet- and armrests. Some also pointed out that it would be more entertainment, including possible device charging. All of these are to make the rear seat travelling more appealing.

Other Thoughts Referring to the Rear Seat

The feeling of safety often coheres with spaciousness and feeling of being in control. Which most rear seats of today are lacking. The rear seat spaces are often in spacious and have a low ceiling, even in larger car models. The same goes with the fact that the rear seat often lacks of sight of the road and surroundings, having the front seat interfering with the view.

Some of the answers refers to having some sort of entertainment, to compensate for the lack of view, while others would prefer traveling like in a train coupe - facing those in the front seat.

4.2.2 The User Needs - Told by Participants at the Vårgårda Fair

By using the KJ - method, the answers from the 21 respondents (figure 24) could be analyzed and divided into different groups. Most of the answers, both male and female respondents, thought that the rear seat in the observed car was comfortable. This referring to the softness of the seat was just enough for it to be comfortable, while the hardness was giving the right amount of support.

Even though the participants thought that the rear seat was comfortable, almost everyone prefered the front seat. This was due to a more bowl-shaped seat, more legroom and the fact that the front seat had more settings regarding the backrest position.

The overall results from this participant observation was that the users would like to have more seat settings such as the ability to change the backrest angle and to change the seat depth, to enable more support to the upper leg. Many of the answers also included the demand of a greater leg space. This all contributed to the conclusion of having a rear seat that have more settings than the rear seat of today, in order to give the same support to a wide range of users.

Figure 24. A normal seating position according to participants at Vårgårda fair.
Author's own copyright.

4.3 SUITABLE VEHICLE INTERIOR SOLUTIONS

Various types of observations were made to observe today's solutions for interior design, in different types of vehicles. Trains, motorhomes and different car brand were visited to obtain information and inspiration. This section describes the results that emerged from these observations.

4.3.1 Different Arrangements in the Car Market Observations

The rear seat in the vehicles of today, have been observed to be different in various cars and brands. The divergent rear seats perceived as very different, where the most comfortable were the ones that were similar to the front seats - a better shaped seat and a more folded backrest. In some cars, the rear seat had very little attention, which could be shown in the seat design and its stiffness. This type of rear seat was experienced as inconvenient and an example of such seat is shown in figure 25. The most uncomfortable seat in all of the observed cars, were the middle seat. This seat had not received as much focus as the outer rear seats, which was shown through receiving lesser space, a more solid cushion and a very straightened backrest.

However, two expensive car models were observed, figure 26 and figure 27, which had a well-designed rear seat. The second row had three broad and comfortable seats with a good angle on the backrest. The car in figure 27 have three self-contained broad seats, were the seats can be moved in the x-axis and the backrest can be folded backwards.

Figure 25. Uncomfortable rear seat. Author's own copyright.

Figure 26. Comfortable rear seat. Author's own copyright.

Figure 27. Adaptive, comfortable rear seat. Author's own copyright.

After each observation, short interviews were made with the automobile salesmen (appendix 2) to enhance the understanding of the customers' demands and thoughts. At the dealership selling a range of car brands, it appeared that the customers had begun to set particular higher demands on child restraints assembly and more legroom space. That the customers set higher demands on the rear seat was also confirmed by the customers in the brand specialized shop.

4.3.2 Reclining Backrest in High Speed Trains

Another solution to meet the users need of reclining the backrest was observed in trains. The seats in high speed trains can be folded backwards, but at the same time as this is done, the seat cushion moves forward (figure 28). This mechanism was tested through this observation and showed how it is possible to implement different ways to variate the angel on the backrest.

The observation indicated that the backrest could be folded seven centimeters backwards at the most, where the varying angle did not require much space. This function is desired in a new rear seat, in order to not interfere the luggage space in the vehicles.

However, this function interferes with the legroom, then the space changes from 36 centimeters in a normal position, to 27 centimeters when the seat is folded. This decreases the legroom and can contribute to a less comfortable seat position for persons with longer legs.

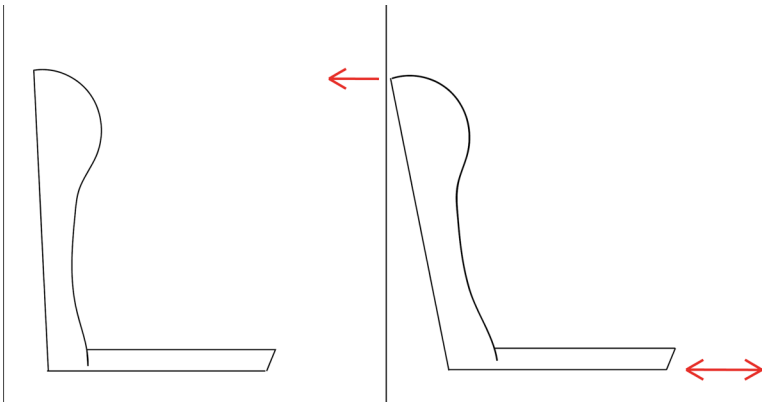

Figure 28. Function of reclining backrest with small interfering with the area behind. Author's own copyright.

4.3.3 Rotatable Front Seats in Motorhomes

The motorhome is unique in the way that the vehicle must fit both during driving and different living conditions. To ensure the most adaptive use of the front seat, they are mounted in a rotatable frame seen in figure 29. This allows the front seats to be used facing the table and rear seat as seen in figure 30 below, when the vehicle is in parked position. This rotation is made possible by the lack of a fitted center console, with the armrest merged to the seat instead.

Figure 29. Rotatable frame in motor home.
Author's own copyright.

Figure 30. Rotated front seat, facing the table.
Author's own copyright.

Furthermore, the front seats are capable of folding forward as in figure 31, while the vehicle is in parked position. This is to enable more space while making a bed out of the table, or to increase the natural light in the living area.

Figure 31: Folded front seat.
Author's own copyright.

This observation resulted in information regarding how the rotatable front seats are already an existing concept, ready to implement in any other vehicle. However, due to the car being less spacious than the motor home, the rotatable frame must be made as neat as possible in order to fit. Further, the integrated armrests give a possibility to remove the center console in the automated cars, without losing the ergonomic advantages this brings.

The foldable seat is something already implemented in ordinary cars, whilst this one gave a vision of how a foldable front seat could perform in an automated car. This could increase both the vision and feeling of having a better overview of the situation when traveling in the rear seat. It also gives the possibility of, for example, placing the legs on top of the folded front seat to enable a more relaxed seating position.

However, these possible front seat solutions will not fit inside the car dimensions of today. Neither will these solutions fit or perform in the cars for the next 10-15, years which is the aim for this study.

4.4 REAR SEAT FUNCTIONS

As mentioned in chapter *3. Methods and Implementation*, a specification of function was made to list the features that meet the demands. All features included in the table 2 have appeared during the pre-study. The features are either main functions, part functions or support functions, where the functions are weighted after these.

Table 2 shows the two main features which ensure that the purpose of the product is met. The table describes that the main functions for the second row are to provide a safe seat for the occupants and to fit all passengers. The part functions as *grant body support* and *allow attachment* are functions needed to fulfil the main function while being able to recline the backrest, allow conversation and offer seat heating are not necessary. While part functions are mandatory, support functions can bring a higher value for the customer.

Table 2. Rear seat function specification. Author's own copyright.

Function	Class	Comment (limit)
Main function		
Grant safe seat	MF	
Fit all	MF	
Allow view	SF	Minimize motion sickness, spacious
Alter backrest angle	SF	Permits ergonomic seat position
Alter seatposition	PF	Permits comfort at longer transit
Allow conversation	SF	Fellowship
Allow personal space	SF	Minimize claustrophobia
Alter seatlength	SF	Femur support
Adjustable seat placement	SF	X-axis, entails personal adaptivity
Offer seat heating	SF	
Grant head support	PF	Minimize whiplash injury
Grant body support	PF	Spread load
Allow folding	SF	Transportation of longer objects
Allow attachment	PF	Seat belt
Allow attachment	PF	Childrestraints - isofix
Minimize gliding	SF	Under seat belt

MF	Main Function
PF	Part Function
SF	Support Function
D	Desirable

This specification of function list was included in the next stage of development, to determine a concept for the rear seat. This was done to get a better overview of what features would be included.

5. RESULTS OF PRESUMED INTERIOR IN AN LEVEL 3-4 AUTOMATED CAR

In this chapter, the results of the rear seat functions are presented. These functions emerged as solutions meeting the results from the user centered studies.

Based on all studies of the user needs, the results could be compiled and evaluated into a concept on the interior of a rear seat. Today's vehicle lacks a comfortable and more customized rear seat and is a big part of why more people prefer to sit in the first row. In order to meet customer requirements, a rear seat concept was created from the user needs.

5.1 ROTATING CHAIRS IN THE FIRST ROW

As the future autonomous vehicle allows a transit without a designated driver, the possibilities of changing the interior are endless. However, while the vehicles still are in stages three to four, at least one person must oversee the transit (SEA, 2014). This means that the first row can only be that much changed.

In order to face the need of an improved conversation situation between the rear and front seat told by both interviews, observations and questionnaire, the front seats are presumed to have a rotation of 15-20 degrees (figure 32) where this rotation grants more space for the front seat passenger.

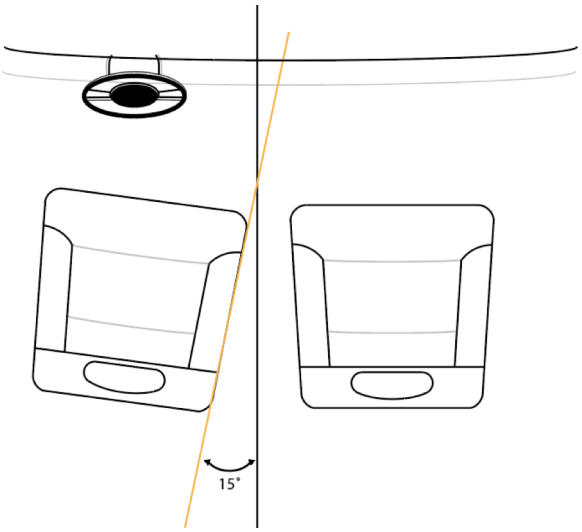

Figure 32. Visionary future front seat rotation angle.
Author's own copyright.

5.2 THREE ADAPTIVE SEATS IN THE VISIONAIRY FUTURE SECOND ROW

In the visionary future second row, there will still be three seats. This is to include as many user segments as possible. These three seats are individual, which grants the user adaptivity. However, the center seat is less prioritized in this study due to interview, observation and questionnaire results pointing to the seat being rarely used.

5.2.1 Bowl Shaped Seat - Increasing Comfort

There is a demand for a more comfortable rear seat that will cause more passengers to sit in the back. The study shows that people lack a more soft and bowl-shaped seat, where such a seat brings stability and convenience. As mentioned in chapter *2.3 SEAT ERGONOMICS*, the body needs support which enables distribution of the body weight, which a bowl-shaped seat does and is why this is included in the new rear seat.

5.2.1 A Reclining Backrest

To meet the needs of the rear seat occupant, in view of both questionnaire, participant observations and interview with automobile salesmen, the rear seat needs to be as adaptive as the front seat. Particularly the possibility for the user to change the backrest angle and the seat cushion length as seen in figure 33.

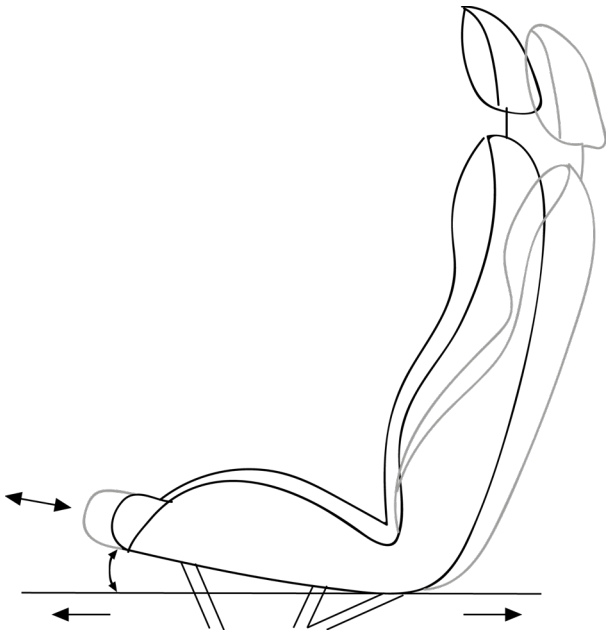

Figure 33. Demonstrating adaptiveness in visionary future rear seat.

In the online questionnaire, it was noted that the comfort of the rear seat should not interfere with the load space in the back. Therefore, to give the occupant as much reclining of the backrest as demanded, without tampering with the loading space, the angle of the seat cushion (β) is raised as in figure 33. By doing this, the backrest is perceived as more reclined than what it actually is. This angle also gives a minimum risk of gliding under the seat belt during a collision or severe braking, and will therefore be for safety reasons as well.

5.2.3 Seat Extension

Having the opportunity to adjust the seat length (figure 33) was something that was desired and emerged from the observations. They want the same comfort as the front seats and this mechanism is something that some of today's vehicles have. Implementing this in the back seat contributes to a higher customer value and allows for a more ergonomic seating position. The seat extension allows passengers to set buttock-popliteal length, where a good length contributes to a good back support for the lower back and a lower risk of discomfort pressure.

5.2.4 Movement in X-Axis

In order to make the rear seat as adaptive as possible, the seats can be moved forward and backward in the x-direction (figure 34). By enabling this action, the user can set the distance from the front seat based on length of the legs.

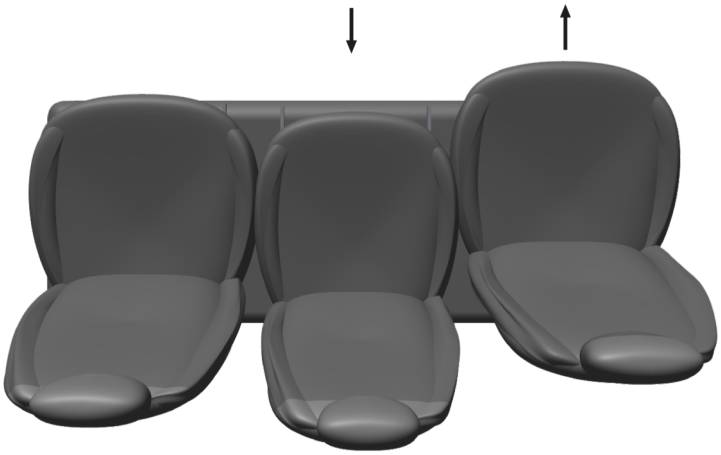

Figure 34. A rear seat seen from above, showing the movement in the x-axis. Author's own copyright.

5.3 SEAT MEASURMENTS

Chapter 2.3 and 3.5 mentions ergonomics, comfort and anthropometry where the denominator is to have a correct measure on the seat. These provide answers to which dimensions are desirable in the creation of a new rear seat, to meet the main function; *fit all passengers*.

The seat cushion with a minimum width of 500 mm is a demand to get the right support. The depth should not exceed the buttock-popliteal length and should have a depth of 430 mm, for both a 5-percentile woman and man. To be designed for all, the extended cushion could have a maximum length of 540 mm, according to the table 1 in chapter *3.5*.

To be able to have a fully supported backrest, with support for head and neck, a height of 900 mm should be adapted, this to fit up to a 95-percentile man (Pheasant, 2006).

These measurements (figure 35) is adapted to give the best support for all passengers, but when different cars have different dimensions, they will need to be adjusted accordingly.

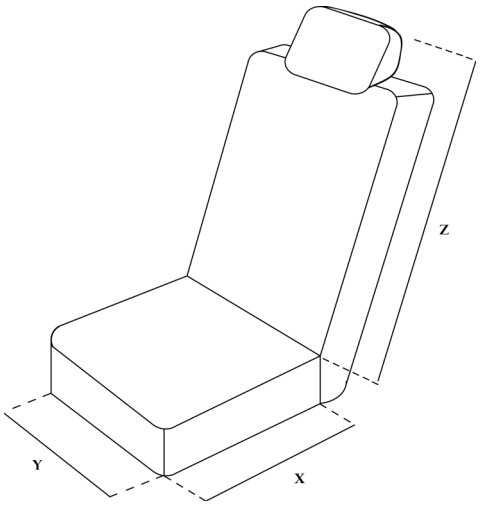

Figure 35. Seat dimensions.
Y= seat width, X= seat depth and
Y= backrest height.

6. RESULTS OF SUGGESTED REAR SEAT SAFETY

This chapter presents the results of the development of an airbag concept.

Throughout all interviews the participants proclaim that car collisions will occur even in the future. This shows that seat belts and airbags will still be an important safety device in all vehicles.

6.1 AIRBAG FUNCTIONS

In order to get all the necessary functions, to meet the main function, a specification of functions was made on an overall airbag.

As seen in table 3, the airbags main function is to protect the occupants. If this is not met, passengers will be injured if a crash occur and, in the worst-case scenario, may lead to fatalities. To prevent this from happening, the product must absorb energy, prevent impact and body injuries - it must fulfill the part functions.

This list was included in the development phase, to ensure that no important features were forgotten.

Table 3. Airbag function specification. Author's own copyright.

Function	Class	Comment (limit)
Main function		
Protect occupant	MF	
Prevent impact	PF	Head impact, front seat
Absorb energy	PF	Minimize impact energy
Allow Out of Position	PF	Protecting different seating positions
Prevent body injury	PF	Från kollision
Prevent causalties	PF	
Allow adaptivity	D	Fit all
Re-usable	D	No discard after collision
Allow safe transportation	PF	Noticable for occupant
Allow mounting	PF	
Contain gas	PF	
Expand rapidly	PF	
Rapidly duration of action	PF	Vent holes that releases the gas
Enclose technology	PF	Technology must fit
Protection in all collisions	D	Frontal, sido, multiple, rear side
Protect the whole body	D	Head, legs, arms, chest, pelvis

MF	Main Function
PF	Part Function
D	Desirable

6.2 AIRBAG PRODUCT SPECIFICATION

A product specification, containing what this airbag concept should fulfill, was conducted after the interviews, observations and the theoretical framework. In order to clarify which of the specifications that are most important, weighting, a scale of 1-5 was made on all requirements, based on the answers obtained during the study. Table 4 shows that all requirements that are desirable, (D), have a lower weighting against the required ones, (R), as these must be met. The scale indicates that 1 has the lowest priority and 5 has the highest.

Table 4 indicates that an airbag must fit the new seat features, such as a reclining backrest and with the seat shifting in x-direction. Another requirement is that the packaging should be small, this because it has a better opportunity to fit the car's interior structure.

To enhance the protection for all rear seat occupants, the airbag must be adapted to everyone, or be able to set in different modes to enable this. Since this is considered important and something that needs to be achieved, these requirements are set to be mandatory. For additional requirements placed on the airbag, see table 4 below.

Table 4. Weighted airbag product specification. Author's own copyright.

Requirement		Weight
Size		
Small packaging	R	3
Light wieght	D	4
Escape post collision	R	5
Fits different types of cars	D	3
Collision		
Energy absorbant	R	5
Protection for all three seats	D	3
Protection during frontal collision	R	5
Protectiong during side collision	R	5
Protection during multiple collisions	R	5
Interrior compatibility		
Compatible with rotatable front seat	R	5
Compatible with sunroof	R	4
Stable	R	5
Compatible with seat cushion angle	R	5
Compatible with seat extension	R	5
Compatible with recline	R	5
Compatible with shitf in x-direction	R	5
Compatible if rotatable rear seat	D	1
User compatibility		
Fits women	R	5
Fits men	R	5
Fits elderly	R	5
Fits children	R	5
Fits rear facing baby restraints	D	2
Deactivation	R	5
No need to discard after use	D	2
		102

R	Requirement
D	Desirable

6.3 AIRBAG CONCEPTUALIZING

The various brainwriting processes resulted in a wide range of ideas (figure 36) and ended with deciding which ideas were most suitable for the rear seat (figure 37) and proceeded to the evaluation process. This section lists the selected concepts and a description on how they work.

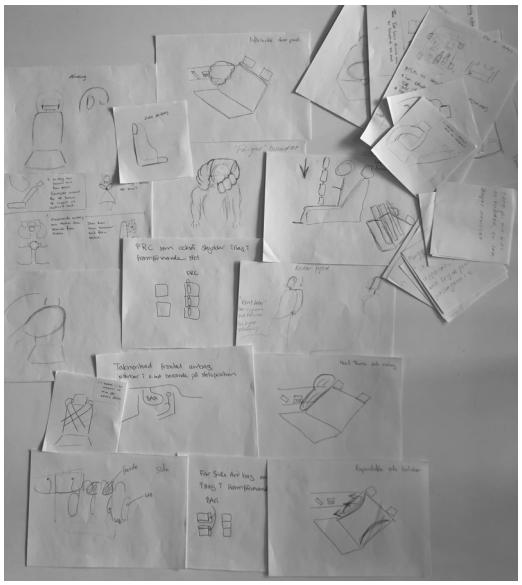

Figure 36. Brainwriting ideas. Author's own copyright.

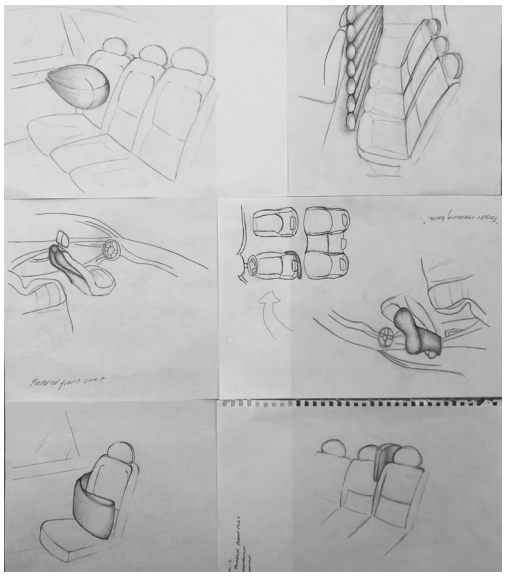

Figure 37. The ideas selected for further analyzing. Author's own copyright.

Inflatable Frontal Curtain

The Inflatable Frontal Curtain, IFC, has an existing technology. This idea is based on placing an additional IC straight through the car, behind the first row as seen in figure 38. This prevents all occupants in the rear seat from hitting the first-row seats in the event of a collision. The idea includes having a split line through the interior ceiling, which means that the ceiling no longer can be made in one part.

This idea has different possibilities regarding shapes and form, which can be decided based on which functions it should fulfill. Furthermore, by having a compact type of curtain the airbag protects the first-row occupants from getting struck by loose objects or unbelted passengers from behind.

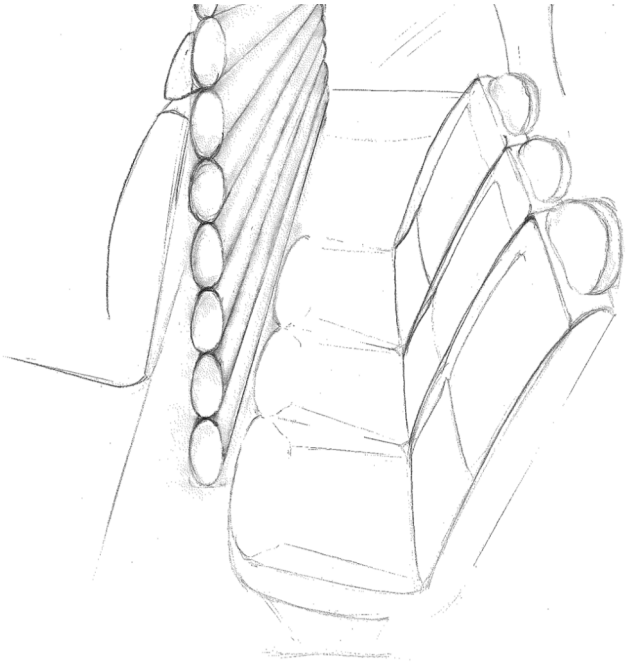

Figure 38. IC Mid Ceiling. Author's own copyright.

Front Farside Reaching Back

This idea is based on using the existing technology from an far side airbag, that is mounted in the front seat. By making the bag larger, in an attempt to let it follow the front seat to the back as seen in figure 39 and 40, it could protect rear seat occupants from hitting the front seat.

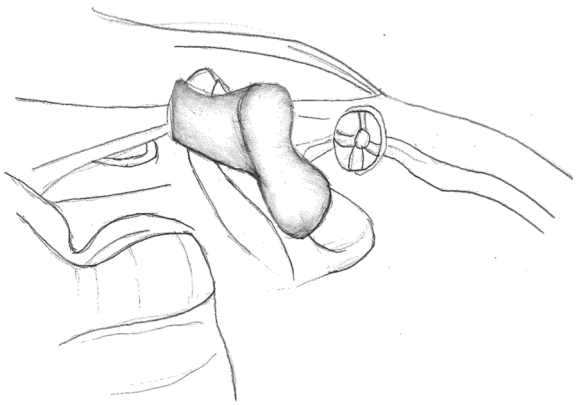

Figure 39. Side view of far side reaching back airbag. Author's own copyright

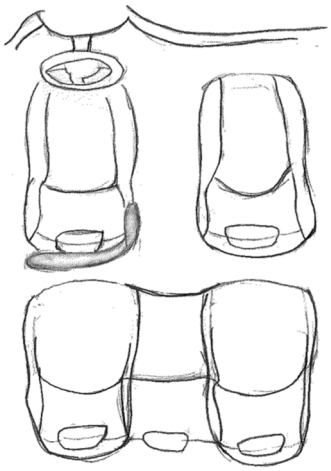

Figure 40. Far side reaching back airbag from above. Author's own copyright.

Padded Front Seat

The padded front seat builds on the idea of making the front seat design less harmful in the event of a rear seat occupant hitting it. This means that the front seats are already padded as seen in figure 41, or filled, with either cushioning or gas. In the event of an impact, the seat would have ventilation holes which opens to extract the air inside the cushioning - absorbing some of the impact energy.

When the pressure from the occupant reduces, the padding is refilled to its original shape. Therefore, the front seat does not have to be discarded after usage of this safety gear. The refilling makes the solution suitable as protection in multiple impact accidents.

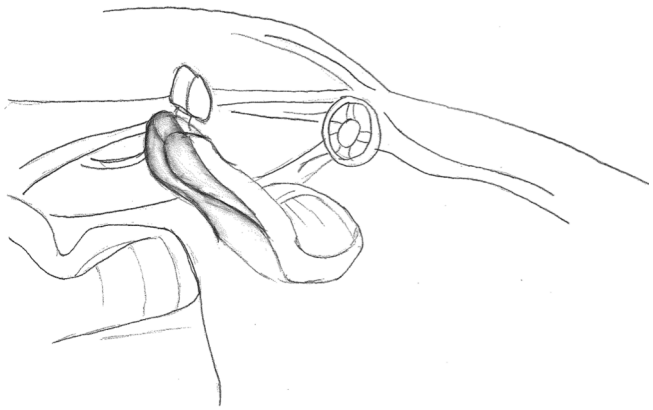

Figure 41. Padded front seat. Author's own copyright.

Door Mounted Frontal airbag

This idea is acting like a frontal airbag, mounted in the door in the rear seat as seen in figure 42. The cushion inflates when the sensor detects a collision and is immediately deflected, to create a softer impact.

Because it is mounted in the door, only passengers in the outer seats receive protection in the event of a frontal collision.

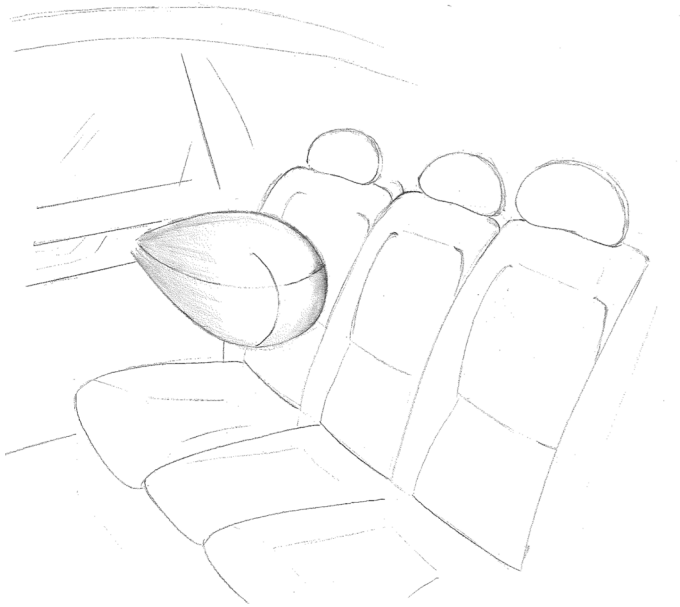

Figure 42. Door mounted frontalbag. Author's own copyright.

Enclosing

The enclosing airbag are mounted in the outer sides of the rear seat. When a collision occurs, the airbag deploys and bends over the passenger as seen in figure 43. This prevents the occupant from launching forward. Furthermore, the side installations entail a rear side protection for the occupant.

The enclosing of the airbag may implicate a feeling of an embrace and a comforting feeling.

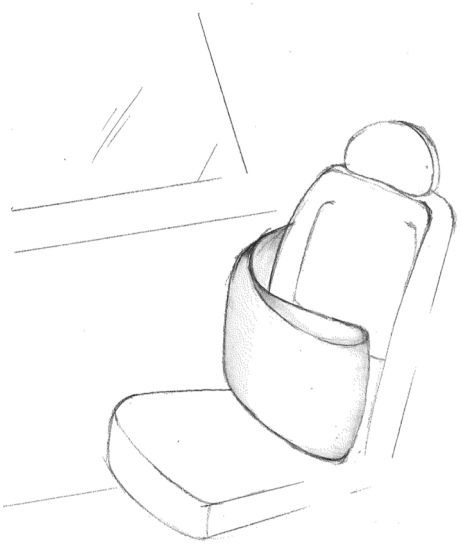

Figure 43. Enclosing airbag. Author's own copyright.

Far Side in Rear Seat Headrest

By implementing the front seat far side airbag, in the rear seat headrests as seen in figure 44, it prevents the occupant's heads from colliding. These airbags are only placed in the headrests of the outer seats, facing the center seat. This placement enables far side protection for all three rear seats.

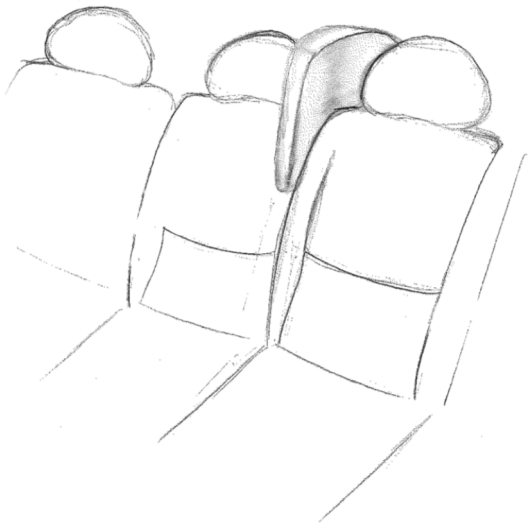

Figure 44. Far side airbag in rear seat headrest.

6.4 CONCEPT ANALYSIS

The different evaluation methods; *PNI matrix, weighting of demands* and *disassembly analysis* was conducted on all concepts that emerged in a final concept. This section describes the results of all of the aforementioned methods.

6.4.1 PNI analysis

In order to create a clear overview of the ideas, a PNI analysis was made. This analysis focused on the positive and negative aspects of the ideas. Table 5 shows the highlights of the PNI analysis, the full analysis can be viewed in appendix 9.

Table 5. PNI analysis highlights. Author's own copyright.

Idea	**P**ositive	**N**egative	**I**nteresting
IC mid ceiling	+ All three seats + Prevents objects from hitting front seat occupants + One bag	- Split line in ceiling - Large bag, expensive - May cause neck injuries, if front seat chair is far ahead	Different patterns, shapes - net, pillar Possibility to extend - covers the legs Split line entails design choices
Front farside reaching back	+ Two in one + Prevents hitting the front seat + Compatible with rotating front seat	- Complex, different type of bags - Large, expensive - No protection for center seat	New
Padded front seat	+ No pyrotechnics + Compatible with rotating front seat + Protection in frontal- and multiple impacts	- Large - Demands new front seat - No protection for center seat	New technology that makes the airbag reusable - returns to original shape Vent holes which opens at impact
Door mounted frontalbag	+ Existing technology + Compatible with rotating front seat	- No center seat protection - Unsafe with rear facing child restraint	
Enclosing (mounted in seat side)	+ Protects both frontal- and side impact + Compatible with rotating front seat + Prevents upper body launch	- Difficult to fit in smaller vehicles - Unsafe with child restraints - Does not fit all body types	Embracing, perceived as safe - as a hug May grant support for pelvis, depending on size
Far side - rear seat headrest	+ Prevents rear seat occupants from hitting each other + Compatible with rotating front seat + Small package, light	- Only head protection - Difficult to adapt to children, shorter persons	Great complement to other airbags

6.4.2 Weighting of Demands and the Concepts Fulfillment

Through the compiled product specification (table 6), with weighting based on legal requirements and wishes, all concepts could be compared and evaluated in a further step. This was to get a result of which concept that meets most requirements. Each requirement that each concept meets got the same score as its weighting. This resulted in two concepts with the highest scores - Inflatable frontal curtain and Far-side in Headrest (table 6). For full evaluation and scoring of all concepts, see appendix 10.

Table 6. Concept fulfilment of product requirements. Author's own copyright

Requirement		Weight	IFC	Comment	Farside in headrest	Comment
Size						
Small packaging	R	3	3		3	
Light wieght	D	4	4		4	
Escape post collision	R	5	5		5	
Fits different types of cars	D	3	3		3	
Collision						
Energy absorbant	R	5	5		5	
Protection for all three seats	D	3	3		3	
Protection during frontal collision	R	5	5		-	
Protectiong during side collision	R	5	-		5	
Protection during multiple collisions	R	5	Maybe		Maybe	
Interrior compatibility						
Compatible with rotatable front seat	R	5	5		5	
Compatible with sunroof	R	4	Maybe		4	
Stable	R	5	5		5	
Compatible with seat cushion angle	R	5	5		5	
Compatible with seat extension	R	5	5		5	
Compatible with recline	R	5	5		5	
Compatible with shitf in x-direction	R	5	5		-	Fits all except center seat
Compatible if rotatable rear seat	D	1	1		1	
User compatibility						
Fits women	R	5	5		5	
Fits men	R	5	5		5	
Fits elderly	R	5	5		5	
Fits children	R	5	5	If the seat shift forward	-	Fits one lenght and above
Fits rear facing baby restraints	D	2	2	If the seat shift backward	2	
Deactivation	R	5	5		5	
No need to discard after use	D	2	-	Unsure if this is possible	-	
		102	95		80	

The table 6 shows which requirements each concept, *Inflatable Frontal Curtain and Far-side in Headrest*, meets. The major difference is that they are adapted to different types of collisions. Other differences are that the Far-side in Headrest only will be installed in the outer seats headrest, which implies that it is not compatible with a reclining backrest or moving the chair in forward or backward. Additionally, The Far-side in Headrest is dependent of the occupant’s height.

6.4.3 Disassembly Analysis

Since there were two concepts, *Inflatable Frontal Curtain and Far-side in Headrest*, which got the highest scores from the other evaluation methods, only those two were chosen to be included in the Disassembly Analysis.

The montage of airbags inside the interior of the vehicles imply that a destruction of the headliner and other assembled parts are inevitable. As the grade of the collisions are ranged from minor to severe, the destruction of the interior can, in some case, be worse than the total damage of the car. This implies the need for a product that does not create more damage than the collision does, in order to minimize the usage of both materials and time. Using an evaluation of the two highest scored concepts, regarding the disassemble and replaceability of the concept, this can be visible.

Accessibility

By developing an airbag in which the location of the montage is in focus, the accessibility can be increased. This element is crucial in the manner that it should be a part of the car that can be reached for replacement with relative ease (Shetty, 2016).

Inflatable Frontal Curtain
The Inflatable Frontal Curtain is montaged in a rail, which is installed in the headliner instead of the structural ceiling of the car, and can easily be accessed.

Far-side in Headrest
As the far-side in headrest is packaged inside the rear seat headrest, implies that the accessibility is limited.

Standardization

An airbag that consists of standardized parts, but also have the product easily montaged by using standard equipment have the effect of increased reliability (Shetty, 2016) and reducing the amount of the replacement operations.

Inflatable Frontal Curtain
This airbag is based on a modular type of component, which implies that the same module can be used in a range of car models. However, the airbag cushion needs to be adapted to the size of the car and therefore there is a need for a range of size modules. Additionally, the frame to the airbag can be changed from an esthetical aspect in order to fit the rest of the car interior, which reduces the standardizations.

Far-side in Headrest
The far-side in headrest placement in the headrest entails that it must be adapted to the design and dimension of the headrest, as well as the packaging mounting requires special tools.

Interchangeability

The interchangeability suggests that the component should be replaceable by a similar component, in flexible non-recalibration way (Shetty, 2016). This implies that the replaceable product creates an opportunity, if the airbag is visible, to be incorporated in the design choices by either the car interior designer or the end user. Furthermore, this enables unused airbags from discarded vehicles being used.

Inflatable Frontal Curtain
The placement at the headliner instead of between this and the structural ceiling, entails a simple exchange to a similar component. Furthermore, this can be used as an aesthetical design choice as the frame is visible. Mounting an unused airbag from a discarded vehicle is also possible.

Far-side in Headrest
In order to use similar components in an exchange, without too much of an effort, requires a full headrest exchange. The components inside of the headrest can be changed, but at a greater effort. To be able to use components from discarded vehicles, it requires that the full headrest containing the airbag is unspoiled and can be used.

Replaceability

To design for replaceability, components have an advantage of being in a modular design. This encourages the replacement by having the time, effort and amount of skill reduced (Shetty, 2016). By incorporating this into an airbag concept, the repair effort and material usage after a collision may be reduced.

Inflatable Frontal Curtain
Since the Inflatable Frontal Curtain is installed as a module in the headliner, only the module needs replacing after deployment. Furthermore, this can be replaced if the technology rapidly improves.

Far-side in Headrest
The replaceability of the airbag components in the Far-side in headrest concept are limited. After airbag deployment, the fabric in the headrest is destroyed and needs to be replaced as well as the airbag. However, replacing the complete headrest is more effective than changing the components.

Through this disassembly analysis the Inflatable Frontal Curtain shows to be the best concept meeting the need for disassemble and replaceability. As the modular frame of the Inflatable Frontal Curtain easily can be replaced, without interfering with the interior, after deflation, given that the collision is minor.

7. FINAL AIRBAG CONCEPT INFLATABLE FRONTAL CURTAIN

The different evaluation methods, PNI, comparison- and weighting requirements and the disassembly analysis all resulted in the same product. The Inflatable frontal curtain is the winning concept. This airbag meets most requirements and provides increased safety for the rear seat in an easy way. It is an airbag that protect all three seats in the same way, everyone gets equal protection, and ensures safety even for the first row.

The best airbag concept, *Inflatable Frontal Curtain*, *(IFC),* is described below.

An inflatable curtain that protects all three rear seat occupants from hitting the first-row chairs in the event of a frontal collision. The Inflatable Frontal Curtain are mounted in a rail, installed in the ceiling of the vehicle and are deployed when the sensors detect a crash. The airbag folds down from the ceiling, approximately one to two decimeters behind the first row (figure 45) and covers the whole area between the two B-pillars. This placement entails a stable airbag, supported by the first-row seats, which can absorb the energy from the second-row occupants in the event of a collision.

Figure 45. Final concept – Inflatable Frontal Curtain. Author's own copyright.

As the Inflatable Frontal Curtain are mounted in a rail, instead of directly in the interior ceiling, it can easily be replaced after deployment without having to demount the ceiling. This simple disassembly is also beneficial for the rescuer in the event of a wedged rear seat occupant, and therefore fulfils the legal requirement of escape post collision.

The airbag consists of elongated cylinders that are stitched together (figure 46), which creates a softer impact. The use of ventilation holes in the fabric minimizes the risk for injuries by the airbag. Furthermore, in order for the IFC to fit different car brands, sizes, and interiors, the installation rail can be adapted as well as the size of the airbag. This creates an opportunity for the car manufacturer to incorporate the rail into the interior design.

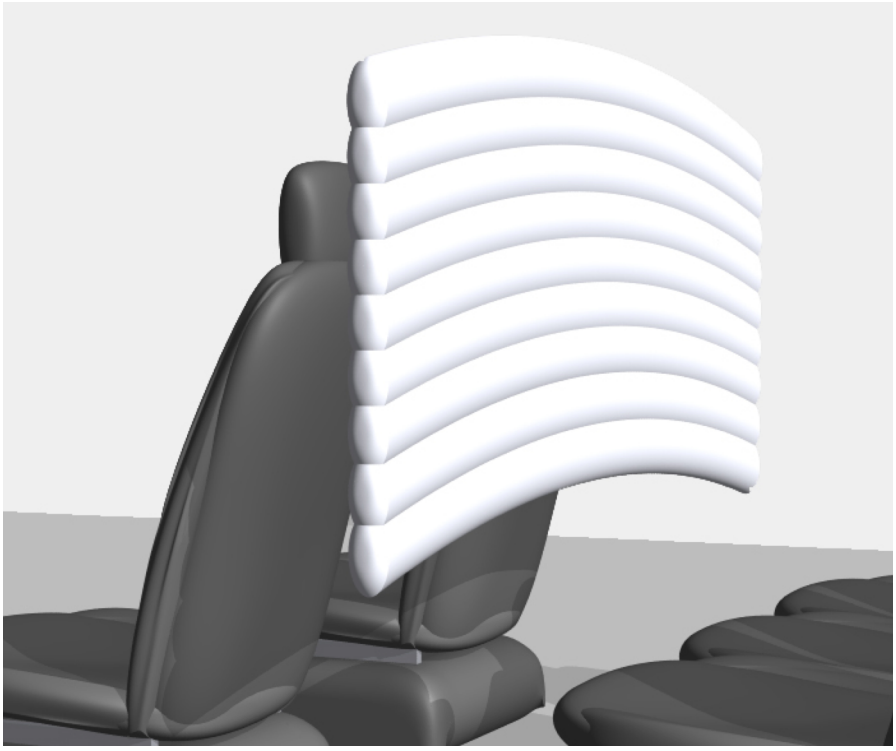

Figure 46. Final concept – Inflatable Frontal Curtain. Author's own copyright.

Since the second row consists of three separated chairs, which can be moved forward and backward in the x-axis, this airbag can protect both children and adults. In the event of using a rearward facing child restraint, the chair can be moved backwards to avoid disconnecting the Inflatable Frontal Airbag. Furthermore, to increase the fulfillment of the *protect all* requirement, the airbag should be adaptive in terms of changing the deployment forces.

Additionally, as the Inflatable Frontal Curtain covers the whole area behind the first-row chairs, it increases the safety for the front seat occupants. This as it protects the first row from unrestrained objects and unbelted rear seat occupants in the event of a collision.

8. DISCUSSION

Following are the unsolved user needs, the rear seat functions, the further development opportunities and the concept choice to be discussed.

8.1 UNSOLVED USER NEEDS

As many diverse user needs emerged from the user studies, there were some that could not be fulfilled by the concepts. This was mainly due to the user needs being unsolvable in a level 3-4 autonomous car, and required a fully automated car. Therefore, the solutions for these needs are better suited to take into account while developing vehicles further in the future.

8.1.1 Lack of Control

During the compiled results from the user centered studies, it appeared that many of the users deselected the rear seat due to lack of outside views. This connects to the feeling of being in control of the situation, but also to a decreased claustrophobia. Enhancing this feeling of safety is important, as the introduction of the autonomous vehicles tends to intimidate the ones that are not used to this new technology. The intimidation of this autonomous technologies can be derived from, as mentioned in chapter *2.3.2 Feeling Safe*, the disruption of the everyday rituals and routines. This disruption in itself causes a sense of losing control, and can make the user more resistant in accepting the new technologies.

The feeling of being safe could be increased by broaden the frontal views for the rear seat occupants. Using the same foldable function as the front seats in motorhomes possess, as seen in chapter *4.4.3 Rotatable Front Seat in Motorhomes*, could improve the situation. However, this function requires the vehicle to be fully autonomous - level 5, in order to get rid of the designated driver in the first row. This solution is therefore something to imply further ahead.

8.1.2 Communication between the first and second row

The user studies also complied that many of the occupants feel unable to communicate between the first and the second row. This implied a need to improve this situation - the users felt that it was important to be able to have a conversation disregarding of where seated. A possible solution is to have the chairs rotatable up to 180 degrees, in order to have the occupants facing each other - as in a train coupe.

This rotatable function requires the vehicle to be completely autonomous, as the driver is unable to have control over the situation if traveling facing the rear seat. Additionally, the vehicle structure needs changing in order to have this function, firstly be broaden.

The interviews suggested that this 180-degree rotation is a desirable function, but are unsure whether it is possible. However, many of the results implied that a small rotation, about 15-20 degrees, could be enough to at least enhance the communication aspect. This would also provide the first-row occupants with an increased travel space.

8.2 MOTIVATION OF REAR SEAT FUNCTIONS

All functions regarding the rear seat has been added in order to create a more adaptive and attractive seat. By increasing the adaptivity, the possibility of meeting as many user needs and fitting the many occupants of the rear seat has been granted. In the best of worlds, these type of adaptiveness is controlled by the seat itself, connected to sensors in order to create the best position for the occupant at the moment.

However, these functions are not a requirement, but desirable in order to increase the customer value and the rear seat safety. Implementing all these functions will be both challenging and contributes to an increased cost for the end user.

In order to minimize the costs, the suggested functions can be optional for the user. This could create a more conscious choice, both regarding comfort and safety. However, this requires that the end user have enough knowledge about the functions and safety aspects.

8.3 DISCUSSING THE CONCEPT CHOICE

After all evaluations, the Inflatable Frontal Curtain was the obvious choice of airbag. This airbag did not only imply a better protection for the passengers in the rear seat, but also for the front seat. The lack of frontal collision protection in the rear seat was an important part in the decision, as well as grant the same type of frontal protection for all rear seat occupants.

That the Inflatable Frontal Curtain won the concept choice over Far-side in headrest was due to that the IFC provides a better protection for all passengers. It provides protection to all three seats. Compared with the Far-side in Headrest, IFC is customized for all passengers, as the safety level of Far-side in Headrest depends on the passenger's length.

Inflatable Frontal Curtain consists of only one airbag and by mounting it in a rail, before installing it in the interior ceiling, it can easily be replaced after usage as noted in chapter *6.4.3 Disassembly Analysis*. Unlike the Far-side in Headrest, which is mounted in the headrest and therefore the full headrest must be replaced after deployment.

Making the airbag module visible, it can contribute to many different aesthetical design choices, but can also give the user an opportunity to renew the interior of the car to create a new impression. This design choices could have an increased environmental effect, but is still a better choice than having to renew the whole car if the user gets tired of the interior. Furthermore, this external module contributes to an easier installation, reparation and replacement.

The feeling of safe is also increased, by having the airbag visible to the occupants. This is otherwise created by putting informative stickers, but seeing the full airbag frame could bring even more safety to the occupants.

8.4 DEVELOPMENT POSSIBILITIES

There are numerous of further potential development, in order to increase the comfort and the safety in the rear seat. During this project, many possibilities have been discussed but not being implemented due to lack of knowledge, and to the limited time.

8.4.1 Placing Occupants in Position

In order to keep the rear seat occupant safe in the event of a collision, the occupant should be seated in a position for which the safety devices are optimized. However, as mentioned in chapter *2.3.1 Comfort,* the rear seat should offer various seating position in order to avoid discomfort. These various positions make the mission of keeping the occupant protected more challenging.

To tackle this issue, without having to optimize the airbag system for several seating positions, the focus lies on placing the occupant in a correct position right before an accident occurs. This is made possible as the various active safety systems used in autonomous vehicles are able to prevent a collision earlier than systems in cars of today.

Backrest Alignment

The possibility for the occupant to change the backrest angle in proportion to the seat cushion, contributes to putting the person out of position, making the safety systems less effective. Using the autonomous vehicles sensors, to get notified of an upcoming unsafe situation, the backrest can collaborate with the seat belt to put the occupant in a better position just before a collision.

The idea is to let the backrest follow the energy in a launching body, until it hits a barrier at the angle of 90 degrees and fasten there. This then prevents the body from falling to far back when the energy returns. By enforcing this backrest angle on the occupant, the seat belt gives a better protection and the energies released in the crash are better distributed throughout the body.

In order for this to function properly, the seat requires the special *belt in seat*, which is a seat belt installed directly in the backrest instead of the B- or C pillar.

Pelvis Positioning

The purpose with pelvis positioning is to prevent the occupant from sliding under the belt in the event of a sudden break or a collision. The frontal part of the rear seat cushion could be mounted in a compressed feather, which releases when the car breaks intensively. This pushes the frontal part of the seat upwards to create a greater angle than 10 degrees that the new rear seat have.

If the sudden stop that releases the feather does not lead to a collision, the seat can easily be pushed down and locked into the original position again.

8.4.2 Future Possibilities

As the collision warning systems that are used today can reduce the risk of an accident, as mentioned in chapter *2.8 COLLISIONS AND INJURIES*, it shows that the passive safety systems can be further developed as well. Implying that the safety systems can predict a collision earlier, it gives more time to place the occupant in a safer collision position. The positioning is to maximize the protection granted by the airbags. This implies that new calculations and constructions needs to be carried out.

8.5 THE NEXT STEP IN THE DEVELOPMENT PHASE

The next step in the development phase would be to create the airbag in computer-aided design program and then try it out in various simulations, this to see if it would work in practice and if it is the best choice of airbag for the rear seat. A prototype would then be built and implemented in different crash test and load cases to see if it protects the intended occupants.

9. CONCLUSION

The rear seat of today is at lower priority than the seats in the first row. Since the front seat have been in the focus for a longer period of time, the fulfillment of user needs is far more than in the second row. The rear seat has less safety systems, in which the focus now has started to increase. This is a direct consequence as the user demands a safer vehicle.

By identifying the users and the preferred way to travel in the second row, a new adaptive rear seat concept has been developed and the purpose has been met. The focus during this rear seat conceptualizing has evolved around these user needs. However, the implemented comfort functions do also, in combine with the Inflatable Frontal Curtain concept, enhance the rear seat safety as was the aim of this project.

The rear seat contains of three separate, adaptive chairs. These chairs have a raised frontal part of the seat cushion, in order to prevent the occupant from gliding underneath the seat belt. Each chair has a foldable backrest and the possibility of extending the seat cushion, in order to provide a more adaptive, ergonomic seating position.

Furthermore, as the separated rear seats can be adjusted forwards and backwards, the safety systems can be better suited. This is due to the adaptive distance between the occupant and the airbag, in order to get the best protection at a collision. In larger vehicles, the usage of a rearward facing child restraint can be used without having to disconnect the Inflatable Frontal Airbag as the chair can be moved backwards. This adjustable distance also increases the legroom for the rear seat occupant.

In order to meet the user needs and raise the customer values; the rear seat concept has an increased amount of functions. These functions give the rear seat a safer, ergonomic and more comfortable seating position.

By implementing an Inflatable Frontal Curtain in the rear, provides the rear seat occupants with a protection in frontal collisions. Together with the seat belt and the other airbag systems this IFC contributes to a reduced risk of severe head injuries. The IFC does not only provides frontal protection for the rear seat occupants, but do also provide a wall protecting the front seat occupants from unsecured items and unbelted rear seat occupants.

The project has led to a suggestion on how to enhance the comfort and improve the safety system in the rear seat, which can equate some of the difference between the first and second row in the level 3-4 autonomous car. However, the implementation of these during the next steps towards an autonomous fleet will be a challenge, as it requires larger car dimensions which contributes to weight increase.

In order to have this concept validated, both the rear seat functions and the inflatable frontal airbag needs to be exposed to different load cases in vehicle safety evaluation tests.

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APPENDIX 1: Online Questionnaire

How would you like to travel in an automated vehicle?

1. Age
- ❑ 15-20
- ❑ 21-25
- ❑ 26-30
- ❑ 31-35
- ❑ 36-40
- ❑ 41-45
- ❑ 46-50
- ❑ 50+

2. Gender
- ❑ Female
- ❑ Male
- ❑ Other

3. Do you have a driver's licence?
- ❑ Yes
- ❑ No

4. How many are there in your family?
- ❑ 1
- ❑ 2
- ❑ 3
- ❑ 4
- ❑ 5
- ❑ 6
- ❑ 7
- ❑ 7+

5. Whom in your family are most often traveling in the backseat and why?

_____

_____

6. Where in the car do you prefer to travel?
- ❑ Front seat
- ❑ Rear seat

7. Why?

_____

_____

8. How are you sitting while traveling in the rear seat?

- ❑ Ordinary, up right
- ❑ Leaning towards the window
- ❑ Leaning towards the armrest in the middle
- ❑ Head leaned against the front seat
- ❑ Legs towards the other side
- ❑ Legs on top of the front seat armrest
- ❑ Feet on top of the front seat
- ❑ Leg/legs pulled up underneath me
- ❑ Lies down
- ❑ Slumped
- ❑ Folded

9. What would you like to do in the rear seat during a longer drive?

- ❑ Converse with the front seat traveler
- ❑ Read a book
- ❑ Listen to music
- ❑ Charge smartphone/tablet/laptop
- ❑ Put my legs up
- ❑ Tilt backrest
- ❑ Lie down
- ❑ Sleep
- ❑ Other

10. Which rear seat factors are important when purchasing a car?

- ❑ Leg space
- ❑ Comfortable seats
- ❑ 2 seats with much space
- ❑ 3+ seats with less space
- ❑ Fitting a child safety seat
- ❑ Easy to step in and out
- ❑ Feel luxurious
- ❑ Other
- ❑ Rear seat is not on my mind

11. Which is more important?

- ❑ Large trunk
- ❑ Spacious rear seat
- ❑ They should not interfere with each other

12. How do you think that the rear seat will look in an automated car?

_____

_____

13. How would you like to travel in the rear seat in an automated car?

_____

_____

14. Any other thoughts concerning the rear seat?

_____

_____

APPENDIX 2: Interview questions with automobile salesmen

Interview performed 2018-02-14

Is it more focus on the rear seat today than it used to be?

Who sit in the rear seat?

Who do you think will sit in the rear seat of automobile cars?

How do you think the passengers would like to / will sit in a future autonomous car?

Do your customers have demands on the rear seat when buying a car?

APPENDIX 3: Interview questions regarding rear seat and autonomous vehicles

Interviews performed 2018-03-06 and 2018-03-09

- Who travels the most in the rear seat?
- How many are traveling in the rear seat? Do you know which is ordinary?
- Which is the most common way to travel in the rear seat, how would people wish to seat?
- What are the legal demands and specifications? Is it possible that they will change in relation to the automated car?
- Which type of accidents are there, how do they happen and what are their consequences?
- How do you travel in the front seat; in order to get the least amount of injuries by the airbag?
- Is it more focus on the backseat today than it used to be?
- Which type of airbags is placed in the rear seat?
- How do you believe the rear seat will be constructed in automated cars and whom would use them?
- What is important to consider while developing a new rear seat?
- What is good to have in mind while developing a safe rear seat?
- How are the automated cars supposed to handle for example accidents? How will this work? Will this change the occupants seating positions, in case an accident occur?
- Is there any way to make the airbag noticeable, but not visible? Is there any advantages/disadvantages by this?
- How about forward collision system? Do you believe that this will be implemented in all automated car? Is this a vital system?

APPENDIX 4: Interview questions, rear seat safety

Interview performed 2018-03-21 and 2018-03-23

- Who travels in the rear seat?
- How many travels in the rear seat? What is most common?
- How are people placed in the rear seat of today?
- Why do accidents occur and which are their consequences?
- Is it more focus regarding the rear seat today than what it has been? Will it be even more?
- How do you believe the rear seat will be designed and whom are going to use it?
- Are you safer in the rear seat?
- Is there a need for protection in the event of an frontal collision? Side collision?
- What is important to have in mind while developing a new rear seat?
- Which type of requirements are there regarding airbags and collision safety? Legal and others.
- How do frontal collisions occur? Will there be any differences in the future?
- Which loadcases are used today?
- How do these affect the rear seat?
- Which are the problems that require solving today?
- Will there be any change of load cases in the future?
- How much energi are the airbag supposed to handle? Will this change in the future?
- Is there any crash tests of families in a vehicle?
- Whom are we trying to protect? Men, women, children, elderly? Is it possible to protect them all?
- Is there any sensors feeling whom are sitting in the seat? Is this possible? Too expensive? Too far away in the future?
- What are seat track sensors?
- Is there any crash test for the rear seat?

- How many are traveling in the rear center seat?
- What should we keep in mind to protect the rear seat passengers at a frontal collision?

APPENDIX 5: Interview questions about injuries, crash dummies and other questions

Interview performed 2018-03-20

How do you think the interior will look like, in an autonomous car in grade 3-4 as well as completely autonomous?

- Will they look different?

Who do you think will buy these cars?

Who's going to sit in the rear seat?

What is most important to focus on, refer to a safe seat position in the rear seat?

What are the general differences in injuries between men and women?
Are these due to length differences or other differences in the body structure?

How do the injuries between men and women differ in the rear seat?
What is the main reason for these?

- Do you think these will be affected or altered in any way when using fully autonomous cars?
- How is the safety of the car going to look like in the cars of the future?

What should we consider when we are going to develop a new airbag?

- How is the safety of the car going to look like in the cars of the future?

Why has there not been more focus on women and female crash dummies earlier? And why has the focus become bigger now?

Are there any child crash dummies and how often are they used?

What should be considered when developing a system that will suit both men, women, children and elderly?

Is it mainly the detachment of the airbag that applies when adapting to children?
How will they be safe without any airbag?

APPENDIX 6: Interview questions regarding collisions, today and in the future

Interview performed 2018-04-11

How many accidents / collisions occur per year?

What is the main reason for these?

What kind of collisions are most common? Why is it like that?

What kind of collision is most dangerous?

Which is least risky for serious injuries?

At what speed are you getting stuck in the car? Both frontal and side collision
Why does this happen?

How big is the risk of dying in a car accident?

Where are the problems today? (where does it lacks of equipment, to be even better)

Is there any equipment missing for the rear seat?

How will collisions appear in the future?

What kind of crash should we target? All or just one?

Can you customize an airbag that can suit everyone? Adults, children, elderly, pregnant?

APPENDIX 7: Interview questions about seat belts

Interview performed 2018-04-20

How does a safety belt work today? (pretensioner, load limiter, etc.)

What is an adaptive belt and how do they work?
- Do they exist in many cars today?

Is there a possibility of height adjustment for the seat belt to be adapted to all occupants?

Do the belts look different in the front and rear seats? If yes, why?

Is there a legal requirement to use seat belt in all countries? - which countries?

When did the legal requirement come to Sweden?
- Why did the law come later for the rear seat?

Were the use of seat belts significant before the law?

Which injuries can you get from a seat belt?
- Why do these occur?
- Is it possible to avoid? Can it be reduced completely or little?

How will the seat belts look in the future?
- Will they still exist and be a legal requirement?
- Will the seat belts restrain how the future seats will be positioned?

APPENDIX 8: Interview questions, Pakistan

Performed 2018-03-26

- Where do you mostly travel while being an occupant in a vehicle?
- Do you have private driver? Or have you had one?
- If you do not have a private driver in your country, where are the occupants seated?
- Who are seated in the back most often? Why?
- Do you have any acknowledgements on where the airbags in your family's car are placed?
- What kind of people do have private drivers?
- Are the cars in property of the family, or is it the driver who owns the car and you buy a service from him?
- Why do you travel in the rear seat? Are the loss of view not that important?
- Why is it “status” to travel in the rear seat?
- Have you noticed any major differences on how people are seated in the cars in, for example, Sweden?

APPENDIX 9: Positive, Negative, Interesting

Concept analysis

Idea	**P**ositive	**N**egative	**I**nteresting
IC mid ceiling	+ All three seats + Prevents objects from hitting front seat occupants + One bag + Compatible with rotating front seat + Prevents hitting the front seat + Safe when unbelted + Safe for children + Existing technology	- Split line in ceiling - Difficult to mount in sunroof - Large bag, expensive - Does not prevent upper body launch - Discarded after one usage - May cause neck injuries, if front seat chair is far ahead - No side protection	Integrate with side IC, one large bag that covers three sides Different patterns, shapes - net, pillar Possibility to extend - covers the legs Split line entails design choices Adjust position in ceiling? If filled longer - protection in multiple collisions Possibilities to use technology that makes it reusable
Front farside reaching back	+ Two in one + No extra component to assemble + Prevents hitting the front seat + Compatible with rotating front seat	- Complex, different type of bags - Large, expensive - No protection for center seat - New product, time consuming - No side collision protection - Discarded after one usage	New Possibility to use technology that makes it reusable
Padded front seat	+ Prevents hitting the front seat + No pyrotechnics + Compatible with rotating front seat + Compatible with sunroof	- Large - Does it work? - Not suited for children - Demands new front seat - Does not prevent upper	New technology that makes the airbag reusable - returns to original shape Vent holes which opens at impact

	+ Safe in out of position + Safe if unbelted + Protection in frontal- and multiple impacts	body launch - No protection in side impacts - No protection for center seat	
Door mounted frontalbag	+ Existing technology + Compatible with rotating front seat + Compatible with sunroof + Prevents hitting the front seat	- Is it possible to mount it in the door? - Is the door stable enough? - No side collision protection - No center seat protection - Difficult to place, x-direction - Unsafe with rear facing child restraint - Discarded after usage - Must have a high pressure in order to be stable, can lead to injuries - No side protection	Possibility to use technology that makes it reusable
Enclosing (mounted in seat side)	+ Protects both frontal- and side impact + Two in one + No extra component to assemble + Compatible with rotating front seat + Compatible with sunroof + No need for support from front seat + Prevents hitting the front seat + Prevents upper body launch	- Difficult to mount - Does it work? - Difficult to fit in smaller vehicles - Unsafe with child restraints - Unsafe in out of position - No protection for center seat - Discarded after usage - Front part gets too close to the face - Does not fit all body types	Embracing, perceived as safe - as a hug Possibility to use technology that makes it reusable May grant support for pelvis, depending on size
Far side - rear seat headrest	+ Prevents rear seat occupants from hitting each	- No protection in frontal-, side- and multiple impacts	Great complement to other airbags

	other + Protection for center seat + Compatible with rotating front seat + Compatible with sunroof + Small package, light + Legal requirement 2020 far side in first row	- Only head protection - Does not prevent hitting the front seat - Difficult to adapt to children, shorter persons - Discarded after usage	Possibility to use technology that makes it reusable

APPENDIX 10: Product Specification

Weighted Concepts

Requirement		Weight	IFC	Comment	Farside in headrest	Comment	FRB	Comment	Padded	Comment	Doorb	Comment	Enclos	Comment
Size														
Small packaging	R	3	3		3		-		-		3		-	
Light wieght	D	4	4		4		-		-		4		-	
Escape post collision	R	5	5		5		5		5		5		-	
Fits different types of cars	D	3	3		3		3		-		-		-	
Collision														
Energy absorbant	R	5	5		5		5		5		5		-	Not that great
Protection for all three seats	D	3	3		3		-		-		-		-	
Protection during frontal collision	R	5	5		-		5		5		5		5	
Protectiong during side collision	R	5	-		5		-		-		-		5	
Protection during multiple collisions	R	5	Maybe		Maybe		Maybe		Maybe		Maybe		Maybe	
Interrior compatibility														
Compatible with rotatable front seat	R	5	5		5		5		5		5	Not if front seats are rotated 180	5	
Compatible with sunroof	R	4	Maybe		4		4		4		4		4	
Stable	R	5	5		5		5		5		-		-	
Compatible with seat cushion angle	R	5	5		5		5		5		5		5	
Compatible with seat extension	R	5	5		5		5		5		5		5	
Compatible with recline	R	5	5		5		5		5		5		5	
Compatible with shitf in x-direction	R	5	5		-	Fits all except center seat	5		5		-		5	
Compatible if rotatable rear seat	D	1	1		1		-		1		-		1	
User compatibility														
Fits women	R	5	5		5		5		5		5		5	
Fits men	R	5	5		5		5		5		5		5	
Fits elderly	R	5	5		5		5		5		5		5	
Fits children	R	5	5	If the seat shift forward	-	Fits one lenght and above	5	If the seat shift forward	5		5	Can be unsafe at a high pressure, must be adaptive	5	Must be adaptive
Fits rear facing baby restraints	D	2	2	If the seat shift backward	2		2		2		-		-	
Deactivation	R	5	5		5		-		-		5		5	
No need to discard after use	D	2	-	Unsure if this is possible	-		-		2		-		-	
		102	95		80		79		79		79		70	