Seat belt and headrest adjustment:
Increasing truck driver comfortability

KATHRINE BERG
ELINOR PETERSSON
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Kathrine Berg
Elinor Petersson

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KTH Industrial Engineering and Management
Machine Design
SE-100 44 STOCKHOLM
Abstract

Truck drivers spend long, consecutive periods of time seated down, and the truck cab becomes their immediate work environment. Therefore, it is important to make sure that this space is properly adapted to fit the driver’s needs well.

The driver seat is something the driver are very much in contact with. The seat can be adjusted in many ways to accommodate for drivers of different heights and body types. However, two of the components which are fixed today are the upper seat belt anchorage position and the headrest. In this thesis project, the aim has been to investigate the adjustment possibilities of these components in terms of desired adjustment range and mechanical solutions.

The first part of the project was spent on ergonomic evaluations of the seat, and finding what properties are the most important when designing a truck seat. Both literature reviews as well as interviews and observations helped build the knowledge foundation to base adjustment concepts on. For example, it was found that to minimise the negative effects of sedentary work, the single most important action is to frequently change the sitting position. Therefore, it is of high importance that adjustment procedures are as simple as possible. It was also found that many truck drivers do not use their seat belt at all, and that having a headrest which is adjustable in height is important for the driver’s visual area.
Several ideas and concepts were generated and evaluated. The initial ideas included both solutions applicable on the current seat belt design, while some would use other means of securing the driver in a collision. The ideas were compared and evaluated, and three were chosen to develop further; one being easy to implement, and two being mechanical solutions both making use of the current seat belt design. These three concepts were investigated more deeply, and were subsequently also compared using different methods for evaluation. Eventually, a final concept was chosen; a mechanical solution in which the seat belt and headrest can be adjusted separately in one and two directions respectively. This concept was further developed in terms of both mechanical as well as visual design.

In the final concept, Hoop, the seat belt is adjusted sideways, as this was proven to give the largest comfortability improvement for the driver. The headrest is adjustable in both height and depth. The mechanisms are locked using ratchets, however, both can be adjusted in what is believed to be the most critical direction without the need to unlock first. The buttons for unlocking the mechanisms are placed directly on the adjustment mechanisms in order to keep the procedure as intuitive and easy to use as possible. The adjustment ranges were determined based on Scania’s anthropometric dataset in order to make sure that the adjustment features will be useful for an as large part of the driver population as possible.

**Keywords**

Anthropometrics, truck, safety, belt, headrest, comfort, ergonomics, seat
Justering av säkerhetsbälte och nackstöd: Komfortförbättring av förarstolen i lastbilar

Kathrine Berg
Elinor Petersson

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Examinator Claes Tisell
Handledare Jenny Janhager Stier
Uppdragsgivare Scania CV AB
Kontaktperson Klaus Schmidt

Sammanfattning

Lastbilschaufförer tillbringar under sina arbetspass många timmar i lastbilshytten, som blir deras direkta arbetsmiljö. Det är därför viktigt att hytten är utformad utifrån föraren och dennes behov.

Förarstolen är en av de komponenter som föraren har allra mest kontakt med. Denna kan justeras på många sätt för att möjliggöra för förare av olika längder och kroppstyper att hitta en körposition som passar just dem. Två komponenter som dock inte kan justeras i dagsläget är positionen av den övre bältesomlänkaren och nackstödet. I detta examensarbete har fokus varit att ta fram hur justering för dessa skulle kunna se ut både i form av önskat justerområde och mekaniska lösningar.


Nyckelord
Antropometri, lastbil, säkerhet, bälte, säkerhetsbälte, nackstöd, komfort, ergonomi, stol
Preface

This thesis project was carried out between the 10th of January and 8th of June at KTH Royal Institute of Technology in Stockholm, Sweden in collaboration with Scania CV AB. We would like to thank Scania and all the people there we have been in contact with for being so welcoming towards us and willing to share their knowledge.

A special thanks to our supervisor at Scania, Klaus Schmidt as well as Anna Lampel and Paulo Fragoso for all the help and feedback throughout the project.

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1 Introduction

This chapter gives an introduction to this Master’s thesis. It consists of; the background for the project, purpose, methods used, and delimitations of the thesis.

1.1 Background

Many professional truck drivers spend much time in the truck driving long distances. The truck cab is their immediate work environment, and possibly also their living space during longer drives. It is therefore important to design the interior to fit the driver to make this space more comfortable and enjoyable.

In trucks, the seat belt is normally fastened to the seat. For safety reasons, it is of high importance that the seat belt is placed correctly in a truck. A poorly positioned seat belt could, in case of collision, cause much damage for the driver. Using a seat belt reduces the risk of being injured by 42% in heavy trucks (Høye, Ervik, Sørensen and Vaa, 2012). If the seat belt fails to hold the driver in place during a collision, he/she risks being thrown around in the cab. If the seat belt is placed on the neck, it can also cause severe injuries for the driver in a collision, as for example injuries on the carotid artery.

When driving longer distances, as truck drivers often do, having a headrest for relief is often appreciated. However, it is of high importance that this headrest is placed properly so that the driver withholds a good visual area while using it. In case the headrest is not positioned properly, the driver’s area of vision could be impaired and possibly lead to an increased risk for accidents.

However, many truck seats today lack the adjustability necessary to properly fit the seat belt and the headrest to drivers of different heights and body types. For example, many drivers complain about the safety belt rubbing the neck in an uncomfortable way. The drivers also have problems to find a comfortable position to rest their head. Because of this, some drivers choose to place the upper part of the seat belt under the arm instead, making the 3-point seat belt function as a 2-point belt instead, thereby increasing the risk of injuring abdominal inner body organs (Grytli, Berge and Nilssen, 2014). By creating an adjustment solution which makes wearing the seat belt more comfortable for the driver, it will most likely be used by a greater number of drivers than it is today. Also, an adjustable headrest would allow for better comfort and a more favourable driving position for a larger part of the driver population.

This thesis project has been carried out in collaboration with Scania CV AB. Scania is a Swedish manufacturer of heavy trucks, buses and engines founded in 1891. Scania’s headquarter is located in Södertälje just south of Stockholm. Today, Scania is wholly owned by Volkswagen Group. In the beginning of 2017, Scania’s market share for trucks in Europe was 16.8 percent (Scania (b), 2017). Currently, Scania has over 46,000 employees and have sites in both Europe and South America.
1.2 Purpose

The purpose of this project is to find a way to improve the comfortability-, ergonomic- as well as safety properties of the truck cab for a larger part of the driver population. This will be done by creating the possibility to adjust the seat belt and headrest to fit drivers of different heights and body types.

1.3 Delimitations

Several delimitations were made to frame the project.

- Scania’s premium driver seat (Recaro) was used as a reference
- Regards were only taken towards seats with air suspension
- The project was aimed towards the seats available for Scania’s newest truck, New Cab Generation (NCG), only
- In the project, visual ergonomics was not studied in particular
- Within the frame of this project, the final concept will not be tested towards applicable legislation

1.4 Method

The design process has been iterative, and several methods were used to reach the best result possible. The project has been undergoing five different phases as illustrated in Figure 1; pre-study, user studies, product realisation, final concept development and final design. The product realisation phase was iterative, where concept generation and evaluation were made several times. Common for all these phases are that they have all started with a diverging period during which a wider perspective was held to create a broad variety of information, before converging to a more specific result.

![Figure 1: The different phases throughout the project](image)

To create a solid base, research was made on three major areas and how they relate to each other. The problem can be related to all these, and the different areas together create the context in which the final product can be placed. These areas are truck seats, ergonomics and safety, see Figure 2.
A large part of the ergonomic and safety research was done utilizing literature sources such as papers and books, but also through different study visits and by physically studying the seats of trucks. In addition to this, specialists, both more specialised towards the truck industry and towards office work, have been consulted to obtain another view on the area. Ergonomists, truck safety specialists as well as specialists within vehicle regulations and materials have been consulted. As information was gathered, a mind map was created to get an overview and to make it easier to determine what areas needed to be further researched, see Appendix 1 – Mind Map.

In the second phase of the project, user studies were conducted. An online survey was used to obtain information and to get insights from users, the truck drivers. In addition to the survey, interviews and observations of truck drivers were also organised to get a better understanding of how it is to work as a full-time truck driver and how the seat belt and headrest are used today.

From the information found in the background research and the user studies, a requirement specification as well as a Quality Function Deployment matrix (QFD) was compiled (Ullman, 2010) in order to translate customer requirements into measurable product specifications. This was further used in the concept generation phase, as the concepts were evaluated and compared towards these. Different concepts for the seat belt adjustment as well as the headrest were generated. Both unsystematic approaches, such as brainstorming and the 6-3-5 method, and systematic ideation methods, like the function-means tree and the morphological matrix, were used (Cross, 2000). This made it possible to find a broad range of solutions to the identified sub-functions.

The concepts were then compared in terms of how well they met the requirements and desideratum. To do this, several methods for comparison and evaluation were used, such as the Pugh’s decision chart and a SWOT analysis. (Ullman, 2010). After doing these analyses, a final concept was chosen.

The final concept was further developed and visualised using 3D modelling software and simple physical mock-ups. A prototype was made, which was then used for evaluation.
2 Truck seats of today

Different existing truck seats are presented in this section. To investigate existing products that might be of interest, trucks from Scania as well as different manufacturers were physically studied.

The cab of a heavy-duty truck forms the work environment for the truck driver. It is of very high importance that the seat is designed to be as ergonomic as possible as the driver spends long periods of time in the truck seat.

Scania today have two separate sub-contractors for their driver seats. These are Isringhausen and Recaro. Scania’s most premium seat is a Recaro seat, while Isringhausen makes the other driver seats. Scania’s selection of seats is shown in Figure 3.

The difference between the seats is the amount of adjustability. The driver would have more possibilities to adjust the Premium seat compared to the Basic seat.
2.1 Seat belt

All driver seats in Scania trucks are air suspended in order to reduce the level of vibration to which the driver is exposed. This means that today, for the driver seats, all seat belt anchorages are fastened directly onto the seat so that they can follow its movement as seen in Figure 4.

In all Scania driver seats, the seat belt retractor is fastened to the lower part of the back, and from that runs up to the anchorage point on the shoulder. This means that the belt will need to travel up the back of the seat. At all points of contact the belt has with the seat travelling up towards the anchorage point, it is of high importance to minimise the friction to have the belt move as smoothly as possible, according to a developer at Autoliv during a study visit.

The position of the seat belt anchorage point vary between the two different manufacturers Scania uses; Recaro and Isringhausen. Example on seats from both suppliers are shown in Figure 5 and Figure 6. None of Scania’s seats has adjustable seat belt anchorages, but as the slot is slightly wider than the belt, it can move a little bit. However, because of the pulling direction of the belt being downwards, it always ends up sitting as far towards the driver as possible.
Scania’s previous premium seat from Isringhausen has a seat belt anchorage design that allows for a slight height adjustment, see Figure 7. The seat belt rests on the shoulder of the driver and can slide in a vertical slot depending on the height of the driver’s shoulder. However, this seat is no longer within the Scania seat range.

For the passenger seat, the seat belt is sometimes fastened to the B-pillar of the cab, which is similar to how the seat belt is anchored in a passenger car, see Figure 8. This is possible since the passenger seats do not always have air suspension, and therefore do not move relative to the cab.
During the search it was found that some trucks from brands other than Scania do have a seat belt anchorage that is adjustable 60 mm in height. Figure 9 below shows a seat from Grammer that has got such a solution. The seat belt anchorage is integrated with the seat backrest and can be adjusted up or down to fit the driver.
2.2 Headrest

Scania’s current driver seats do not have separate headrests, but come with an optional possibility of tilting the upper part of the backrest forward, in total 14°, see Figure 10. By doing this, the driver can obtain an effect similar to that of a headrest. This feature is popular amongst drivers, but cannot be adjusted to properly fit drivers of different heights. Also, for drivers of certain heights, it leads to a poor sitting posture according to a vehicle ergonomist at Scania.

![Figure 10: Adjustment possibility on the upper part of the backrest.]

The only current Scania truck seat which has an adjustable headrest is the reclining seat, which is only available as a passenger seat, see Figure 11. The reclining seat is Scania’s most recent seat design and it has been created to be a comfortable seat in which the driver can relax during breaks. It can both recline and be rotated 90°. The headrest is strapped onto the seat and attached using Velcro. It can be adjusted in height by sliding up or down to fit the person using the seat. The headrest cannot be adjusted in depth and also cannot be locked in a specific position. However, the headrest is easy to adjust, and can be adjusted while seated.
Figure 11: Headrest attachment on Scania’s reclining seat (Scania (a), 2017)
3 Sedentary work

As driving a truck requires a static work position, it is important to study how this type of work affects the body and how any negative effects can be avoided. In this chapter, findings from the research regarding sedentary work are presented.

During the past decades, the number of back and neck troubles have increased despite the fact that today, the load level is lower in many occupations (Bohgard, Karlsson and Lovén, 2010). Even work that is not physically demanding has a high risk of strain injury, especially muscular related injuries. Science shows that work requiring only a small percentage of maximum muscular power can also give damage on the macular fibres. The damage is frequently found on musculus trapezius, which stabilises the shoulder blade and the arm. Common for the stresses and/or strains that give these types of damages is that they are present throughout the workday on sedentary work; such as driving and office work.

A study by Bohgard, Karlsson and Lovén (2010) shows that some factors are more likely to give neck and back related pain. The most relevant for this project are listed below:

- Work posture: lifted arms and bended neck increase the risk of pain
- Body measurements: being too short or too long for the work environment
- Sex: statistic shows that more women have troubles from performing low physically demanding work
- Age: the risk of getting problems increase with age

Today people spend extensive parts of their day seated, especially in developed countries where many occupations are carried out from a seated position. This sedentary lifestyle is one of the main reasons why a great deal of the population have back problems (Bohgard, Karlsson and Lovén, 2010). Sitting still for longer periods of time have several negative effects on the human body according to a study by Kroemer (2001). For example, it will lead to compression of body tissue, a lower metabolism, worse blood circulation and will also cause fluids to accumulate in the lower legs. Therefore, any furniture should allow for body movement and various postures by providing sufficient adjustability.

The sitting posture is important when it comes to avoiding pain and back problems caused by sedentary work. According to Bohgard, Karlsson and Lovén (2010), the natural curvature of the spine and lumbar lordosis should be maintained while seated. For example, when sitting on a flat seat surface, the pelvis is rotated backwards. Thereby, the lumbar spine cannot withhold its natural curvature resulting in a less favourable sitting posture. The posture for neck and head should also be kept according to the natural curvature, but are much dependent on the viewing area during work. Placement of objects that has to be observed is therefore also an important factor for the posture. An illustration of the recommended viewing area can be seen in Figure 12.

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Some recommended key features to follow when designing a workspace for sedentary work are listed below (Bohgard, Karlsson and Lovén, 2010):

- The angle between the backrest and the seat should be 100-120°
- The backrest should follow the curvature of the back
- The seat should not be larger than necessary
- There should be a backrest available for resting, even though it is not in use during work
- The chair should not limit necessary movements during work
- The chair should allow the user to vary and adjust sitting posture as much as possible
- The adjustment controls should be intuitive for them to be used

Science shows that even though discomfort is dismissed, it doesn’t necessarily mean that comfort will accrue and that back problems will be avoided, as stated by Bohgard, Karlsson and Lovén, 2010. Comfort is a complex term which is dependent on many different factors, and these could for example be well-being, feeling of being relaxed. While comfort is described in a more subjective aspect, discomfort is described with physical and biometrical aspects such as; stiffness, pain and feeling numb (Zenk, Franz and Bubb, 2011). It is difficult to describe comfort without talking about discomfort. However, comfort and discomfort should not be described as opposites, but rather as two completely separate scales which only partly overlap (Kroemer, 2001). Discomfort is therefore perhaps more of interest when studying ergonomics (Bohgard, Karlsson and Lovén, 2010). Because of that, when doing evaluations, it might be better to ask the user to rate discomfort rather than comfort.
4 State of the art

In addition to looking at truck seats, research was also made on other type of applications connected to seated work and adjustability. This chapter includes information and findings about existing solutions in these areas.

When studying truck seats it is reasonable to look at other types of chairs. A truck seat might be more comparable to an office chair or a wheelchair than a regular passenger car seat. This is, for example, due to the difference in risk of injuries and that the truck driver also spend longer consecutive periods of times in the seat.

In order to get inspiration and to study office chairs more closely, a visit was paid to the Stockholm Furniture Fair, which is an annual trade fair held at Stockholmsmässan in Älvsjö. At this fair, different types of furniture are exhibited, and a large part is devoted to office solutions. In addition to the Furniture Fair, a visit to Kinnarps’ showroom in Sickla was arranged. Kinnarps is a Swedish company and is Europe’s leading supplier of workspace solutions. At their showroom many different chairs were presented, including chairs from other manufacturers, such as KAB seating, as well. In addition to the more empirical research that was conducted at these two occasions, other solutions were also looked for online.

4.1 Sitting posture

One type of chair which was examined more closely was the saddle chair. Saddle chairs allow for a wider angle between the thighs and the torso, meaning that the spine is able to retain its natural curvature, see Figure 13. When using a saddle chair, it is therefore very important to keep the feet position directly below the body instead of in front of it, says a physiotherapist who work with saddle seating specifically.

![Figure 13: Sitting posture at regular office chair versus saddle chair (Aluro, 2017)](image-url)
A saddle seat might not be easily integrated with the current car or truck interior. In order to be able to use such a seat for these applications, the whole interior would need to be redesigned and pedals would need to be moved.

Another tendency found amongst office chairs was movement towards the so-called flexible office chairs. These chairs have some instability in the seat to activate the user’s muscles and to increase the blood flow even at sedentary work. Most office chairs were also built flexible to follow the user’s movements when, for example, switching between sitting by the desk and leaning back to talk to a colleague. This calls for the user to move around more, which was also discussed much; that one should change positions often instead of keeping the same throughout the whole work day.

Kinnarps’ high end chairs have many possibilities for adjustments. Most chairs can be adjusted to fit most people, but the chairs also come in two different sizes to capture a greater range of users. Many chairs have adjustability for lumbar support, seat depth and the height of the backrest, which also adjusts the lumbar support height. The chairs also have a rocking function, so that the chair will move with the user. This makes the user vary their posture throughout the day.

Another topic discussed was the importance of control placement. In order to make sure the user actually adjusts the seat, the procedure must be intuitive and the controls must be easy to use. For example, the company RH has been working on making the different controls distinctive in shape, so that the user can easily feel which controls to use for which purpose. This is especially important for truck seats, as the driver might want to be able to adjust the seat while driving longer distances.

When a user starts using a new office chair, it is common to only adjust the height and not take the time to use the other controls. This is because the users are often familiar with this type of adjustment, and since most office chairs have the lever to adjust the height and the seat depth on the right hand side. To break this pattern, Kinnarps moved the adjustment controls around on their newest chair Capella. When moving the controls around, the user needs to actively find the different adjustment controls. Thereby, it is more likely that he/she will adjust the seat in a greater number of ways.

KAB seating makes office chairs and seating for construction vehicles, which is what their seats are original designed for. These office chairs are heavy and cannot be adjusted as much as Kinnarps’s office chairs. KAB seating’s office chairs are designed for 24 hour use, which means they must last longer than a regular office chair, and they should be comfortable to sit in for longer periods of time, according to the in-house sales person at Kinnarps. The height adjustment on the headrest are on these chair similar to the one found in passenger cars, though it has a tilting function as well, see Figure 14.
4.2 Headrests in other applications

Different office chairs were also investigated in terms of headrests. A number of different methods to adjust the headrest were found, see Figure 15. These are, for example, headrests which are adjustable in height, depth and shape. The studied headrests were found in different applications such as office chairs, wheelchairs and passenger cars.
The Malmstolen office chair had a headrest mechanism where the headrest is folded and bendable, so that it can be formed to fit the user, see Figure 16. On Kinnarp’s office chairs, the headrest can be adjusted by pushing a lever at the back of the headrest, see Figure 17. The lever to adjust the headrest is easy to manoeuvre, and gives the possibility to adjust the headrest in depth and height.
Since the truck driver will spend much time in the seat, ergonomics play a large role in the development of truck seats. In order to make sure the final concept will have sufficient adjustment range, it is crucial to find the right body dimensions to base the design on. Therefore, it is important to study the field of anthropometrics closely.

When studying anthropometrics, measurements of different body parts and body segments are collected (Bohgard, Karlsson and Lovén, 2010). These can be used in the product development process for determining certain product dimensions to make sure that a product is usable and fits its target audience.

For these type of products, being a seat belt adjustment mechanism and a headrest, collecting the right anthropometric data is central to make sure the adjustability range is appropriate to cater for an as large part of the driver population as possible. The anthropometric dataset must be selected carefully, as it has been shown that different occupational groups might have distinctive anthropometric characteristics that differ from the general population (Guan, Hsiao and Bradtmiller, 2012).

Obesity is an important factor when it comes to wearing seat belts in cars. The body mass index (BMI) and the tendency not to wear seat belts are connected in a linear matter; the higher the BMI, the more seldom seat belts are used according to a study done by Høye, Ervik, Sørensen and Vaa (2012). Comfort issues and the length of the seat belt might be two factors part of the reason why drivers with high BMI choose not to use the seat belt.

The anthropometric data is often normally distributed for larger populations. From the data, different percentiles can be found (Bohgard, Karlsson and Lovén, 2010). Usually, the 5th and 95th percentile is used as limitations when designing products and work areas after anthropometric data. The 5th percentile means that only 5% of the population is smaller, while the 95th percentile means that 95% of the population are smaller than the given measurement.

When only one or two different body dimensions are of interest, the 5th-to-95th-percentile approach is giving an acceptable result (Hsiao, Whitestone and Wilbur, 2015). When using the 5th-to-95th-percentile approach, the data connected to these percentiles is used and the product is designed to fit all within these percentiles. However, when multiple body dimensions need to be taken into account, this approach will result in cumulative unaccommodating rate, as the relations between different bodies dimensions are not the same for all people, see Figure 18.
In these cases, the anthropometric data should be used in a multivariate manner instead, meaning that the relations between different body dimensions will be taken into account as well.

5.1 Anthropometrics at Scania

At Scania, this multivariate approach has been taken to anthropometric data. Instead of analysing and applying data from the different body dimensions separately, data for the different body dimensions are analysed in relation to each other. The data is based on numerous measurements, and from the information found, different 3D models, manikins, have been constructed to represent the international driver population. These manikins together form the *Scaniafamiljen*, which in many cases are the basis of design for ergonomics at Scania. *Scaniafamiljen* is a collection of 19 manikins, 10 male and 9 female. All manikins have different body dimensions to give the best approximation of the database.

However, in this project, the anthropometric data was analysed as univariate as for the different adjustment mechanisms, only one or two body dimensions at a time were of interest. Therefore, analysing the data in a univariate manner will not result in any large-scaled accumulated errors, as it would have if several measurements were to be taken into account.

The measurements that will be used are based on Scania’s database *Scaniafamiljen*. From this database, the minimum and maximum measurement from the manikins will be selected. The measurement ranges used in this thesis are presented in Table 1.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Range min-max (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body-height</td>
<td>511</td>
</tr>
<tr>
<td>Sitting-height</td>
<td>274,1</td>
</tr>
<tr>
<td>Shoulder sitting-height</td>
<td>180,2</td>
</tr>
<tr>
<td>Shoulder-width deltoidal</td>
<td>144,4</td>
</tr>
</tbody>
</table>
The different types of measurements used are explained in Figure 19.

In Figure 19, the different types of measurements used are explained. These include body height, sitting height, shoulder sitting height, and shoulder width deltoid. The measurements of interest were also visualised in relation to the Recaro seat, see Figure 20. Here, the outer and upper point of the shoulder is shown for the smallest and largest manikins.

In Figure 21, the smallest female manikin and the largest male manikins are placed in the Recaro seat in order to visualise the large differences in body dimensions.
Figure 21: Scaniafamiljen’s smallest female and largest male manikins placed in the Recaro seat. The image was created in CATIA using the RAMSIS manikins and a CATIA 3D model of the Recaro seat.
5.2 Seat belt position

To find out how the current seat belt fits Scaniafamiljen a RAMSIS analysis of the seat belt position for the Recaro premium seat was made by a vehicle ergonomist at Scania. RAMSIS is a 3D-CAD ergonomics tool, which is used to develop ergonomic vehicles and cockpits (Intrinsys, 2017). All 19 manikins in Scaniafamiljen were placed in the Recaro seat with seat belt on.

The simulation shows that the seat belt would rub the neck of at least six of the manikins. The seat belt would only rub the neck of the male manikins. However, on the female manikins the seat belt seems to, in the analysis, be held in place by their breasts, which is not very accurate for the real-life situation. Testing different placement of the anchorage shows that in order to prevent the seat belt from rubbing the neck, it might be more effective to move the seat belt anchorage sideways than to move it upwards.

The finding that it might be more effective to move the seat belt anchorage outwards also aligns with the findings in another study by Karlsson and Tullock (2017). In this study, the user perception on the seat belt anchorage position in passenger cars was investigated empirically. Nine seat belt anchorage positions were proposed to 79 test subjects of different heights, who graded their discomfort. In this study, the findings were that moving the seat belt anchorage outwards generally gave a bigger result in improving the seat belt comfortability than to move it in height. In their study, the preferred seat belt position was located 340 mm outwards from the median plane of the seat.
6 Safety and regulations

Due to the context of the truck seat, the safety aspects are of high priority. In order to minimise the risk for injury for the driver in case of an accident, the chain of events in a collision was studied. In addition to this, any applicable legislation was identified.

For trucks, the worst collision scenario is to drive into the trailer of another truck, according to an accident researcher responsible for crash tests at Scania. This type of collision is the most common type of collision in central Europe and often occurs at speeds around 30-35 km/h. The major reason to why these collisions are the most common is the large amount of queues on roads in these areas. In Sweden, the most common type of collision is frontal collision with passenger cars or roll-overs.

6.1 Seat belt

The chain of events connected to colliding with a truck differs from that of a passenger car, and therefore, the requirements on safety equipment vary between the two vehicle types. In a truck, the seat is suspended to reduce the amount of vibration the driver is subjected to. In the event of a collision this air suspension mechanism together with the fact that the seat belt is fastened to the seat causes the whole seat to tilt back and forth creating a rocking movement. The steering wheel is designed to move away during a collision to not injure the driver. Also, the driver’s knees hitting the instrument panel is often what stops his/her movement forwards. The whole cab is designed to move backwards in the event of a collision to minimise the deformation, which is important as the deformation zone is much smaller in trucks compared to for example passenger cars.

In case of a collision, the seat belt will keep the user in place in order to minimise the risk of injury. According to instructions, the seat belt should be placed as close to the neck as possible, while still being placed comfortably. The seat belt should run over the chest middle point, as this is a part of the body which can carry much load according to an Autoliv developer. It is also preferable to have a wider belt, as this will distribute the load better. If the belt runs across the ribs, there is a high risk of breaking these in the event of a crash. It is also important to not have the backrest leaning backwards too much, as this could possibly result in the user sliding under the seat belt in case of a collision according to Trafikverket (2015).

A Norwegian study revealed that in 2013, 80% of heavy-duty vehicle drivers use seat belts. This indicates that drivers of heavy vehicles possibly overestimate their safety and feel safe not wearing the seat belt. The percentage of drivers using seat belts is higher for drivers of new trucks compared to older trucks. A seat belt reminder is installed in newer trucks, which is part of the reason why drivers of these vehicles use seat belts more often. Of drivers killed in fatal crashes, 64% did not use seat belts as stated by Haugvik (2014). In case of an accident, the greatest risk for being killed is if the driver is ejected out of the truck, with a 55% mortality risk (Berg, Niewöhner, Bürkle and Morschheuser, 2001).
**Seat belt functionality**

Seat belts are designed to decrease the severity of the user’s deceleration in a collision, and do this by absorbing the crash energy in a controlled manner (Autoliv, 2017). The seat belt system is often equipped with pretensioning mechanisms as well as a load limiter. However, due to the larger movement of the seat during a collision, the latter is not necessary in truck applications.

The seat belt retractor construction consist of a housing, a spool to which the webbing is fastened and several different locking mechanisms. For example, there are sensors that detect sudden accelerations/decelerations and violent pull-outs of the webbing (Autoliv, 2017, b). For belts fastened to the seats, there is also a self-adjustable mechanical sensor (SAMS), which adjusts the belt fastening as the seat is adjusted; for example, when the backrest is tilted.

In the event of a collision, the seat belt function as follows (Takata, 2017).

1. The Electrical Control Unit (ECU) detects a signal from the collision sensors of the vehicle. This signal could for example be sent because the speed suddenly drops, the brakes suddenly are applied or the steering wheel is turned sharply.
2. The ECU evaluates the signal. If the signal is evaluated to be a collision, the pretensioners are activated.
3. The pretensioners are activated by a small powder charge. The pretensioners retract the seat belt webbing (the belt) in order to remove any slack. The pretensioners are usually non-reusable.
4. The energy of the movement is absorbed. This is done using, for example, supplemental restraint systems such as air bags.

In Scania trucks, pretensioners are not standard for all trucks; the customers can add this if they wish to do so.

In addition to the usual seat belt design, there are also motorised retractors which tighten the seat belt as soon as it detects the possibility for a collision. This also serves a warning function, as it will alert the driver.

6.2 Headrest

In terms of headrest placement it should, for passenger cars, be placed so that its top is in line with the top of the user’s head. The distance between the headrest and the back of the head should be as small as possible (Trafikverket, 2013).

When colliding in a truck, the forces that the driver will be subjected to are different from those in a passenger car. For example, the risks for whiplash injuries in trucks are not significant according to an ergonomist as well as an accident researcher responsible for crash tests at Scania. Therefore, the headrests in trucks become more a matter of comfortability. The reason for this is that the effect of someone crashing into a truck from behind is minimal.
6.3 Applicable regulations

The current legislation from The United Nations Economic Commission for Europe for seats can be found in ECE R14, R16, R17 and R25 (UNECE, 1995). In ECE R14, seat belt anchorage placement is concerned, in R16 safety belts, R17 the strength of seats, anchorages and headrests and R25 concerns headrests. However, the only legislation focused on is R14, which describes the space in which it is allowed to place the effective seat belt anchorage point. This delimitation was made as the headrest is of much less matter for the truck cab safety than the seat belt is. The effective seat belt anchorage represents a stiff point from where the belt is free to move.

The space can be determined using the seat geometry and its dimensions. The required seat specific geometric information is the location of the H point, the distance S from the upper seat belt anchorage to a median plane, and the backrest angle. The distance S is the distance between the median plane of the seat and the effective upper belt anchorage. The H point, in short, represents the hip point of a person sitting in the seat. This point should, with a certain tolerance, be placed in the same position as the R point, which represents the reference driver position in the cab.

For the Recaro seat, S is determined to be $S = 210 \text{ mm}$, the backrest angle is $15^\circ$.

The area within which the effective seat belt must be placed is shown in Figure 22.

![Figure 22: Legal placement of seat belt anchorage visualised together with a Recaro seat (Internal Scania)](image-url)
The distances between the marked points in Figure 22 are presented in Table 2.

**Table 2: Parameters for the safety area**

<table>
<thead>
<tr>
<th>Distance</th>
<th>Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HZ</td>
<td>530</td>
</tr>
<tr>
<td>ZX</td>
<td>120</td>
</tr>
<tr>
<td>XJ1</td>
<td>60</td>
</tr>
<tr>
<td>DH</td>
<td>693</td>
</tr>
<tr>
<td>BH</td>
<td>470</td>
</tr>
<tr>
<td>CH</td>
<td>450</td>
</tr>
</tbody>
</table>
7 User needs

To get a good understanding of the users’ needs and desires, and to reveal valuable information about the context, user studies with truck drivers were performed. In this chapter, the methods and findings from the user studies are presented.

To collect information and insights from the users regarding for example the seats and driving habits, an online survey was sent out. The survey contained questions about the comfortability of the driver seat in general, as opposed to questions regarding just the seat belt and headrest, in order to not bias the respondents.

In addition to the survey, interviews and observations of both distribution truck drivers as well as long haulage drivers were organized to get a better understanding of what it is like to work as a full-time truck driver. The interviews were held contextually in order to make it possible to observe while interviewing, and also so that the driver would be in the right setting when talking about the seat comfortability. Table 3 shows information on the data that was collected.

<table>
<thead>
<tr>
<th>User study type</th>
<th>Number of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey</td>
<td>230</td>
</tr>
<tr>
<td>Interviews and observations</td>
<td>10</td>
</tr>
</tbody>
</table>

The data collected from both the interviews, the observations and the survey were compiled and analysed. The interview answers and the observations were analysed together, but separate from the survey answers due to the differences in depth.

7.1 Insights from survey

The survey was created to get inputs on comfort, on the driver seat and seat belt as well as the habits of truck drivers. To get as many respondents as possible, the survey was sent out to over 20 different haulage contractors as well as posted on the Scania Group Facebook page. The target audience was truck drivers with different types of driving modes and different types of trucks, including trucks from brands other than Scania.

In total, the survey had 230 respondents. It can be seen in full in Appendix 2 - Survey. Questions on adjustment possibilities, the use of seat belt and frequencies of adjustment were asked. Questions on suggestions for improvement were also asked, though many respondents did not answer these more open-ended types of questions.

The survey answers were analysed using Excel (Microsoft Office 2013). The respondents of the survey were mainly males, see Figure 23. The survey had respondents from nearly 40 different countries, and Swedish, Norwegian and British were most common nationalities.
Most of the drivers were young; under 40 years old, see Figure 24, and 60% of the respondents drive Scania trucks.

Which type of driving the drivers performed varied, although, long-haulage driving was the most common as seen in Figure 25.
Although the weight varied much, the stature of the drivers was mainly between 171 cm and 190 cm, see Figure 26.

The survey shows that most of the drivers do not know which seat they use. However, over 40% says that they have advanced seats with the maximum amount of adjustment possibilities and
only 5% says they have a low-end seat. Over 60% says they have the possibility to adjust the upper part of the back, and 42% of the respondents say they would never use this type of function. Almost all of the respondents usually drive the same truck, and they would generally only adjust the seat whenever they enter a new truck.

The survey also shows that nearly 60% claims that they always use the seat belt. In its turn, 70% of these use it according to instructions, see Figure 27 and Figure 28.

![SEAT BELT USAGE](image)

*Figure 27: The seat belt usage ratio on a scale from “never” to “always”*

![DO YOU USE THE SEAT BELT AS SUPPOSED TO?](image)

*Figure 28: How often the drivers use the seat belt correctly, on a scale from “never” to “always”*

When it comes to both the comfortability of the seat belt as well as the overall comfortability of the seat, the opinions are quite varied. However, for both, most people rank them towards the higher half of the scale, see Figure 29 and Figure 30. The distribution of ratings on how
comfortable the seat belt is, which ranges from 1-6 where 1 very uncomfortable and 6 is very comfortable, is quite even between respondents of different statures. Of the drivers with a stature from 161-190 cm, about 30% rank the comfortability as a 1-3, while 60% rate it 4-6. The biggest difference is that divers from 171-180 cm have higher frequency of rating the comfortability with a 6. In this group, 32% rates the seat belt comfortability to 6, whereas in the groups 161-170 cm and 181-190 cm, only 10% and 14% do so.

Figure 29: How comfortable the drivers think the seat is

Figure 30: How comfortable the drivers think the seat belt is
Personas

From the data, several personas were constructed. These were built to visualise and present the survey data as well as to serve as references throughout the project. The different personas each represent a survey respondent with either specifically interesting input, or they as individuals were able to represent a larger group of survey respondents. In total, 8 personas were created. These are presented below. The dots represent the satisfaction level with each of the seat properties.

**Person 1**

- **Age:** 18-30
- **Weight:** 122-130 kg
- **Height:** 171-180 cm
- **Nationality:** Norwegian
- **Truck brand:** Scania
- **Distance per week:** 1150 km
- **Hours per week:** 55
- **Experience:** 7 years

**Use of seat belt**

[ ] [ ] [ ] [ ]

**According to instructions**

[ ] [ ] [ ] [ ] [ ]

**Comfort seat**

[ ] [ ] [ ] [ ]

**Comfort seat belt**

[ ] [ ] [ ] [ ]

**Adjustment possibilities**

[ ] [ ] [ ] [ ] [ ]

*I normally drive long-haulage. I think the seat have bad support for my back and the headrest is too far from my head. I do not use the seat belt. I never adjust the seat because I always drive the same truck. I can't adjust the headrest enough, even though my seat has the possibility to adjust the upper part of the back since it is a Recaro seat.*

**Person 2**

- **Age:** 18-30
- **Weight:** 85-90 kg
- **Height:** 165-170 cm
- **Nationality:** Finnish
- **Truck brand:** Scania
- **Distance per week:** 2700 km
- **Hours per week:** 45
- **Experience:** 8 years

**Use of seat belt**

[ ] [ ] [ ] [ ] [ ]

**According to instructions**

[ ] [ ] [ ] [ ] [ ] [ ]

**Comfort seat**

[ ] [ ] [ ] [ ]

**Comfort seat belt**

[ ] [ ] [ ] [ ]

**Adjustment possibilities**

[ ] [ ] [ ] [ ] [ ]

*I normally drive long-haulage. I think the seat belt is too high up and it gives me a cut on my neck. I usually use the seatbelt as I'm supposed to, but I don't think it is comfortable at all. I normally adjust the seat when I enter the truck. My seat has an adjustment for the headrest. I don't think the seat suit short people and I think this has to be improved.*

**Person 3**

- **Age:** 18-30
- **Weight:** 75-80 kg
- **Height:** 171-180 cm
- **Nationality:** Norwegian
- **Truck brand:** Scania
- **Distance per week:** 250 km
- **Hours per week:** 10
- **Experience:** 9 years

**Use of seat belt**

[ ] [ ] [ ] [ ] [ ]

**According to instructions**

[ ] [ ] [ ] [ ] [ ] [ ]

**Comfort seat**

[ ] [ ] [ ] [ ]

**Comfort seat belt**

[ ] [ ] [ ] [ ]

**Adjustment possibilities**

[ ] [ ] [ ] [ ] [ ]

*I normally drive a truck used for construction. I don’t think it is a matter of the seat, but rather of my sitting posture. Normally the upper part of my neck feels uncomfortable after a couple of hours of driving, but this depends on the day, etc. I adjust the seat whenever I enter a new truck. My seat has an adjustment for the headrest, but I normally don’t adjust it. Truck driving is my part-time job so I don’t invest time in adjusting my seat. I have a pretty new truck which I really enjoy driving, even on uneven roads. I think the air suspension works very well.*

**Person 4**

- **Age:** 18-30
- **Weight:** 75-80 kg
- **Height:** 161-190 cm
- **Nationality:** Chinese
- **Truck brand:** Scania
- **Distance per week:** 15 km
- **Hours per week:** 40-40
- **Experience:** 8 years

**Use of seat belt**

[ ] [ ] [ ] [ ] [ ]

**According to instructions**

[ ] [ ] [ ] [ ] [ ] [ ]

**Comfort seat**

[ ] [ ] [ ] [ ]

**Comfort seat belt**

[ ] [ ] [ ] [ ]

**Adjustment possibilities**

[ ] [ ] [ ] [ ] [ ]

*I normally drive distribution. I don’t drive the same truck every day, but I adjust my seat when I enter a new truck. I think the seat is a bit too hard, so I would say I never use the seat belt. I plug it in before I enter to avoid the seat belt alarm. I don’t know if it’s possible to adjust the seat belt anchor. I feel like I can adjust the seat the way I would like to.*
Age: 41-50  
Weight: 95-100 kg  
Height: 180-190 cm  
Nationality: Norwegian  
Truck brand: Scania  
Distance per week: 2000 km  
Hours per week: 50-60  
Experience: 15 years

Use of seat belt:  
According to instructions:  
Comfort seat:  
Comfort seat belt:  
Adjustment possibilities: 

I drive long haulage. I normally put the seatbelt over my shoulder and under my stomach. I adjust the seat whenever I enter a new truck. I think the seat is lovely, almost too good to sit in.

Age: 31-40  
Weight: 72-80 kg  
Height: 170-180 cm  
Nationality: Irish  
Truck brand: Scania  
Distance per week: 2000 km  
Hours per week: 45  
Experience: 2 years

Use of seat belt:  
According to instructions:  
Comfort seat:  
Comfort seat belt:  
Adjustment possibilities: 

I drive a LORIK vehicle. My LORIK seat has a great deal of adjustment possibilities. I most often use the upper back adjustment. It would be nice with electrical adjustments, including memory of at least three drivers.

Age: 41-50  
Weight: 51-60 kg  
Height: 150-160 cm  
Nationality: German  
Truck brand: Scania  
Distance per week: 3000 km  
Hours per week: 50  
Experience: 23 years

Use of seat belt:  
According to instructions:  
Comfort seat:  
Comfort seat belt:  
Adjustment possibilities: 

I drive a distribution truck. There is no proper back position, it would be nice to have a seat designed for women. I normally put the seatbelt under my arm, otherwise it would cut and rub my neck. My seat has many adjustments options, but it is not possible to adjust the upper part of the back. I adjust my seat 3-7 times a day. As a woman, I'm too short to adjust my seat correctly.

Age: 31-60  
Weight: 220-310 kg  
Height: 160-170 cm  
Nationality: Swedish  
Truck brand: Scania  
Distance per week: 80-90 km  
Hours per week: 15  
Experience: 7 years

Use of seat belt:  
According to instructions:  
Comfort seat:  
Comfort seat belt:  
Adjustment possibilities: 

I normally drive a distribution truck. Either I use the seat belt according to instructions or I don't use it at all. I normally take it off when I connect or disconnect the trailer. I adjust the seat when I enter a new truck. My seat has adjustment for upper back, but though I rarely adjust it. I have large breasts and a big belly, and the seat belt tend to rise up to my throat, which I think is pretty uncomfortable. However, it doesn't stop me from using it.
7.2 Insights from interviews and observations

In total, ten interviews with drivers were made. The interviewees were two drivers at the Scania test track together with two distribution drivers and six long haulage drivers from Scania Transport Labs. All the drivers were interviewed while they were performing their specific type of driving in order for the results to be as accurate as possible. A general interview guide was used as a basis for discussion, but all interviews were held in an unstructured manner. The interview guide can be seen in Appendix 3 - Interview guide.

After conducting the interviews and observing the drivers, the data was analysed by clustering it in various categorisations, see Figure 31.

![Figure 31: Analysis of interviews and observations](image)

Different topics were identified amongst the data, and eventually, these were combined to form several insights. These are presented below.

**Sitting position**

**Insight:** Drivers want to be able to change sitting position when driving, but some feel like they cannot change sitting position as freely as they would like to.

“When you’re sitting in a seat for so long, you definitely want to change sitting position frequently”

When driving longer distances, most drivers want to be able to change how they sit in order to avoid pain. However, some drivers find that they cannot move enough to find the type of sitting position they would like to have.
**Insight:** There are different ways to change sitting posture; either move yourself while keeping the seat static or adjusting the whole seat, and these are used in different situations.

“When you need to manoeuvre the vehicle, you need to sit in a more upright position”

For example, when driving on a highway, it was common to change sitting posture while leaving the chair static. However, when approaching a city, it was more common to re-adjust the seat, too. Generally, the drivers seemed to want to sit a bit further back and lean backwards when driving on a highway, and sit more upright when driving in a city.

**Components**

**Insight:** The headrest is of high importance for the sight.

“I have progressive lenses, and if the headrest cannot be adjusted, I can’t see anything when I lean back”

If the seat has no headrest, the driver cannot lean back without a reduced area of vision. However, if the headrest is too much to the front, that affects the sight in a negative way as well. Almost all interviewees said that they always use the headrest/upper back adjustment if there is one, which also means that this is a much appreciated feature which people miss if it is left out.

**Insight:** It is annoying to put on and take off the seat belt.

“I never wear the seat belt when driving shorter distances, however, I do wear it on highways”

When talking to the drivers, it was found that most people do use the seat belt, but if they do not, it is when they drive shorter distances or need to exit the vehicle many times. In order to increase the seat belt usage, it is therefore crucial to create a seat belt which is easy to put on and take off.

**Insight:** Placing the seat belt anchorage in the B-pillar has different results depending on the seat position.

“When the seat belt is anchored in the B-pillar, it is not even close to my body and runs straight in front of my face”

If the seat belt anchorage is placed in the B-pillar, it is very important to study the different positions of the seat in terms of moving it forward and backward, as some positions might result in the seat belt not sitting tight on the body.
**Insight:** It is important that the seat belt allows for a certain degree of freedom of movement for the driver.

“I need to unbuckle my seat belt in order to pull down the sun visors, and I’m very tall”

It was found that some of the situations in which the drivers do not use the seat belts are if they need to move around in the cab. This could for example be in order to get a good line of sight when reversing.

**Insight:** The shape of the seat belt outlet and the pulling direction are important to consider when designing the seat belt anchorage.

“My seat belt jams all the time”

During an interview, it was mentioned that for Scania’s previous premium seat, in which the belt outlet is designed to be a vertical slot, the seat belt sometimes get jammed. This annoys the driver, and might be yet another reason to not use the belt if you are just going for a shorter distance.

**Insight:** The placement of the seat belt anchorage is of high importance

“In some trucks I need to put a scarf around the seat belt to avoid red marks on my neck”

Some people think that the seat belt is very uncomfortable since it rubs their neck and leaves red marks.
8 Summary of information collection

*From all the research that was conducted, several conclusions could be drawn.*

Both the research regarding sedentary work and the user studies comes down to the importance of keeping a varied work position. When designing seat adjustments, it is therefore important to make them easy to use so the driver really does so. For this, inspiration could be drawn from office chairs and their adjustment controls. For example, the headrests of office chairs have a wide range of adjustment possibilities giving good support when resting, which is what is desired by the truck driver population, too.

The seat belt usage is high, but the data also shows that there are many drivers who do not always use the seat belt. When analysing the data, it seemed like most of the drivers that do not always use the seat belt do not use it in situations where they are driving shorter distances. This could for example be in distribution or construction applications. By allowing for easy adjustment of the belt, the chance of motivating more drivers to wear the seat belt could be increased. If so, a safe work environment could be achieved for a larger part of the driver population.

Also, easy adjustment would cater for the driver’s need to, when driving, continuously change his/her position. In the user studies, it was found that drivers actually need to change their sitting posture depending on what type of driving they are currently performing. Most of the drivers explain that they like to vary their driving position, when sitting still for a long period of time. They also vary their position when driving in, for instance, cities or at harbours. When they have to manoeuvre the truck in narrow streets etc., the driver like to be more upraised, compared to driving on the motorway, where they like to lean back and have a more relaxed posture. This is also the findings from an internal Scania study about different drivers’ sitting postures. Shorter people tend to sit more upraised to get a better overview when driving.

It is also important to design the belt anchorage and the headrest so they can be adjusted to fit a large part of the population. This is vital to achieve a sitting posture in which the natural spine curvature is held. Scaniafamiljen was chosen as the anthropometric dataset to base the adjustment design on, and the body dimensions of interest are the body height, the sitting height, the shoulder sitting height and the deltoidal shoulder width. Based on the anthropometric dataset, the seat belt adjustment range was chosen to be minimum 70 mm sideways, and the headrest should be possible to adjust at least 200 mm in height. These adjustment ranges were chosen based on the body dimension differences within Scaniafamiljen. Although the headrest adjustment range will not cover the complete sitting height span of Scaniafamiljen, a 200 mm adjustment range is expected to be sufficient. This estimation was partly based on the user study results showing that very few drivers are shorter than 160 cm.

When looking at other seat belt adjustment studies, it was found that it might actually be more beneficial to move the anchorage sideways instead of in height, if improving comfort is what is sought for. Also, both from the literature research as well as the user studies, it was found that proper headrest adjustment, especially in height, is highly important for keeping a good
visual area. If the headrest cannot be adjusted properly, the safety is impaired. In order to ensure the driver has a good enough area of vision it is important that he/she can adjust the headrest well enough.

As the seat moves relative to the B-pillar, it might be better to place the seat belt in the seat. Not only do the seat move because of air suspension, but also as the driver moves the seat forward or backward. If the seat belt is anchored in the B-pillar, this seat movement will have a large impact on how well the belt fits on the driver, which limits the driver’s movement in terms of what positions are safe for the seat to be in if a collision was to occur. Therefore, the focus was kept on fastening the seat belt to the seat.
9 Product realisation

This chapter gives an understanding of the concept generation and development process in this project. Several concept generation methods have been used in order to develop good concepts based on the applicable knowledge. These methods and concepts are all presented below.

9.1 Requirement specification and QFD

A requirement specification as well as two Quality Function Deployment (QFD) matrices (Ullman, 2010), one for the seat belt and one for the headrest, were made. The requirement specification and QFD:s were based on the insights from both the background research as well as the user studies.

The requirement specification can be seen in Table 4. It is divided into three parts; headrest, seat belt and general, where general requirements apply to both the headrest and the seat belt.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Desideratum</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Headrest</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The headrest should be adjustable at least 200 mm in height</td>
<td>The headrest must provide good sight</td>
<td></td>
</tr>
<tr>
<td>The headrest should be possible to adjust from a sitting position</td>
<td>The headrest should be possible to adjust using only one hand</td>
<td></td>
</tr>
<tr>
<td>Should support the neck while driving</td>
<td>Should be adjustable in depth</td>
<td>To be able to fit a wider range of drivers</td>
</tr>
<tr>
<td><strong>Seat belt</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The belt position should allow the driver to move in the cab</td>
<td>To be able to fit a wider range of drivers</td>
<td></td>
</tr>
<tr>
<td>The seat belt should be adjustable at least 70 mm sideways</td>
<td>Should be adjustable in five steps</td>
<td>If mechanical</td>
</tr>
<tr>
<td>Should be adjustable in at least three steps</td>
<td>The seat belt should not fold in its slot</td>
<td></td>
</tr>
<tr>
<td>The anchorages should be placed within the region specified in the ECE regulation</td>
<td>Not jam</td>
<td></td>
</tr>
<tr>
<td>Not scratch the neck</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>General</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The solution should be easy to implement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Easy to reach</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Easy to adjust</td>
<td>Both the headrest and the seat belt</td>
<td></td>
</tr>
<tr>
<td>The solution(s) should fit the Swedish</td>
<td>The solution(s) should fit</td>
<td></td>
</tr>
</tbody>
</table>
The solution(s) should invite the user to change his/her sitting posture regularly

The adjustment controls should be easy to recognise

The adjustment controls should be intuitive

Possible to disassemble

Possible to recycle material

The QFD:s were then made based on this requirement specification, one for the seat belt adjustment and one for the headrest. In the QFD, the customer requirements are broken down to be more precise, and are converted to technical product attributes as well as ranked by importance. Also, a few selected existing products were compared to find any weak spots. The two QFD:s can be found in Appendix 4 - QFD.

The competitive evaluation for similar products showed that for the seat belt anchorage, the areas in which the existing solutions perform less well were adjustment range and jamming. For the headrest, the existing solutions compared were two office chairs and the truck seat. The areas in which the truck seat performed much worse was in providing good sight and supporting the neck. In these areas, much inspiration should be drawn from the office chairs.

9.2 Idea generation

After the requirement specification and the QFD:s were made, different ideas for the seat belt adjustment as well as the headrest were generated. Several ideation methods, such as brainstorming and the 6-3-5-method (Ullman, 2010), were employed. The different unsystematic idea generation methods were chosen since it was essential to get as many different ideas as possible in the beginning of the concept generation, and using a variety of methods help to achieve that. To supplement the ideas from these unsystematic approaches, different more systematic approaches were also used, as for example the Morphological matrix (Ullman, 2010) and the Function-means tree (Cross, 2000). These gave more detailed ideas to develop further later in the process.

Ideation

Initially, brainstorming ideas were made on post-it notes, mainly to get started thinking about different ways of solving the problem. This was performed individually in several, shorter sessions. Some of the results from these sessions are shown in Figure 32, and these for example include ideas of an adjustment mechanism built into the seat backrest and headrests created by inflating an internal air compartment.
Subsequently, three function-means trees were made; one on the seat belt holding the driver in place, one on the seat belt adjustability and one on the headrest adjustability. Here, the different functions and ways of achieving these were investigated in steps. In Figure 33, an excerpt of the function-means tree for the seat belt anchorage adjustment in shown. Appendix 5 - Function-means tree.
With the function-means trees, the product was broken down into distinct functions which could be solved using several means. Thereby, a greater understanding of the different solution possibilities was achieved and could be combined.

**Ideation session**

In order to widen the perspective even more, an ideation session was organised. To this session, eight thesis workers at Scania were invited to together brainstorm on adjustment solutions for both the seat belt and the headrest. The participants were then divided into two teams. In the first part of the session, the 6-3-5-method was used to generate different ideas together. After all ideas had passed by all team members, the participants were asked to in the two groups combine their ideas to form three different ones plus an additional “wild card”-idea. These in total eight different ideas were then presented to all participants. A selection of the ideas is presented in Figure 34 to Figure 40.
Figure 34: An airbag to fully replace the seat belt

Figure 35: An articulated seat to allow for a high level of adjustability

Figure 36: A seat which will form to fit the driver

Figure 37: A seat with several sections which can tilt or be adjusted in height

Figure 38: The seat belt anchorage mounted similarly to a crane that can be rotated and adjusted in length

Figure 39: A headrest possible to rotate and thereby adjust in depth
9.3 Five chosen ideas

The outcomes from the idea generation were collected and combined to form six different, general ideas on how to solve the problems. One of these was removed for confidentiality reasons. The five remaining ideas were:

- Airbag
- New belt geometry
- Vest
- Multi
- Guides

Some of the ideas above are for the seat belt adjustment only, while some would incorporate solutions for both the seat belt and the headrest. Different executions of these ideas were investigated in order to be able to compare them to each other.

**Airbag**

In this idea, the seat belt is replaced with an airbag, see Figure 41 and Figure 42. The airbag is inflated in case of a crash and will be placed and shaped so that it will hold the driver in place when inflated. The Airbag is integrated in the driver seat, both on the side and above the driver’s shoulders.
The advantage of this concept is that there would be no need for a seat belt, and the driver would therefore not be experiencing any discomfort from this when driving.

**New belt geometry**

Here, the belt shape can be altered in order to keep it from rubbing the driver’s neck. A strap could be pulled to change the angle with which the belt runs from the upper anchorage over the driver’s upper body, see Figure 43. Another solution would be if the part of the belt crossing the upper body was possible to move along the hip belt, also changing this angle, or to create a belt that runs vertically from the shoulder down to the hip belt.
By changing the belt geometry only, the seat itself could be left untouched. This would result in a solution easy to implement for the existing seats.

**Vest**

In the Vest solution, the driver would, instead of wearing a seat belt, put a vest on which in its turn is fastened to the seat, see Figure 44. The fastening mechanism could be clips or hooks fastened to the seat, or it could be magnetic and only activated in case of a crash. The vest could be tightened at the sides in order to make sure it fits drivers of different sizes. Each driver will have a personal vest, which fits all driver seats.
Figure 44: Vests, which could replace the belt and be fastened to the seat in different ways

Just like the previous idea, this solution would mean that the changes necessary to make on the seat structure would be minor, as the attachment points could be attached to the current design.
**Multi**

A various range of headrests and seat belt anchorages is adjusted independently of one another, see Figure 45 - Figure 52. A large number of different solutions for both the seat belt as well as the headrest were generated. These ideas were later combined using a morphological matrix.

*Figure 45: Link bar adjustment for belt anchorage*

*Figure 46: Link bar seat belt adjustment, can adjust the seat belt anchorage both sideways and in depth*

*Figure 47: Folded safety bar, similar to roller-coaster bar*
Figure 48: Seat belt anchorage adjusted outwards, to move the seat belt away from the neck.

Figure 49: Seat belt anchorage placed on the side to adjust in height. The anchorage is locked in position by a geometrical lock and can be unlocked by lifting the whole anchorage.

Figure 50: Seat belt anchorage with the possibility to move the lock in a grid, to give high range of adjustability.
Guides

This solution was meant to be a simplified version of the seat belt adjustment, using fixed guides with different slots in which the belt could be put, see Figure 53 - Figure 56. The drivers could themselves choose a suitable belt position. This idea gave the possibility to attach the seat belt in the B-pillar. It is an easy solution that could easily be implemented for the existing seat.
**First concept elimination – narrowing down the amount of concepts**

The ideas were then compared in terms of how well they met the requirements and desideratum. The generated ideas were compared using a decision matrix, see Table 5. This chart was used mainly as a hint for which solutions might be better to develop further. The criteria used were based on the requirement specification. Even though all ideas might not alone solve both the seat belt adjustment and the headrest adjustment problem, they were evaluated in the same chart. Therefore, the scores should not be treated as definite.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Airbag</th>
<th>Vest</th>
<th>Multi</th>
<th>New belt</th>
<th>Guides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fits body - height</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Fits body - width</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Give good neck support</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Adjustability range</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Easy control of movement</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Controls easy to understand</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Easy to implement</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Driver acceptance</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Similarity with current solution</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Adaptable to regulations</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Safe</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Possibility to change sitting position</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
<td>34</td>
<td>59</td>
<td>36</td>
<td>46</td>
</tr>
</tbody>
</table>
The criteria used were:

- **Fits body – height**: How likely it is that the idea will fit the driver population in height.
- **Fits body – width**: How likely it is that the idea will fit the driver population in width.
- **Give good neck support**: How well the neck will be supported, for example in terms of viewing area. The solutions which did not incorporate a headrest solution were not scored.
- **Adjustability range**: How much adjustability the ideas incorporate.
- **Easy control of movement**: How easy it will be for the user to control the movement of the seat belt anchorage or headrest.
- **Controls easy to understand**: How intuitive the solution is likely to be.
- **Easy to implement**: If the solution is easy to implement for the existing truck seats.
- **Driver acceptance**: How likely it is that the driver will actually use the feature.
- **Similarity with current solution**: How close the new solution is to the current. Since the seat belt design is well established, it is believed that it would be better to stay close to this.
- **Adaptable to regulations**: If the solution is likely to conform with the current legislation.
- **Safe**: If the solution will be able to hold the driver tight and in place in case of a collision.
- **Possibility to change sitting position**: Since it was found in the background research that one must be able to change sitting position regularly, it is important that the solution allows for this.

The different ideas were scored 1-5 depending on how well they fulfilled each of the criteria. If the criterion was not applicable to an idea, it was not scored for that specific criterion. When the total score was calculated, two ideas stood out as better performing than the others. These were the Multi solution and the Guides solution. These were therefore chosen as the ones to develop further.
9.4 Concreting the three concepts

As these two ideas were both broad and more of general approaches on how to solve the problem, they needed to be made more concrete. For this, a morphological matrix was used, see Table 6. The morphological matrix was split into one part for the headrest and one for the seat belt anchorage. The functions identified included:

- **Seat belt anchorage**
  - Adjust in height
  - Lock/unlock (the controls the user interacts with for adjustment)
  - Locking mechanism (for locking position)
  - Adjustment (type of mechanism)
  - Placement (placement of anchorage)

- **Headrest**
  - Adjust in depth
  - Adjust in height
  - Locking mechanism (for the headrest position)
  - Adjustment (the controls the user interacts with to adjust the headrest)
  - Placement (of the controls)
  - Shape (how the shape of the cushion is created)

Different ways of achieving the desired functions was then put into the matrix, all originating from either the multi or the guides ideas. The solutions were then combined in different ways to create more detailed concepts. Initially, the combinations were made to, for example, be the most economic, the most luxurious, the best mechanical solution etc. Subsequently, three different directions were determined to base the concepts on. These were “Link Lux” “Hoop”, and “Impleasy”. Two of these concepts were created to be high-end mechanical solutions and one was created to be easy to implement.

<table>
<thead>
<tr>
<th>Seat belt</th>
<th>Adjust in height</th>
<th>None</th>
<th>Separate adjustments</th>
<th>Link Lux</th>
<th>Hoop</th>
<th>Impleasy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lock/unlock</td>
<td>Button</td>
<td>Lever</td>
<td>Snap (guide)</td>
<td>Friction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Locking mechanism</td>
<td>Geometrical</td>
<td>Friction</td>
<td>Screw</td>
<td>Electrical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjustment</td>
<td>Link bar</td>
<td>Rail</td>
<td>Screw</td>
<td>Guide</td>
<td>Slot</td>
<td></td>
</tr>
<tr>
<td>Placement</td>
<td>On top</td>
<td>To headrest</td>
<td>B pillar</td>
<td>On side</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Headrest</td>
<td>Adjust in depth</td>
<td>Air</td>
<td>Screw out</td>
<td>Link bar</td>
<td>Friction/hinge</td>
<td>Fixed</td>
</tr>
<tr>
<td>Adjust in height</td>
<td>Telescope</td>
<td>Air</td>
<td>Slot</td>
<td>&quot;Lift&quot;</td>
<td>Link bar</td>
<td>Screw</td>
</tr>
<tr>
<td>Locking mechanism</td>
<td>Geometrical</td>
<td>Electrical</td>
<td>Friction</td>
<td>Screw</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjustment</td>
<td>Button</td>
<td>Lever</td>
<td>Twist</td>
<td>Pulling/none</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Placement</td>
<td>On side</td>
<td>On back</td>
<td>By seat controls</td>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shape</td>
<td>Memory foam</td>
<td>&quot;Nail mat&quot;</td>
<td>Air</td>
<td>Foam</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6: Morphological matrix

- **Link Lux**
- **Hoop**
- **Impleasy**
After the concepts were created by combination, they were further developed in terms of, for example, mechanisms.

**Link Lux**

This concept, Link Lux, is based on link mechanisms, see Figure 57.

![Figure 57: The first concept, Link Lux](image)

The seat belt anchorage is fastened to the back of the seat using two links, see Figure 58. As a button on the back of the anchorage is pushed, the anchorage will be possible to move sideways. The links will be able to rotate around the fixation points, moving the anchorage position sideways and slightly upwards. Geometrical constraints will control the positions, between which the anchorage can be placed, see Figure 59.
Figure 58. Link bar mechanism for adjusting the seat belt anchorage

Figure 59. Geometrical constraints control the link bar rotation span

The headrest draws inspiration from headrests of office chairs, and is connected to the backrest using a link bar mechanism. This mechanism allows movement in both depth and height as well as a tilt motion, see Figure 60. The mechanism is locked and unlocked using a button on the back of the headrest, which has been placed to be intuitive to use as well as to make it easy for the user to manoeuver the adjustment motion. As the button is pushed, a wire is relieved. When this happens, the springs placed in the joints will push the geometrical locks apart, thereby making it possible to move the headrest, see Figure 61. As the button is released, the wire will tighten again, locking the mechanism in its position.
Figure 60: Adjustment possibilities for the headrest

Figure 61: Mechanism for the headrest adjustment
Hoop

In Hoop, the P-shaped seat belt anchorage is possible to slide sideways. This prevents the seat belt from rubbing the neck and makes it fit most drivers. Also, the P-shape makes it possible to adjust the belt to sit even further out than the seat structure, see Figure 62.

Figure 62. The second concept, Hoop

The anchorage can be adjusted outwards by pushing/dragging without unlocking any mechanism. To adjust it back inwards, a button is pushed to unlock movement in this direction, see Figure 63. This makes it easy and fast for the driver to adjust it away from the neck. The anchorage itself here is more of a belt guide. The seat belt runs up through a slot behind the anchorage and then through the P-shaped anchorage, which holds the seat belt in place, see Figure 64.
The headrest, which draws inspiration from office chairs just like the Link Lux headrest, is adjustable in height using a telescope construction to get a large range of adjustment. The telescope mechanism can be adjusted in several steps. To achieve the possibility of changing the headrest depth, the headrest can be rotated, see Figure 65. A ratchet wheel allows rotation in one direction. The mechanism makes it easy for the driver to adjust the headrest in depth, only using one hand to adjust it outwards. To adjust it back to its natural position, a lever is pushed to release the ratchet wheel and the headrest can be rotated freely.
As shown in Figure 66, the headrest shape has been formed to fit the head. It has also been created to be comfortable for the driver no matter what angle it is adjusted to be in.

![Figure 66: Different shapes to make the headrest comfortable when adjusted in depth](image)

**Impleasy**

Impleasy was developed to be a concept as simple as possible, to make it easy to implement on the existing seat. Impleasy can be seen in Figure 67.

![Figure 67: The third concept, Impleasy](image)

In order to adjust the seat belt position, the belt can be put into different slots. The seat belt is secured by a lid, which locks using a snap function. For more details see Figure 68.

The headrest is fastened to the backrest in tracks, and can be pushed up and down to fit the driver’s height. It is held in place with friction, see Figure 69. This is a concept which would
be possible to implement for the existing driver seats, and therefore, it is regarded as an economical and time-saving way to create seat belt and headrest adjustability.

Figure 68: Locking mechanism on seat belt guide  Figure 69: Detailed adjustment on headrest

**Second concept elimination – choosing the final concept**

The three concepts were compared and discussed based on their possibilities of implementation, their user friendliness as well as their possibilities for adjustment. To identify and evaluate any possible strengths, weaknesses, threats and opportunities for the different concepts a SWOT analysis, which can be seen in Appendix 6 - SWOT, was carried out. Some of the insights from this analysis were, for example:

- The drivers might not use the adjustment if it is too complicated to do so, as it might possibly be for the Impleasy concept
- The Impleasy concept could allow for placing the belt in the B-pillar
- Both the Link Lux and Hoop concept would require design changes of the seat
- Both Link Lux and Hoop would allow for good adjustability both in terms of the seat belt and the headrest

In addition to the SWOT analysis, both a weighted decision matrix as well as a Pugh’s matrix were used for evaluation, in which the current Recaro seat was used as the reference. These are shown in Appendix 7 – Decision matrix. The concepts Link Lux and Hoop stood out in both of these. In the Pugh’s matrix, Link Lux scored more ‘+’, but it also scored more ‘-‘ as compared to Hoop. However, in the weighted decision matrix, Hoop scored significantly better than Link Lux.

Based on these analyses as well as discussions with design engineers at Scania, Hoop was chosen as the final concept.

Hoop gives the best possibilities for the driver to adjust both headrest and seat belt. For example, the seat belt anchorage adjustment for Hoop allows the user to choose between more positions than both the Link Lux and Impleasy concepts do. The headrest is adjustable both in height and in depth and the mechanical design is believed to be more robust than, for example, the Link Lux headrest.
9.5 Detailed development of final concept

When the final concept was chosen, ideas for different mechanisms to achieve the desired movement and locks were generated. In order to find the most suitable mechanisms for the final concept, a workshop was held with design engineers at Scania from the cab interior group. New ideas on mechanisms for both the headrest and the seat belt anchorage were generated.

The goal for both adjustment mechanisms was to achieve easy adjustment in order for the driver to actually use the functionality. Therefore, it was decided that the seat belt anchorage should be possible to move outwards without the need to actually unlock the mechanism. The headrest would, in the same way, be possible to rotate outwards without the need to push a button.

A few of the generated ideas were then visualized using 3D models made in CATIA (Dassault Systèmes, 2017), before a final mechanism was chosen. To ensure a functional prototype, and to get the right size and shape for the product, simple mock-ups were created. This gave a good understanding of the mechanism and of which improvements were needed before determining the final design and making the final prototype.

Seat belt
Initially, some different ideas for mechanisms were generated and hand-sketched. Some of these are shown in Figure 70.
In addition to free brainstorming around different mechanism design, existing solutions for similar problems were also researched. For example, for the seat belt, one mechanism which was looked at more closely was an Autoliv seat belt adjustment mechanism sitting in the B-pillar of passenger cars, in which a button unlocks the anchorage movement in one direction. This mechanism allows movement similar to what was required from the seat belt anchorage.

Some of these ideas were then visualised as CAD models too, to investigate them even further. These mechanisms are shown in Figure 71 - Figure 74, and these include both ratchet mechanisms as well as a threaded mechanism.
**Figure 71**: Mechanism 1. The button is pushed and rotates around its fastening point, unlocking the sideways movement of the anchorage.

**Figure 72**: Mechanism 2. The button is pushed downwards, and unlocks against the ratchet plates, which are facing down, unlocking sideways movement of the anchorage.

**Figure 73**: Mechanism 3. The wheel and pin is rotated, and as the pin is threaded, the "spool" will move along it, thereby changing the seat belt position.

**Figure 74**: Mechanism 4. When the button is pushed, it rotates and thereby forces the hook to do so as well, unlocking the movement.

**Headrest**

In terms of headrest adjustments, inspiration was initially drawn from ratchet wheels, and for example ratchet wrenches, see Figure 75. In these, the direction of rotation can be shifted using a small switch.
With the offset in this type of mechanisms, different mechanisms for the headrest were also brainstormed. Soon, two of these mechanisms stood out as either easier to implement or more robust than the rest. These two are presented below in Figure 76. Both mechanisms are locked using ratchets. One of the mechanisms is unlocked by a button pushing two ratchet plates aside, while the other is unlocked using a lever.

From these mechanisms, the one with the ratchet plates was chosen as the final mechanism due to its simplicity and its robustness. If the mechanical design is reliable, it will function for a longer time, meaning that the product life span will be prolonged.

**Mock-ups**

When the final mechanisms for both the seat belt anchorage as well as the headrest were chosen, different mock-ups were created to physically test their functionality, shape and size, see Figure 77 and Figure 78. Both mechanisms were 3D-printed and the headrest shape was hand-formed from Styrofoam. The creation of mock-ups was performed in iterations to fine-tune the final design.
Figure 77: The first, 3D-printed mock-up of the seat belt anchorage

Figure 78: Hand-formed mock-ups of the headrest cushion to determine its shape and size, where the right-handed shape was chosen as the base to build on further on
10 Result

This chapter gives a description of the final design, how the mechanisms work and how the user is supposed to go about using the adjustment features.

The result, Hoop, is designed to fit the reference seat and consist of a headrest and seat belt anchorage possible to adjust to suit a larger driver population, see Figure 79 and Figure 80. The upper part of backrest has been modified to make sure that the adjustment range is accommodated for.

![Figure 79: Front view, Hoop](image)
The seat belt anchorage can be adjusted sideways, see Figure 81.

The headrest can be adjusted in height by simply lifting it up or pushing it down, and the depth can be changed by rotating the cushion.
The seat belt anchorage is adjustable 70 mm sideways and the headrest can be adjusted 200 mm in height.

For both the mechanisms, a red colour was chosen for the buttons. This colour makes them clearly visible and identifiable. Both buttons have been also placed directly onto the mechanisms, so that they will be easily found and reached. The colours were also chosen to fit the reference seat.

The shape of the belt slot in the P-shaped anchorage is slightly curved, thereby allowing for a more comfortable belt position and direction. Another reason for this curved outlet is to lower the risk of the belt jamming. The anchorage dimensions were chosen in order to provide a good grip for the user when adjusting, and its curved sides makes it both comfortable and aesthetically more interesting.
As the headrest is tilted, the head contact point will change. The headrest shape was designed with this in mind; the curved underside ensures comfortability no matter where on the headrest the user will be placing his/her head.

10.1 Mechanism
Both mechanisms are locked using ratchets, and are relieved using a button.

**Seat belt**
The different components of the seat belt anchorage are shown in Figure 83.

![Figure 83: The different components of the seat belt anchorage](image)

The shape of the lever and the ratchets allows movement in one direction without pushing the button, so that adjusting the anchorage outwards will be as fast and easy as possible. The angle on the tip of the lever was designed to be 30° in order to ensure this functionality (Raucent, Nederlandt and Johnson, 1997). The rail has got grooves on each side in which the anchorage slides, and the anchorage has also got two profiles on each side also contributing to increased stability.

When unlocking the mechanism, a button is pushed rotating a hook so that the ratchet mechanism unhooks. When it does, it is possible to move the anchorage along the rail, see Figure 84 and Figure 85.
Headrest

The headrest mechanism design and its different components can be seen in Figure 86. The mechanism has been designed to be easy to assemble, as almost all components are inserted from only two directions.
The headrest is locked in its rotational position using opposite ratchet plates. A spring holds these together, and when they are in contact, the rotation is locked in one direction. A section view of the headrest mechanism can be seen in Figure 87.

![Figure 87: The headrest mechanism which is locked using a spring to clamp the two ratchet plates together](image)

When the red button is pushed, it will push the axle away from the, in Figure 87, white coloured ratchet plate, thereby allowing rotation in both directions.

In addition to the rotational movement, which changes the headrest depth, the headrest can also be adjusted in height. The structure on which it is attached can be slid further into or up from the slot in the headrest fastening, see Figure 88. It is held in place using snap locks, which have been designed for easy up/down movement. The structure attaching the headrest to the seat was designed to be wide with the intention of creating a robust feel.

![Figure 88: Design of the headrest fastening to the seat. The upper right figure shows the snap structure that sits in the seat, and the lower right figure gives a closer view of the snaps on the side of said structure](image)
10.2 Dimensions

Below, in Figure 89 - Figure 91, the dimensions for the different components are shown. All dimensions are in millimetres.

*Figure 89: The overall Hoop dimensions*
The dimensions of the headrest fastening can be seen in a section view in Figure 92. The snap locks has an angle of $21^\circ$ to be able to slide well into and out of the grooves on the side of the structure (Raucent, Nederlandt and Johnson, 1997). The structure is attached to the backrest of the driver seat.
Material selection

The seat belt anchorage as well as the headrest consists of both plastic as well as metal parts. For example, both mechanisms require a strong and rigid base, but the outer shell was determined to be made from plastic to aesthetically fit with the rest of the cab interior. As Scania generally only use certain, specific materials for all their components, the chosen materials needed to be adapted to this.

In order to determine what materials to use, different materials were compared using CES EduPack (Granta Design Limited, 2016). As sustainability properties were one of the important factors, the Eco Indicator 99 was considered. The Eco Indicator 99 expresses the total environmental impact of the material. It is a method used to assess a component’s life cycle impact in terms of human health, ecosystem quality, and resources (Goedkoop and Spriensma, 2001). This rating gave a better picture for a material life cycle impact, because each of the compared materials has a distinct life cycle. The rating for each material was found in EduPack.

The manufacturing method and whether the materials are commonly used at Scania were also essential factors, in addition to mechanical and physical properties. The different materials amongst the commonly used at Scania were first compared in terms of Young’s modulus and density, Figure 93 as well as the Eco Indicator 99, see figure Figure 94.
Polypropylene reinforced with glass fibre has a low environment impact. It also has a relatively high Young’s modulus and elastic limit compared to the other materials that were
considered. This and the fact that it is one of the standard materials at Scania used in several truck cab components makes it a suitable material to use for the P-shape in the anchorage as well as the headrest spacer. However, the outer cover of the seat belt anchorage will be of PC/ABS to ensure good aesthetics.

Carbon steel was chosen due to its elastic limit as well as the fact that it is a standard material for springs at Scania. Bake hardening steel has a high Young’s modulus, and its possible manufacturing methods fit the preferred manufacturing method for the rail. It is also one of the materials commonly used at Scania.

As POM is an ideal material for snap fits and moving parts, it was chosen for the gear wheels, the anchorage button and the headrest structure. POM has got a high Young’s modulus and performs well in terms of environmental impact. POM with Teflon (PTFE) was chosen for the anchorage lever to get a lower friction between it and the button. The material for the headrest button was chosen to be PC/ABS.

For the pillow, a polyurethane memory foam was chosen. It has a soft feeling and was chosen mainly for comfort purposes.
Materials for all components are presented in Table 7, and the material properties are shown in Table 8.

**Table 7: Material, volume and manufacturing method for each component**

<table>
<thead>
<tr>
<th>Component</th>
<th>Material</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail</td>
<td>Bake hardening steel</td>
<td>Bending</td>
</tr>
<tr>
<td>Lever</td>
<td>POM (Copolymer, 2-20% PTFE)</td>
<td>Injection moulding</td>
</tr>
<tr>
<td>Anchorage button</td>
<td>POM</td>
<td>Injection moulding</td>
</tr>
<tr>
<td>P-shape</td>
<td>PP (homopolymer 30% glass fiber) core with PC/ABS cover</td>
<td>Injection moulding</td>
</tr>
<tr>
<td>Pin x2</td>
<td>Carbon steel AISI 1060</td>
<td>Cold drawing</td>
</tr>
<tr>
<td>Headrest button</td>
<td>PC/ABS</td>
<td>Injection moulding</td>
</tr>
<tr>
<td>Axle</td>
<td>Aluminum</td>
<td>Milling</td>
</tr>
<tr>
<td>Gear wheel</td>
<td>POM</td>
<td>Injection moulding</td>
</tr>
<tr>
<td>Structure</td>
<td>Aluminum</td>
<td>Milling</td>
</tr>
<tr>
<td>Pillow core</td>
<td>Polyurethane foam</td>
<td>Moulding</td>
</tr>
<tr>
<td>Spring x2</td>
<td>Carbon steel AISI 1060</td>
<td>Cold drawing</td>
</tr>
<tr>
<td>Axle lock</td>
<td>POM</td>
<td>Injection moulding</td>
</tr>
<tr>
<td>Spacer</td>
<td>PP (homopolymer 30% glass fiber)</td>
<td>Injection moulding</td>
</tr>
<tr>
<td>Fastening screws</td>
<td>Carbon steel AISI 1060</td>
<td>Standard components</td>
</tr>
<tr>
<td>Fastening nuts</td>
<td>Carbon steel AISI 1060</td>
<td>Standard components</td>
</tr>
<tr>
<td>Structure with snapfits</td>
<td>POM</td>
<td>Injection moulding</td>
</tr>
<tr>
<td>Cover x2</td>
<td>PC/ABS</td>
<td>Injection moulding</td>
</tr>
</tbody>
</table>

**Table 8: Material properties (CES EduPack, 2016)**

<table>
<thead>
<tr>
<th>Material</th>
<th>Price [SEK/kg]</th>
<th>Yong’s modulus [GPa]</th>
<th>Density [kg/m³]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP (homopolymer 30% glass fiber)</td>
<td>21.4-23</td>
<td>5.67-6.78</td>
<td>1.12·10⁻¹-1.14·10³</td>
</tr>
<tr>
<td>Aluminium (6061 T6)</td>
<td>19.2-22</td>
<td>68.74</td>
<td>2.67·10⁻¹-2.73·10³</td>
</tr>
<tr>
<td>Bake hardening steel</td>
<td>4.98</td>
<td>200-221</td>
<td>7.8·10⁻¹-7.9·10³</td>
</tr>
<tr>
<td>Carbon steel AISI 1060</td>
<td>4.98-5.06</td>
<td>208-216</td>
<td>7.8·10⁻¹-7.9·10³</td>
</tr>
<tr>
<td>Polyurethane foam</td>
<td>85.6-94.2</td>
<td>0.044-0.026</td>
<td>78.4-81.6</td>
</tr>
<tr>
<td>POM (Copolymer, 2-20% PTFE)</td>
<td>39.5-49.9</td>
<td>2.132-4.8</td>
<td>1.39·10⁻¹-1.41·10³</td>
</tr>
<tr>
<td>POM (homopolymer)</td>
<td>29-31.4</td>
<td>2.76-3.59</td>
<td>1.41·10⁻¹-1.43·10³</td>
</tr>
<tr>
<td>ABS + PC</td>
<td>33.3-36.9</td>
<td>2.41-2.62</td>
<td>1.07·10⁻¹-1.15·10³</td>
</tr>
</tbody>
</table>

### 10.4 Sustainability

In order to ensure a successful design, it is important to consider sustainability when developing a product. When looking at and evaluating the sustainability of the seat belt anchorage and the headrest, three different perspectives were taken; ecological sustainability, social sustainability and economical sustainability.
Ecological sustainability
Both when choosing the material for and designing the components of the two different mechanisms, the ecological sustainability perspective have been taken into consideration. For example, possible materials were compared in terms of their Eco Indicator 99 score, which is an assessment of the material’s environmental impact.

The mechanisms have also been designed with the intent of them being easy to disassemble when needed. By keeping a good material hygiene, the different materials can be taken care of properly at the product end-of-life. Also, if a specific mechanism component needs to be replaced, it can easily be without the need to switch the fully functioning parts as well.

Social sustainability
Both the seat belt anchorage adjustment as well as the headrest adjustment will make it possible for the truck driver to adjust the seat to fit them properly. The drivers will be able to, to a larger extent, achieve a good working posture regardless of their body type or gender and thereby, their work environment will be improved. By doing this, and any work-related stresses or strains can also be minimised, leading to better personal health.

By adjusting the seat belt anchorage outwards, the driver can find a seat belt position that they think is comfortable. If wearing a seat belt is made more comfortable than it is today, it is likely that more people will use it. This leads to the safety level being increased for a larger part of the driver population, and that many severe injuries can be avoided.

Both controls are situated on the actual adjustment mechanisms in order to make the adjustment procedure as intuitive as possible for the driver to easily use them while driving. With an intuitive and easy-to-use adjustment procedure, it is more likely that a large majority will do so more frequently, and thereby, a more varied seated position can be achieved.

Economical sustainability
When choosing material, the material cost has been taken into consideration as a factor to minimise while still making sure the materials are strong enough to ensure a safe design. There can also be an economical gain in the fact that components of the mechanism can be replaced individually. By designing with this in mind, it can be made sure that no parts are switched out unnecessarily.

Also, the design of the mechanisms have not only been developed to be easy to disassemble, but to assemble as well. By this, it can be made sure that the production costs are held to a minimum.

Even though the seat today looks different compared to what it would need to look like for these mechanisms to fit properly in terms of fastening to the seat structure, the required changes are minor. For the Recaro seat, the alternations to the seat structure would be minimal; the structure of the headrest has to be removed. All new parts on the redesign can be attached to the old structure.
By improving the work environment for the truck driver, the risk for any work-related strain injuries or such is minimised. This will not only lead to a better work environment for the driver, but would also mean that costs related to this are reduced. By making the work environment even better, an additional value is created for the customer, which benefits Scania in the long run.

10.5 Evaluation
To be able to evaluate how successfully the final concept solves the stated problematics and whether it meets the requirements or not, comparisons with both the requirement specification as well as the QFD:s were made.

Comparison with requirement specification
If the final concept is compared to the requirement specification found in Table 4, it can be concluded that it do fulfil almost all of the previously determined product requirements and many of the desideratum as well. For example, the headrest is adjustable in both height and depth, and the driver could adjust it while seated down. The seat belt anchorage is adjustable 70 mm sideways and the headrest can be adjusted 200 mm in height, and both can be adjusted in several steps. Also, both mechanisms are designed to be easy to implement and disassemble, too.

By placing the adjustment controls directly on the mechanisms, the adjustment procedure is believed to be intuitive and easy to understand and reach. That, and also the fact that both mechanisms can be adjusted in one direction without the need to unlock them, will most likely contribute to many drivers using them regularly. However, it would need to be evaluated whether the solutions would actually encourage more frequent adjustment.

When determining the adjustment ranges, anthropometric data for Scaniafamiljen was studied. With the final design, the whole shoulder width range will be covered by the seat belt anchorage adjustment. The desired headrest adjustment range in height is currently not enough to cover the sitting height difference within Scaniafamiljen. However, it is believed that the height and form of the headrest will ensure that the whole range will be able to use it comfortable anyway, since the heads of the taller drivers will just hit the upper part of the headrest instead.

Evaluations would also need to be performed to determine how well the final concept performs in terms of the desideratum. For example, physical tests would need to be conducted to evaluate how the headrest affects the driver’s sight. The driver’s area of reach with the seat belt on, and whether it risks folding in its slot and jamming would also need to be evaluated physically.

Comparison with QFD
When studying the seat belt anchorage and headrest QFD:s, the final concept fulfils almost all product specifications stated here, too. The two specifications which are not entirely fulfilled is that the headrest controls should be placed on or in front of the seat, and that the solutions would require no seat redesign. In terms of control placement, the controls have instead been
placed logically on the mechanisms, and so that the adjustment movement is clear and intuitive. Regarding the necessary seat redesign, this has been held to a minor. Hoop would only require removal of the headrest steel structure and redesign of the anchorage connection to the steel structure of the seat.

**Comparison with applicable legislation**

If the final concept is compared to the area for legal placement of the upper seat belt anchorage, it can be concluded that it fits within this area, see Figure 95.

*Figure 95: The redesigned upper back of the seat visualised together with the current seat design. As shown in the figure, the seat belt anchorage point still lies within the regulated area, and will do so even when adjusted to its outermost position*
11 Prototype

A prototype was built in order to evaluate and test the final concept. The final prototype is presented in this chapter.

Prototypes of the adjustment mechanisms were 3D-printed and fastened to a Recaro seat. The upper part of the seat and the headrest cushion were milled from high-density polyurethane foam, see Figure 96 to Figure 99.

Figure 96: The prototype fastened to a Recaro seat

Figure 97: The headrest in its tilted positions
11.1 Physical evaluation of prototype

The prototype was used for evaluation of the concept and the current design. Several insights regarding the design were discovered:

When testing, the snap locks of the headrest structure showed to be difficult to test using the 3D-prints, as they were too brittle, both due to the 3D-print material as well as the 3D-printing method.

When pulling the seat belt through the anchorage, it was discovered that the anchorage would benefit from having a more rounded belt slot, so that it becomes more of a shoulder over which the belt runs. This would result in less wear on the belt and that it would run more smoothly when the driver pulls its end. All edges with which the belt will be in contact should also have a larger round. Another way of creating a smoother belt movement would be to in the outlets use a plastic with an additive such as Teflon.

Also, when testing the headrest adjustment possibilities, it was discovered that the ratchet plates should preferably have a larger amount of ratchets. This would allow for more precise adjustment, so that the driver can really find a suitable headrest position.

Regardless of the discoveries, the current design and prototype were fully functional and possible to evaluate physically. The controls were easy to reach and could be adjusted from a seated position. Both mechanisms were possible to move in one direction without unlocking the mechanism, as desired.

People of different heights were asked to try the functions, see Figure 100 to Figure 102. The people who tested the prototype were of different heights. The people shown in the figures below are 188, 176 and 160 cm tall. During these tests, it could be concluded that the adjustment features to a very high extent fills its purpose.
What was found from these tests was that the shorter people wished for the seat belt anchorage to sit further out than those who were taller. It was also found out that the headrest needs to be able to sit lower than it does today, and for that, the upper part of the backrest needs to be shaped so that it can.
12 Discussion

In this chapter, the result is discussed in terms of whether it fulfils the set goals and what could possibly have been done differently. Recommendations for further work are also given.

In this project, user studies were conducted in order to gather information from users regarding improvement areas for the seat. In total, 10 interviews and observations were held and the survey had around 230 respondents. In an ideal situation, the number of interviews would have been higher and the interviewees would have been from different haulage contractors to ensure that the information is fully applicable to the larger driver population.

In terms of product development methodology, all the methods used in this project have been useful and have informed the decisions. The mix of different ideation methods, and the fact that these incorporated both systematic as well as unsystematic approaches, proved to be successful in terms of generating a broad variety of ideas. The different concepts were visualised as 2D drawings throughout the development process, in order to be able to compare them to each other. However, it was not until the detailed mechanism design that 3D CAD models and physical prototypes were used to test and verify certain concepts. Preferably, simple mock-ups would have been created earlier in the process to communicate shapes, sizes and adjustment ranges. By doing this, a deeper understanding of the concepts and their differences could have been achieved.

The focus for the current detail design has been to achieve a model which is possible to use for testing the mechanism and adjustment procedure, and therefore, the concept resolution has been chosen for this. The further work would therefore need to include adapting the design for the chosen manufacturing method. This work has been commenced within this project, but as it has not been the focus, more time needs to be spent here.

In this project, no major calculations on collision loads have been made. The concept has not been evaluated in terms of solid mechanics. The next step of the process would need to be to ensure that the current design is strong enough to either withstand a collision or to, in these situations, break in a controlled way. If the mechanism (or parts of it) would break in a collision, any loose parts in the cab must be avoided.

When designing the seat belt anchorage components, it was considered to make the P-shape using two separate parts; a metal core with a plastic cover. However, when studying different materials and talking to material experts, it was found that a glass fibre reinforced plastic might be strong enough. It might very well be able to withstand the loads of which it will be subjected to in a collision, and therefore, the final decision fell on making the P-shape as one component out of this material. If the calculations reveal that it will not be strong enough, a metal core might be a good solution to strengthen the construction.

As of now, the adjustment controls have been placed in positions where they would be easy to access for the driver, so he/she, if desired, can adjust the belt and headrest on the go. In the further development of the adjustment mechanisms, this should be confirmed by performing user tests with the physical prototype. For this, a group of people covering the Scaniafamiljen anthropometric range would be preferred.
In terms of applicable regulations, only ECE R14 has been studied in more detail. In a truck environment, the seat belt is of much higher importance when it comes to the driver’s safety than the headrest is. Therefore, this seemed like a reasonable delimitation to make in this project. However, in order to ensure a fully feasible final product, all applicable regulations would need to be considered. Therefore, this needs to be part of the further development process.

When determining the adjustment range, it was estimated that a 200 mm headrest adjustment in height would be sufficient. However, to accommodate for the shortest drivers, the adjustment range might need to be extended, or the lowest headrest position would need to be moved down. This would need larger modifications to the seat structure, which is one reason to why this was not done within this project.
13 Conclusion

When looking to the final concept and the project goals, some conclusions could be drawn regarding the result. These are presented below.

- Adjusting the seat belt anchorage outwards should be enough to solve the existing problems with today’s, static seat belt.
- The adjustment procedure should be made easy and intuitive for the driver to use it, and one way of doing so is to, as in the final concept, place the controls directly onto the actual adjustment mechanisms.
- The next step in the product development process should be to look into collision loads and verify that the concept can withstand these (or break in a controlled and desired manner).
- The adjustment ranges cover the anthropometric ranges of Scaniafamiljen, except for the sitting height. However, the shape of the headrest is believed to make up for this fact by offering support anyway.
14 References


Fragoso, P. 2015. Anthropometry overview, internal document, Scania


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**Software:**
Excel 2013 Microsoft Office

CATIA V5, Dassault Systèmes 2017

RAMSIS Industrial Vehicles, The Human Solutions Group 2017

Appendix 1 – Mind map

Here, the mind map made to create an overview of the area is presented.
Appendix 2 – Survey

Presented below is the survey that was sent out to different haulage contractors as well as posted online through the Scania Facebook page.

Truck seats

Hi!

We are two students from KTH Royal Institute of Technology, Stockholm Sweden. We are currently doing our Master’s thesis studying the comfort of seats of heavy-duty trucks. By filling this survey out, you would help us in our research very much. The information will only be used internally at Scania and, of course, for our thesis. Thank you!

Kathrine Berg & Elinor Petersson

1. What truck brand do you usually drive?
   Mark only one oval:
   ○ DAF
   ○ Iveco
   ○ MAN
   ○ Mercedes-Benz
   ○ Renault
   ○ Scania
   ○ Volvo
   ○ Other:

2. How many hours are you driving per week? (Approximately)


3. How many hours do you drive at a time (without leaving the driver's seat)?
   Mark only one oval:
   ○ Less than 30 minutes
   ○ 30 minutes - 1 hour
   ○ 1-2 hours
   ○ 2-3 hours
   ○ 3-4 hours
   ○ More than 4 hours

4. How long distances do you usually drive per week? (km)
5. What of the below suits your driving the best?  
Mark only one oval.

☐ Distribution (shorter transports)  
☐ Construction  
☐ Long-haulage (longer transports)  
☐ Other

6. How comfortable do you think your seat is?  
Mark only one oval.


Very uncomfortable  
Very comfortable

7. In what ways do you think the seat is uncomfortable?


8. How often do you use the seat belt?  
Mark only one oval.


Never  
Always

9. Do you use the seat belt in the way you’re supposed to?  
Mark only one oval.


Never  
Always

10. Explain how you use it (when you are not using the seat belt in the way you’re supposed to)


https://docs.google.com/forms/d/18s9v9Wc61fG2Jy26dRmIk5AeS9Ov+QvQ8jx7C/le/7dFmLa7H4oledit 2/5
11. How comfortable do you think the seat belt is?
   Mark only one oval.

   1  2  3  4  5  6
   Very uncomfortable  ○ ○ ○ ○ ○ ○  Very comfortable

12. How many adjustments does your seat have?
   Mark only one oval.

   1  2  3  4  5  6
   Almost none  ○ ○ ○ ○ ○ ○  All available

13. How frequently do you adjust your truck seat?
   Mark only one oval.

   ○ At least 3 times a day
   ○ 1-2 times a day
   ○ When I enter a new truck
   ○ 1-4 times a week
   ○ Never
   ○ Other: ______________________

14. Does your seat have any adjustability for the upper back/head rest?
   Mark only one oval.

   ○ Yes
   ○ No
   ○ Don’t know

15. How frequently do you use the adjustment for the upper back/head rest?
   Mark only one oval.

   1  2  3  4  5  6
   Never  ○ ○ ○ ○ ○ ○  Always

16. Can you adjust the seat in the ways you want to? If no, please describe.

   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
17. Do you usually drive the same truck?  
Mark only one oval.  
☐ Yes  
☐ No  
☐ Most often  
☐ Don't know  

18. Do you see any specific improvement areas when it comes to the seat? (Explain)  


19. Gender  
Mark only one oval.  
☐ Female  
☐ Male  
☐ Other  

20. Age  
Mark only one oval.  
☐ 18-30  
☐ 31-40  
☐ 41-50  
☐ 51-60  
☐ Over 60  

21. How long have you been working as a truck driver? (years)  


22. Nationality  


23. **Height**  
*Mark only one oval.*  
- [ ] Shorter than 150 cm  
- [ ] 151-160 cm  
- [ ] 161-170 cm  
- [ ] 171-180 cm  
- [ ] 181-190 cm  
- [ ] 191-200 cm  
- [ ] 201 cm or taller

24. **Weight**  
*Mark only one oval.*  
- [ ] Less than 50 kg  
- [ ] 51-60 kg  
- [ ] 61-70 kg  
- [ ] 71-80 kg  
- [ ] 81-90 kg  
- [ ] 91-100 kg  
- [ ] 101-110 kg  
- [ ] 111-120 kg  
- [ ] 121-130 kg  
- [ ] More than 130 kg

25. **Is the seat the orginal seat? (The one that came with the truck)**  
*Mark only one oval.*  
- [ ] Yes  
- [ ] No  
- [ ] Don't know

26. **What type of seat are you sitting in?**  
*Mark only one oval.*  
- [ ] Isringhausen  
- [ ] Recaro  
- [ ] Grammer  
- [ ] Don't know

---

https://docs.google.com/forms/d/182x9WveiHGZjd6dDPkX5A350vTiQVXCLuLCLdFmLa7Hr4olw/edit
Appendix 3 – Interview guide

This interview guide was used as the basis for the interviews with truck drivers. However, all interviews were held in an unstructured manner.

Kontextuella intervjuer
Intervjuerna hålls i lastbilen då föraren sitter i stolen. Intervjuerna ska hållas ostrukturerade, men följande områden bör täckas in.
Börja med att säga att vi arbetar med att undersöka komfortförbättring av stolen, och vill se hur förarens arbetsdag ser ut. Hur det är att åka distributionslastbil/long haulage-lastbil
Börja med att observera utan att berätta detaljer!

Inledande frågor:
Ålder?
Hur länge har du varit lastbilschaufför?
Hur lång är du?
Fråga/se efter vilken stolstyp som sitter i lastbilen
Fråga om hyttyp(?)
Kolla passagerar stolen
Fråga om hur han tycker stolen är (komfort)
Sitter du bra?

Titta på följande:
Hur föraren tar på bältet
Hur sitter föraren i stolen. I början och sen efter lång tid.
Om han använder det hela tiden, även korta sträckor
Hur han sitter med huvudet mot nackstödet
Hur många gånger har är tvungen att gå ut och in
Hur bältet sitter på föraren? (Ser det ut att skava? Sätter föraren ev. krage på jackan mellan bälte och hals?) Har han mycket kläder på?
Använder föraren ev. knäck-funktion i ryggstödet?
Sträcker han sig mycket runt i hytten?
Rättar har ofta till bältet?
Hur är nackstödet inställt?

Frågor efter att nödvändig data samlats in på punkterna ovan:
Tycker föraren att säkerhetsbältet sitter bra?
Tycker du att du kan ställa in stolen på de sätt du vill?
Är det några områden på stolen som du tycker kan förbättras?
Appendix 4 – QFD

The Quality Function Deployment matrices (QFD:s), based on the requirement specification, are presented below; one for the seat belt anchorage and one for the headrest.

### Seat Belt Anchorage QFD

<table>
<thead>
<tr>
<th>Enheter</th>
<th>Y/N</th>
<th>Y/N</th>
<th>Y/N</th>
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<td>5</td>
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<td>3</td>
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### Headrest QFD

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<th>Y/N</th>
<th>Y/N</th>
<th>Y/N</th>
<th>Y/N</th>
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<tr>
<td>2</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
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</tr>
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### Competitors

<table>
<thead>
<tr>
<th>Konkurrenter</th>
<th>Recaro</th>
<th>Isri Lyx</th>
<th>Grammer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Y Y Y Y - Y Y N</td>
<td>0 Y Y N - Y Y N</td>
<td>0 Y Y Y - Y Y N</td>
</tr>
</tbody>
</table>

### Goals

| Målvärdens | 70 Y Y Y Y Y Y Y |

Datum: 6 mars 2017
Produkt: Headrest

<table>
<thead>
<tr>
<th>Kundviktning</th>
<th>Produkt-egenskaper</th>
<th>Nuvärde</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scania</td>
<td></td>
<td>a: Kinnarps</td>
</tr>
<tr>
<td>Driver</td>
<td></td>
<td>b: Recaro/Isri</td>
</tr>
<tr>
<td>Kund-önskemål</td>
<td></td>
<td>c: Malmstolen</td>
</tr>
</tbody>
</table>

<table>
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Kundviktning:

Scania
- Easy to adjust
- Provide good sight
- Adjust from sitting
- Support neck when driving
- Comfortable
- Intuitive control
- Encourage posture change

Driver
- Fit population
- Adjustable in height
- Adjustable without seeing
- Adjustable in depth
- Adjustable in width
- Possible to tilt
- Controls on or in front of seat

Kund-önskemål:

- Drivers
- Adjustable in height
- Adjustable without seeing
- Adjustable in depth
- Adjustable in width
- Possible to tilt
- Controls on or in front of seat

Nuvärde:

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<th>c</th>
<th>d</th>
<th>e</th>
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<td>1</td>
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Konkurrenter:

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<td>Kinnarps</td>
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<tr>
<td>Recaro/Isri</td>
<td>N Y Y N Y Y N N</td>
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<tr>
<td>Malmstolen</td>
<td>Y Y Y Y Y Y N Y</td>
</tr>
<tr>
<td>Målvärden</td>
<td>200 Y Y Y Y Y Y Y Y</td>
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Datum: 6 mars 2017
Appendix 5 – Function-means trees

The function-means trees created for the seat belt anchorage as well as the headrest are presented below.
### Appendix 6 – SWOT analysis

**Link Lux**

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
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<tbody>
<tr>
<td>- Possible to adjust independently</td>
<td>- Incoherent?</td>
</tr>
<tr>
<td>- High adjustability range</td>
<td>- Seat belt anchorage only adjustable between two positions</td>
</tr>
<tr>
<td>- Easy to implement</td>
<td>- More complicated mechanism for securing the headrest</td>
</tr>
<tr>
<td>- Proven headrest adjustment feature</td>
<td></td>
</tr>
<tr>
<td>- Simple link bar mechanism for seat belt anchorage</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Threats</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Can work for many seat designs</td>
<td>- Similarity to Kinnarps (patents?)</td>
</tr>
<tr>
<td></td>
<td>- Cannot be adjusted enough</td>
</tr>
</tbody>
</table>

**Hoop**

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Possible to adjust independently</td>
<td>- Need to redesign the backrest</td>
</tr>
<tr>
<td>- Possible to adjust further sideways</td>
<td>- Cannot adjust headrest in depth</td>
</tr>
<tr>
<td>- Intuitive controls</td>
<td>- Cannot adjust seat belt anchorage in height</td>
</tr>
<tr>
<td>- Slim design</td>
<td></td>
</tr>
<tr>
<td>- Separated adjustment and slot</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Threats</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Opportunity to add adjustment in height for seat belt anchorage</td>
<td>- Look fragile</td>
</tr>
<tr>
<td>- Opportunity to add adjustment in depth for headrest</td>
<td>- Cannot be adjusted enough</td>
</tr>
</tbody>
</table>

**Impl ease**

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Easy to implement</td>
<td>- Limited amount of slots</td>
</tr>
<tr>
<td>- Cheap</td>
<td>- Headrest not adjustable in depth</td>
</tr>
<tr>
<td>- Easy to adjust headrest</td>
<td>- Headrest depth fixed</td>
</tr>
<tr>
<td></td>
<td>- Have to to turn around and use both hands to adjust</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Threats</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Can place belt in B-pillar</td>
<td>- Drivers might not use the function if it is too complicated</td>
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</table>
Appendix 7 – Decision matrix

Pugh’s decision matrix
The current Recaro seat was used as reference.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Reference</th>
<th>Link Lux</th>
<th>Hoop</th>
<th>Impleasy</th>
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</thead>
<tbody>
<tr>
<td>Options of adjustability</td>
<td>o +</td>
<td>+</td>
<td>s</td>
<td></td>
</tr>
<tr>
<td>Low cost</td>
<td>o -</td>
<td>s</td>
<td>+</td>
<td></td>
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<tr>
<td>Easy to implement</td>
<td>o -</td>
<td>-</td>
<td>+</td>
<td></td>
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<tr>
<td>Driver acceptance</td>
<td>o +</td>
<td>s</td>
<td>-</td>
<td></td>
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<tr>
<td>Easy to adjust</td>
<td>o s</td>
<td>s</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Adjustable with one hand</td>
<td>o s</td>
<td>s</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Range of population covered</td>
<td>o +</td>
<td>+</td>
<td>s</td>
<td></td>
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<tr>
<td>Intuitive controls</td>
<td>o +</td>
<td>+</td>
<td>s</td>
<td></td>
</tr>
<tr>
<td>Easy to understand</td>
<td>o -</td>
<td>s</td>
<td>+</td>
<td></td>
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<tr>
<td>Support</td>
<td>o +</td>
<td>+</td>
<td>s</td>
<td></td>
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<tr>
<td>Provide good sight</td>
<td>o +</td>
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sum + 6 4 2
Sum - 2 1 4
Sum s 3 6 5

Weighted decision matrix

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<td>Easy to adjust</td>
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<td>Range of population covered</td>
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<td>Intuitive controls</td>
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