Sun glare solution for trucks

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KTH Industriell teknik och management

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Master thesis at Scania CV AB

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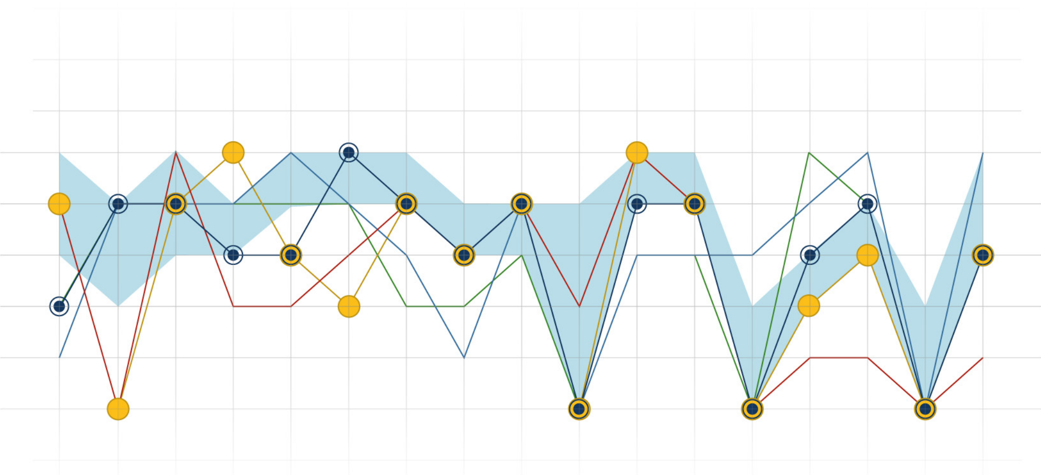

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Sammanfattning

Examensarbetet är utfört i samarbete med Scania CV AB och är en del av masterutbildningen Teknisk Design på Kungliga Tekniska Högskolan, Stockholm, under 2014. Arbetet har fokus på de interiöra solskydden i Scanias lastbilar.
Målet med examensarbetet var dels att kartlägga när, var och på vilket sätt solbländning är ett problem för lastbilschaufförer, dels att ta fram ett koncept som utgår från detta arbete.

Scania är en välkänd lastbilstillverkare som profilerar sig med hög kvalitet. Fordonen anses tillhöra toppskiktet av lastbilar vad gäller tillförlitlighet och förarmiljö. De solskydd som är monterade i Scaniahytterna idag är traditionella, liknande de som återfinns i personbilar. Intervjuer och observationer av förare visade på stora svårigheter att nå passagerarskyddet från förarplatsen; många tvingas lätta från sin stol för att nå och detta påverkar trafiksäkerheten.

Projektet gjorde initialt en kartläggning över var forskningen står i fråga om metoder för att mäta bländning och om detta kan appliceras på arbetet inom Scania. Slutsatsen är att man i stort inte skulle gynnas av att anamma denna typ av metoder. Uppmätningar av lastbilar och konkurrenters fordon gjordes för att förtydliga dagens läge med avseende på solskydd och samtidigt utveckla ett förslag till metod som skulle kunna användas långsiktigt.

Utifrån insamlad kunskap utvecklades konceptinriktningar som testades mot förare i form av prototyper. Två koncept jämfördes i ett slutligt användartest i en lastbilshytt.

Det slutgiltiga konceptet består av ett förarsolskydd samt ett passagerarsolskydd, precis som tidigare, men med den stora skillnaden att dessa kan sammankopplas. Föraren behöver inte utsätta sig och andra för risker, utan kan enkelt koppla ihop de två och fälla ner. Det finns ett på/av-läge i förarskyddet vilket gör att det är valfritt när de ska vara ihopkopplade eller inte. Passagerarskyddet styrs med förarskyddet och kan därför låsas i flera olika lägen för att skydda mot bländning. Inuti båda solskydden finns en förlängande del som kan dras ned med hjälp av ett handtag. Det är också ställbart i olika höjder.

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2014-09-11	Carl Michael Johannesson	Carl Michael Johannesson
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Abstract

This Master of Science thesis work is written in Stockholm 2014 in collaboration with Scania CV AB and as a part of the Technical Design Master education at Royal Institute of Technology. The project focuses on interior sun visors in Scania trucks.

The objective of the thesis work was divided into two parts; to map when, how and in what way sun glare becomes a problem to truck drivers and also develop a concept that solves those problems.

Scania is a well-known manufacturer of trucks and has a profile that stands for high quality. The trucks produced by Scania are considered to be among the best regarding reliability and driver environment. Today, the sun visors that are mounted in Scania cabs are traditional and similar to the ones in cars. A result from interviews with, and observations of, drivers showed that there are difficulties when it comes to activating the passenger visor. To be able to reach the visor on the passenger's side, many drivers are forced to stand up from the seat, something that jeopardises traffic safety.

Initially, a mapping of research reports that have been made about sun glare measuring methods was made. The question was whether the work at Scania would benefit from these methods or not. The conclusion is that, in large context, this probably would not be the case. Measurements of trucks and competitor vehicles were made in order to clarify and map the different sun glare solutions that exist today. This was also a way to develop a suggestion for future measuring methods.

From the knowledge gathered, several concepts of various kinds were developed. Selected concepts were prototyped and evaluated by drivers. Finally two concepts were mounted in an actual cab and compared by users. This led to the final concept choice.

The final concept consists of a parted sun visor, as before, but with the difference that these parts can be coupled. The driver no longer needs to endanger him/herself and others when activating the sun visor, since they can easily be connected and folded down. There is an on/off mode at the driver's visor that allows the driver to decide whether the visors should be attached or not. Inside both visors is an extended part that can be pulled down and placed in different positions to fully cover the driver vertically.

FOREWORD

First of all we would like to thank our excellent supervisor Elin Tybring at Scania for all her support and advice while writing this thesis. And a big thanks to everybody at RCDE for making our stay so very informative and pleasant.

We would like to thank Carl-Michael Johannesson, our supervisor at KTH for helping us up the final steps of our studies.

Scania employees Olov Karlsson and Karolina Stoltz Länta for showing us around the cab and explaining the sun visors and windshield.

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Maria Isaksson for letting us borrow her as a human measuring device and source of input.

Anders Karlsson, the firefighter that taught us how to drive trucks and buses.

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We also would like to thank all the employees at RCDS for unknowingly brightening our days at our desk at Scania.

Final thanks to Anna Svensson and Per Larsson for donating a component that enabled the construction of our final prototype.

Thank you!

Caroline Egstam & Alexander Möllerstedt

Stockholm, September 11, 2014

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1 Introduction

The introduction presents the background of the thesis and also describes the purpose and goals of this project. The delimitations that were made in this master thesis work and the overall process will be explained.

1.1 Background

This project is a master thesis work at the Royal Institute of Technology (KTH), Stockholm. It concludes the engineering programme Design and Product Development and master Industrial Design Engineering. The project is performed at truck manufacturer Scania located in Södertälje, Sweden. More specifically it is attached to the group RCDE responsible for physical vehicle ergonomics in the product development at Scania. The subject is glare and sun visors. Timeframe for the project is March to August 2014.

1.1.1 Visual ergonomics

The following definition of visual ergonomics has been approved by the International Ergonomics Association's Technical Committee for Visual Ergonomics (Toomingas, 2014):

> *"Visual ergonomics is the multidisciplinary science concerned with understanding humanvisual processes and the interactions between humans and other elements of a system. Visual ergonomics applies theories, knowledge and methods to the design and assessment of systems, optimising human well-being and overall system performance. Relevant topics include, among others: the visual environment, such as lighting; visually demanding work and other tasks; visual function and performance; visual comfort and safety; optical corrections and other assistive tools."*

Sufficient and consistent vision is one of the most important features to any road-based vehicle. It also has a great impact on ensuring a perceived sense of safety while manoeuvring. Glare is considered among the strongest factors influencing a person's ability to properly see (Nazzal, 2005). The phenomenon can be caused by the Sun, artificial lights, reflections caused by either of these sources or a combination thereof.

Both physical and psychological aspects affect the comfort of the driver. For the driver to experience a safe working environment, clear vision of the road and its surrounding is necessary. Insufficient vision can manifest itself in the driver, both physically and psychologically. Factors such as heart rate (rising) and skin temperature (falling) undergo a documented change as drivers are exposed to glare. The graph in Figure 1 by researchers Gao and Pei demonstrate the effect of glare on drivers' heart rate. (Gao & Pei, 2009).

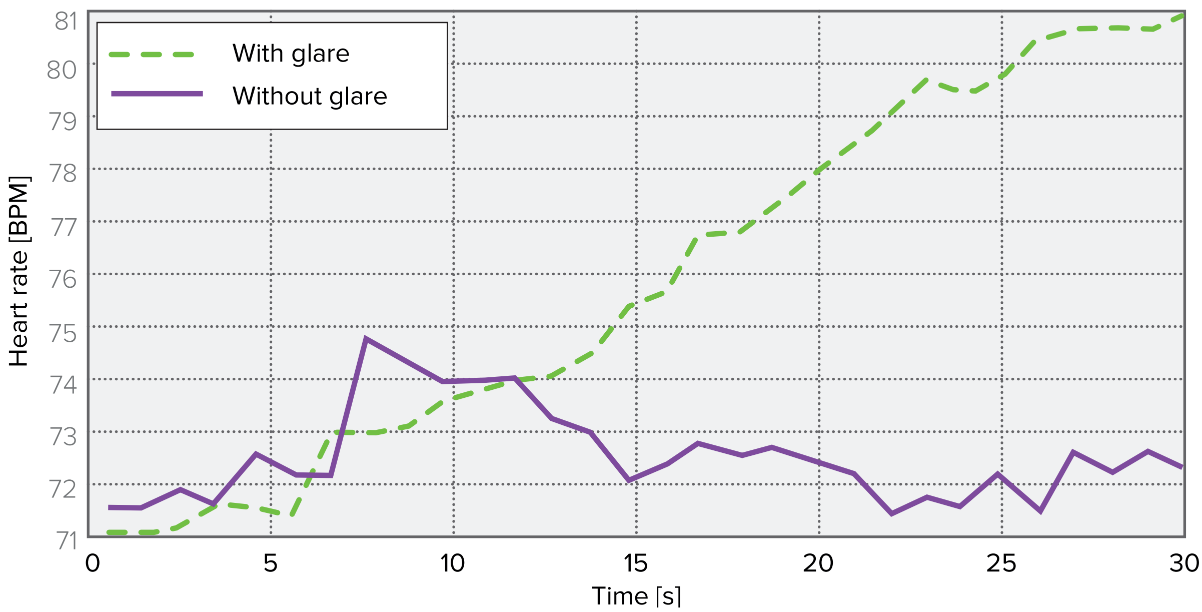

Figure 1 Heart rate as a function of time. Illustration adapted for display reasons, original by Gao & Pei, 2009.

Apart from directly affecting drivers in various physiological ways, driving under insufficient lighting conditions can prove hazardous and even deadly. Every year, many accidents occur as a result of glare.

1.1.2 Visual ergonomics in trucks

Existing trucks all use relatively similar solutions to prevent glare from disturbing the driver's sense of vision. Retractable blinds are commonly used on the sides, and in some cases in front of the driver. Hinged shades commonly seen in cars are similarly used in trucks, both in the front windshield and doors. In addition to these types of solutions, visors are sometimes mounted on the outside and thereby blocking some sunlight from affecting the driver. Regular curtains are used to darken the cab at night, thereby achieving a black out. All of the above mentioned methods have been used in trucks for a long time, with little or no progress made regarding actual functionality.

To solve the problem with sun glare always means a balance between a wide field of view and adequate protection. In addition to this come external factors such as cab design, mirror placement and driver position that in different ways affect the solution.

In general, sun visors and blinds are considered a non-prestigious part of a truck. Other factors matter when choosing a vehicle. Visors are also not used on a daily basis, which further lowers the estimated need for them. When the time comes to actually use them, they can mean the difference between being able to continue driving or not.

Hillevi Hemphälä states in her PhD thesis that visual ergonomics is an interdisciplinary discipline that demands a holistic view (Hemphälä, 2014). This statement strongly highlights the challenge of countering glare in the cab environment of a truck. A truly functional solution requires the labour of many stakeholders. Great visual environments have beneficial impacts on people's health and perception of their work in general. This conclusion is supported by other research studying how drivers are affected by one of the major major influences on the insufficient visual environment – glare.

1.2 Problem definition

Scania's solution to the sun glare problem, in shape of sun visors, does not provide an edge compared to the competition. There is a need to map and clarify the issue of sun glare for truck drivers in order to provide a foundation for further improvement. The need covers when, how and in what way glare becomes a problem, and also when sun visors are insufficient or even an issue.

1.3 Purpose

The purpose of this project is to examine driver's needs with respect to glare caused by sunlight. Knowledge should be gathered, both through studies and existing research, to support further work in this field. This serves to fulfil a long-term purpose of collecting knowledge that in the end improves and assists future development. The compilation of this material will aid RCDE in its work preventing sun glare, both by introducing methods and data, and also by supplying the group with arguments to why this should be a prioritised issue. A short term purpose focuses on evaluating the state of current products. This serves to both learn the state of things, and also to develop methods of collecting such data. Finally, using gathered material, a concept will be proposed with the intent of challenging the way in which Scania solves the glare issue. This concept will provide a forum to further illustrate the findings of earlier parts of the project.

1.4 Goals

A short list of what is to be accomplished; summarising previous sub-chapters in a bullet list format.

- Gather comprehensive material on light and its relation to drivers.
- Collect insights from users and other stakeholders concerning the issue of glare.
- Benchmark current solutions to the problem with glare.
- Map solutions that are currently not being used in trucks.
- Develop a concept that uses and illustrates gathered knowledge.
- Prototype concept and evaluate with users.

1.5 Delimitations

This is the main list of delimitations that were made. Some were set early in the project while others were implemented as development had begun. Therefore, not all branches of the work comply with this total set of entries. Additional lists of delimitations have been added to further define the direction of specific areas of the project.

- The main focus of this report is to eliminate sun glare for the *driver*. A passenger-oriented solution might also be provided, but the driver is the main ambition.
- The character basis throughout the project is a set of body types explained in *2.5 Anthropometry*, representing drivers of different height. Development will strive

to enable full functionality for a person of shortest possible stature, regardless if it succeeds or not.

- Focus on windshield and side windows. The roof window will not be discussed since early interviews with drivers rejected it as an issue of very little interest.
- The benchmarking is concentrated to flagship trucks of other brands that correspond to Scania Topline. These trucks are manufactured by competitors Mercedes-Benz, Volvo, DAF. *2.3.2 Competitors* provides more detailed information.
- The project will not focus on glare from oncoming traffic. Research shows that glare from traffic does not affect drivers' physiology such as reaction time and pulse (Ranney, et al., 1999). Nighttime driving is an exception comparable to regular cars. Interviews with drivers classified it as a non-issue.
- The solution should be possible to implement within five years from today. This is decided upon to match the "face lift" of trucks that are made every third-fifth year. The solution should therefore be a possible part of such a release. This also secures a clear separation of a long term and short term perspective.
- The solution should be based on existing technology although it could be inspired by other industries or segments. This limitation is set to match the presumed implementation time above.
- Geographically, a set of locations is chosen to represent important markets, described in *3.1.1 Sun elevation.*
- A maximum road inclination of 6 % (3.43 degrees) will be set to account for inevitable topography. This angle does not represent a worst case scenario, but rather a maximum normal case scenario. 6 % is the maximum inclination of most roads in Sweden.
- The new solution should be constructed to fit the existing cabs without any changes of the existing cab measurements, such as a-pillars etc. Minor adjustments to roof shelf and similar would be accepted as a natural part of a different solution.
- The solution will not be exposed to vibration and crash tests of 3G, 40G respectively. Engineer's requirements included as part of QFD.
- The project will result in a mock-up of a new solution. Extent and purpose of this is further defined in later chapters.
- The solution will not rely on electronics. This is due to difficulties in estimating requirements of electronic devices: where it should be placed and what other internal components would have to be moved. Keeping close to the user centered work of RCDE is prioritised.
- Manufacturing is only considered a small part of the project. Regular guidelines regarding DFM and DFA would be applied to some extent in a final prototype. The project assumes that Scania can use the same manufacturing methods as with already existing current or similar solutions.

1.5.1 Delimitations of prototype

Following the previous delimitations set upon the project, further details were added with regard to the prototype:

- The prototype will act to improve performance in windshield only. Performance in driver's door is considered acceptable in the examined trucks. Passenger door remains an issue. Regulations state that the mirrors on this side of the cabin must not be covered. Such regulations means that, in reality, a solution based on electronics is necessary; this is in turn ruled out by previous delimitations.
- The prototype will be based on currently used sun visors. This decision was made to keep the development close to the current solution, therefore supporting comparisons and discussion.
- The solution will not be a pull-down blind, something that is applied in a number of competitor trucks. Instead, the solution should aim to perform as good as blinds in areas where they prevail, while at the same time retaining the benefits of using sun visors. As with a solution using smart glass, roller blinds are a somewhat of a readily available fix.
- The Scania trucks have a rail that carries a curtain used for closing the cab off during nights. This rail is not to be touched or moved.

1.6 Process

In order to organise the project work in an effective way, the book *Agil projektledning* served as inspiration. Work is divided into sprints of two weeks each. Prior to each sprint a planning session takes place to further define the general outline. At the end of each sprint there is a delivery and reflection over the past weeks. This keeps the work moving forward and secures a continuously improving process (Gustavsson, 2011).

The project was divided into two main phases: the first one focuses on gathering of knowledge and should result in data mapping of the Sun, documentation of driver's needs, and benchmarking. It will also formulate a foundation for upcoming work. Following the spirit of agile product development, the work of phase one is seen not just as steps on the road to the next, but as a set of stand-alone deliverables. Knowledge gathering is therefore not just the compulsory "research" that is required of every project; it should be viewed as something both part of the final outcome, and at the same time constituting a product of its own. The process is illustrated in Figure 2. A-C are deliverable outputs while D represents the final outcome.

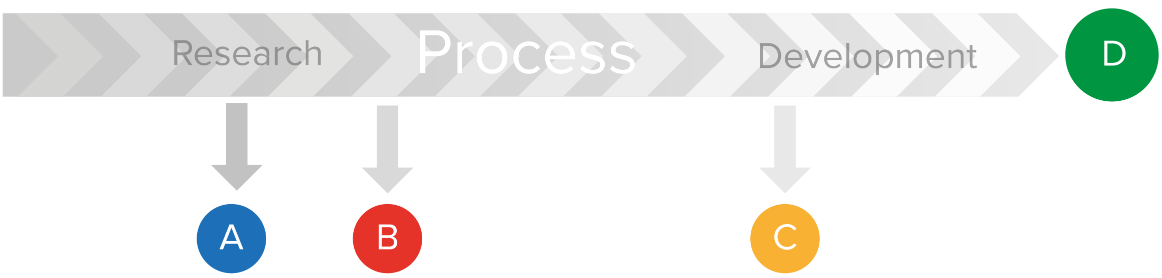

Figure 2 Process breakdown where the work is divided into Research and Development.

Phase two is in every aspect based on its predecessor. This is where product development makes use of previously gathered knowledge and continuously improves and builds more of it. The process becomes more iterative and the need for an agile mindset increases. Methods described in Service Design Thinking (Stickdorn & Schneider, 2011) and Bootcamp Bootleg (Plattner, 2010) will act as driving forces. These are further described in *3 Method.*

Halfway through the project a presentation is scheduled at Scania. At this presentation, the work so far was presented to the employees of RCDE. Final presentations will be held both at Scania and at KTH.

2 THEORETICAL FRAMEWORK

The theoretical framework will cover the areas light, visual ergonomics, trucks, regulations, anthropometry and future technologies. Some of the covered topics will not be used as basis for the development of a final prototype, but the collection and analysis of them will play an important role in the material delivered. Sections such as the one describing the measuring of light are therefore more extensive than had they been written with the sole purpose of supporting a final concept.

2.1 Light and Sun terminology

When it comes to light and the direction of the Sun, a lot of terms can appear confusingly similar. This part of chapter two will clarify these terms in order to avoid confusion later on.

2.1.1 Illuminance vs. Luminance

These two terms are often mistakenly confused. Illuminance is a measure of the incoming light. Luminance on the other hand describes how much light is reflected from the surface of an object. In essence, it describes our perception of how bright objects are. The former will be most commonly used in this report.

2.1.2 Azimuth and Elevation

Azimuth specifies the direction in which you would find the Sun as seen on a compass. The vector from the user to the Sun is projected on a reference plane established by the horizon. A base vector pointing north usually defines zero degrees.

Elevation in turn describes the altitude of the Sun. This is defined as the angle between the horizontal plane and the centre of the Sun in relation to the user. They are both illustrated in Figure 3.

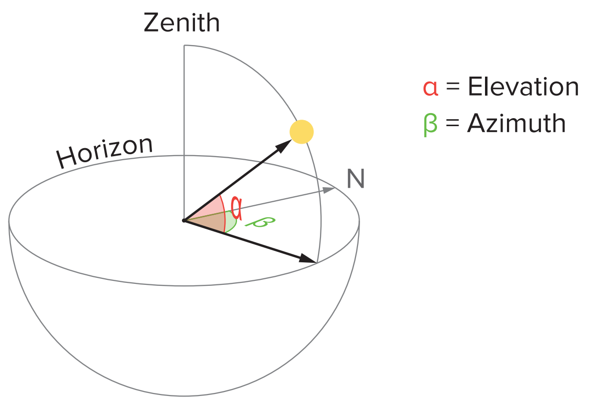

Figure 3 Illustration explaining elevation and azimuth.

2.2 Light

The following sub-chapters touches upon many areas that were not used in the final concept. This knowledge is rather a short documentation of relevant research, presented as a standalone delivery. Connecting with later predictions of future use of smart glass, many of the studied articles will hopefully be able to serve as a springboard to keep Scania in front of its competitors. For example, observing the development that is happening in the area of smart glass, means of evaluating glare through materials of varying light transmittance will soon be a necessity.

Light is a very complex but well studied phenomena. A wide variety of fields are concerned with the behaviour of light in relation to human perception. Interpretation of light is directly linked to the complexity of the mind and human brain. Despite being studied by so many areas of science, light is still not perfectly understood. The way in which light interacts with other objects of the physical world is relatively known; this is however not the subject of this project. It is rather in the relation to the human user that difficulties arise. Since perception of light is very much a subjective experience, subjective means of measurement are a necessary component. Many researchers have tried to develop standardised and trustworthy ways to gather data from users' experiences. These are in short described in the following chapter. Despite a lot of effort being invested in trying to mathematically describe glare, it is often described as a highly subjective phenomena that requires user participation and subjective evaluation (Velds, 2002).

2.2.1 Sun glare

Sun glare, or the perception of it, is the result of high contrasting light in the visual field. The effect is very dependent on external factors such as ambient light as well as size and number of glare sources.

Glare is also subjective and can be divided into two types: disability and discomfort glare (Nylén, 2012). *Discomfort glare* is something that happens more often than people would recognise. Again, everything is subjective, but a common example would be sunlight reflecting off snow or some other reflective surface. It is not comfortable, but you would still be able to clearly see and distinguish objects in the surrounding environment. The zone between comfort and discomfort is known as the *Borderline between Comfort and Discomfort* (BCD).

An example of using BCD is found in the research by Wonwoo Kim and Jeong Tai Kim. As it turns out, test subjects are more susceptible to glare in the upper visual field, especiallt frontwise and above the view direction. A much larger sensitivity could be measured to the immediate left and right. In general, the lower visual field is also more sensitive to glare than the upper. A graph describing this is presented in Figure 4. Darker areas represent angles that drivers experience as highly sensitive. Test subjects were placed at the center 0, facing "into the paper". A light source moved from the outside towards the centre until test subjects stopped its movement and marking the BCD (Kim & Kim, 2010).

The BCD metric is commonly accepted and could be used in future work to assess glare instances.

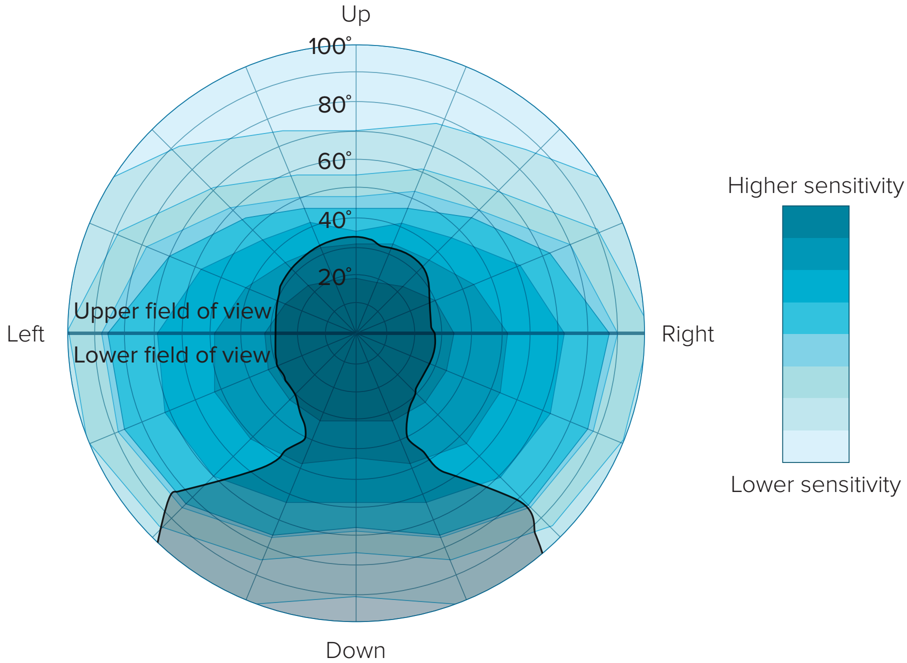

Figure 4 Chart of glare sensation over the visual field. The areas marks the lines at which a certain light source going from the periphery and inwards reaches the borderline between comfort and discomfort (BCD). Figure adapted from (Kim & Kim, 2010).

Disability glare would occur when you are driving and the Sun is set at such a low angle that you hardly see the road, you are forced to activate the sun visor and lower the speed in order to continue. This type of glare is more clearly defined and studied. What happens is that light is scattering in the eye and as a result laying a luminous veil over the retina. The effect of this is lowered contrasts in the retinal image and a disability to distinguish objects (Nylén, 2012). Older people suffer from this effect at lower amounts of scattering. This is because their eyes are already working with a reduced ability to perceive contrasts. The difference between discomfort and disability is more or less a matter of measurement and the BCD is also highly subjective.

2.2.2 Measuring light

As part of the examination of drivers' visual comfort, methods of predicting glare were evaluated with the intention of applying them to a truck environment. This section is part of the knowledge-based delivery of the project.

The foundation and framework for all research on glare in relation to driving was created by Holladay and Stiles during the late 1920's. At this time, terms such as disability glare were for the first time coined and explored (Mace, et al., 2001). A lot of research has since then been made – primarily though to improve visual conditions at office workspaces.

In measuring light, and describing the effect of light on a subject, context and surrounding environment is a key factor. Tolerance to glare or strong light is for example greatly increased when sitting in a brightly lit room (Nazzal, 2001). This tolerance has also been shown to vary depending on factors such as ethnicity where Asian subjects are more tolerant to glare than Caucasians (Kim & Lee, 2007). A strong correlation to age has also been established, although this is not as unexpected as previous revelations (Theeuwes, et al., 2002).

Furthermore, the scenery or view affects the discomfort experienced by test subjects. A nice view basically raises the amount of strong light that is tolerated, compared to a dull or blank view (Osterhaus, 2005). Both the variable of a brightly or dimly lit room and the effect of scenery to glare perception would have major impact on a driver. The driver is assumed to be constantly on the move. Both the scenery and the contrasts between the illuminated outside and the inside of the truck would always be changing.

A distinction is often made between horizontal and vertical light when measuring. Horizontal light measures the light landing on a horizontal surface. This type of measurement is often of key interest when evaluating an office environment or any situation that resembles reading from a flat book. Since most of the research concerning light conditions is applied to office environments, it follows that the measurements used are mostly horizontal and simulate someone reading or writing on a flat desk. Vertical lighting on the other hand is measured using a vertical surface and is the most commonly used method for evaluating glare in traffic situations. This type of measurement is at the same time used more often when working with office environments due to computers becoming the primary tool. This development would make it easier to translate methods used to measure office conditions to cars or trucks.

There are a number of methods for evaluating glare. A majority of these focus on artificial light sources. Very few methods attempt to describe light from normal daylight conditions or sources that are considered large. The first and foremost reason for this is the difficulties in reproducing results based on the daily weather conditions. Of all the methods that exist, none are free from criticism or flaws that make them more or less restricted to certain conditions. These restrictions are often related to daylight or large sources. Also, no international standard for implementing and monitoring glare has yet been developed (Nazzal, 2001). This means that every method uses its own set of standard regarding distance to light source, ambient temperature and so on.

A few of the methods used to measure glare are listed in Table 1.

Table 1 Different methods of measuring glare.

VCP	Visual Comfort Probability
UGR	Unified Glare Rating
DGI	Cornell equation/Daylight Glare Index
BRS/BGI	BRS Glare Index
DGP	Daylight Glare Probability
CGI	CIE Glare Index

Quite a few of the existing methods are modelled on earlier ones or at least developed with respect to known shortcomings. There is also a significant time span encompassing the methods. For example one of the oldest, VCP, was introduced in 1966 as opposed to DGP that was first used in 2006. Seeing as DGP is the most contemporary model, no studies other than the authors' own were found that properly evaluated it. Their article also provided a short but comprehensive guide to the most common rating indices (Wienold & Christoffersen, 2006). According to the authors, DGP provides a strong correlation between the prediction model and users' perception of glare. Comprehensive tests were performed in an office environment using more than 75 subjects and CCD camera-based technology combined with analysis software such as Evalglare. This software evaluates the amount and degree of glare based on pictures taken with at camera.

Other studies have proven Evalglare to be a reliable prediction tool but at the same time encouraging further development of the glare metrics such as DGP (Suk & Schiler, 2013). Once again, the intended purpose of this and similar software is to improve the environment in office spaces. The setup is in many ways similar to a driver's environment, but the differences are at the same time striking. It is at the same time quite a complex and rigorous way of measuring glare. To be useful it would probably have to be simplified further. An example of DGP in use is pictured in Figure 5.

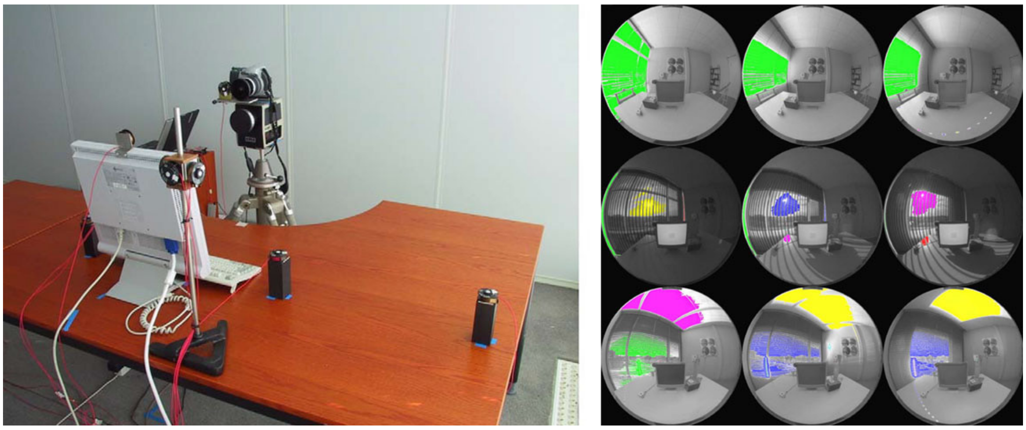

Figure 5 The setup by researches developing DGP and evaluating with Evalglare software. Right picture shows input images and highlighted areas. Pictures used with authorization from authors (Wienold & Christoffersen, 2006).

Other indices such as BRS and CIE have been evaluated by researchers and deemed incapable of producing reliable results, especially in situations where the glare source is considered large (Kimura & Iwata, 1990-1991). These findings are supported by further research concluding that applied lighting design still relies on personal judgment and creativity, not on scientific method (Osterhaus, 2005). Both UGR and VCP have been rejected as valid methods when measuring daylight (Nazzal, 2005, p. 296).

Further difficulties arise when translating these methods developed for office environments to vehicles. A truck environment is constructed in such a way that it resembles something in between an office and an outdoor environment. Traditional office tasks do not require the subject to stare out through a nearby window, but rather at a desk or a screen placed inside the room. It is also a lot more dynamic than a window in a building that can be imitated more closely by a set of static lights. This setup is reflected throughout the research focusing on office lighting and differs remarkably from one that would imitate a truck environment..

Knowledge concerning aspects such as glare prediction models could however very well be of future use. It could work also as a means of motivating demands set by visual ergonomics. Ergonomics is an area of expertise that often faces hard data with its own subjective evaluations. Quantifiable knowledge should therefore always be embraced, at least as a means of getting the point through to other departments and groups.

2.2.3 Glare in relation to users

Effect of glare caused by sunlight is a difficult thing to study when not in a completely controlled environment. Performing measurements using the Sun presents a number of difficulties in keeping the tests consistent. Instead using substitute light is an alternative. This method has been tried and tested by several research teams concluding that a broad range of factors affects the perceived discomfort. The discomfort caused by glare is very much dependant on the background illuminance and its relation to the main source of light (Shin, et al., 2010). How the light source is composited and in what way the user is exposed to it has a considerable effect on the outcome. The difference could be for example several small lights as opposed to one large source of light. Light coming from the fringes of the field of view as opposed to being turned on and off in front of the subject.

A valid and lasting method of evaluating glare in relation to users would be optimal. However, the scientific community has still not united around a particular set of rules regarding these measurements (Hopkinson, 1957, p. 309). It is therefore unlikely that a perfect solution will be available in a close future.

Furthermore, the subjective perception of discomfort varies a lot between individuals. This means that statistical data can be difficult to both create and analyse in a useful manner. Focus is therefore directed at user's perceived comfort compared to a base value. A side effect of this is that reproducible data that can be used to compare subjects is not created the way it would if there were actual measurements with instruments. The benefit though, is that this method has proven to be the least of many evils. It is also more likely that a company like Scania would use the, often, easier to implement subjective methods.

2.2.4 Glare in traffic

There is very little research that study glare in relation to trucks. Expanding the applicable search area to cars gives a couple of themes that are more or less examined by researchers. One of these is how the effect of strong light affects the ability to identify contrasting objects. Long term effects of glare on physical properties such as reaction time and problem solving has also been studied. When driving, 90 % of cognitive input is gathered through vision – where light, of course, is a determining aspect (Hagita & Mori, 2013).

Only a small amount of glare can potentially result in pedestrians not being noticed due to impaired contrasts. This is especially true at night. It has been proven that glare, even in small amounts, cause slow traffic and irrational speed fluctuations (Auffray, 2007). Other studies point out that while traffic indeed slows down when subject to glare, it is not nearly enough to prevent potential accidents. Perhaps efforts should be made to warn drivers of glare and create incentives to slow down properly. Also, the problem of glare is not limited to sunrise and sunset; discomfort and substantially reduced contrast sensitivity can occur at elevations as high as 20° (Woodruff, 2004). The link between glare and traffic accidents has been proven in several other studies (Hagita & Mori, 2011) and (Choi & Singh, 2006). As shown in Figure 6 below, accidents involving cars are more frequent when the Sun is in front of or nearly in front of the driver. This is true both for vehicle-to-vehicle, but even more so for vehicle-to-person accidents. Study involving 18,042 accidents.

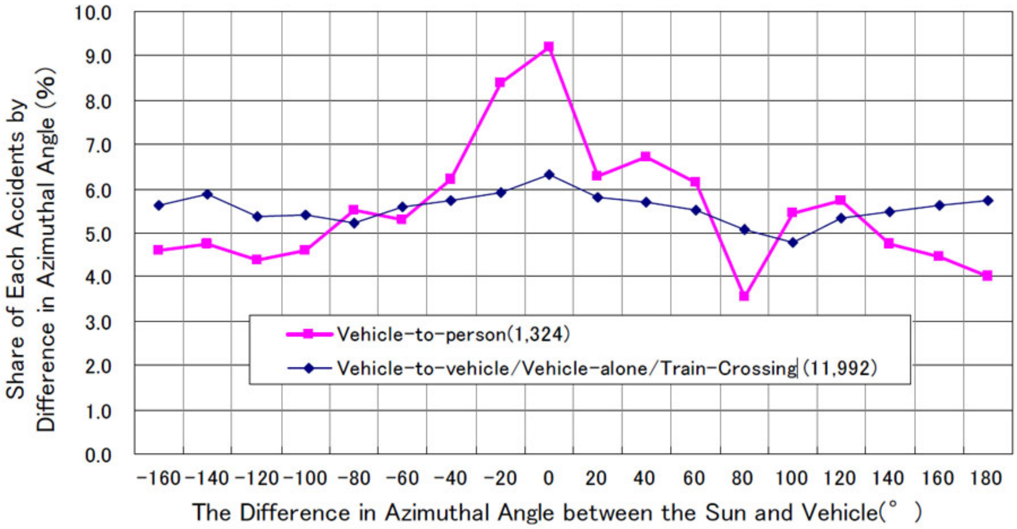

Figure 6 Relation between azimuthal angle of sun from car and accidents in Chiba district, Japan. Graph used with authorization from authors (Hagita & Mori, 2011).

Statistics actually linking glare to traffic accidents are hard to find but Swedish Väg- och transportinstitutet provides data based on police reports. The data stretches over a six year period and includes several factors responsible for accidents of different magnitude (Land & Nilsson, 2002). Focus on the contribution of glare to the total number of accidents is presented in Figure 7.

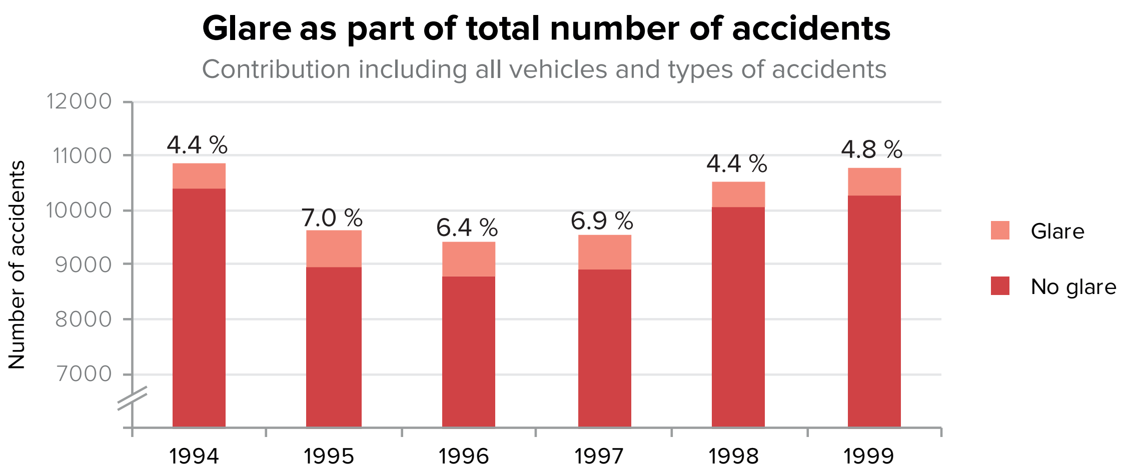

Figure 7 Contribution of glare to total number of accidents. Data by Väg- och transportinstitutet (Land & Nilsson, 2002).

The same source also separates vehicle types into different classes in relation to type of accident. Isolating the data linked to heavy trucks gives the number of glare-related accidents as percentage of total amount Figure 8 reveals increasing trends when studying serious and minor injuries.

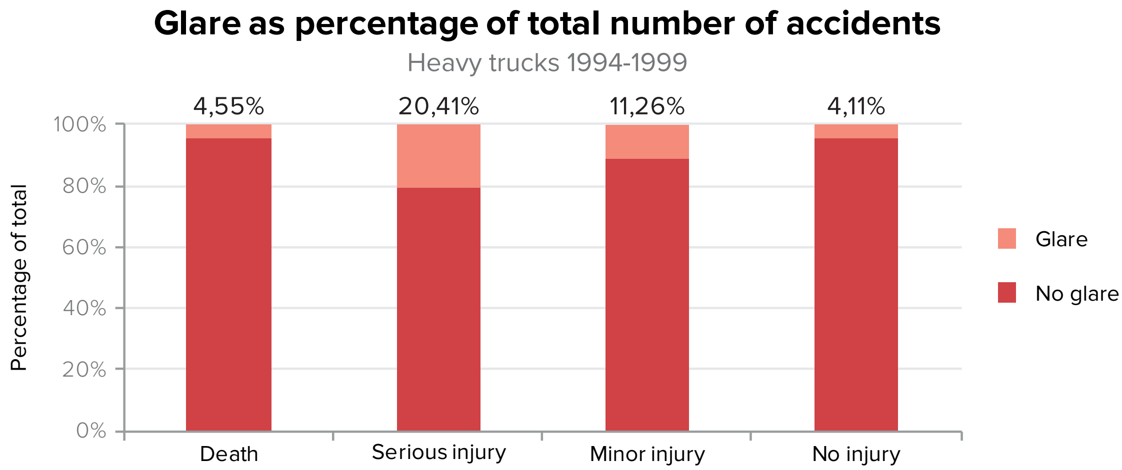

Figure 8 Contribution of glare as percentage of total separated into type of accident. Data by Väg- och transportinstitutet (Land & Nilsson, 2002).

Most studies of cars could be applied to trucks. There are however a few differences between cars and heavy trucks. For example, light hitting the vehicle from the rear could potentially affect truck drivers more than car drivers. The difference is due to the lack of a rear view mirror limiting truck drivers' options. Studies have shown however that long term exposure to glare in side view mirrors doesn't affect physical abilities connected to reaction time. Experienced truck drivers were put in a realistic virtual reality environment for 8 hours while their physiological data as well as response times were measured (Ranney, et al., 1999).

2.3 Trucks

Scania manufactures trucks using a modular system that maximises customisation and minimises the amount of components used in different platforms. A lot of expenses can therefore be cut in all stages of development, manufacturing and usage. Allowing customers to build their trucks from different components also means that there might be no obvious difference between a few set of trucks.

The cab is the part of the truck that houses the driver. Currently, the company retails three different cabs known as P, G and R. There are no definite boundaries between the configurations and all alternatives could be used to complete almost any given task. Various configurations of the cab is presented in Figure 9.

Figure 9 Scania cab overview (image courtesy of Scania).

The P-series is often favoured in the *Distribution* segment with a lot of urban transports like distribution of everyday goods. The P-series is what you usually see trafficking the streets of a city delivering goods to grocery stores and similar.

The G-series was introduced in 2007 as a middle ground between existing platforms. It is commonly used in the segment referred to as *Construction*, with tasks such as moving heavy material to and from construction sites.

The R-series is the largest and most expensive of the mentioned cabs. It is often associated with the third and final segment called *Long haulage.* This cab competes with flagship trucks from other manufacturers and comes delivered with the strongest engines and most spacious interiors.

As previously mentioned, there are no rules as to which model should actually be used in any given situation. Some limitations exist but beyond that it is up to the customer to specify a unit according to their needs. A short cab can for example not be fitted with a bed and a R730 truck would often be over powered for use in daily distribution. The numbers mark the amount of horsepower put out by the engine.

Notice also the varying heights of the roofs. These come in configurations defined as low, normal, high and topline. The interior space of the cab changes dramatically as roof height is increased up to the topline model. Figure 10 gives examples of three configurations of different cab type and roof height.

Figure 10 Scania P-, G- and R-series with different height configurations (image courtesy of Scania).

2.3.1 Markets

The European market is Scania's strongest source of income – only considering sales of trucks. Following that is South America where the company has a strong presence in Brazil. There is currently no commitment on the North American market. The numbers in Table 2 show that there are Scania trucks being used on most latitudes of the globe, something that is important to consider when using sun elevation as a delimitating reference.

Table 2 Number of trucks sold, by region (Scania CV AB, 2011).

Europe	27 720
South America	15 391
Asia	8 089
Eurasia	6 798
Africa and Oceania	3 053

2.3.2 Competitors

The truck industry is generally smaller than the car industry and also considered a lot more stable and forgiving in comparison to the latter. A number of companies have been around for a long time. Among these, Scania defines Mercedes and Volvo as prime competitors at the very high end of the market. Following these are manufacturers such as DAF, MAN, Iveco and Renault.

2.3.3 Historical perspective

Earlier vehicles – often manoeuvred with a steering stick and lacking any sort of roof – naturally did not deliver any protection against the Sun. Not much has happened since the idea of sun covers was introduced sometime after the development of modern cars as we know them.

Looking back at earlier Scania trucks reveals similar, albeit primitive, solutions to the same problem. Pictured in Figure 11 below is a Scania-Vabis Typ 1343 (1914-1920) and a Scania-Vabis 1925 bus using different solutions still recognised in current trucks.

Figure 11 Scania truck (left) with external and internal covers. The bus (right) uses a more innovative approach.

2.3.4 Truck anatomy

There are several parts of a truck that is important to understand to properly comprehend this report. Some of the most important features are pointed out in Figure 12. First off are the a-pillars (1) that support the front of the truck and constitutes an integral part of the basic cage. These are the same as in cars. Just as in cars, manufacturers strive to make them as thin as possible to facilitate a wide field of view. The b-pillar is highlighted by (2). It is also part of the structural cage and is the piece of geometry that limits a driver's wide field of to the immediate left and right. The whole "box" containing the driver's compartment is referenced to as a cab. As previously stated in *2.3 Trucks*, this can be modified and customised using the Scania modular system. The final number (4) attempts to highlight the hidden chassis. This is the foundation upon which the rest of the truck is built around. Chassis height can vary between trucks and it is therefore important to account for this variation when measuring based on eye height.

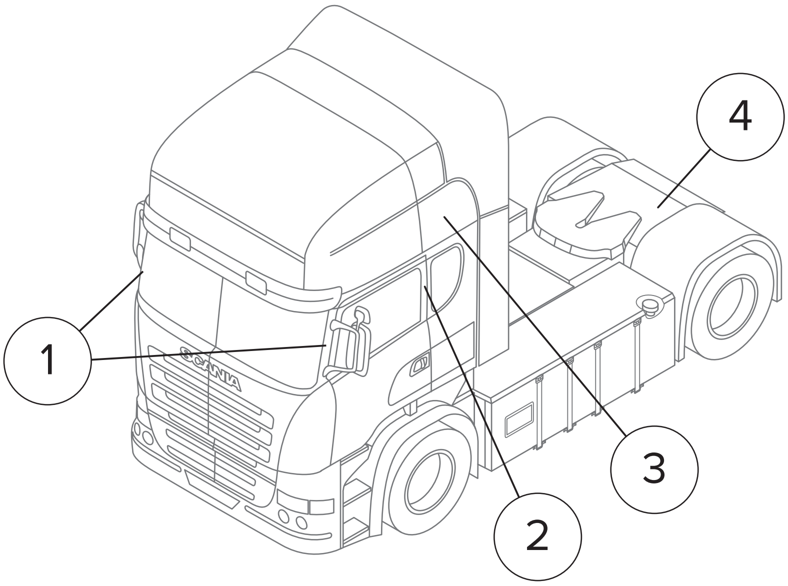

Figure 12 Prominent features of a truck. (1) a-pillars, (2) b-pillars, (3) cab, (4) chassis.

2.4 Regulations

There are of course an unlimited numbers of regulations and laws regarding road safety and vehicles. Only those related to vision and windows will be presented in short here.

2.4.1 Transmittance

In Sweden, the law states that the front windscreen must have a transmittance of at least 75 % in both directions. Other windows must similarly have a transmittance of 70 %.

This is defined in Vägverkets föreskrifter om bilar och släpvagnar som dras av bilar that states:

> *”31 kap. Sikt och sikthjälpmedel*
>
> *10 § Ruta i bil skall i förarens siktfält ha en ljusgenomsläpplighet i båda riktningarna av minst 75 % för vindruta och minst 70 % för annan ruta.”*

Translated roughly to: 75 % transmittance in windshield and 70 % in other windows. Most countries have regulations like this. There is often a distinction between front, side and other windows. Front windshield is usually restricted to 70-75 % Visible Light Transmittance (VLT). Australia is a remarkable exception going as low as 35 % VLT on all windows (Ritrama, 2014).

Many cars have a small label at the top of the windshield that states AS1, Figure 13. This line separates the bottom of the windshield regulated by AS-1 (American Standard 1) from the top-most brim. Above this line there is often a tint below the AS-1 70 % VLT. Most countries define specific distances from the top of the windshield that can be legally tinted.

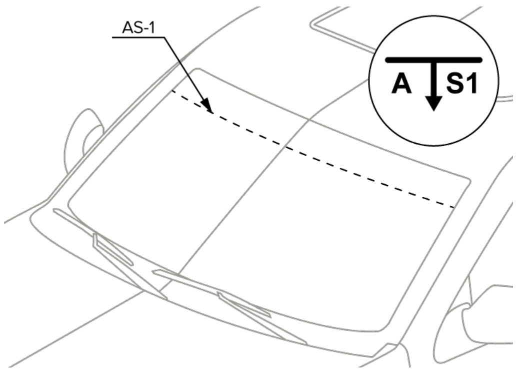

Figure 13 AS-1 line is defined a certain distance from the top of the windshield.

The regulations as they are defined today will most likely be outdated and unable to properly encompass a possible shift to smart glass that dynamically tints the window. To truly enable a shift to smart glass, manufacturers of trucks and cars would have to work for updated rules. Laws and regulations are further debated in the discussion chapter.

2.4.2 Obstructing sight

Regulations state that mirrors cannot be obstructed from the driver's field of view. This would include possible sun visors. Especially the passenger door is subject to this since it is impossible to reach any visor or blind installed there. Of the trucks that were later benchmarked, only Volvo had some kind of protecting feature in the passenger door. Such a feature actually limits the view of the mirrors and is therefore not according to regulations. All trucks had a roller blind installed in the driver's door, but this can easily be deactivated to permit view of the side mirrors.

2.5 Anthropometry

Anthropometry refers to the study of human measurements and limitations. (Boghard, et al., 2011) It is strongly associated with industrial design and human interaction with the workplace. The field of human factors has been growing to become a more and more influential part of product design.

2.5.1 Stature

The project operates to include a wide range of body types – especially varying heights. Sun glare is documented to affect mostly short people. Little effort is generally required to satisfy tall people in a solution. This is true both for reachability as well as how often and at what times sun glare becomes an issue. Being of a shorter stature affects not only how often you are subject so glare, but as a consequence also how often you are required to activate available means to counter it.

To allow physical evaluations of trucks and concepts, three real persons of varying height were used in testing, see Table 3. Two of these were the project members themselves while the third part was played by a continuously available Scania employee. These three persons represented a good enough span of people with respect to stature. Percentiles are based on *Swedish anthropometrics for product and workplace design* published in 2009 (Hanson, et al., 2009).

Table 3 Body measurements for three test subjects

Person	Female	Female	Male
Height [m]	1.53	1.74	1.94
Percentile [%]	1.0	83.4	99.3

2.5.2 Strength

Arm and hand strength is a key factor when activating sun visors as well as roller blinds. Strength is affected greatly by arm position and general posture of the subject. Information on the strength of a person interacting with objects at a distance from the body is presented in Figure 14. Data and illustrations are adapted from The Measure of Man and Woman (Dreyfuss, 1993).

Data was available in two sets. The arm stretched out straight out in front of the person pictured below describes a person sitting down. As opposed to this, the measurements of the arm angled 30° are based on a person standing up. No data was found describing forces at such an angle while the person is sitting.

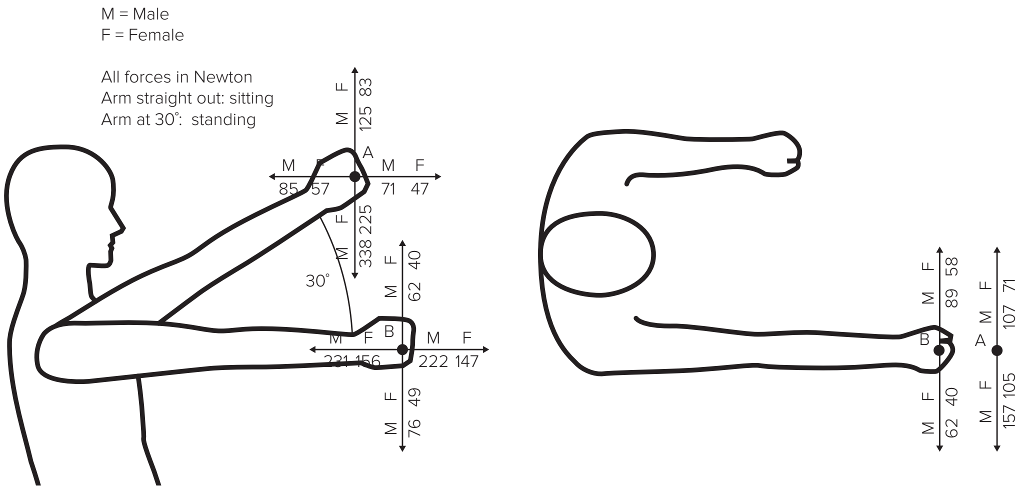

Figure 14 Subject strength when interacting with the near environment. Adapted from The Measures of Man and Woman (Dreyfuss, 1993).

The movement performed when for example lowering a sun visor is not considered what would be defined in the source as *sustained force*. Neither does it fit the description of *frequent use*. Therefore, to include 95 % of the population (US population), the forces attributed to a female person should be multiplied by a factor of 2/3.

2.6 Future technologies

Roughly speaking, within the truck industry, a complete new generation of trucks is introduced about every fifteen years. In between the generations, retailers usually launch iterations with minor improvements to the engine or the design. Therefore, when discussing future technologies, these time spans have to be considered.

A technology considered to have a substantially growing potential is what goes under the common name “smart glass”. Another widely used term is “dynamic glass”, instead describing the principal idea behind the product. These solutions exist both as personal glasses and windows ranging from aerospace to architectural applications. They can be implemented using traditional glass, polymer or even as a retrofitted film.

Smart glass solutions were examined more thoroughly as candidate for a long term solution to glare. A lot of stakeholders at Scania and KTH suggested that the project should take a direction involving smart glass. An examination of the technology and an explanation to why the project did not choose this direction would therefore seem necessary.

A number of different approaches separate smart glass technology. Of these, a few present interesting opportunities that can be related to this project. These are: electrochromic, photochromic, suspended particle devices (SPD) and liquid crystals. A comparison between their benefits and shortcomings will be presented on the following pages and attached appendices. A short presentation on polarizing filters will also follow.

2.6.1 Smart glass market

The demand for smart glass has been increasing every year since it first got popularised as a luxury product used at financially strong offices or residential houses belonging to a very fortunate few. Several reports predict the market to explode in the coming years, resulting in both increased performance and significantly reduced cost.

According to BCC Research, the global market for smart glass-relate products will increase to $4.2 billion in 2016 (BCC Research, 2012). It is primarily the transport and aerospace industry that will be responsible for driving this growth, not architecture, an industry that is often associated with these products. Figure 15 shows the significance of the transport industry as a driving force behind smart glass. A lot of progress and, more importantly, implementation has been made in this particular industry. From electrochromic rear view mirrors that automatically prevent glare panoramic roofs in luxury brands such as Mercedes and BMW. The Boeing Dreamliner 787 showcases the technology in its passenger windows, introducing the technology to an even broader market.

Other predictions follow the same trend. Markets and Markets predict the global smart glass and smart window markets to be worth $3.83 billion by 2017 (Markets and Markets, 2014). Navigant research estimates a price reduction by 50 percent by 2022 (Martin, 2013). Upcoming patents for retrofitting SPD-film on existing windows will likely result in huge installations on building facades, further dropping the price; especially smaller applications like windshields would benefit from this. A lot of both private and governmental investments are put into this to help tackle heating and cooling of buildings.

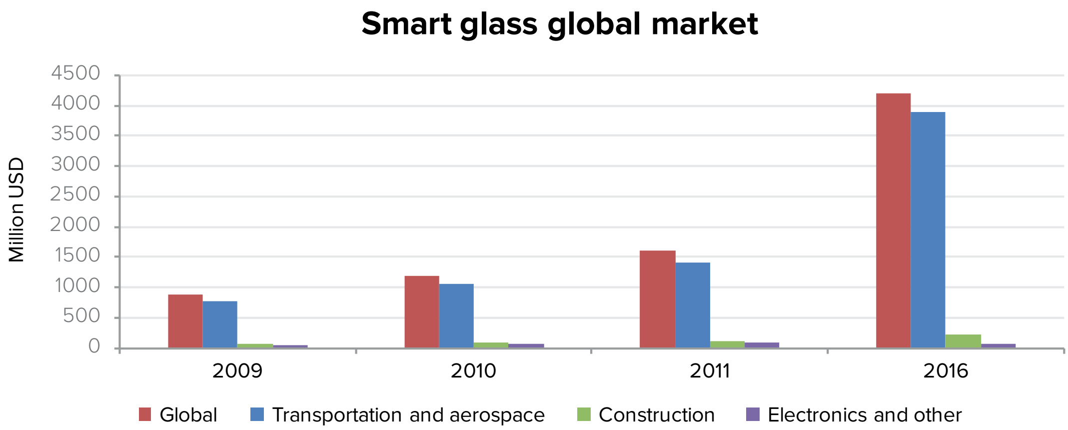

Figure 15 Market shares by industry according to data by BCC Research (BCC Research, 2012).

2.6.2 Technology comparison

The various technologies are described in detail in Appendix A. A short summary of their performance in relation to each other is given in Table 4. In short, the SPD technology looks most promising. Both current applications such as panoramic roofs in cars and the ongoing development make it stand out as a strong candidate for future use. Electrochromic glass is a strong second with liquid crystals not really presenting a viable option. This is mostly because of the lack of adjustable transmittance. SPD also has the benefit of operating at an inverted power consumption as opposed to the others. If there is a power shortage it will return to its clear state. Both electrochromic and liquid crystal technology turn dark when current is removed. Another benefit of SPD is the relatively fast speed of activation and consistency of the tint. Numbers describing transmittance max/min are not definite since manufacturers claim different performance. These would have to be examined product-by-product. As a general rule, max and min values follow each other. The max transmittance is one of the factors keeping this solution from being an option. Combined with the transmittance of windshields the value falls well below the required 70-75 % as described in *2.4.1 Transmittance*. Photochromic technology has too many shortcomings to be an option.

To summarise: max transmittance must be improved. SPD-film that could be retrofitted to a windshield would make this technology highly interesting.

Table 4 Comparison of smart glass technology

Type	SPD	Electrochromic	Liquid crystal	Photochromic
Speed	1-3 seconds	Up to minutes*	Instant	>5 minutes
Steps	Adjustable	Adjustable	On- Off	Self adjusting
Transmittance max	70 %	60 %	60 %	90 %
Transmittance min	10 %	5 %	~1 %	15 %
Consistency	Excellent	Inconsistent tint	Excellent	Degrading
Consumption	100 V 0.5**, 0.05 W/sf	10 V 0.02 W/sf	24-100 V 0.5 W/sf	-
Film	Under development	Under development	Yes	Yes

*Depending on application size
**Power during switch

A lot of companies involved in smart glass were more than eager to demonstrate the performance of their product – always in relation to a meeting with a sales representant. The project's intention was to receive small samples of the different materials in order to evaluate their performance against glare. This was proved not possible due to patenting reasons and the efforts were put on hold.

One of the companies was Vision Systems that has reportedly already installed SPD sun visors in trucks from another manufacturer. Their solution is constructed to snap on rather than being attached as a thin film, see Figure 16. SPD film (thin sheet, as opposed to glass window) that can be retrofitted is a sought after solution especially considering energy efficiency in existing buildings. Large environment programs are financially backing up companies developing this technology and a solution will most likely be available within 5-10 years.

Figure 16 SPD glass attached to windshield, by Vision Systems. Notice the black rim revealing this solution as a snap-on window rather than a thin film.

3 Method

In this chapter, the most important methods and processes will be documented. Major themes are sun studies, benchmarking, user studies and finally the collective methods related to product development.

3.1 Sun studies

Data on the Sun's movement was gathered, this was to be used together with other input; mostly that created by benchmarking. This type of information gives precise measurements that are helpful when assessing user needs.

External data is gathered from the National Oceanic and Atmospheric Administration (NOAA, 2013); this is in turn based on equations from *Astronomical Algorithms* by Jean Meeus. The selected input gathers data on sun elevation and azimuth and is distributed at 6 minute intervals throughout the day. More detailed data is available in Appendix B.

3.1.1 Sun elevation

It is impossible to estimate what directions trucks are angled throughout the globe. It is however possible to draw conclusions concerning the Sun's elevation at different latitudes. The elevation varies a lot depending on where you are and also when the measurement is taken. It is important to gather data from a representative set of latitudes across the globe. The sites chosen are presented in Table 5. These locations represent a broad range of latitudes and therefore cover various sunlight properties at any given day of the year.

Table 5 Geographical locations and their respective coordinates.

Location	Latitude	Longitude
Tromsö	69°40'58''N	18°56'34''E
Södertälje	59°11'45''N	17°37'41''E
Shanghai	31°12'N	121°30'E
Singapore	1°17'N	103°50'E
São Paolo	23°33'S	46°38'W
Buenos Aires	34°36'12''S	58°22'54''W
Cape Horn	55°58'47''S	67°16'18''W

These locations are spread out at evenly spaced latitudes as shown in Figure 17. Tromsö and Cape Horn represents the extremes. Beyond these latitudes, very few people live and even fewer trucks operate here. Södertälje represents the Nordic market, while Shanghai represents both the Asian and European markets. The locations stretching from Singapore through Cape Horn covers most of the South American market as well as large parts of Africa and Australia.

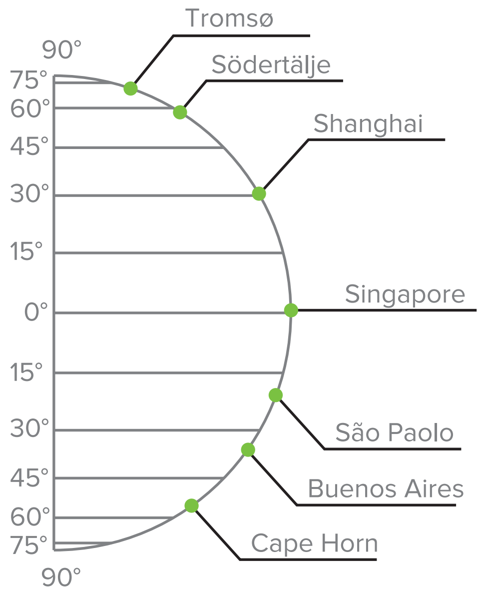

Figure 17 Selected locations and their placement along the surface of the globe.

3.2 Benchmarking

Direct sun glare will only affect the driver when the Sun's elevation does not exceed such an angle as to hide it above the roof of the truck. Therefore, it is necessary to map the maximum angles at which the Sun can be directly seen, and disturb, the driver. Indirect glare and the general brightness of the sky would still be a problem when the Sun is outside the field of view; this type of glare is however not as prominent.

Data will be gathered to measure the maximum vertical viewing angle at intervals covering a 180 degrees field of view in front of the driver. Measurements will also be taken to map the horizontal angles that are not shielded by activated sun covers.

Central to examining the Sun's movement around the cab will be the eye height. As previously mentioned in *2.5.1 Stature* three persons will serve as test subjects during the benchmarking. Since this project is not a strictly scientific creation, results gathered this way will be more than sufficient. Further thoughts on benchmarking methods are found in the discussion.

To keep the process as controlled and stringent as possible, the subjects will adjust seating position according to their own preferences. This will produce results that are consistent, whereas trying to manually imitate a taller or shorter person would present additional problems. A very precise approach is of course desirable and something discussed later.

Data will be gathered on a flagship Scania truck and equal models from competitor brands shown in Table 6. The chosen competitor trucks are within the same range of trucks in order to compare in an adequate way. Comparing the largest Scania R-cab with a much lower cab would for example not generate comparable data.

Table 6 Brands and models examined during benchmarking tests

Brand	Model
Scania	R780 CR19T 6x2/4
Volvo	FH Globetrotter XL 4x2T 460hp Eu6
Mercedes-Benz	Actros IV StreamSpace (1843) LS 4x2 (F 13)
DAF	XF Space Cab 410

The trucks participating in the tests are displayed in Figure 18 below. The pictures show the vehicles parked at the designated spot used to perform the measurements.

Figure 18 The tested trucks from left to right: Scania, Volvo, Mercedes, DAF.

Measurements will be taken in and around the trucks. A maximum vertical viewing angle is measured at a distance of 5 m from the driver's position. This angle will be measured at points simulating an azimuth angle of 180° in front of the driver, see Figure 19. The maximum vertical viewing angle (effectively measuring how much of the sky can be seen) will thereby be measured across the whole field of view. Differences in vertical viewing angle will through this method be identified.

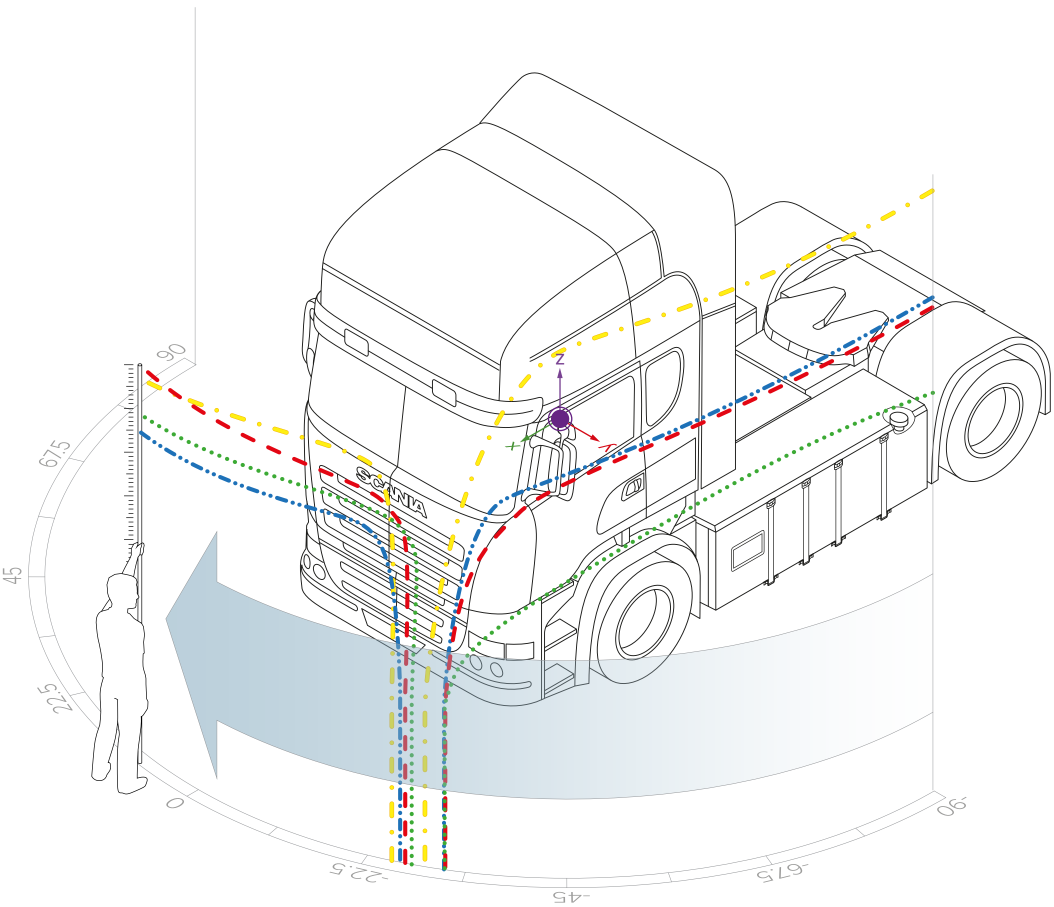

Figure 19 The procedure of measuring maximum vertical viewing angles around the cab.

In total, 17 measurements will be made at predefined azimuthal angles around the driver. In the case of an a-pillar or mirror blocking the view at a certain angle, measurements will be taken as close as possible. All measurements and details are logged using the template show in Appendix C.

The subject's eye height will also be measured to adjust for any variations across the trucks. Eye height is measured in relation to both the floor and the ground. Ground measurement is crucial to compensate the varying truck heights. Floor measurement is used to check for measurement errors due to positioning and also as a comparison to sun visor height. Eye height is measured using spirit level and tape measure.

Horizontal angles will finally be measured to map what angles are not blocked when the sun covers are activated. These angles are found primarily around the a-pillars and in some cases between the sun visors. The positions of a-pillars are similarly noted. A-pillars are black in Figure 20. White spaces surrounding them symbolise gaps between them and the covered angles (grey).

By marking the position of a certain angle on the ground, the distance to this point from nearby known angles can be measured by tape ruler. Angles are calculated based on known radius and chord distance.

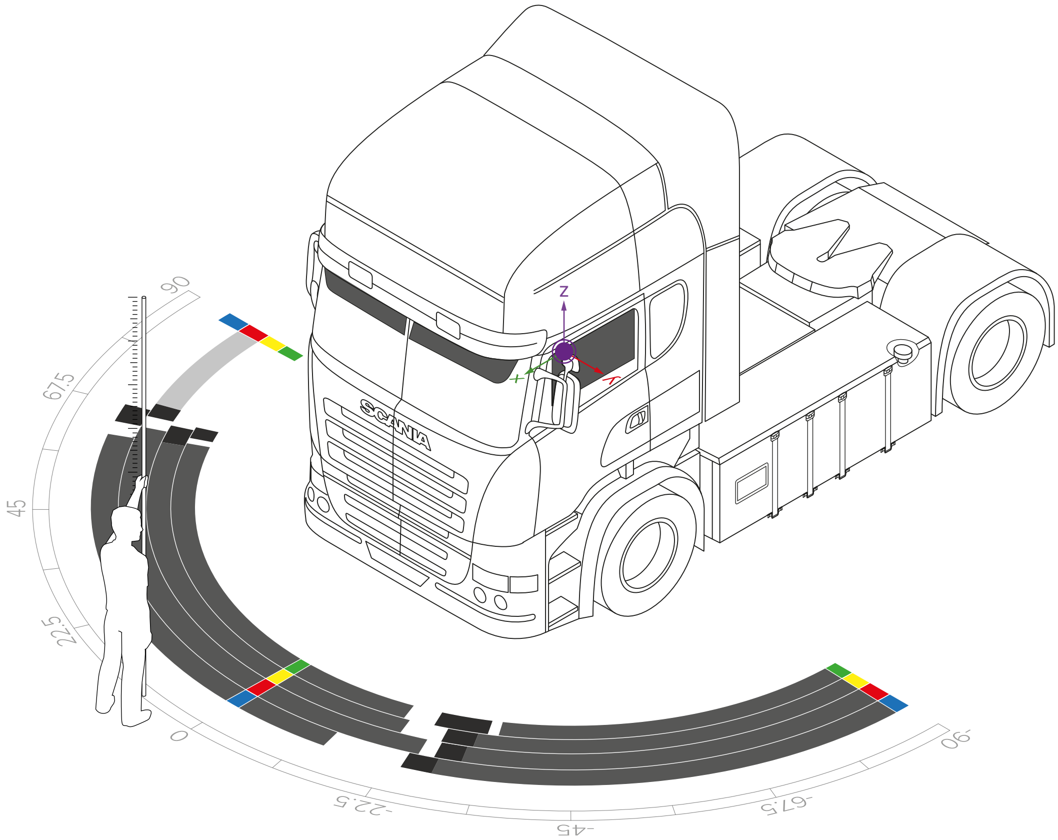

Figure 20 Measuring horizontal angles showing locations of a-pillars and gaps between these and sun visors.

Measurements are interpolated to complete the total field of view in front of the driver, thereby describing the maximum elevation of the Sun at all angles. Conclusions will be possible to draw based on data gathered from trucks and the comparison between them.

3.3 User studies

Previous studies of sunlight and glare have pointed out the difficulties in replacing user perception with more quantitative methods. Subjective methods of evaluating have proven to be superior. Interviews and studies focusing on user participation will therefore be of great importance. The way in which these are interpreted and analysed will determine if the output will be of a purely qualitative nature or more close to a semi-qualitative one (Trost, 2012).

User studies will be divided into two phases split between research and development. The material that is gathered prior to the actual product development will be analysed and used as a basis for further work. During the development phase, further user input will be used to evaluate and improve as part of the iterative process.

3.3.1 Pre-development

Interviews will be of great importance during the initial phase of the project. Gaining early knowledge about the subject is a key factor to the success of the project. There will be direct access to end users and individuals along the entire life cycle of the product. Test drivers at Scania's own facilities are an important asset with experience of these types of questions.

Adaptive interviews

Adaptive interviews (Peterson, 2000) will be the initial form of interviewing technique. A predefined set of questions are used as a guideline to quantify a certain perception, attitude or similar. During the interview, however, not all of the questions are necessarily used. The choice of questions to be asked varies depending on previous answers and the direction of the interview. This way, the general mindset and attitude of participants can be captured, even in cases where the interviewer did not anticipate the outcome.

The primary group being subjected to this method are drivers at Scania Transportlaboratorium. All drivers involved have extensive experience of different brands of trucks and their tasks vary from distribution to long-haulage.

Contextual interviews

Contextual interviews, as in interviewing and studying drivers within the context of the truck, will be held early on in the project. With this setup it is possible to both observe and discuss physical features in a more relaxed environment. The subject feels at ease being the one in a familiar situation. A lot of details that would never spring to mind when being interviewed across a table can now be highlighted. Behavioural characteristics can similarly be noted and questioned.

Preparations for both adaptive and contextual interviews are made according to Design Thinking methods defined by Stanford's d.school. *Interview preparation* and idea generation using *Saturate and group* help form the initial meetings with users (Plattner, 2010).

Scania Transportlaboratorium was used to recruit subjects. Contextual interviews were also held with other users and stakeholders but in stationary cabs.

Questionnaires

As a follow up to in-depth interviews, questionnaires help build input from a wider group of users. This is useful when there is already a direction set – often defined through the initial interviews. A stronger case can be built when letting users participate in the forming of demands related to the product development.

A questionnaire clarifying the problems and needs regarding sun visors is to be distributed to haulage contractors throughout Sweden. The aim with the survey is to get a solid base for the development phase. Drivers are asked to explain the problems they experience when driving and describe the different zones within the truck that might be affected by sun glare. This rather quantitative information helps build a foundation for the QFD, as explained later. Construction of the questionnaire was made with Enkätboken as a guiding reference (Trost, 2012).

The questionnaire can be found in Appendix B. Please note that the original was online based and that some of the questions were answered by using drop-down menus.

3.3.2 During development

Many methods here are similar to those mentioned in *3.3.1 Pre-development*; the difference might be that in the development phase there is a stronger direction and intention set by the project. These methods will not be repeated. Instead, a short presentation of those that were unique to the development phase will follow.

Brainstorm

A brainstorming session is to be held at the beginning of the development phase. The participants will be people that have limited knowledge about the truck industry and sun visors in particular in order to stimulate unexpected ideas. As a guide, This Is Service Design Thinking will be used (Stickdorn & Schneider, 2011, pp. 180-183). Again, D.school's Bootleg Bootcamp is used. This time the sections *Brainstorm Rules* and *Facilitate a Brainstorm* serve as inspiration. A set of exercises and scenarios are prepared in order to keep the session going forward.

User tests and evaluation

Exposing concepts and ideas to users will mostly depend on prototypes of varying levels. Sketches and simple discussions will also be used, but the ability to touch and manipulate an object greatly increases the amount of valuable input.

Initial prototypes, and even sketches, will look for possible directions and the wide perspective of things while discussing with users. Later prototypes are full scale and even mounted in a mock-up cab or rig. When using 1:1 sized prototypes, observations and questions regarding important touch points can provide important knowledge and insight.

3.4 Product development

Based on the information gathered about the Sun and after the user studies are made, the product development phase will take place. User demands and all functions that the new product should possess will be arranged in a Quality Function Deployment that will be used throughout the development work. The concept generation stage will follow and eventually lead to prototyping.

3.4.1 Quality Function Deployment

The most valuable guide through the product development phase will be the Quality Function Deployment matrix. Here the project will gather input from a wide set of inputs to help formulate the direction of future work.

Quality Function Deployment matrix, also known as QFD, is a method developed in Japan during the 1960's. It was developed to combine the large mass of information that is often related to a product development process. This attempt strives to combine qualitative and quantitative user input and link it to engineering features. By doing this it creates a link from the designer of a technical component all the way back to the user. In the QFD the customer's needs, the developer's opinion and the purpose of the product are all combined (Ullman, 2010, pp. 45-170).

The results from benchmarking, questionnaire and interviews will be linked into a QFD matrix. Other matrices are available, but this particular method balances complexity with usability in a way that suits the project process. The aim here is to gather as much of the different data inputs as possible into one comprehensive document. In this way, relations and functions can be tracked back through the project. By limiting the number of user demands and responding functions to below 20, the dynamic abilities when using the matrix is not lost due to complexity. In short, the workflow follows as below:

1. Initial interviews with users and other stakeholders.
2. Detailed questionnaire connecting with large amount of users. Focus using find-

ings from previous interviews.

3. Benchmarking of trucks.
    3.1. Physical measurements of trucks.
    3.2. Subjective studies of user environment.
4. Quantify data from interviews, questionnaires and benchmark.
5. Enter data into QFD matrix. Add relations between entries.
6. Iterate analysis and adjustments of QFD output in order to guide process

Studies of, and with, users are covered in *3.3 User studies*. Input from employees at Scania will also play an important role in shaping the direction of the early project. Benchmarking of current models including competition is covered in *3.2 Benchmarking*. Data and input will then be fed into the QFD-house and used in the on-going process. The principle of the QFD matrix is explained in detail below with numbers relating to Figure 21.

1. Customer requirements from different types of users are collected in a list. The relevance and importance of these demands are graded by users and the project. Requirements are often gathered by qualitative methods while the grading of them is based on quantitative studies. In this case interviews and questionnaire respectively.

2. The demands set up by users are met by functional requirements that are measureable. For example the demand "spaceship must travel fast" could be met by "max speed [km/h]". Target or limit values are set to indicate acceptable or desirable values. An indication to whether it is desirable to maximise or minimise this function is also added. The interrelationships between functional requirements is then analysed in the top triangle of the matrix.

3. User demands and functional requirements are connected by analysing relevance between them. This is traditionally done by distributing points according to how well they correspond to each other. A connection is given 0, 1, 3 or 9 points.

4. Current models including competition is graded by their performance related to each of the customer demands in (1). Several factors including future planned rating, improvement factor and sales point can be added to a final weighing that reveals important demands. This grading is usually performed by users and later used as a guide to set product direction. In this case the project graded the competition.

5. Technical priorities are summarised by multiplying user rankings from (1) with interrelationships from (3). This gives the importance of each functional requirement. In this particular project a slight adjustment of technical priorities was made based on insights gathered from questionnaires, interviews and discussions. Some of these had not been recognised by the studied population but were still considered crucial to some users.

6. Competitive benchmarking is performed to compare products based on technical requirements. Target values to each of the requirements are then supposed to be set as a final outcome. These values are measurable and comprise the basis for further

development. To simplify the use of the matrix in this project, benchmarking was executed in a comparative style where products were ranked in relation to each other, as opposed to measuring absolute performance. This provided a much faster and dynamic method, especially since many measurements were in fact more or less subjective. Given more time and equipment, a proper benchmarking could have been performed. This approach was however deemed beneficial in this type of project.

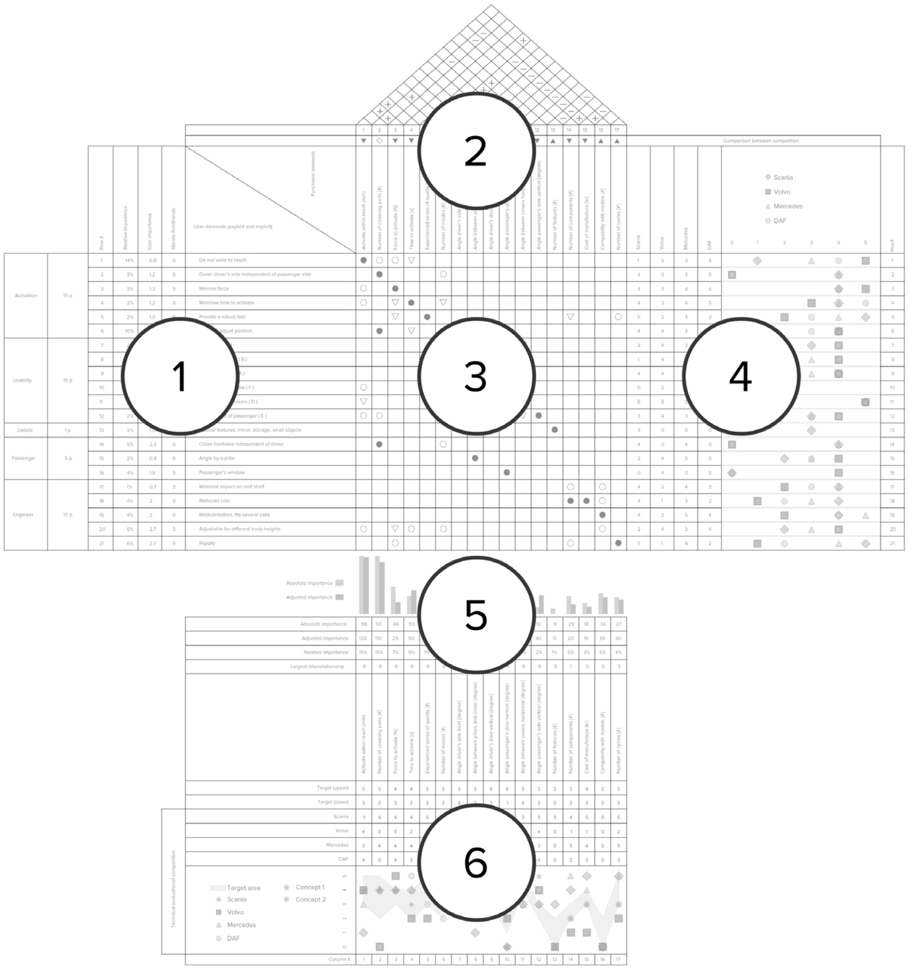

Figure 21 The QFD matrix and its major steps.

The final part of the QFD matrix (6) is then used throughout the project. Uses ranges from simply keeping everyone going the same direction to evaluating concepts.

3.4.2 Concept Generation

By following the five-step method described in Product Design and Development (Ulrich & Eppinger, 2008, pp. 99-120), the problem with sun glare is broken down into pieces and subproblems. The five-step method is not only suitable when creating an overall concept, but also a great way of finding concepts for sub-systems, which was applicable in this project. The five steps within the method can briefly be described as follows:

1. Clarify the problem; understanding, identify critical subproblems
2. Search externally; benchmarking, lead users, literature
3. Search internally; individual knowledge within the group, idea generation
4. Explore systematically: organize the thinking of the team and synthesize solution fragments. A Classification tree helps divide all possible solutions into several individual classes in order to ease comparison. By making a classification tree it is possible to easily build branches over different solutions, and early in the development stage detect promising directions.
5. Reflect on the solutions and the process

3.4.3 Concept evaluation

Instead of introducing new methods of evaluation such as a Pugh-matrix, the project kept to the structure provided by the QFD. This way a continuity and relation to the defined user demands was secured throughout development. Evaluation of final concepts will only use the final part of the QFD (6), something that provides a simple yet deeply rooted method.

3.4.4 Prototype and test

The concepts chosen to develop further from the output of the QFD, should be prototyped and tested. Prototyping is a well-known and commonly used method in product development. This project will use prototypes as “proof of concept” as described by Ullman. (Ullman, 2010) By letting users test the prototype, the developers become aware of the strengths and weaknesses of the concepts, and are able to improve it within the next iteration.

3.4.5 Iterations

In the product development phase the project wanted to have room for several iterations. The iterations were planned as follows:

1. Initial concepts. Gathering material and ideas that has been collected during the first weeks. Examining directions and themes based on outcome.
2. Structured concept generation based on identified classes and/or functions. Split the problem into sub-components and develop solutions to each of these. Keep concept development structured and organised.
3. Based on previous classes and functions: identify themes that separate concepts into groups based on criteria.
4. Filter and eliminate themes. Create and update delimitations concerning both project and prototype.
5. Prototypes based on selected theme. First iteration of fully functional prototypes exposed to users.
6. Re-focus based on insights and input from user meetings.
7. Second generation of fully functioning prototypes. Full size prototypes tested in truck or mock-up. Evaluating function and physical touch points by interviewing and observing test subjects.
8. Final evaluation and conclusions.

4 Implementation

This chapter explains how the methods, described in previous chapter, were implemented. Major themes are sun studies, benchmarking, user studies and finally the collective methods related to product development.

4.1 Sun studies

The Sun's elevation was recorded using data from NOAA at two different days using the geographical locations defined in *3.1.1 Sun elevation*. Equinox at March 20 2014 and the southern solstice (winter solstice in the northern hemisphere) at 21 December 2013 were used as reference dates. This presented two types of extremes of the Sun's elevation.

From the graphs below it is obvious that the Sun travels very differently at the given dates and latitudes. Figure 22 shows the least extreme case. All the curves are gathered together a lot more than in the following figure. At either equinox the Sun is aligned with the plane defined by the equator. It follows that a person standing on the equator will have the Sun above his/her head at noon. The Sun reaches its highest position at noon all throughout the spectrum. It does not, however, reach an elevation similar to that near the equator, as can be seen in Figure 22. In Tromsö it is instead close to 20 degrees.

Although a linear approximation of the Sun's elevation would be close to correct, it will not render a completely accurate number. The information in the graphs below will later be used in conjunction with results from benchmarking to show for how many hours sun glare is a problem.

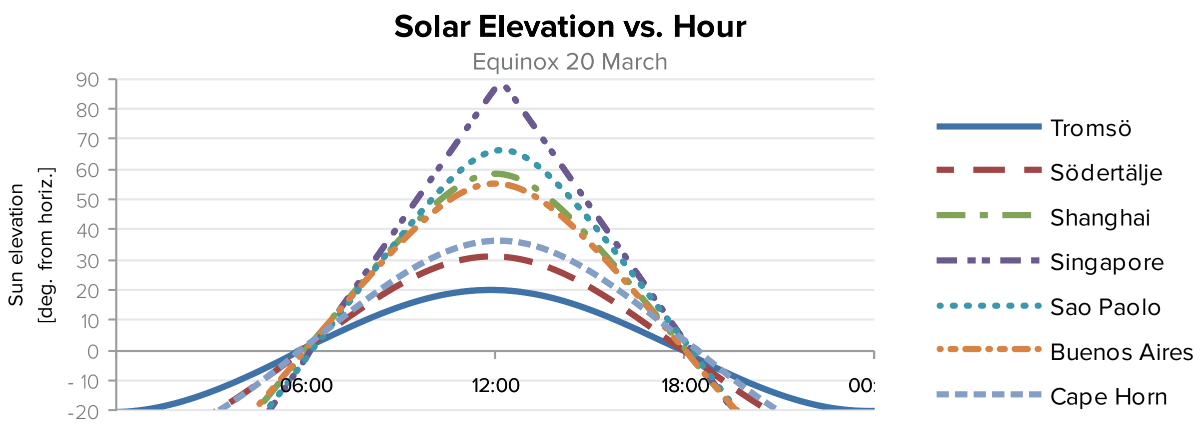

Figure 22 Sun elevation at equinox, presenting a very non-extreme situation.

Figure 23 shows elevation during the southern solstice. Sao Paolo is now situated near the normal pointing from Earth's surface to the Sun – a similar situation to Singapore previously. Sao Paolo therefore experiences a near linear elevation up to approximately 90 degrees from the horizontal plane. Furthermore, the more extreme latitudes are subject to very limited amounts of daylight. In Södertälje the Sun follows a very low path during the hours of light. When examining glare, a low path during relatively few hours could present a worse scenario than for example the one in Sao Paolo.

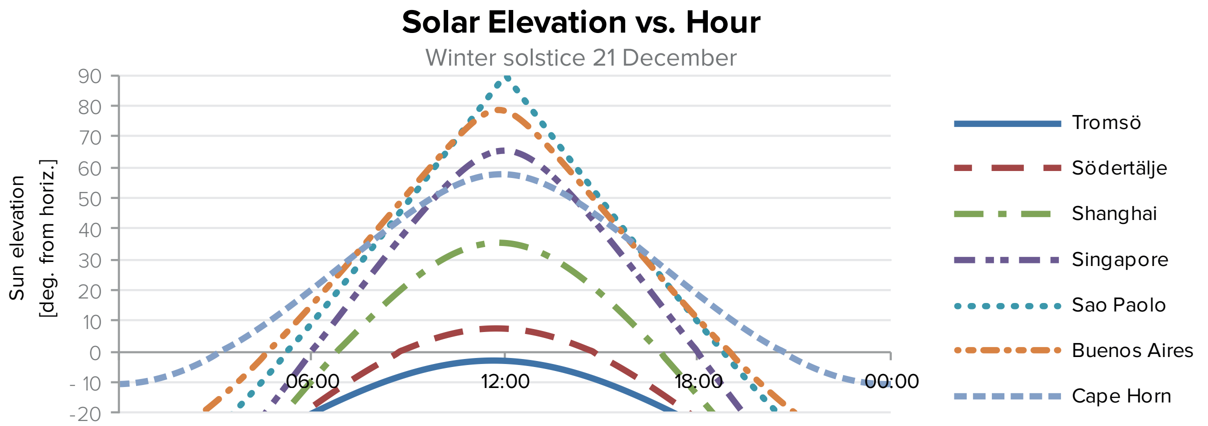

Figure 23 Sun elevation at southern solstice, the most extreme situation.

Further detailed data used in the above graphs can be found in Appendix C.

4.2 Benchmark

Two types of tests were performed during benchmarking. The first measurement visualised how much the drivers were able to see by measuring a vertical angle. In the second test, all sun covers were activated at their maximum vertical level. Any gaps, such as between the a-pillars and sun covers, were noted and the horizontal angle the gap caused was measured. Test subject's eye height and the vertical height of activated sun covers were also examined.

4.2.1 The trucks

Scania Topline and three competitor trucks were used in the benchmark tests. Detailed specifications are found in Table 6 in *3.2 Benchmarking*. The trucks had different types of sun covers. Both Scania and Mercedes Actros used traditional sun visors and a pull down roller blind to cover the driver's door. The solution that is used in Scania Topline can be seen in Figure 24.

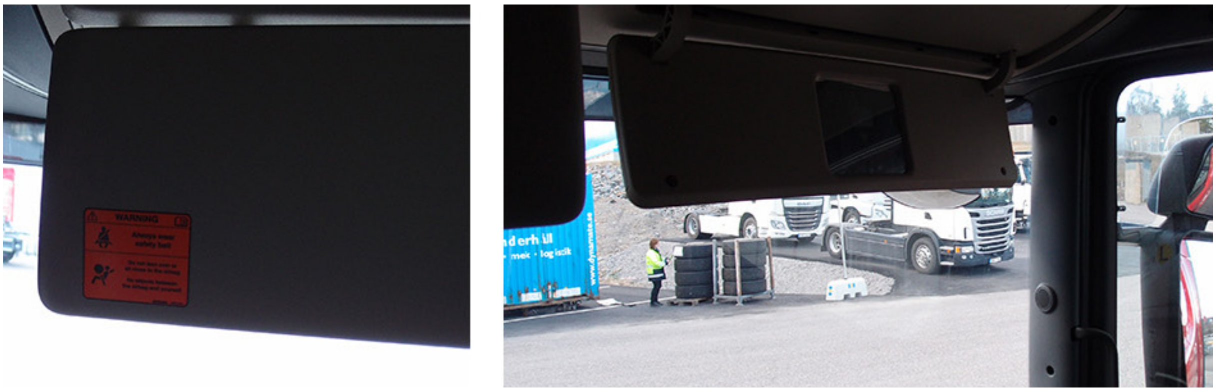

Figure 24 Scania has a parted solution in the front windshield and a roller blind in the driver's door.

Volvo and DAF have roller blinds both in the front windshield and in the driver's door. Volvo was the only truck that had the ability to cover the passenger door, in this case with another roller blind. This appears not to be according to regulation, as described in *2.4.2 Obstructing sight*. The one installed in the windshield of the same truck was operated using an electrical motor, Figure 25.

Figure 25 Volvo's solution consists of blinds everywhere; driver's door, windshield and passenger door.

The front roller blind used by DAF is manual, as opposed to the one installed in the Volvo, Figure 26.

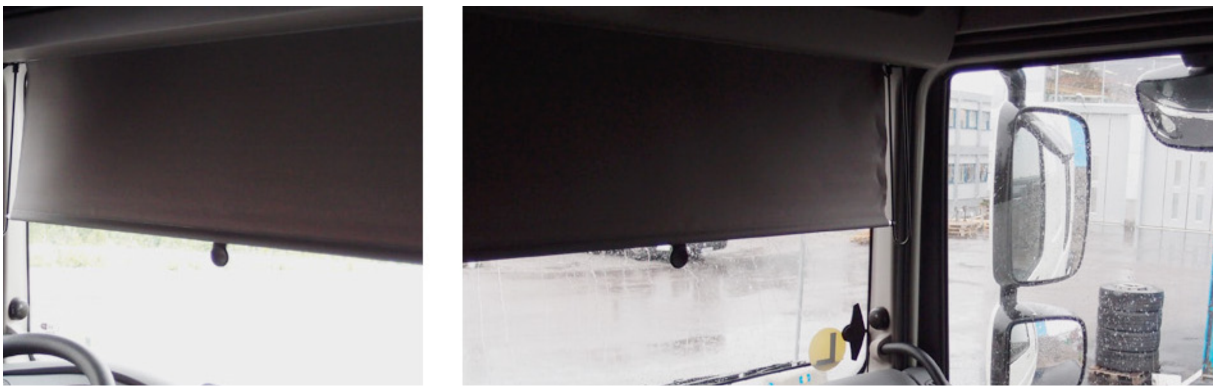

Figure 26 DAF uses manual blinds.

Mercedes uses a similar setup to Scania Topline. The sun visors are placed under the roof shelf and on driver's door the also have a pull down blind, Figure 27.

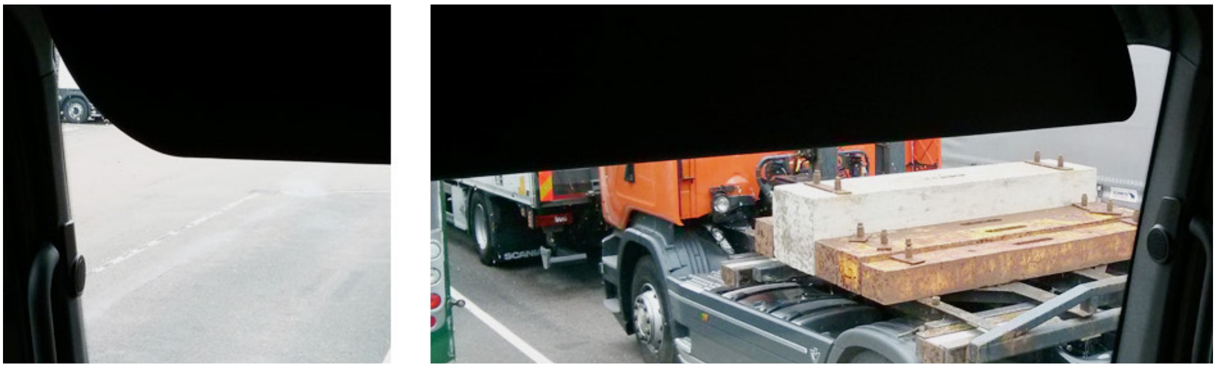

Figure 27 The sun cover solution in Mercedes is closely related to the ones in Scania Topline.

Visual representations of the actual trucks used in the tests were in many ways a necessity. The primary reason beyond having to explain the components in text is that these trucks are often equipped differently. When discussing Mercedes Actros, for example, many drivers imagine the latest version equipped with two electrical blinds in the windshield.

4.2.2 Test subjects

Since the tests were performed over a period of two days and being rather time-consuming, the authors of this report themselves acted as test subjects. This eased any additional measurements to be made after the tests were completed. Using the same person throughout the tests was also crucial in order to get consistent results. A third person, subject C, was also used to get the measurements of a shorter person. However, the results of subject C are only available for certain tests. Basic information of test subjects' data is presented in Table 7. Average eye height from floor was measured when sitting in the driver's seat, after completed tests.

Table 7 Test subjects' data

Subject	A	B	C
Physical height [m]	1.94	1.73	1.53
Average eye height from floor [m]	1.20	1.15	1.03

4.2.3 The procedure

The primary goal was to examine and map at what sun elevations the driver risks being exposed to glare. All the trucks were one at the time placed at the same flat paved parking lot, Figure 28. The driver's position was lined up so that it matched the centre point of the prepared semi circle.

Figure 28 The spot where the trucks would park is marked in the picture to the left. The specific angles to be measured have been marked in the picture to the right.

The ground of the parking lot was marked according to Figure 28. Spots where the measurements took place were measured and marked.

Prior to measuring anything, the trucks had to be parked in such way that the driver's head was on top of the marked spot representing Origo. Aligning the truck according to the major axis was also important since parking at an angle would rotate the measured output. The spot indicating zero degrees (facing straight forward) would then be incorrect with a few degrees.

A custom-made PVC tube device with a variable height between 149.0 and 410.5 cm was used to measure the vertical angle seen from the driver's seat, Figure 29. At some positions the height of the stick was insufficient and a box had to be used as a prolonging support under the stick. This box was measured to properly accommodate for the extra height.

Figure 29 The measuring device.

The horizontal angles where the sun visors did not provide any cover, and therefore exposing the driver to sun glare, were marked on the ground, as seen in Figure 30. The a-pillars were also marked using the same method.

Figure 30 An example of the marks painted on the ground to show where the experienced gaps are and a-pillars are situated.

By measuring the distance from known angles to the measured points, the angular difference could be calculated using equations for deciding chord length.

4.2.4 Horizontal and vertical field of view

The resulting measurements were gathered and filtered to smooth out any spikes caused by errors in measurement. The measurements of Subject B are illustrated in Figure 31. The graph is also adjusted for a normal scenario with roads rising 6% (3.43 degrees). This is approximately the maximum angle of most common roads in Sweden, but it is not an extreme scenario of the kind that can be found in mountainous areas. Everything is measured from the driver's point of view, meaning -90 degrees equal the immediate left while +90 degrees similarly equal immediate right. The driver's eyes are positioned at the spot marking Origo.

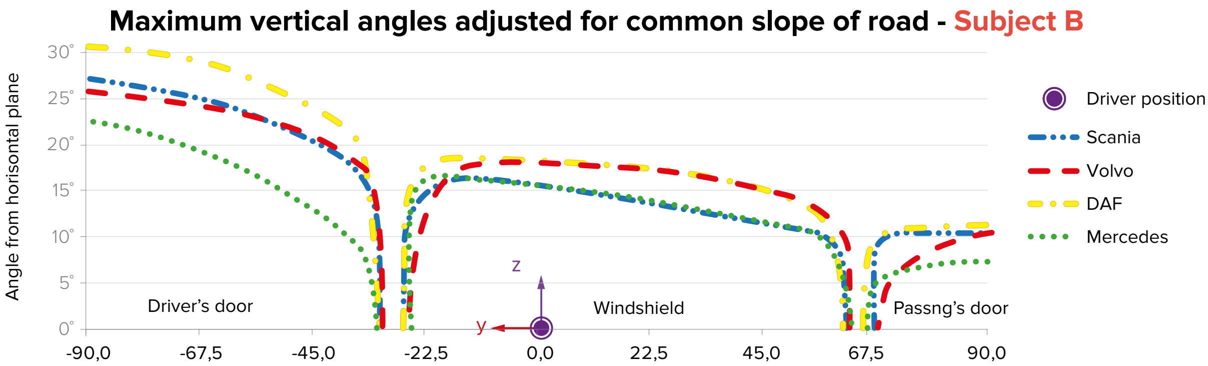

Figure 31 Vertical viewing angle showing window contours. The windshield is in the middle, and on the sides are driver's door and passenger door. The graph is adjusted for a normal road scenario with a 3.43 degrees incline.

Similar graph for Subject A and a combined graph of both subjects is available in Appendix E. Figure 32 and Figure 33 combine the vertical and horizontal angles for each subject respectively. Medium grey areas indicate horizontal angles that are covered by the activated sun visors. Gaps between these, and the black a-pillars, reveal angles that are not covered by sun visors.

These gaps can be a major nuisance to drivers and should therefore be minimised or eliminated. Outside the horizontal measurements, the vertical ones (coloured) have been wrapped to more closely match actual appearance.

Figure 32 presents the results of the taller person (Subject A). The results reveal a difference between the trucks, both regarding horizontal and vertical angles. Vertical differences are most easily seen in the window of the driver's door. This window is located relatively close to the subject, as opposed to the passenger window. Simple geometry then explains why the driver's door has a larger spread and, in general, a larger angle. The passenger door on the other hand has a lower vertical viewing angle and a much more densely grouped result.

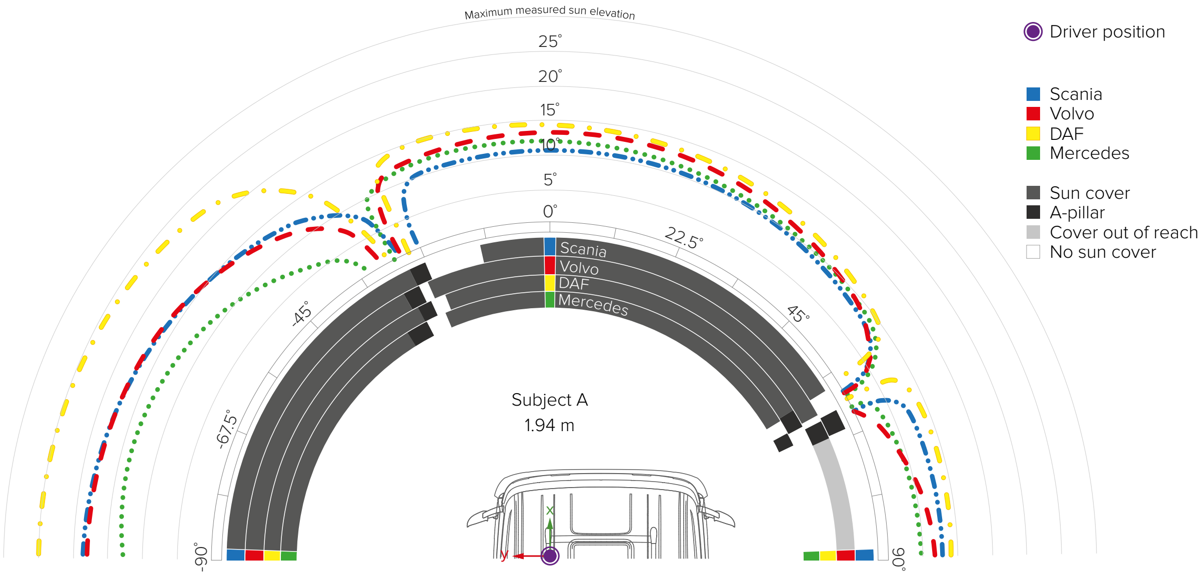

Figure 32 Illustration of Subject A's visual field with activated sun visors

Figure 33 illustrates how Subject B experienced the view with different sun visors. The results are similar but with a-pillars slightly rotated outwards due to the fact that Subject B is seated closer to the windshield. The small gap that is visible outside the left a-pillar in the Mercedes should be noted. This occurred because the roller blind in the driver's door did not provide enough cover for the driver. Another thing to be considered here is that the window of the Mercedes had a very curved shape compared to the other trucks. Shorter drivers would experience even larger gaps of this kind due to their position, as they are closer to the windshield.

As for the other measurements, Subject B experiences larger angles of vertical visibility than the taller Subject A. The two subjects did however reveal similar pattern, which in turn might demonstrate that the employed method is relatively accurate.

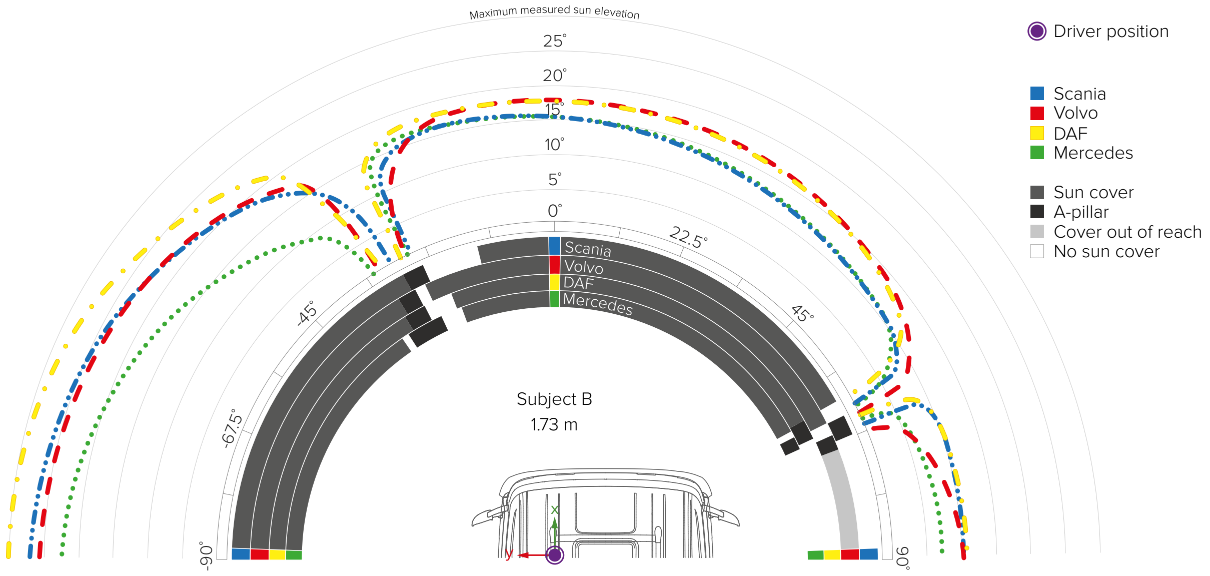

Figure 33 Illustration of Subject B's visual field with activated sun visors.

The results reveal that among current generation of trucks, blinds, as used in the Volvo and DAF, perform well when assessing horizontal angles around a-pillars. Scania Topline does not keep up with competition, especially at the left a-pillar. The sun visor does not fully use the potential space in the cab; it is instead constructed to follow the design of the roof shelf and this makes it cover less than the competitors.

4.2.5 Vertical height of activated sun cover

The test subject's eye height was also measured both in relation to interior floor and the outside ground. All measurements had to be subtracted with the eye height from the ground to be able to calculate viewing angles. Vertical distance from eye height to floor was used primarily for the analysis later, where consistency as well as height in relation to activated sun covers will be processed.

The results from measuring the height of the activated sun covers from the floor is presented in Figure 34. Blinds generally outperform traditional sun visors. Subjects A and B can achieve total coverage in most trucks. The exception is Mercedes where the average eye height of Subject B falls short of the actual visor (measured eye height of both Subject A and B was actually lower than the activated sun visor in this specific truck). Subject C, with a height of 1.53 m, has such a low eye position that none of the trucks manage to match it.

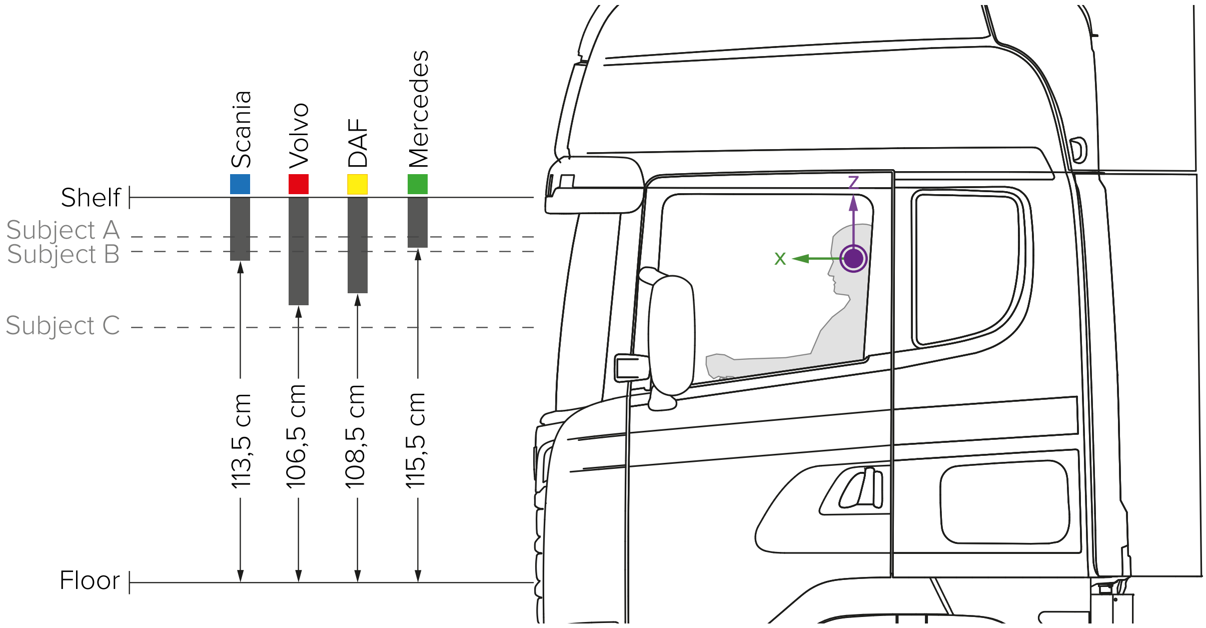

Figure 34 Vertical heights from floor of activated sun covers. Figure including the average eye height of Subjects A, B and C.

The measured distances from activated sun cover to the floor can be compared to the recorded eye heights in each of the trucks. Figure 35 below illustrates the previously mentioned case where the sun visor in the Mercedes did not reach low enough. Neither of the subject's eye heights was above the sun visor, although the average eye height of Subject A was positioned just above. It is interesting that the Mercedes truck seems to induce a particularly low seat position and at the same time performing poorest among the sun covers. Both subjects had a spread of +/- 5 cm from their average eye height.

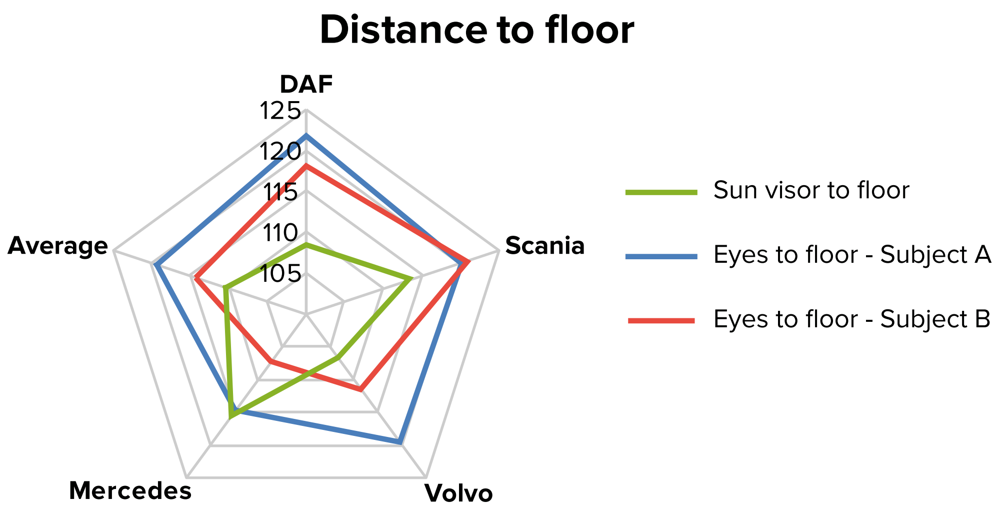

Figure 35 Subject's eye height compared to the vertical height of activated sun covers.

4.3 Synthesis of sun studies and benchmark

Combining the previously measured angles with data that maps the elevation of the Sun at different latitudes, a time factor can also be estimated. The resulting graphs display the number of hours the Sun is positioned at elevations above the horizon that is also within the driver's field of view. This field of view is limited by the maximum vertical viewing angle that was measured in the benchmark tests. Important data is gathered in Table 8.

Table 8 Input and data used.

Subject	A	B	C
Subject height [m]	1.94	1.73	1.53
Truck model	Scania Topline		
Max vertical angle (0° horiz.)	10.1	15.1	20.6

A shorter person experiences a much greater vertical viewing angle (seeing a larger portion of the sky) than a tall person. As a consequence, the shorter person is also exposed to the Sun for a longer period of the day than a taller person. This can clearly be seen in Figure 36 where the difference between the tallest and shortest driver is almost consistently a 100 % increase in sun exposure.

Figure 36 shows sun exposure during equinox preceding summer in the northern hemisphere. This is theoretically the least extreme day of the year; all latitudes receive a decent amount of light. However, in Tromsö the Sun's maximum elevation happens to coincide with the shorter person's maximum vertical viewing angle. In combination with a very flat path, this provides a short driver in Tromsö with the joy of looking at the Sun for 12 hours.

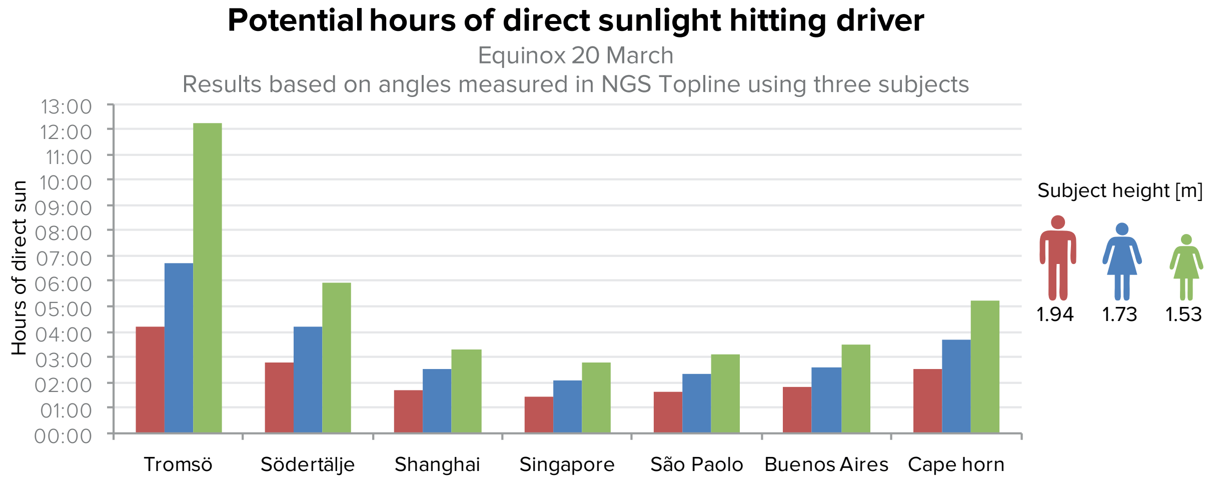

Figure 36 Sun exposure during equinox for three drivers of different height.

In comparison to the previous graph, Figure 37 uses the extreme winter solstice – a date when the northern hemisphere is at its darkest due to Earth's angle from the Sun. Consequently, Tromsö does not receive any natural light at all. In Södertälje something interesting happens; as the Sun's path reaches its lowest (it climbs to a maximum elevation of 7.48°), all three drivers experience the same amount of light. The tall driver's maximum viewing angle was measured at roughly 10°. Therefore this date is close to the maximum possible sun exposure for this driver. It will reach its maximum the day the Sun climbs to 10° and peaks at the top of the windshield.

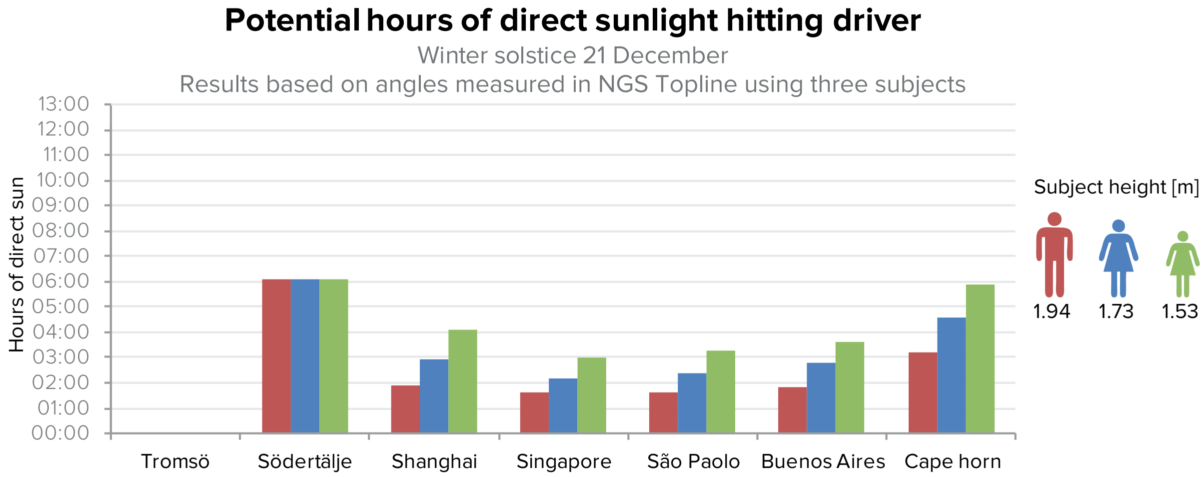

Figure 37 Sun exposure during winter solstice (northern hemisphere) for three drivers of different height.

It is important to notice that the output data is only a measurement of potential sunlight. Trees, hills and other factors would block light from the field of view. Not to forget clouds that would in at least Södertälje effectively hide the Sun during most days close to winter solstice.

4.4 User studies

Interactions with users were made throughout the project. Earlier meetings worked to identify broad issues that were further investigated both within the project and in conjunction with further user meetings. A large part of these studies were performed as part of the general information gathering and covered in *4.4.1 Pre-development*. As development started, meetings with users focused on more and more specific issues. These are described in *4.4.2 Development phase*.

4.4.1 Pre-development

In order to get a deeper understanding how the sun visors of today are constructed, interviews with Olov Karlsson, responsible for sun visor development, were held. The person in charge of windshields, Karolina Stoltz Länta, was also interviewed in relation to smart glass and the possibilities of a future use.

User studies were initially made at Scania Transportlaboratorium and Scania Demo Center where a questionnaire was developed in collaboration with a group of seven experienced drivers. Adaptive interviews (Peterson, 2000) were held during two sessions, one in the context of a moving truck and one around a table while drinking coffee. A third session was held in conjunction with the project getting the opportunity to drive trucks and buses at Scania Demo Center. Insights gathered during these meetings combined with knowledge gained through general discussions with employees helped form questionnaires.

These questionnaires were sent out to haulage contractors in Sweden. The document consisted of 12 questions, of which some were multiple-choice questions. One consisted of a picture where the driver was supposed to rank the areas within in the driver environment according to importance and experienced problems. By using qualitative interviews to construct a mostly quantitative questionnaire, important issues could be quantified and later incorporated in the QFD matrix.

The answers from the questionnaire gave a deeper understanding of the drivers' discomfort due to glare and also visualized what problems they wanted to solve. The diagrams presented below summarise the results from the survey. In total, 35 drivers responded.

Figure 38 is a staple diagram of the brands that drivers preferred. The purpose of including this question was to kick-start respondents' thinking about known trucks and the properties of different solutions. It therefore has a very general character; there is for example a big difference between various Mercedes trucks. However, it gives some indication to what brands the respondents are familiar with, as well as their general preferences.

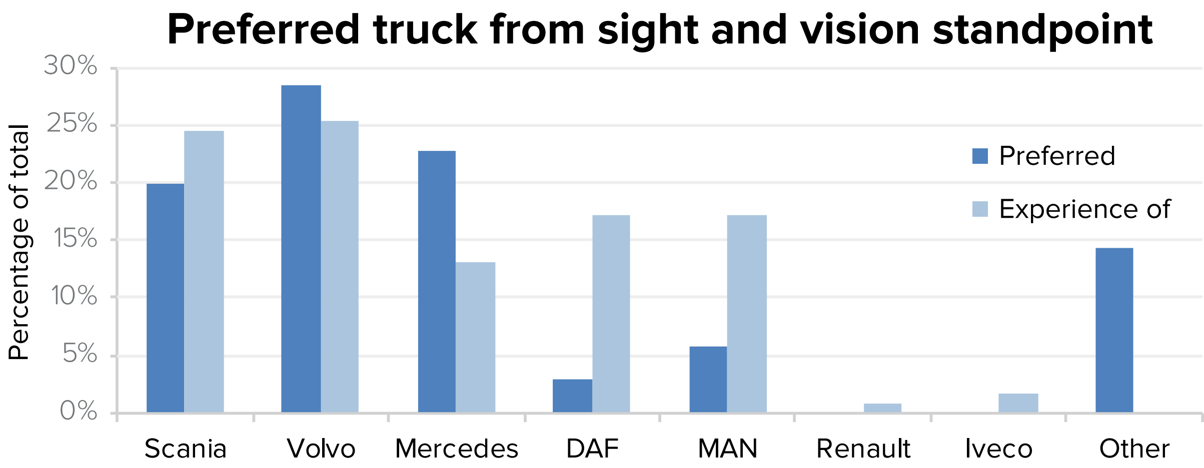

Figure 38 Drivers named brands they had used and also their favourite.

The survey also queried into the activation process of the sun covers. Reachability, speed and force needed were among other things weighed against each other. The result is presented in Figure 39. From this graph it is possible to read the total number of respondents. A number of non-respondents to this particular question can also be noted.

Figure 39 should be studied with focus on comparing the height of dark fields representing 6, and also the total height covered by numbers 4-6. These represent the number of respondents highlighting a feature as highly important, at the same time including those that a lot of drivers consider relatively important (giving the feature a grading of 4 or higher).

Categories being weighed are from the left in Figure 39:

- Reachability: how close it is to reach the sun glare protection
- Parting: the ability to activate only certain parts of the sun cover because it is divided into several parts
- Activation force: how much force does the driver feel he/she needs to activate
- Time to activate: how much time does it take to activate

- Robustness: does it feel durable
- Number of modes: if it can be half-activated, are there any additional fold-out etc

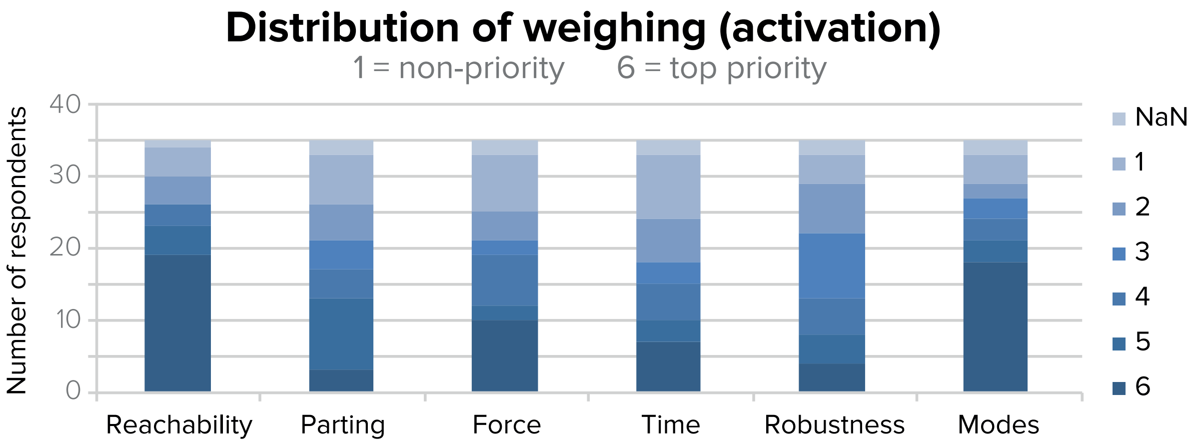

Figure 39 Distribution of weighing made by truck drivers on predefined features of the activation process.

A decision was made to simplify the weighing to minimise the amount of incomplete and misinterpreted answers. The original concept was to distribute 15 points freely among the predefined alternatives. Trials proved however that this caused some confusion and miscalculations. The online survey format provided no way of limiting the input to a total of 15 points. A simplification was made to rank the alternatives from 1-6. This distribution was then adapted to fit the required 15 points.

Different methods were examined to adapt the distributed points. A combination of favouring a large percentage of high numbers and at the same time considering a large bulk of mid-to-high numbers was preferred. This recognised those cases where many had given a feature the top priority as well as those where many had given it a high priority. Figure 40 illustrates a few of the adaptation methods. The light blue named "Average" was later used.

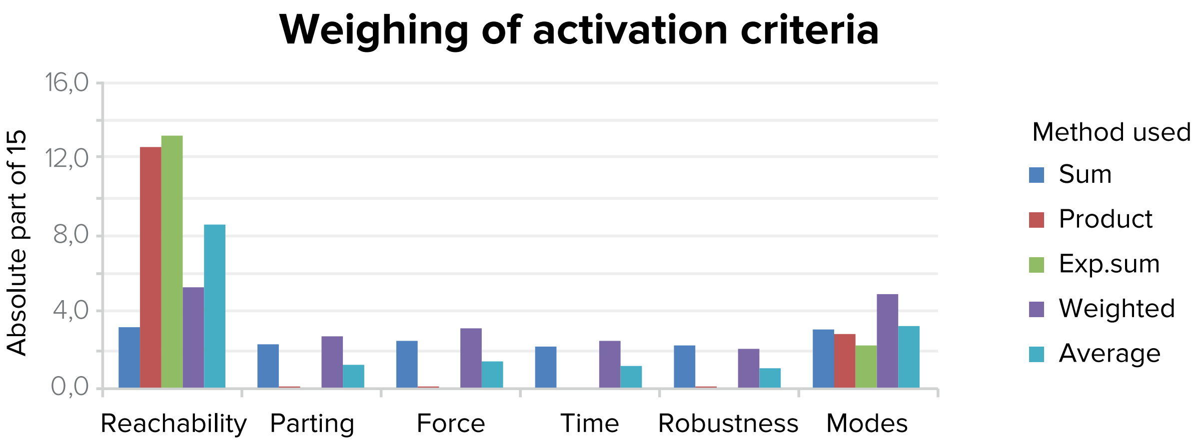

Figure 40 Different methods of adapting user input. Light blue "Average" was used in further work.

A similar weighing was performed by users, this time on problem areas defined in Figure 41.

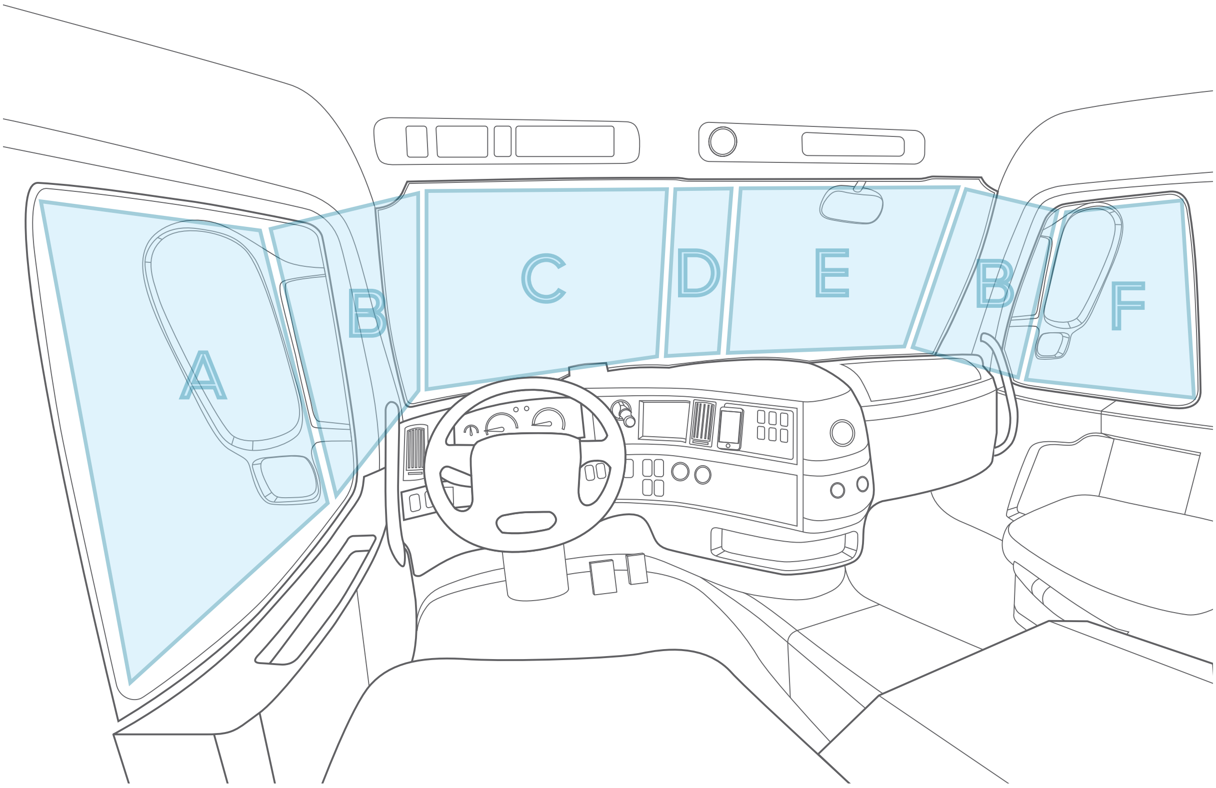

Figure 41 Different zones as seen from the driver's point of view.

The distributed answers are illustrated in Figure 42. Horizontal axis corresponds to picture above.

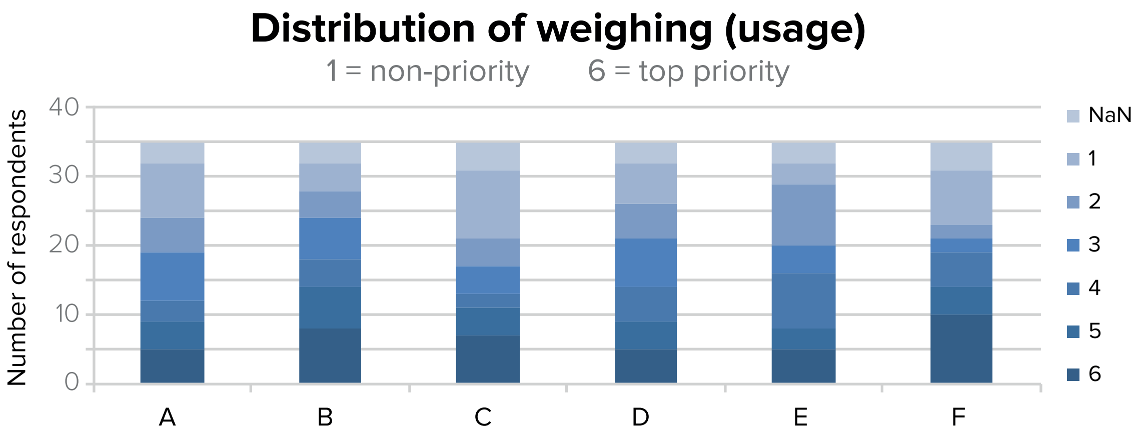

Figure 42 Distribution of weighing related to problem areas.

The resulting weighing in Figure 43 shows that areas B and F (a-pillars and passenger window respectively) were prioritised by many users. This corresponds directly to Figure 4 in *2.2.1 Sun glare* where this area is described to be more sensitive to glare than others. It could be that an increased sensitivity in these areas further magnifies the perceived discomfort.

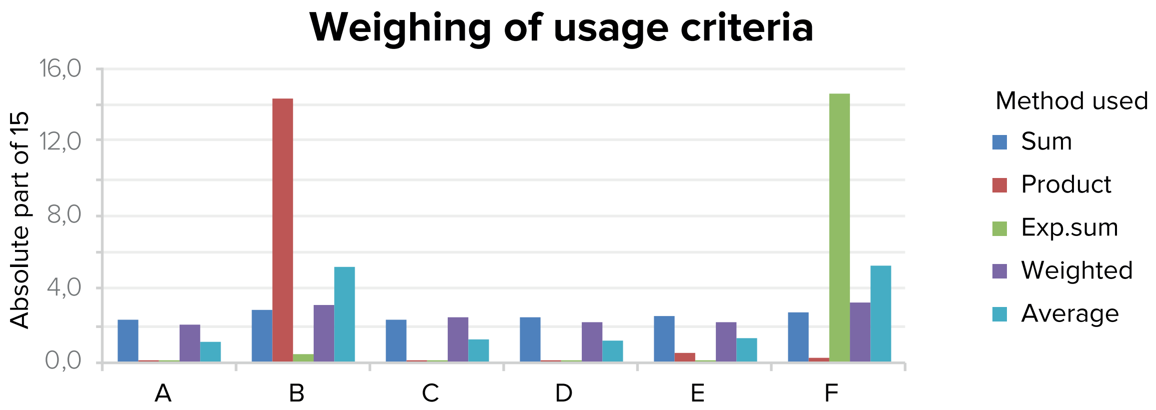

Figure 43 Resulting weighing. Again, the light blue "Average" was used.

Some of the drivers that replied the questionnaire also stated what properties an ideal sun cover solution should have:

"It should be able to adjust height and width, maybe also alter the distance between sun cover and the head"

"It should be similar to a curtain and I want to have the possibility to adjust the driver's cover independent of the cover on the passenger side"

"It should just work without ever being noticed"

"You press a button within reach to activate the sun cover. It is important that it can be extended vertically when the sun is low. It should be easy to wipe off and fix if it breaks down"

The things drivers stated as most important were taken under consideration in the development phase.

4.4.2 Development phase

As the project developed through delimitations and crossroads, more information had to be gathered concerning certain focus areas. The areas of utmost importance were identified as reachability, activation and angles where the driver is exposed to sun glare (both vertical and horizontal).

A female person with a height of 1.53 m (Subject C in previous studies) was observed and interviewed about the driving environment in a Scania Topline equipped with today's sun visors. Subject C has a truck driver's license and previous experience of driver environment. Photos, Figure 44, and measurements of the person are shown below.

Figure 44 The 1.53 m test person is demonstrating how she tries to reach the sun visor.

Many unique insights were made from studying a shorter person. The most important are presented in short format here:

- A short person (150-155 cm) cannot even touch the roof shelf when sitting in a normal driving position. The studied subject would need an additional 15 cm of arm and hand length to actually touch the shelf. See left image in Figure 44.
- The above concludes that an activation mechanism, or button, that strays from the nearest part of the roof shelf is insufficient if a claim should be made to include drivers of this stature.
- An observation was made that reaching forward is more difficult than reaching upwards. This difference was due to the subject "diving" over the steering wheel as opposed to reaching and perhaps standing upwards.
- Reaching the sun visor on the passenger side is impossible.
- There is a lot of standing or semi-standing happening as sun visors are activated.
- Gaps between a-pillars and sun visors happen at a much lower part of the sun visor. Longer persons had small gaps manifesting themselves along the top to middle contour of the visor. Shorter persons experiences gaps closer to the bottom contour. This part of the sun visor is often curved due to space being limited by other components such as the rail, illustrated in Figure 45.

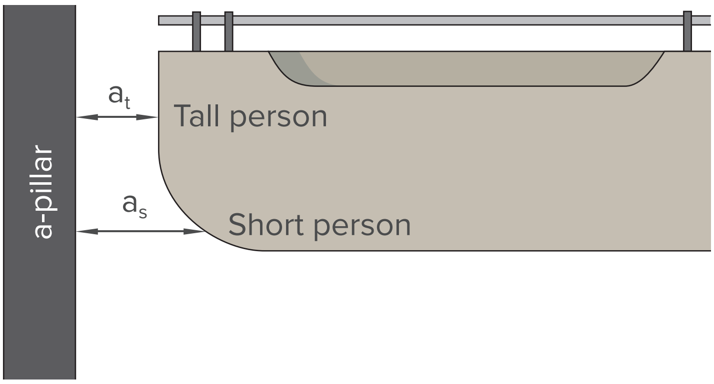

Figure 45 The height difference results in different gaps

4.5 Combining input into QFD

The results from sun studies, benchmark, interviews and questionnaires were combined into a Quality Function Deployment matrix. (Ullman, 2010) This method worked particularly well in a case such as this where data from a number of both qualitative and quantitative studies were to be combined. The output, consisting of functional requirements, is weighed by the matrix. Complete QFD matrix is saved for reference in Appendix F.

The output of the weighing procedure is presented in Figure 46. A quick guide to the procedure is found in *3.4 Product development*. An "adjusted importance" has been added considering factors that were highlighted during other parts of the user studies. For example, very few drivers had problems with the sun visors not reaching low enough for them to be useful. This is however a major issue for some of the drivers as found out through the open-ended questions. Adjustments were therefore applied to accommodate these issues.

The requirements most relevant for further development were also highlighted to ease the reading.

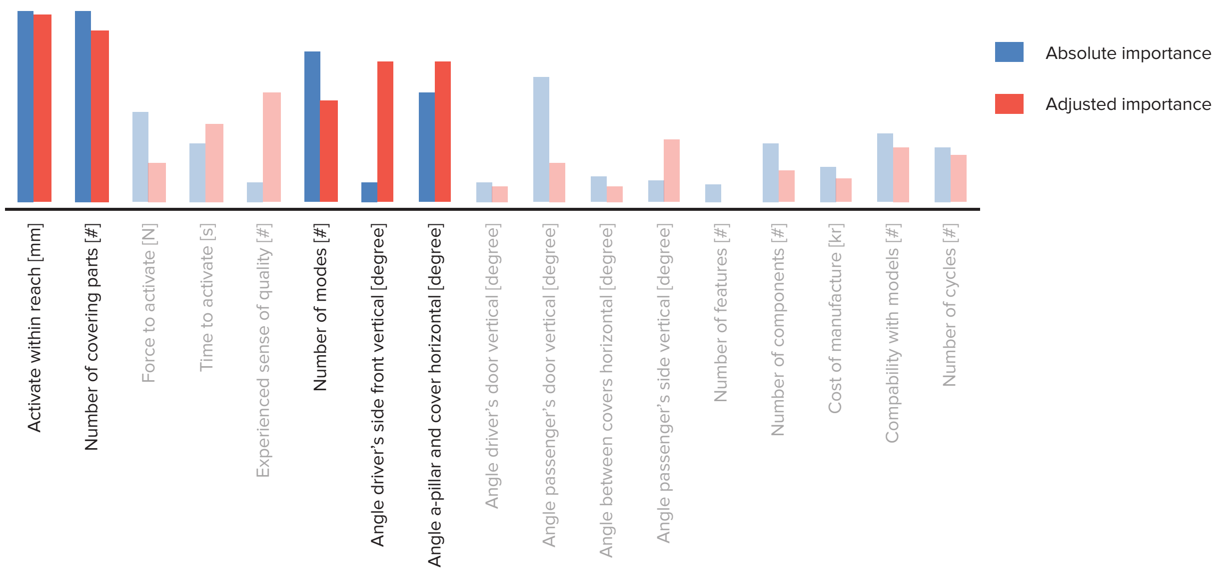

Figure 46 Functional requirements as output by QFD. Highlighted entries are areas that will be subject to further focus through development.

Finally, the benchmarked trucks were graded according to their performance versus the same functional requirements. By grading them relative to each other, the process was kept manageable and dynamic. It also means that new concepts can easily be added and compared to previously tested products. Results are shown in Figure 47. The area marked with light blue colour shows the target area for the new concept developed in this project.

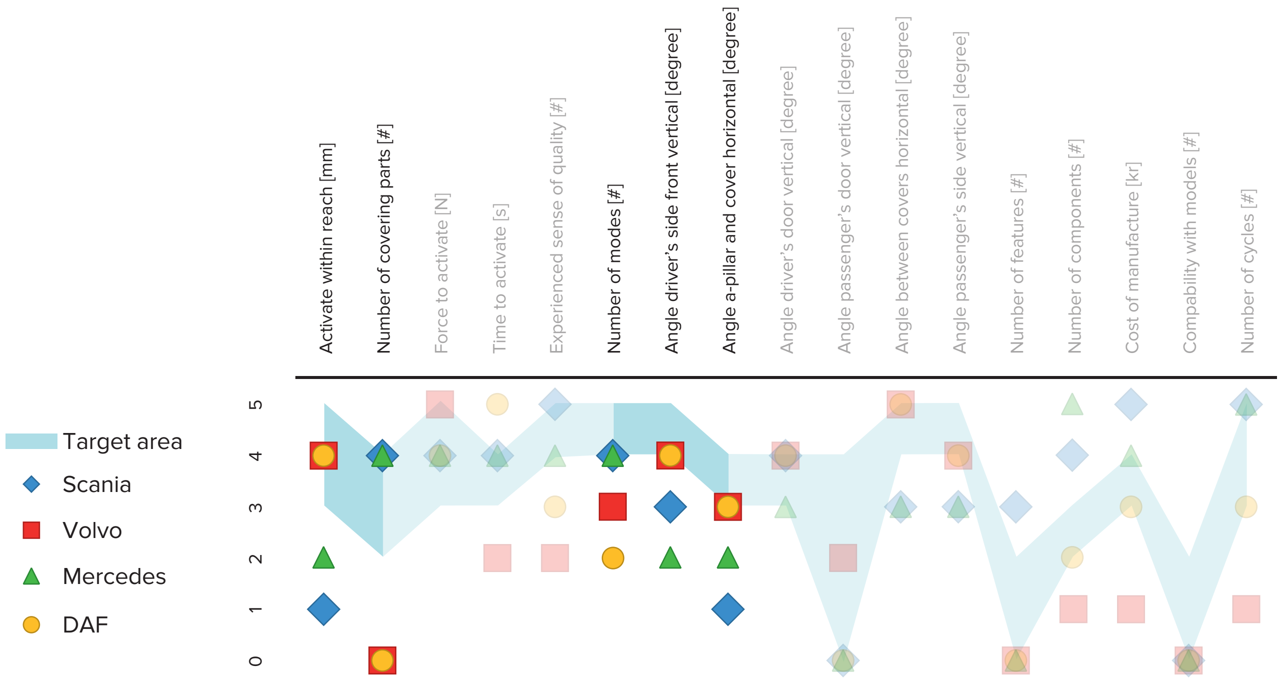

Figure 47 Truck performance in relation to functional requirements.

The complete matrix is attached in Appendix F.

5 Concept

In order to organise the concept generation work as effective as possible within the time limits of the project, the five-step method described in 3.4.2 Concept Generation was used as a basis. The concept generation was also focused on generating solutions that solve the problem areas identified in the pre-development and from the professional driver's point of view.

5.1 Implementing the five-step method

The concept generation method used in the project consists of five steps by Ulrich and Eppinger (Ulrich & Eppinger, 2008, pp. 99-120) and the results from these steps are described below:

Step 1
The problem with sun glare was clarified further to get a deeper understanding of the critical subproblems. In this case, it narrowed down to these main areas: reachability, vertical cover for short drivers, parted solutions (as opposed to one-piece blinds), gap around a-pillar on driver's side and gap on passenger's side

Step 2
A benchmark was made on similar trucks within the same range as Scania Topline to compare existing solutions and map their strength and weaknesses. Experienced drivers from Scania Transport Lab were also a great source of knowledge during this step through their experience of the cab environment. A lot of the knowledge gathered through articles and literature was also helpful, often in being able to limit and filter directions.

Step 3
Knowledge within the project was created through idea generation and refined in iterative sessions of concept generation. Much of the knowledge that had been external (unknown to the project members) earlier had now been internalised.

Step 4
Solutions and ideas from the idea generation process were organised in a Classification tree. Similar ideas and solution of the same problem were gathered at the same branch of the tree. Classes and themes were regularly gathered and slowly delimited or steered away from.

Step 5
The fifth and last step of this method means time to reflect on the solution and the process. The project should question the quality of the solution and whether there are alternative ways to see the problem. These kinds of reflections were made regularly, but especially during the final stages of the concept generation phase. Earlier reflections focused more on improving the process and thereby hopefully improving the final output. This was connected to the 2-week sprints that divided the project into shorter segments.

5.2 Idea generation

The dedicated idea generation phase began many weeks into the project. It followed activities that had been examining the problem both physically and through literature. This process created many ideas that were stored for later use, but at the time suppressed to keep them from forming solutions too fast.

5.2.1 Brainstorm

Based on the problems and subproblems identified in the first step of the five-step method, a phase of brainstorming was initiated. The listed subproblems served as inspiration when ideas were developed through the brainstorming, and later, sketching. Functions responding to chosen parts of the problem were focused on one at a time. By doing this, ideas on solutions exclusive for a specific problem, not depending on other parts or even the main idea, were created. Many of the ideas from the brainstorming were developed into sketches, some more feasible than others. Figure 48 displays a selection of sketches from varying stages of early development.

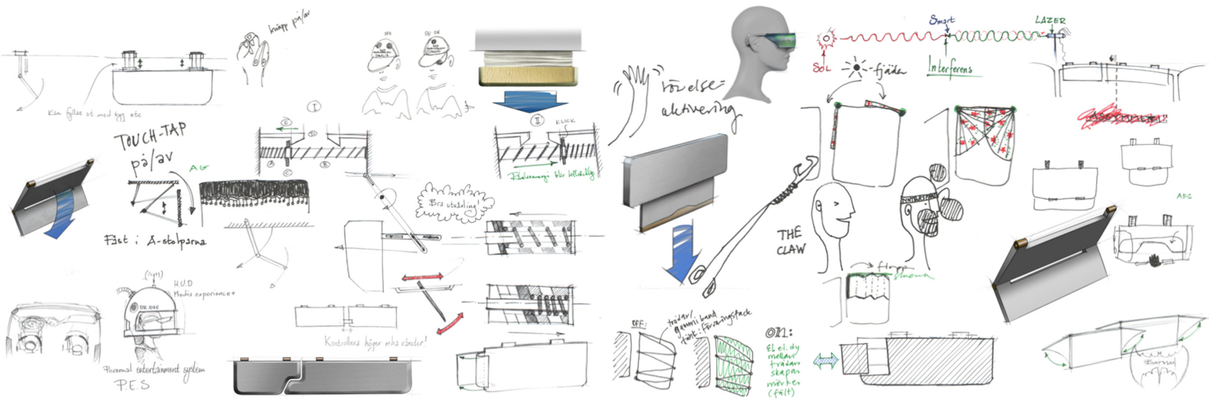

Figure 48 Outcome from the brainstorming sessions.

The different kinds of solutions could then be combined into a complete solution to solve the overall sun glare problems. Samples of how the sketches were organized into different categories are shown in Appendix G. The ideas that were chosen to be developed further and to be evaluated by professional drivers are presented below.

5.2.2 Choosing direction

All throughout the development choices were made regarding direction and limitations. A couple of the most important separations are illustrated in Figure 49. There was always a wide scale going from lo-tech to hi-tech. Concepts appearing in the near vicinity of or even on the driver were also plentiful. Solving the problem from outside the truck, or even in space, did not generate as many suggestions.

Due to events unfolding at Scania during the development phase, a direction was chosen that put the concept very near the current solution. To be able to comply with the delimitations set before and during the project (see *1.5 Delimitations*) the solution should be possible to implement within five years. Some of the developed solutions were therefore discarded as non-compatible. Other ways of solving the sun glare problem were iteratively generated and developed further from the brainstorming sessions.

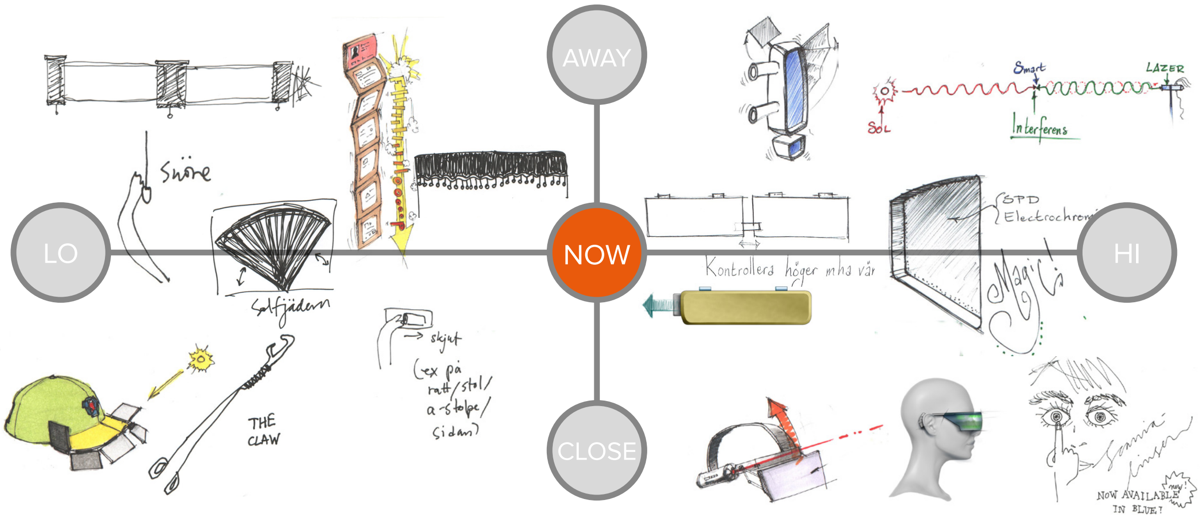

Figure 49 Separations of concepts into groups. Lo-tech, hi-tech and distance from driver.

5.2.3 Concepts that minimise sun glare for drivers

These concepts are all based on the shape of the existing sun visor but have various improvements and alterations. The decision to keep the existing shape of the sun visors as a base for a new concept was made in order to keep the robust feeling Scania aim to have on all their products. The first solutions are equipped with a pull down function to cover vertically, the following ones with an extracting device to cover the gap by the a-pillar and the last solutions reduce the problem of reaching the cover on the passenger side.

Vertical angle from driver's seat

This issue was proven to be a non-issue to most drivers. Both the questionnaire and benchmark tests showed this. However, a couple of the respondents to the questionnaire, as well as the shorter person experienced major problems with current solutions. This is therefore a highly prioritised issue. Concept 1 is activated as the classical sun visor and can as a further step be pulled down, exposing a curtain or blind of undecided fabric, see Figure 50.

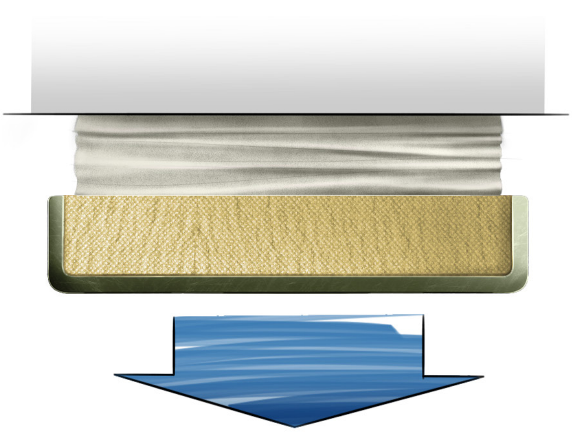

Figure 50 Concept no 1

Concept 2 is a hinged solution in the same shape of the existing sun visor, but instead constructed out of two parts. What differentiates this concept is that it is possible to fixate the joint in different angles according to the driver's preferences. By being able to adjust the angle, and therefore lengthen the sun visor, short drivers might benefit from this solution. A major improvement is the fact that drivers can activate it fully by using one hand in one single motion. Other multi-step concepts rely on two actions where the second often requires the driver to lean forward out of normal reach. Concept no 2 is shown in Figure 51.

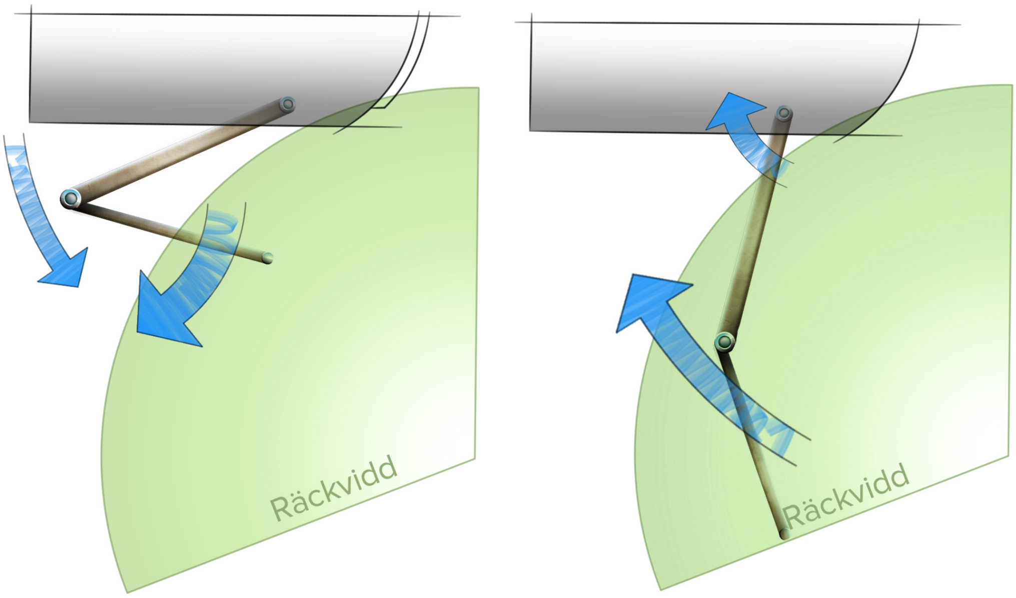

Figure 51 Concept no 2

Another way to achieve the extension is to make a smaller blind that is built-in into the primary sun visor, Figure 52. This solution could be constructed in several ways using different materials.

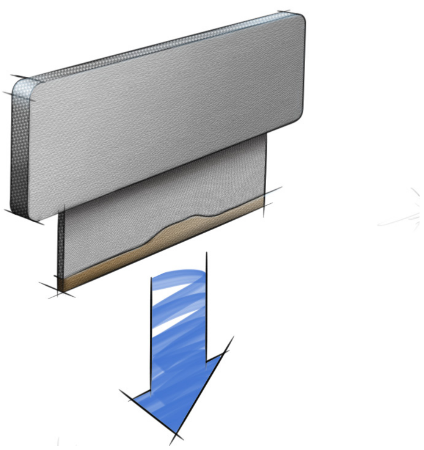

Figure 52 Concept no 3

The extended piece will not take any additional space beyond the original sun visor. It is activated by the driver who is reaching the handle on the lowered visor and pulling down the extension.

Gap around a-pillar

Concept 4 has a rotating device on the outer side of the driver's sun cover that the driver activates when he/she finds the glare disturbing, Figure 53.

Figure 53 Concept no 4

The activating part in concept no 4 is inspired by a fabric hand fan with its great storage properties. Just as a fan it can easily be folded to fit into a very small space and still create a great volume when unfolded. The device is stored inside the visor and could be activated in several different ways.

Another way of solving the a-pillar gap problem is concept no 5 with its solid extruding part that is activated in a sliding fashion, Figure 54.

Figure 54 Concept no 5

The piece that elongates the sun visor is hidden on the inside when not in use. It could be activated in several, for example by "press-click-extract" or with an external handle at the bottom of the sun visor that is manually drawn horizontally to the left and links to the inner extraction part. Another option is to have it activate automatically alongside the visor. This would minimise the actions required by users.

Enable activation of Sun visor on passenger side

Concept A is a parted sun visor where the driver's and the passenger's units are equally sized. Activation of the passenger visor is facilitated through a locking mechanism that connects it to the driver's sun visor, Figure 55. This way the driver can operate both visors.

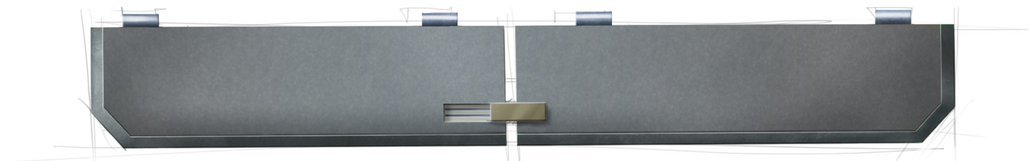

Figure 55 Concept A

The driver no longer needs to bend over in a hazardous way while driving but simply grab the nearest sun visor and attach the other. This could for example be further assisted with a magnetic mechanism that simplifies the activation process.

Making sun visors of different width eases the activation of the passenger's unit. Concept B shows how an asymmetrical visor solution could look, Figure 56.

Figure 56 Concept B

The right visor visualized in Figure 56 is made wider than the left one. The driver can without effort reach not only the front visor but also the visor on the passenger's side. These kinds of visor do not require any other mechanisms than those of today.

A third way to ease handling of the passenger visor is to incorporate both into the front visor, Figure 57. The driver can use only the front visor, and if needed, fold out the other plate to cover from glare coming from the right side of the truck. By doing this, the precipitated part can be set in the angle that suits the driver the most.

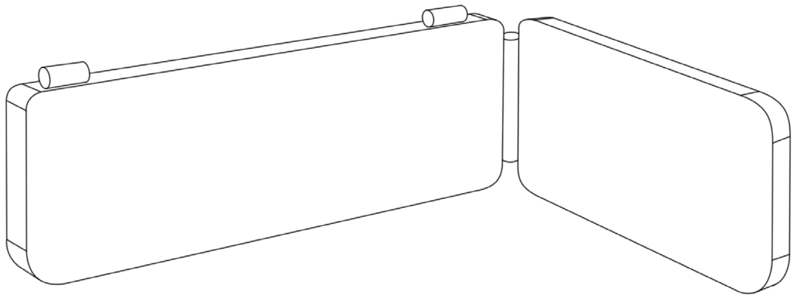

Figure 57 Concept C

Since the foldable part is stored together with the driver's sun visor it will not use any space in the roof shelf on the passenger side.

5.3 Prototyping and testing

In the middle of the concept generation phase, a full-scale model of the interior of a Scania R-cab was constructed. This helped the project visualise the driver environment and see possibilities and also limits within the cab. The model is seen in Figure 58.

Figure 58 The full-scale model of the driver's environment in the Scania R-cab.

The simple cab model was primarily used as inspiration during the stage of concept generation, to picture the environment in a way other than from the inside of a fully equipped Scania R cab. Being able to cut through and work within the otherwise hard roof shelf provided valuable to testing some of the prototypes.

In a latter period, cardboard was also used to make the prototypes. It was chosen because of its material properties: it is lightweight, stiff and easy to cut. Cardboard could be used in ways that remind the user of the plastic material used in sun visors today. The first prototypes were made very simple and the second round of prototypes more detailed with rudimentary, yet working mechanisms for users to evaluate.

5.3.1 First round of prototypes

A first generation of prototypes was made to experiment with simple mechanisms such as joints and sliding features. Different means of locking and unlocking movements were similarly tested. Important measurements of existing ideas were modelled and varied, but no full-scale models were constructed. The most important knowledge gathered at this stage was how to build a prototype out of cardboard and tape that would mimic the movement and rigidity of a manufactured component.

5.3.2 Second round of prototypes

These concepts all focused on how to solve the identified issues with the vertical angle for short drivers and the gap between the a-pillar and sun visor at the driver's part of the cab. Since this is a user-centered product, the users evaluated the concepts through external decision. This means users' are part of the decision process (Ulrich & Eppinger, 2008, pp. 125, 128). The benefits and drawbacks of these concepts were determined with help from drivers at Scania Transport Lab. All participants had long experience of trucks and are employed by Scania. Concept 1-5 were turned into simple prototypes: three concepts examining how to lengthen the sun visors for short drivers and two that minimised the gap between a-pillar and sun visor. Concepts A-C were not considered appropriate for testing at this stage; they were either too complex or more dependent on physical features that are better examined in a cab environment.

The ideas were discussed and evaluated by gathering around sketches and testing cardboard prototypes, Figure 59 to Figure 63. Drivers were also asked if the concepts had the robustness and the Scania feeling and if they believed the solution could be implemented in a Scania cab.

Figure 59 Prototype of concept 1

Figure 60 Prototype of concept 2

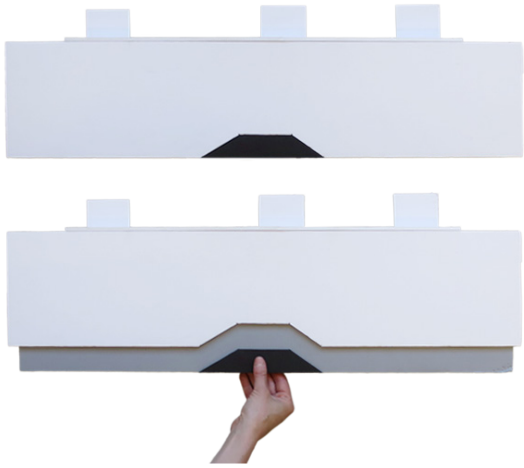

Figure 61 Prototype of concept 3

Figure 62 Prototype of concept 4

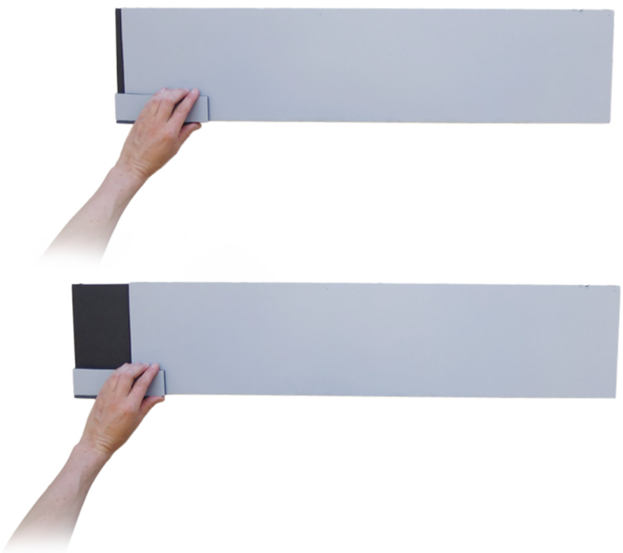

Figure 63 Prototype of concept 5

The drivers' general opinion was that "the less fuss the greater solution". Mixed material, as in Concept 1 and 4 was rejected. Concept 1 was described as something from their grandparents' time. These opinions could however be sprung from material choices and construction of the prototypes in question. Concept 1, for example, could be fitted with a roller blind similar to the ones that many drivers favour above anything else. A second generation prototype would in this case provide input with less distraction coming from the simplified construction.

Drivers did not find the gap between a-pillar and front sun visor as disturbing as the inability to lengthen the visor downwards and therefore chose that the project would develop Concept 3 further. The test group stood united in the opinion that a visor with an extendable component with the width of the sun visor could help especially short drivers. Concept 3 was described as simple and easily accessible. The two prototypes extending to minimise the gap vis-à-vis the a-pillar were deemed to make the product too cluttered. An additional action extruding the visor downwards was thus accepted, while at the same time rejecting a horizontal action extruding towards the a-pillar. A suggestion to make the extruding action automatic would probably be acceptable.

Concept 2 was considered a good idea since one action could activate and extend it a very long distance. Questions were raised regarding having something pointing at a very steep angle so close to your eyes. The folding structure also results in a very large gap near the a-pillar.

No prototypes were brought that solved the issue of reaching the passenger's sun visor. An animated discussion was instead held around the sketches that were brought illustrating the concepts A and B. None of the drivers could actually reach existing visors. A common method was to activate them during a red light. The asymmetrical solution was accepted without much discussion. Perhaps it would look odd? No one had previously seen or used an asymmetrical sun visor. Controlling both visors with the one in front of the driver resulted in a more nuanced discussion. A lot of emphasis was put on the importance of the mechanism and details of such a solution. It must not in any way appear clumsy in the way it operates. Robustness and sense of quality would also be a primary concern.

This time, like every meeting with drivers, the passenger's role was discussed. Especially when evaluating the asymmetrical solution the question was asked if the passenger would now control a larger portion of the forward view. But none of the drivers have ever accepted the passenger's role in the cab, instead explaining that driver goes first and passenger sits quiet.

5.3.3 Concept direction

Based on evaluations by drivers and further input by Scania, decisions could be made regarding the future direction of the project. Meanwhile, the QFD was revisited to help refocus on requirements that were of most use and importance.

The selected direction focuses on improving reachability of the passenger's visor and also improving the vertical height covered. Minimising the distance between visor and a-pillar will not be further examined, other than maximising the sun visor's size; current generation cabs are equipped with unnecessarily small visors. The extruding mechanisms and folding features will be put on hold to prioritise the selected direction.

5.4 Final concepts

Two concepts were further examined, both aiming to keep very close to the existing sun visors. Their primary function is to facilitate the handling of the passenger's sun visor. Earlier Concept A and B, from now on referred to as *Spring clutch* and *Asymmetrical*, are visualised in Figure 64. The former controls the passenger's visor by automatically locking it to the driver's while the latter displaces the separating line closer to the driver.

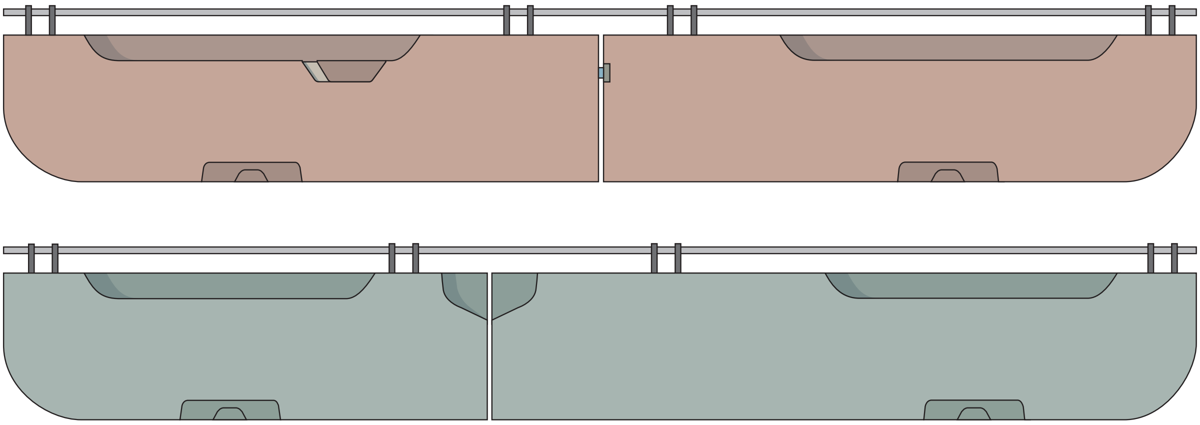

Figure 64 Spring clutch, (red), and Asymmetrical, (blue).

The Spring clutch concept works by a hidden mechanism that might need a short explanation. Figure 65 highlights the main handle that is used to either lock or unlock the passenger's visor. It works similar to a clutch. At the end of a rod is a spring mechanism that locks the two visors together whenever they pass each other and the clutch is set in activated mode. When users move the handle to the left position, no locking action occurs. This is also the procedure required to deactivate already locked visors.

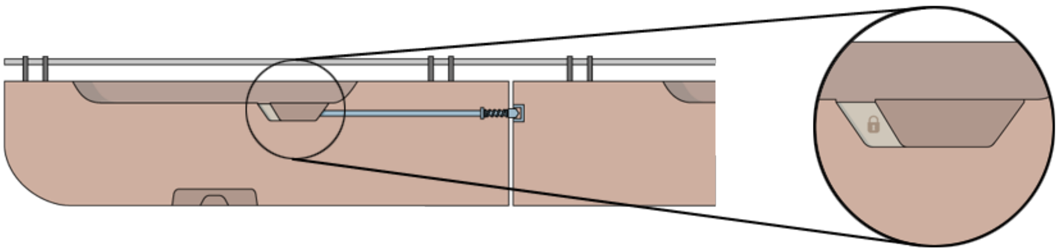

Figure 65 Detail explaining the basics of the locking mechanism. The picture illustrates the locked mode.

Both Spring clutch and Asymmetrical are able to accommodate the already chosen Concept 3, employing a downward extruding component. These two concepts were built as full-scale cardboard models and mounted inside an actual Scania cab to be evaluated as described in "Prototype and test", by Ulrich and Eppinger. (Ulrich & Eppinger, 2008, p. 125). The models are shown in Figure 66. Backgrounds have been edited to minimise the risk of sensitive material being displayed, unfortunately eliminating any indication of scale (except the hand). The total length of the prototypes is slightly less than 2 meters.

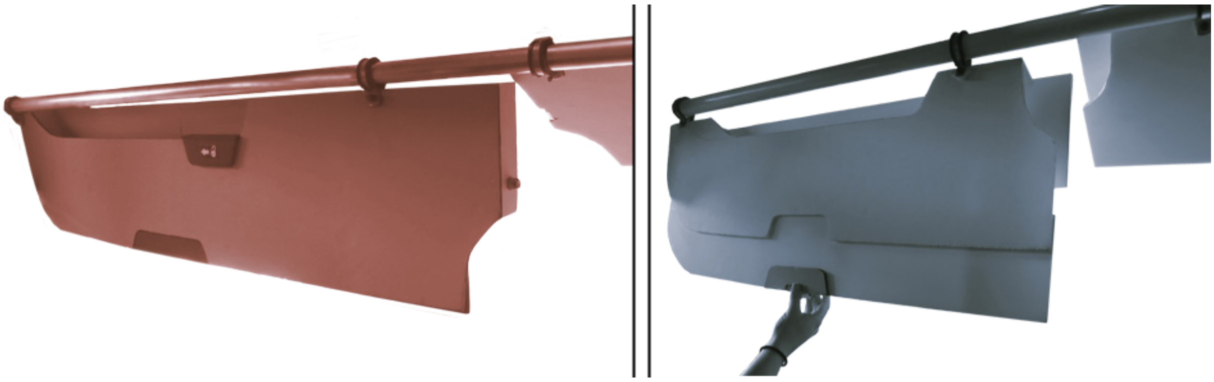

Figure 66 Both concepts mounted in the context of a cab.

5.5 User tests

A total of eight test persons were asked to try out the prototypes and rank several attributes/properties of the concepts. This served as a base for the evaluation of the ideas. The user's way of interacting with the prototypes was observed and documented. Heavy focus was put on discussion and suggestions to improvements for the two concepts. User opinions about the prototypes are listed below:

Asymmetrical

- Some users have to stand up in order to reach the passenger visor
- The upper body is often turned and have to be pushed away from the seat to be able to reach; might jeopardize vehicle control momentarily
- Too high friction
- Great handle. Natural angle
- Do not see any aesthetical problems with the asymmetry
- Increase angle of the contact surface
- Feels a bit dangerous if activating while driving
- Good angle where you turn down the passenger sun visor, no need to turn the arm, which eases a lot!
- Feels similar to a car
- Clean and neat

Spring clutch

- Feels “new”
- Has the Scania feeling
- Not completely intuitive how to make it stop
- Good for drivers with big bellies, no need to bend forward over steering wheel
- The design of the handle to attach entices the user to use the whole hand, not a “thumb grip”
- Place the handle more in the center
- Wishes two steps: on/off
- Likes the concept with attachment
- The attached part should not be activated from the beginning
- Easy to reach, nice to not try to reach the passenger sun visor
- Easy to use

The extended part inside both solutions was installed in the prototypes and therefore evaluated once more by the test users. General input about the extended part was that the function felt autodidactic and robust. The users experienced great coverage on the sides, especially shorter people, but suggested that the activation button should be made for the thumb only. They were positive to the fact that it is hidden within the sun visor; it gives it a clean look without unnecessary additional material that might distract the driver. Observations of the users are similarly presented below:

Asymmetrical

- No question as to how the activation process is performed
- Still some amount of reaching and balancing, but big improvement compared to symmetrical solution
- The angle of the contact touch point is essential to balance the force required
- The cut out area must not be too small on the driver's side to properly accommodate access to the passenger's visor
- Cut out further moves the contact area away from the user. Larger cut out means longer reaching distance

Spring clutch

- Difficulties understanding the locking mechanism the first time using the prototype. Attached icon helped
- Prototype seems to balance on the edge of feeling a bit fragile, possibly affecting user input. User's don't know how much force can be applied
- Friction inside the mechanism makes it difficult to manoeuvre
- Varying ways of gripping the main handle. Should preferably be controlled by shape and execution
- Predefined set of actions helps instruct the user through the test
- Visor manipulation is easy when user has understood the mechanism
- Spring pulling the handle into locked position is confusing and perhaps unnecessary

Observations regarding the extendable blind were also made. As opposed to the Spring clutch handle, experiencing a number of different grips, everyone operated the blind and it's locking button in a similar fashion. The same grip with a natural position of the thumb on top of the button was observed throughout the users. Size and shape of the button could be modified to improve the contact area. The small shape was more due to technical reasons.

The test persons ranked both solutions and the result is shown in Figure 67:

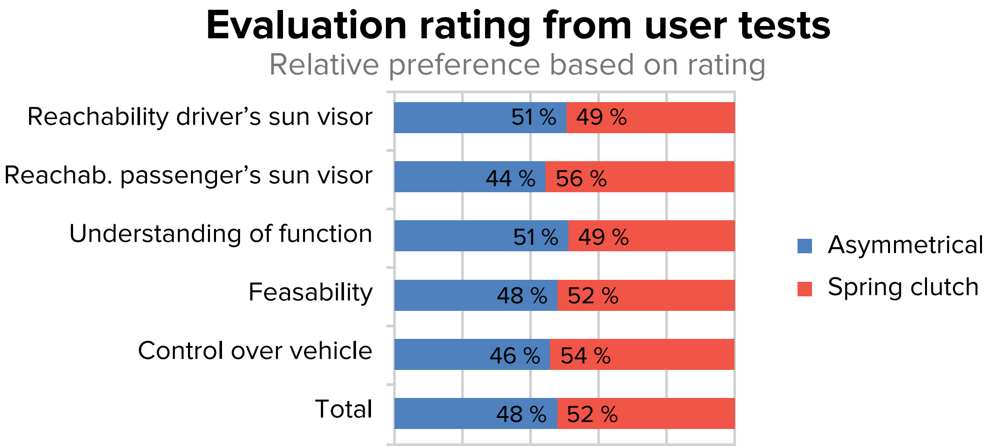

Figure 67 The rated properties of both concepts.

Since the test persons ranked both concepts very similar, the concepts were also rated by the project in a QFD. The same QFD that compared the trucks in *3.2 Benchmarking* was used for this purpose. The estimated results are presented in Figure 68 below, where the star symbolises Spring clutch and the triangle is the Asymmetrical concept. The light blue area represents the target area that was set at the beginning of the project.

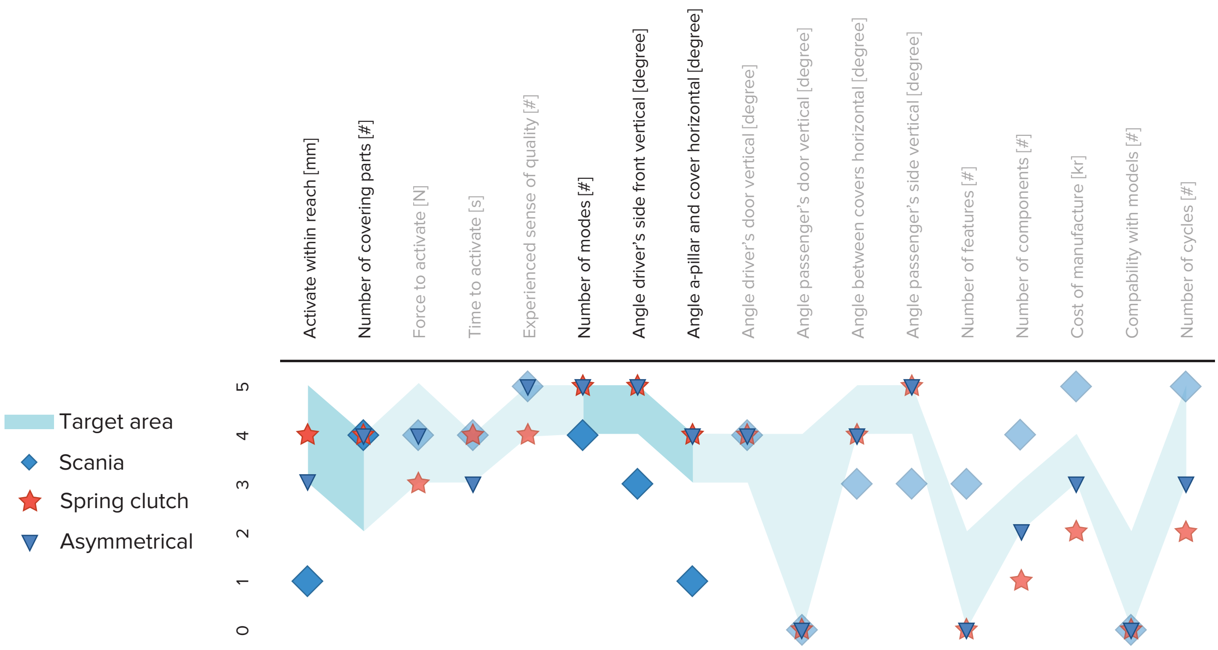

Figure 68 Spring clutch and Asymmetrical concepts compared to the current solution.

5.6 Conclusions from evaluation

The preferred concept, based on evaluation questions, observations and performance comparison is Spring clutch. The quantitative user evaluation was a near dead race between both concepts. The output from the QFD shows that Asymmetrical gets an overall higher score but Spring clutch performs better on two highly valued user demands; it can be activated within reach and the time to activate both sides is considered shorter. The differences are very small, but at the same time very important. This sort of result is a direct consequence of working so close to already existing products. One point in the QFD matrix can mean a great deal in reality.

Observations and general comments made during testing also served as important guidelines. Several users described the Spring clutch as a new and edgy solution, something that the existing sun visor was missing. This was defined as part of the problem in *1.2 Problem definition* and an aspect that speaks in favour of the new concept.

Findings and conclusions regarding both concepts are presented below.

5.6.1 Findings – Asymmetrical concept

The dividing line was moved 190 mm from the previous line of symmetry, as seen in Figure 69. This measurement was developed from the previous observation on the reachability of the short person that was made during the evaluation of the trucks. Stretching to this point on the roof shelf was the maximum possible distance before the movement became inconvenient. The addition of the cut-out to accommodate a grip moved the actual point of contact back again a few millimetres towards the symmetry line. This was not accounted for when the prototype was made. Reachability was still acceptable, but the shorter person could have benefited from moving the dividing line a couple of millimetres closer.

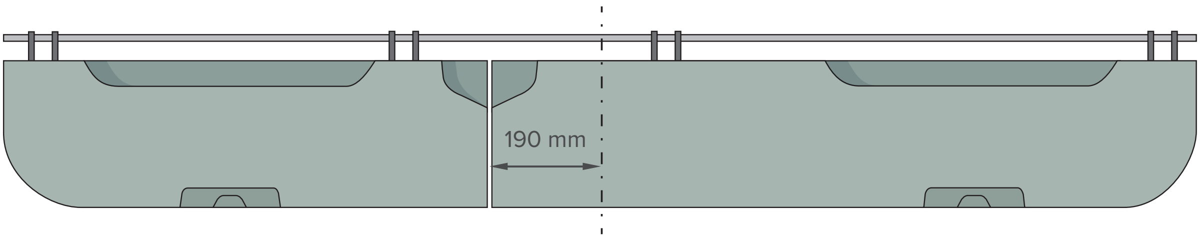

Figure 69 Distance between dividing line and symmetry line.

The most important feature, apart from the actual position of the dividing line, is the grip that enables users to activate the passenger visor. This piece of geometry was discussed and tried on a small scale before constructing the final prototype. Through examination of arm and hand direction, the shape shown in Figure 70 and previous illustrations was chosen. It is desirable to keep the hand at an angle such that it is lined up with the rest of the arm; especially during the first moments of the activating movement. Enabling the use of your body to pull down the visor helps – as opposed to using your arm. Pulling strength can be limited at these angles can be severely limited, as show earlier in *2.5.2 Strength*.

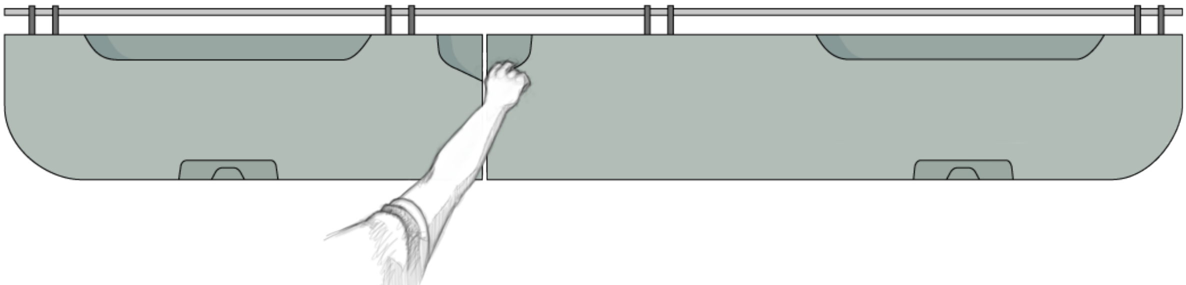

Figure 70 A suitable contact surface is preferred to reduce user discomfort.

Various forms were discussed. The chosen angle and relatively large cut-out proved fortunate. A concept similar to the one on the right in Figure 71 was in question, but such a shape had limited access to the actual contact point. Other ideas would force the user to grip either horizontally or vertically.

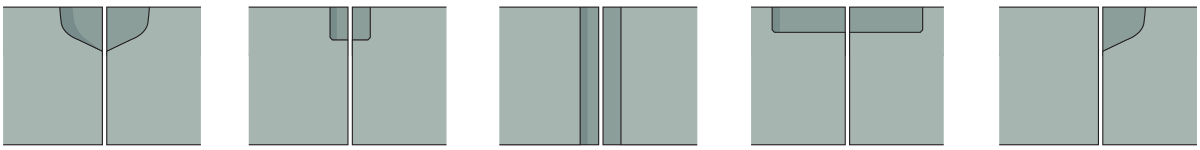

Figure 71 Many cut-out variations can be used. Alternative on the far left was preferred and also used in the prototype.

Moving the dividing line away from the symmetry line also affects the way sun visors are used. Figure 72 below illustrates the two situations. If we postulate that the green zone (d_{sym} and d_{assym} respectively) is the single most important area for the driver when creating a good visual environment; it then follows that this zone should be kept as free from disturbances as possible. As a natural consequence, the sun visor (d) in front of the driver should be activated as seldom as possible. Not only does it prevent the driver from reading signs, it also affects the experience of space and volume in the cab.

By making the driver's visor smaller and the passenger's equally larger, the area directly in front of the driver can be kept clear from disturbances *more often*.

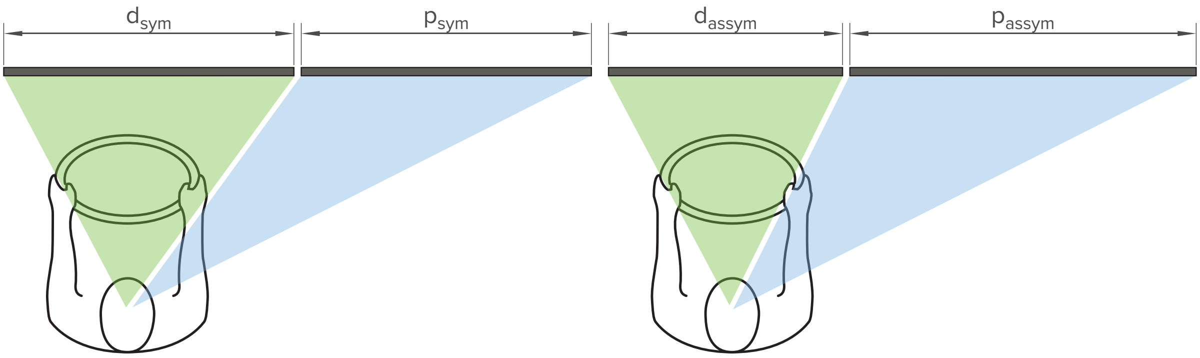

Figure 72 Angles covered by the sun visors, both in a symmetrical (left) and asymmetrical (right) setup.

5.6.2 Findings – Spring clutch concept

One of the most debated features of the prototype evaluations was the main handle controlling the Spring clutch concept. Observing users created a lot of valuable input. First, it should be noted that the prototype was constructed in such a way that a spring pulled the handle into the locked, right position. If users wanted to deactivate the clutch, a force had to be applied to pull the handle left. This spring mechanism was necessary to overcome the force generated by the spring actually locking the two visors together. Figure 73 illustrates the two states and the hidden mechanism attached to the handle.

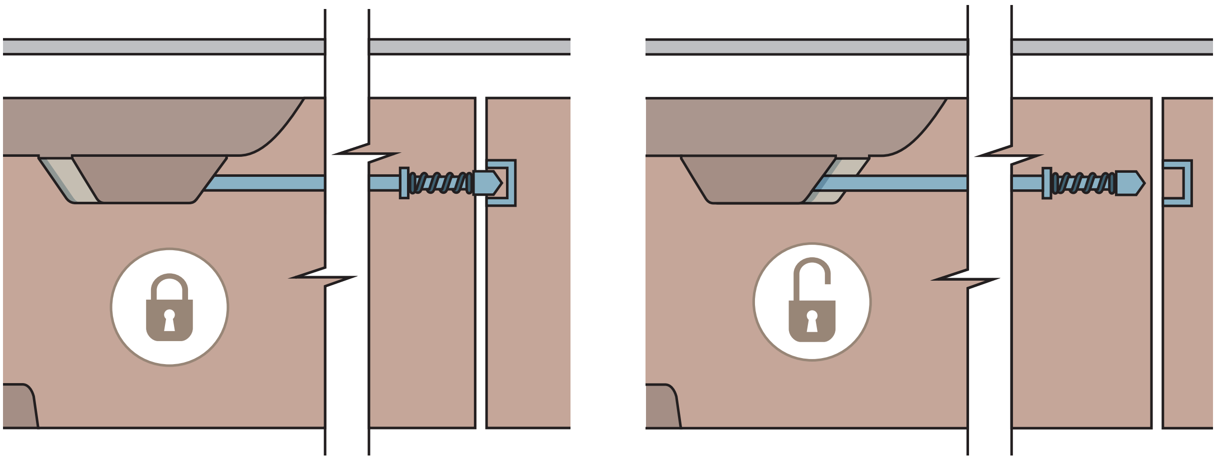

Figure 73 User chooses one of two states.

It was decided that the handle should be in the right position when not manipulated by users. The illustration in 2.5.2 Strength shows that a person is stronger when pulling the handle to the left than in the opposite direction. With a reversed setup, users would have to apply outward force to the right and at the same time control both visors since they are then attached to each other.

Among the most requested features was to get rid of the spring pulling the handle in one direction, and instead just having two modes that can be set. If the driver never uses the passenger visor, the handle will always stay in the unlocked, left position. This idea is of course superior, and something worth testing without the limitations of cardboard prototypes. The only obstacle is overcoming the force applied by the spring clicking into position and locking the visors. With a properly constructed system, this force would be reduced substantially.

Another interesting point was the gripping technique employed by users. Two primary methods were used: one using a thumb and the other setting a firm hammer grip around the handle, both displayed in Figure 74. It was discussed whether the shape and colour of the grip affected users approach to manipulating it. As it was, the handle was constructed around and on the outside of the visor's surface. A solution that puts it in line with the surface would probably make it look less like a bulky rubber handle.

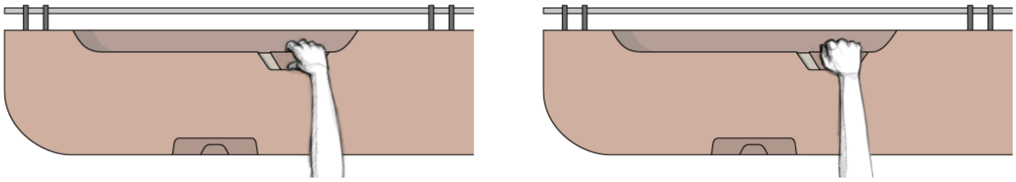

Figure 74 Thumb grip and hammer grip.

Several testers used both grips – adapting them to different situations. When activating the visor, the thumb grip was often used; probably due to the more natural angle of arm and hand. Deactivating the visor often resulted in users applying the hammer grip to better push the visor. These observations were not consistent and some users simply switched back and forth at random.

Unlike Figure 75, the prototype was fitted with a single icon picturing an unlocked padlock and an arrow indicating an unlocking motion to the right. This proved valuable in helping users understand the required task. A handle placed in line with the surface of the visor would probably not need the arrow; padlocks themselves indicate a second state being available.

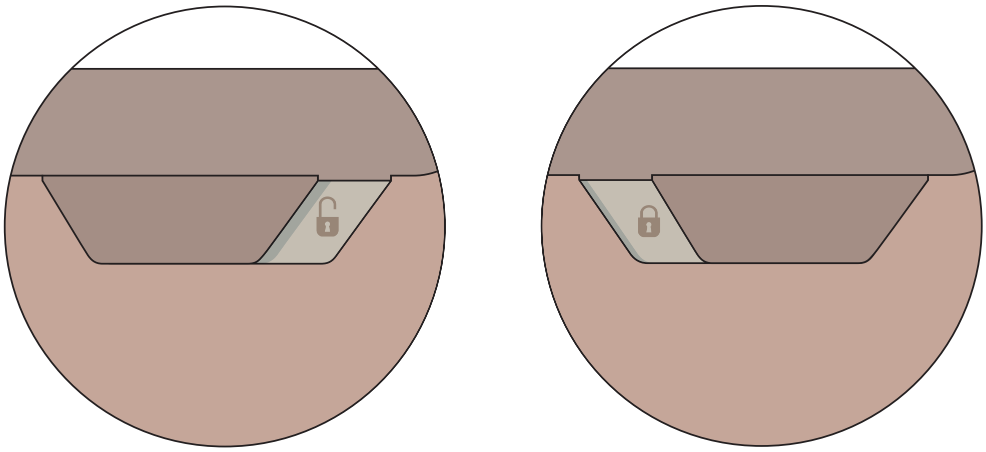

Figure 75 Illustrations indicating clutch states.

5.6.3 Findings – Pull down blind

The grip used to manipulate the pull down blind worked more consistent than the one main handle previously discussed. Everyone used the same grip, placing their thumbs on the designated button allowing vertical movement. A system preventing the blind from moving vertically was constructed to keep it in place in case of sudden impacts caused by bumps in the road. Figure 76 illustrates the downward motion of the blind.

Figure 76 The blind is activated by first pressing the release button.

At first a system depending on friction was tested. This proved unreliable and balanced just on the edge of dropping the blind. A step-based system was instead implemented using a rack and a gripping tooth. The new system was a lot more reliable and almost as seamless as the previous one.

One important insight had been the difference in gap length between a-pillar and visor, depending on driver's eye height. With the pull down blind, the large gap experienced by short persons is reduced as illustrated in Figure 77.

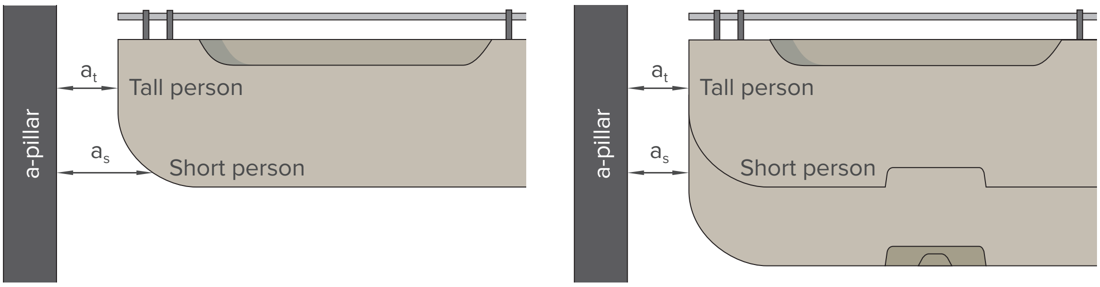

Figure 77 Gap before and after activation of blind.

5.7 Favored concept

The Spring clutch concept was favored after user tests and internal evaluations. Despite a seemingly neck to neck result against the Asymmetric concept, the two most important features (reachability to passenger side and control over vehicle) were the ones where the difference was the most prominent. Even more so when discussing the issue with users, instead of simply following the input given through their evaluation sheet. A small lead might at the same time indicate a significant difference. This since users compared the concepts against each other and often gave the better solution just one or two points more than the other.

6 DISCUSSION

This chapter is divided into headings more or less following the chronology of the report. The iterative nature of later parts of the project makes it difficult to isolate a subject to a certain time and place. A set of major headings therefore separates this chapter into themes.

6.1 Process

The project was organised according to agile principles that had been acquired last semester at KTH. In retrospect, this way of working proved valuable both to keep the project running, and also to guide it in the, hopefully, right direction. The approach of many small deliveries instead of just one final "ultimate concept" helped making sober decisions regarding where to put the effort.

Had this been a larger project involving more project members or even subgroups, the agile methodology could have proved even more valuable. With only two members it often feels superfluous. The bi-weekly reviews are perhaps not crucial when everyone already knows everything, but they contributed to a feeling of finishing small deliveries and starting from a fresh page.

6.2 Theory

A large portion of the work was directed towards gathering knowledge on the various implications of glare. It early became obvious that Scania did not have the deep knowledge that the project thought perhaps could be of use. Following the agile mindset, studying glare and how it is measured was considered a standalone delivery. Initially, there was an intention to employ this knowledge later in the project. In many ways it instead became an examination of whether Scania would benefit from the methods used by scientists or not.

6.2.1 Methodology

In conclusion, the company would not benefit much from adopting the methods examined. Some approaches, like measuring physiological input from users performing various tasks, would be fairly simple, and in many cases useful, to embrace. Others, like measuring glare using cameras, require too complex preparations and generate results of no actual value. Especially in the environment within a truck; most experiments focus on small lights in a controlled environment – for a reason.

If and when smart glass becomes a viable alternative, some of these methods will be a necessity. One problem is the scientific community's lack of unity. An established standard of measuring glare would be proved valuable. A challenge faced by many working with human factors is the often subjective or undefined arguments that must be used against departments armed with hard facts and numbers. Any method or standard would therefore prove a vital weapon.

6.2.2 Statistics

Numbers and statistics proving the dangers of glare were found and should be considered by anyone with responsibility over the larger priorities. People die because drivers are subject to discomfort or even disability glare and several sources have demonstrated this. A problem with any data like this is the ambiguity over what actually caused the accident.

6.2.3 Smart glass

The possibilities of smart glass were examined with the intent of performing user tests and hopefully seeing it through as a concept. Recent development makes the product a highly likely feature of future trucks. The situation might be such that the truck industry moves ahead of the car industry due to the more dire need. This of course requires the glare issue to be prioritised as a serious problem.

Manufacturers and patent holders all responded to the project's requests of receiving samples. Actually receiving samples required papers to be officially signed and stamped. This process was therefore put on hold. User tests would have proven fascinating but transmittance requirements would not have been met by any of the samples.

This product is still accelerating from an immature stage, something illustrated by the constant mix up between the various technologies. Regulations will have to adapt and update in order to facilitate a move towards smart glass. The way they are formulated today will cause confusion and unnecessary obstacles. Instead of measuring transmittance, the industry should measure visual performance. Is high transmittance always favourable? Not if disability glare prevents the driver from actually seeing anything. This is where a developed method of measuring for example readability through a window would be crucial.

6.3 User studies

Studies of and participation by users was a recurring and important activity throughout the project. Some instances proved more useful than others. A few resulted in minimal valuable input.

6.3.1 Questionnaire

First is the questionnaire that was sent out to respondents. The questions had been formulated together with drivers and by using early knowledge of the problem. Similar cases were studied and the most important conclusion was to keep it short and simple. Our efforts were believed to be successful in that a high degree of valuable answers were received. Still, many skipped certain questions or misinterpreted where possible. The mix of quantitative and qualitative questions meant that driver's opinions could be compared to the rankings and input. A large number of companies were contacted, but the project did not gather information that could be used to examine the sample population further. Smaller contractors were however more compliant than larger.

As the project approached final concept evaluations, a more extensive set of user input would have been beneficial. The activation process could for example have been split into several sub-actions, each being ranked independently. This would have required such a division being implemented as early as the questionnaire, when little was known about interaction with trucks.

User interaction studies

Several sets of small and large user studies were performed within the context of cabs. Among these are the final concept evaluations. A general theme is that observations provide powerful insight. Exploring peculiarities and sudden findings together with the subject was also an important source of findings. Flexibility and not sticking to the script was a key factor. Using predefined scales often resulted in confusion and answers susceptible to doubt and over analysis.

6.4 Benchmark

The benchmarking exercises were interesting in that way that a method, implementation and evaluation had to be developed. The measured data is still considered valuable and likely unique. Of even greater value is the judgement on whether the method is useful or not.

The principle is absolutely an important piece of knowledge that will hopefully be developed further. Results showed coherence between the two test subjects, although some interesting variation occurred caused by human factors. Any method used to evaluate products must be free from human dependence to be useful in the long run.

A rig measuring eye points in relation to the gas pedal is therefore recommended. A simple laser pointer mounted to rotate horizontally and vertically would enable one person to map a much larger set of data from the inside of the cab. No markings or sign language would be required and a detailed contour of the windows would be generated. This method would also enable a similar mapping of activated sun visors. A welcome addition since these are often curved. The largest possible sources of errors are presented below:

- Finding the correct eye position. Both height and horizontal coordinates. At least keeping them at the same height throughout the sessions.
- Parking the truck correctly. Results would otherwise be skewed. Patience is necessary.
- Consistency. Is everyone measuring from the same spot? Did the subject move during the session?
- Knowing what model and equipment is being mapped. Are there other variations? The team worked with flagship trucks, but these can still vary a lot. Everyone praised the Mercedes, but our came equipped with a completely different set of visors. It was also believed that all current Scania trucks came equipped with a pull down blind in the driver’s door. This was not true, as figured out later in the project.

6.5 Implementation

The choice of phrasing here helped define the final phase not only as a packaged result or outcome, but rather as a set of deliveries; each being with its own value, depending on the audience.

6.5.1 Delimitations

Further delimitations were set continuously through the project and especially during the implementation phase. This was due to a steady flow of new insights and the need to push the project forward. Some of these delimitations were defined to severely narrow the development. As an outsider, this might seem like cutting away all the good stuff; focusing on the small steps instead of taking the liberty of huge leaps. However, after immersing oneself into the problem, one can often find the most interesting challenges hidden in the smallest problems.

Some delimitations were set to keep the project interesting and in line with the educational framing. Would a theoretical solution involving smart glass be a fantastic solution? Yes. Would it pose a challenge or promote a valuable dialogue? Probably not. The same thing is valid for roller blinds. They perform well and are extremely popular among drivers. But such a project would only spend time inquiring a large number of people if they can, theoretically, move this or that component. The same problem would occur if a highly electrical solution would be chosen. Good solution, but a lot of moving around under the shell.

6.5.2 QFD

The matrix that managed to stay updated all throughout the project proved a reliable guide and compass. It would have proven even more valuable if the project involved a large group of members. The method is however something that would fit a group like RCDE whose task is in many ways analogous to that of the QFD: linking user demand and analysis with technical components.

At the end of the project it became evident that the original input should have been made more detailed. But this would probably have resulted in fewer answers. And a true matrix could be the subject of a project in itself.

The approach of not using absolute measurements but instead relative comparisons was truly helpful and kept the discussion dynamic. It also meant that every time the output graph was revisited, things were moved and changed. In a larger context, with numerous involved departments, this would probably cause problems. Being only two persons, it was rather a way of tuning the output as new input was added.

6.5.3 Concept

In this project it was interesting to develop a solution that was related to the solutions of today. The solution almost all drivers suggested was electrical curtains. This was never considered during this project due to the fact that curtains are considered an already well-functioning solution.

The greatest lesson is that a not-good-enough prototype is nearly as bad as no prototype at all. Test subjects, especially external ones, instantly react on the things that are not supposed to be discussed. Subjects that are themselves used to quick prototypes that require some imagination are a lot more forgiving in this situation.

The mock-up of a truck was not used extensively, but when it was it helped simulate mechanisms that would have been impossible to reproduce in built trucks. Later prototypes would not have benefitted from the hollow roof shelf so it had probably served its purpose anyway.

Users' understanding of the principle behind one of the final prototypes was often not instantaneous. Perhaps a more thorough description would have been useful. Observation of user's initial reactions would then not be as useful; these observations provided strong insights.

Users also compared the two concepts to each other and this might be a reason why they received so similar marks. Often, one was rewarded with just one single point more than the other to show that it was superior. An evaluation of more developed concepts, properly mounted, would have been very interesting. Using three concepts could also have given a more decisive outcome. Separating the evaluated features and mechanisms into several prototypes would probably have resulted in models closer to a final product. As it were, a lot of complexity had to be built in using relatively simple materials.

7 Conclusion

The project examined the science behind glare. It was concluded that the methods used by researchers are both too advanced and at the same time not competent enough to be of value; however, a number of definitions and concepts could be of use to anyone working with visual ergonomics.

If smart glass would become a viable option in the future, a great number of examined methods would become valuable as guidelines. Smart glass was evaluated and deemed as a likely future product, judging both by market increase and technology breakthroughs.

Benchmark and user studies quantified the current situation and provided a starting point for further development. All input data was gathered in a QFD matrix, a method that was prove useful in this sort of work where user demands are linked to complex products.

The concepts were chosen to comply with a short-term timeframe. Users evaluated the final prototypes in order to provide the project with insight and knowledge about further steps. Conclusions could be made about the activation process of the two concepts. One concept was preferred based on users' and the project's input although these evaluations indicated a close call between the concepts. Additional prototypes would be necessary to properly evaluate features such as activation force.

8 Future work

In this very last chapter, a few ideas and thoughts about possible future work within the field of sun visors are presented. It also includes some observations and suggestions that might be of value for developers working with sun glare solutions for trucks.

Truck drivers are the ones with most experience of the environment within the truck. Throughout the project, observations of drivers were made combined with interviews and very revealing discussions. RCDE is encouraged to continue working with their user-centered and perhaps even user-driven approach.

As a general recommendation, continuous and improved measurements should be made on trucks in order to stay updated with, and ahead of, the competition brands. Knowledge about the competitive situation is key to defining future directions. Ideas concerning improvements have been discussed with RCDE staff, and actual steps towards an improved method have in some ways already been taken.

All the information in the QFD could be valuable for further development of sun visors. It might serve as a baseline or be incorporated in existing methods. The content is however not as interesting as the method itself. Original principles and ideas governing the QFD matrix were defined to solve the same tasks that RCDE work with daily. This could be worth examining further.

Methods used by researchers studying glare should on the contrary probably be left to mature until the need arises. Such a scenario would be for example the evaluation of several types of coloured glass or smart glass. Keywords and definitions previously mentioned would be a first step of knowledge, before venturing into full-scale evaluations.

Since both concepts got very similar results in the evaluation, the suggestion is that continued development could be made on any of them; parts of them could also be combined or extracted. The prototypes within this project were of rather simple character and that might have affected the final concept choice. It is imperative that the evaluated functions are developed until they resemble a final-product-scenario.

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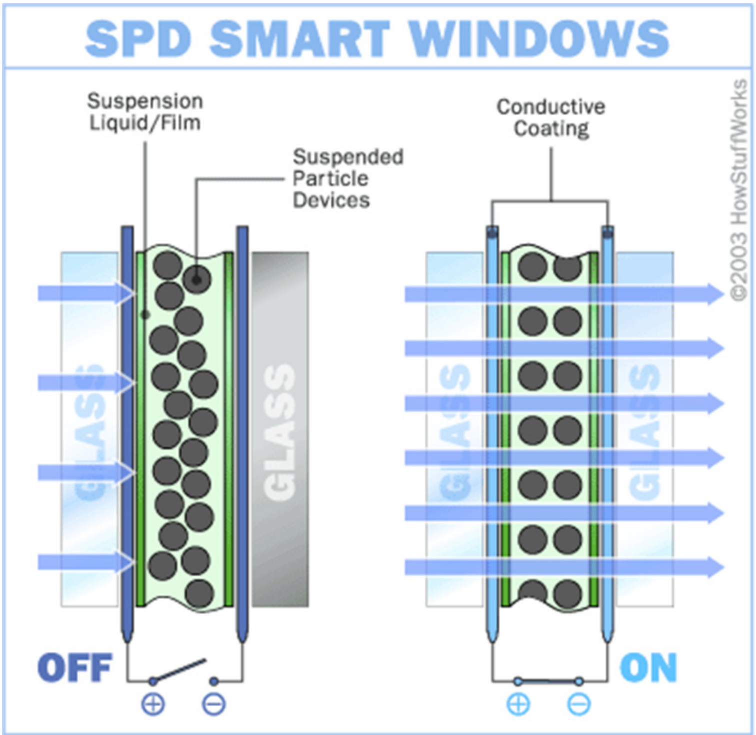
APPENDIX

Suspended particle devices

Many consider suspended particle devices (SPD) together with electrochromics to be the future of smart glass.

A large amount of very small particles are suspended in a liquid that is in turn sandwiched between suspension films and the glass or polymer casing. By applying a current through the conductive coating, the particles arrange themselves in a pattern that permits the transmission of light. This process is almost instantaneous up to three seconds. The current can be adjusted to vary the amount of light passing through the window. In its inactive state, the particles filter more than 99 % of UV light. SPD is used by Mercedes in their sunroofs and also in several airplane types. It is also energy efficient. One manufacturer claims that 15 large windows can be powered for less energy than would be required by a night-light.

SPD, which operate off an AC voltage or battery power, consume a very minute power of 0.05 watts/square feet maximum.

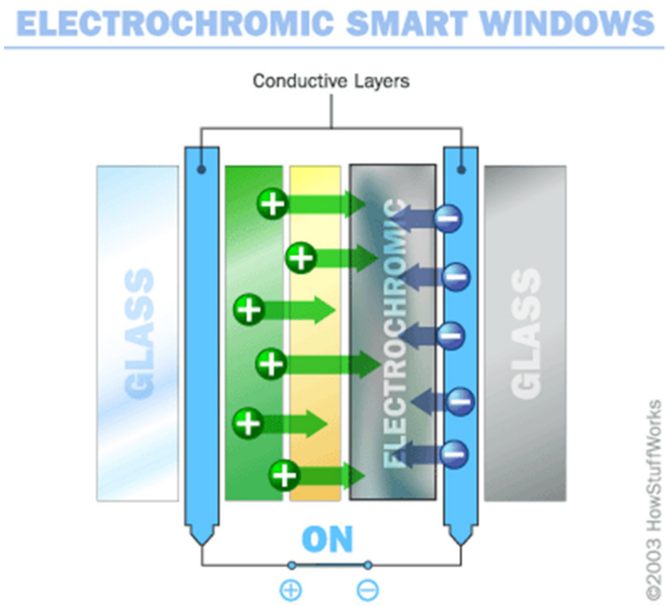


Electrochromic glass

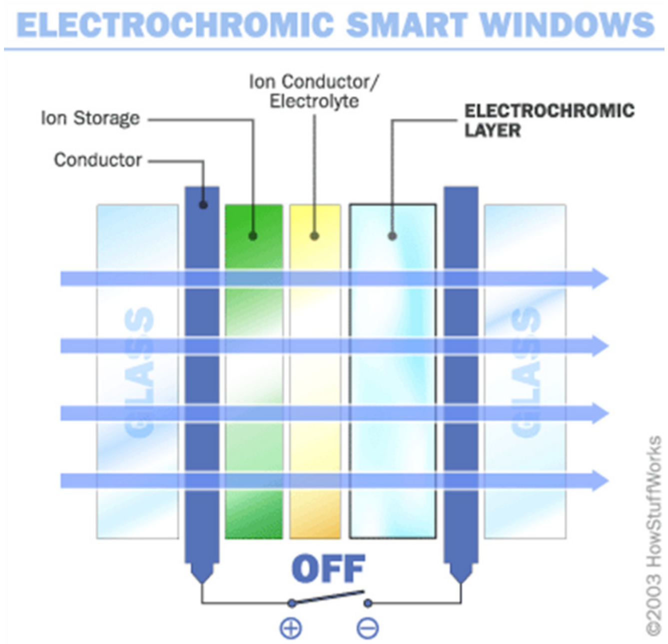
These products act in a similar way, yet they differ in some aspects. Similar to Suspended particle devices, users can adjust the amount of light transmitted by gradually increasing voltage through the conductor. Unlike SPD, the window is clear when no electricity is applied. Where SPD performs homogenously and responsively, electrochromic windows slowly darkens from the edges and inward. For large windows, this process can take minutes. The resulting tint can also be non-consistent, especially in large applications. The setup provides some degree of transmittance even in its darkest state.

One significant difference is the way in which electrochromic glass changes and upholds a certain state. Unlike SPD, no electricity is required as long as no changes are made. Voltage is required only when the amount of light through the window is to be altered. The solution is therefore very energy-efficient even compared to the other technologies.

Slow response times and uneven tint changes when used in large applications has led to electrochromic glass being used mostly in smaller applications such as rear view mirrors and airplanes like the Boeing Dreamliner 787. As of today, there exists no electrochromic film that can be retrofitted on to a window.



When switched off, an electrochromic window remains transparent.

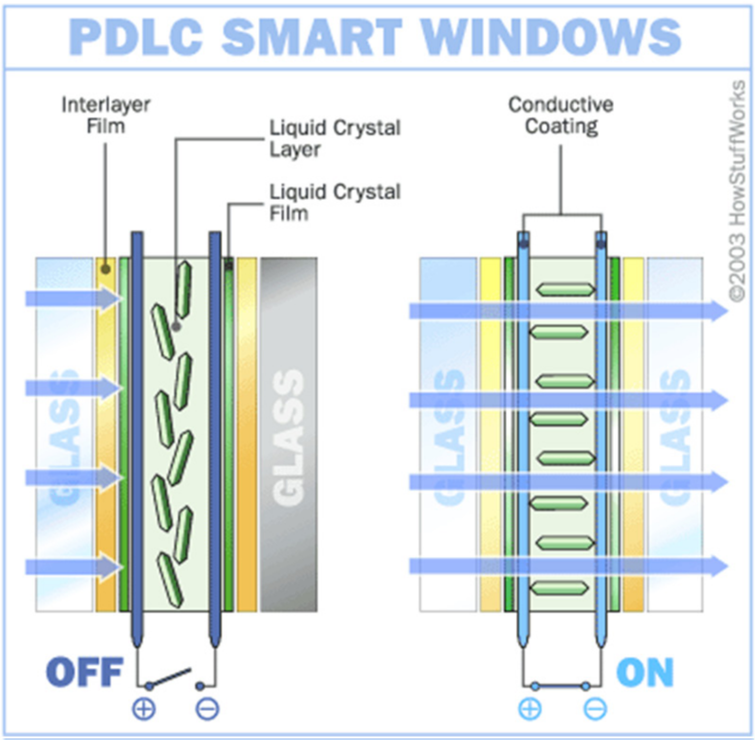


When switched on, a low volt of electricity makes the electrochromic window translucent.

Liquid crystals

Liquid crystals, or Polymer dispersed liquid crystals (PDLC), are similar to Liquid crystal displays (LCD). As with previously explained methods, conductive layers affect the content of a sandwiched material. In this case the material is a layer of liquid crystals. In the off state, the crystals are randomly distributed and arranged. This provides a completely opaque window, compared to electrochromic glass that never blocks out all incoming light. When a voltage is applied to the conductive coating, the crystals are arranged in such a way that light is permitted through the glass. The switch from transparent to opaque happens in milliseconds, making it the fastest of the methods.

The instant switch is at the same time a binary one that will not allow users to adjust the amount of light transmitted through the glass. Liquid crystals can be installed on existing windows using a film that is applied on the inside.

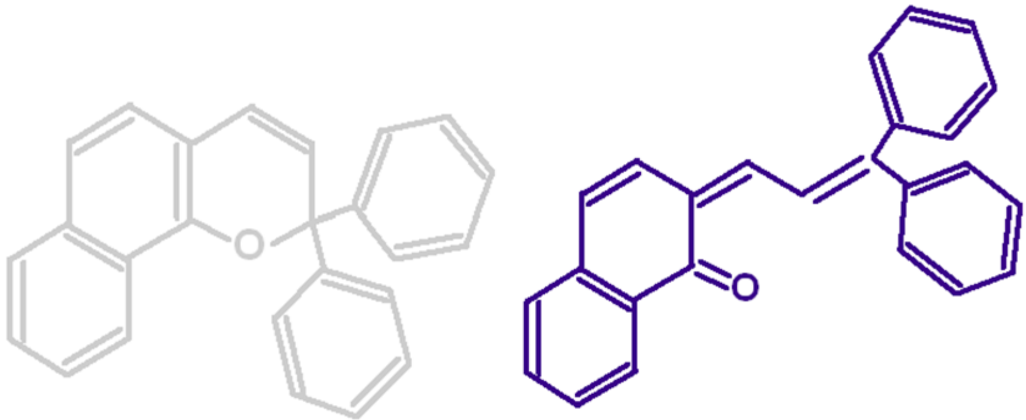


Photochromic glass

Sunglasses work either by simply blocking out light using glass of a certain colour, or by using polarisation that lets through light waves with a certain direction. Both methods result in only a fraction of light reaching the user's eyes and thereby reducing the effect of strong light.

Photochromic glass is not just a dynamic pair of sunglasses. It operated in a completely different manner. The result is somewhat similar to what is achieved by regular sunglasses, but contrary to previously described methods, there is no conductive layer affecting a core material. Instead, photochromic glass contains molecules that react to UV light by changing their molecular structure. This change is what results in a decreased transmittance of light.

Photochromic lenses are mostly used in glasses and are generally plastic. There are a number of reactive molecules available. Reaction time is slow compared to previous methods. Up to 80 % of light is filtered within 15 minutes with about 50 % in under a minute. However, the reverse process takes longer time with up to an hour for the glass to clear completely. The reaction is also not very precise in adjusting for issues like glare. UV light is available in large quantities even if it is a cloudy day, meaning the glasses darken more or less every time the user steps outside. Temperature affects the reaction; in low temperatures the glasses darken a lot and they are not recommended in extreme conditions e.g. while driving snow mobiles. The reaction would at the same time be hindered inside a windshield that filters most UV light. Finally, photochromic lenses become less reactive with time. Within three years of use (as personal glasses), the effect is noticeable. Photochromic film is available in sizes used on windshields.



Smart glass summary

Type	SPD	Electrochromic	Liquid crystal	Photochromic
Speed	1-3 seconds	Up to minutes*	Instant	>5 minutes
Steps	Adjustable	Adjustable	On- Off	Self adjusting
Transmittance max	70 %	60 %	60 %	90 %
Transmittance min	10 %	5 %	~1 %	15 %
Consistency	Excellent	Inconsistent tint	Excellent	Degrading
Consumption	100 V 0.5**, 0.05 W/sf	10 V 0.02 W/sf	24-100 V 0.5 W/sf	-
Film	Under development	Under development	Yes	Yes

*Depending on application size
**Power during switch

APPENDIX B - QUESTIONNAIRE

Solskydd i lastbilar

Denna enkät är en del av ett examensarbete på KTH som utförs för att förbättra lastbilsförares arbetsmiljö med avseende på solbländning.

Din kunskap och erfarenhet som lastbilsförare är ovärderlig för att kunna genomföra projektet och ta fram bättre lösningar!

Enkäten tar ungefär fem minuter.

Hur många år har du kört lastbil?

☐	☐	☐	☐
1-10	11-20	21-30	30+

Vilken typ av lastbil har du använt i din yrkesroll som förare?
Flera alternativ kan väljas

- ☐ Scania
- ☐ Volvo
- ☐ DAF
- ☐ MAN
- ☐ Mercedes
- ☐ Renault
- ☐ Iveco
- ☐ Annan

Vilken typ av körningar gör du i huvudsak?
Flera alternativ kan väljas

- ☐ Fjärrtransport
- ☐ Distribution
- ☐ Anläggning
- ☐ Special/Annat

Förarhytten

Vilken tillverkare anser du är bäst sett till sikt- och synmiljön?
Med hänsyn tagen till solbländning

- ☐ Scania
- ☐ Volvo
- ☐ DAF
- ☐ MAN
- ☐ Mercedes
- ☐ Renault
- ☐ Iveco
- ☐ Annan

Vad är det som särskiljer denna?

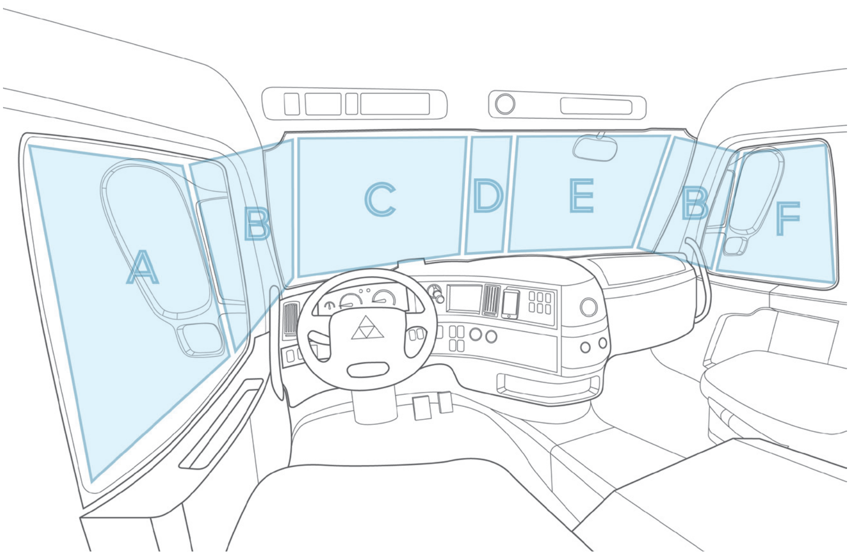
Solljus

Rangordna zonerna i bilden nedan efter hur stora problem du har med solljus, även EFTER att du aktiverat solskydden.
6 innebär störst problem, 1 minst.
Varje siffra får endast förekomma en gång!

A	B	C	D	E	F
☐	☐	☐	☐	☐	☐

I min bedömning utgår jag främst från tillverkaren...

____



Befintliga lösningar

Vilka typer av solskydd har du använt?
Flera alternativ kan väljas

- ☐ Solskydd framruta
- ☐ Solgardiner framruta
- ☐ Solskydd sidoruta
- ☐ Solgardiner sidoruta

Utifrån de lösningar du har använt, vilka är de största bristerna med dagens lösningar?

Solskydd fram: ____________________

Solgardin fram: ____________________

Solskydd sida: ____________________

Solgardin sida: ____________________

Vilka är de största fördelarna med dagens lösningar?

Solskydd fram: ____________________

Solgardin fram: ____________________

Solskydd sida: ____________________

Solgardin sida: ____________________

Användning

Rangordna nedanstående påståenden efter hur högt du prioriterar dem.
6 prioriteras högst, 1 lägst.
Varje siffra får endast förekomma en gång!

- ☐ Ska inte behöva sträcka mig
- ☐ Ska kunna täcka förarsidan oberoende av passagerarsidan
- ☐ Ska aktiveras med minimal kraftansträngning
- ☐ Ska minimera tiden för aktivering
- ☐ Ska kännas robust och stadig
- ☐ Ska kunna justeras i olika lägen

Drömprodukten

Hur skulle du vilja att ett solskydd fungerade och såg ut?
Även övriga kommentarer och tankar kan skrivas här

Appendix C - Sun data

Elevation spread [units of 6 min]

Equinox 2014-03-20							
Elevation	Tromsö	Södertälje	Shanghai	Singapore	Sao Paolo	Buenos Aires	Cape Horn
α<0	117	115	118	119	118	119	113
0≤α<10	42	27	17	14	15	16	24
10≤α<20	66	29	16	12	15	17	26
20≤α<30	15	49	16	14	15	17	30
30≤α<40	0	20	17	14	32	42	47
40≤α<50	0	0	20	12	19	29	0
50≤α<60	0	0	36	14	26	0	0
60≤α<70	0	0	0	14	0	0	0
70≤α<80	0	0	0	12	0	0	0
80≤α	0	0	0	15	0	0	0
Daylight	123	125	122	121	122	121	127
Total	240	240	240	240	240	240	240

Winter solstice 2013-12-21							
Elevation	Tromsö	Södertälje	Shanghai	Singapore	Sao Paolo	Buenos Aires	Cape Horn
α<0	240	179	139	120	104	96	64
0≤α<10	0	61	19	14	16	18	31
10≤α<20	0	0	20	15	17	16	25
20≤α<30	0	0	26	15	14	18	25
30≤α<40	0	0	36	16	15	16	24
40≤α<50	0	0	0	16	15	16	27
50≤α<60	0	0	0	20	14	16	44
60≤α<70	0	0	0	24	15	18	0
70≤α<80	0	0	0	0	15	26	0
80≤α	0	0	0	0	15	0	0
Daylight	0	61	101	120	136	144	176
Total	240	240	240	240	240	240	240

Elevation spread [percentage of Day Total]

Equinox 2014-03-20							
Elevation	Tromsö	Södertälje	Shanghai	Singapore	Sao Paolo	Buenos Aires	Cape Horn
α<0	49%	48%	49%	50%	49%	50%	47%
0≤α<10	18%	11%	7%	6%	6%	7%	10%
10≤α<20	28%	12%	7%	5%	6%	7%	11%
20≤α<30	6%	20%	7%	6%	6%	7%	13%
30≤α<40	0%	8%	7%	6%	13%	18%	20%
40≤α<50	0%	0%	8%	5%	8%	12%	0%
50≤α<60	0%	0%	15%	6%	11%	0%	0%
60≤α<70	0%	0%	0%	6%	0%	0%	0%
70≤α<80	0%	0%	0%	5%	0%	0%	0%
80≤α	0%	0%	0%	6%	0%	0%	0%
Daylilght	51%	52%	51%	50%	51%	50%	53%

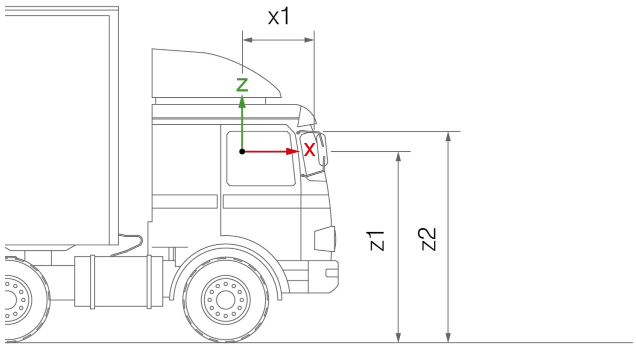
Winter solstice 2013-12-21							
Elevation	Tromsö	Södertälje	Shanghai	Singapore	Sao Paolo	Buenos Aires	Cape Horn
α<0	100%	75%	58%	50%	43%	40%	27%
0≤α<10	0%	25%	8%	6%	7%	8%	13%
10≤α<20	0%	0%	8%	6%	7%	7%	10%
20≤α<30	0%	0%	11%	6%	6%	8%	10%
30≤α<40	0%	0%	15%	7%	6%	7%	10%
40≤α<50	0%	0%	0%	7%	6%	7%	11%
50≤α<60	0%	0%	0%	8%	6%	7%	18%
60≤α<70	0%	0%	0%	10%	6%	8%	0%
70≤α<80	0%	0%	0%	0%	6%	11%	0%
80≤α	0%	0%	0%	0%	6%	0%	0%
Daylight	0%	25%	42%	50%	57%	60%	73%

Elevation spread [percentage of Daylight Total]

Equinox 2014-03-20							
Elevation	Tromsö	Södertälje	Shanghai	Singapore	Sao Paolo	Buenos Aires	Cape Horn
α<0	0%	0%	0%	0%	0%	0%	0%
0≤α<10	34%	22%	14%	12%	12%	13%	19%
10≤α<20	54%	23%	13%	10%	12%	14%	20%
20≤α<30	12%	39%	13%	12%	12%	14%	24%
30≤α<40	0%	16%	14%	12%	26%	35%	37%
40≤α<50	0%	0%	16%	10%	16%	24%	0%
50≤α<60	0%	0%	30%	12%	21%	0%	0%
60≤α<70	0%	0%	0%	12%	0%	0%	0%
70≤α<80	0%	0%	0%	10%	0%	0%	0%
80≤α	0%	0%	0%	12%	0%	0%	0%
Daylight	123	125	122	121	122	121	127

Winter solstice 2013-12-21							
Elevation	Tromsö	Södertälje	Shanghai	Singapore	Sao Paolo	Buenos Aires	Cape Horn
α<0	100%	0%	0%	0%	0%	0%	0%
0≤α<10	0%	100%	19%	12%	12%	13%	18%
10≤α<20	0%	0%	20%	13%	13%	11%	14%
20≤α<30	0%	0%	26%	13%	10%	13%	14%
30≤α<40	0%	0%	36%	13%	11%	11%	14%
40≤α<50	0%	0%	0%	13%	11%	11%	15%
50≤α<60	0%	0%	0%	17%	10%	11%	25%
60≤α<70	0%	0%	0%	20%	11%	13%	0%
70≤α<80	0%	0%	0%	0%	11%	18%	0%
80≤α	0%	0%	0%	0%	11%	0%	0%
Daylight	0	61	101	120	136	144	176

Appendix D - Benchmark template



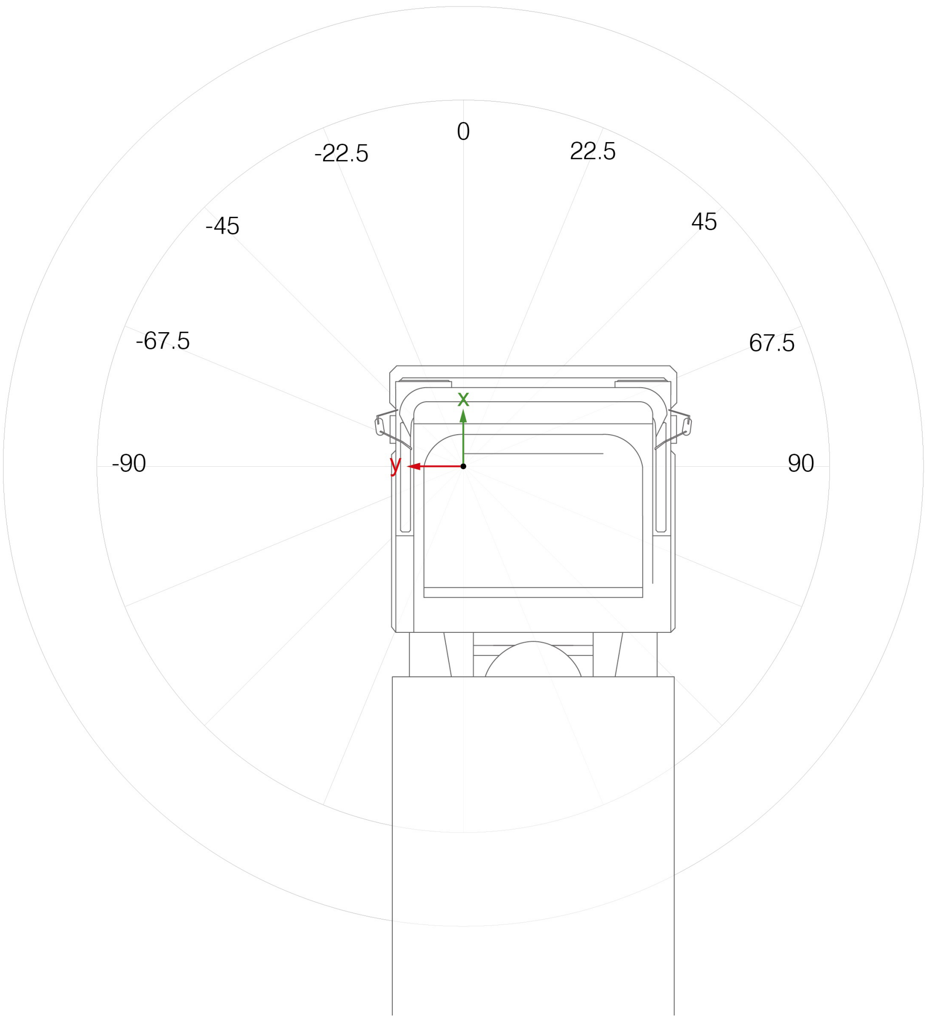
Fordon

☐ F1 ☐ M2 ☐ M5

x1

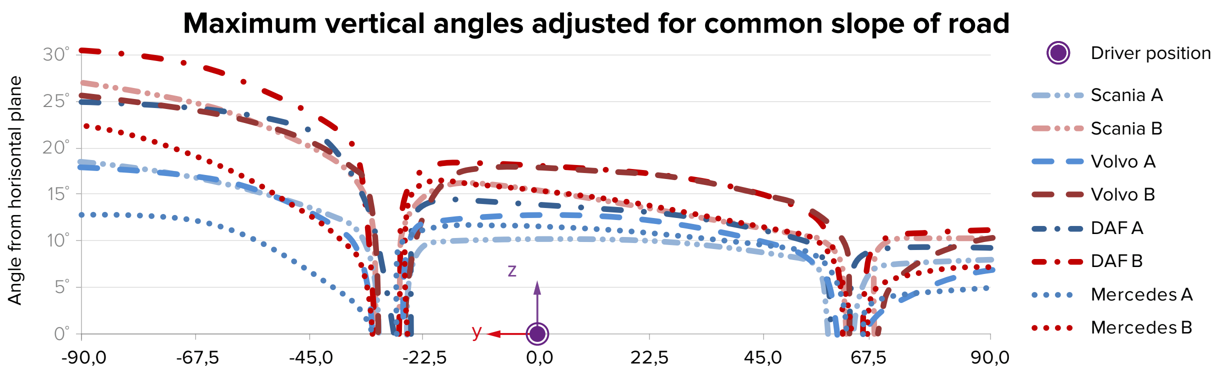
z1

z2

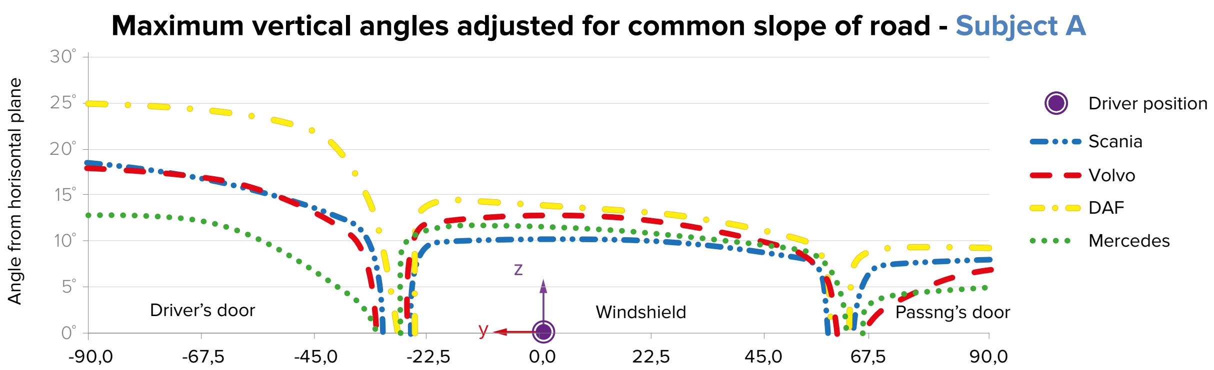


APPENDIX E - BENCHMARK DATA

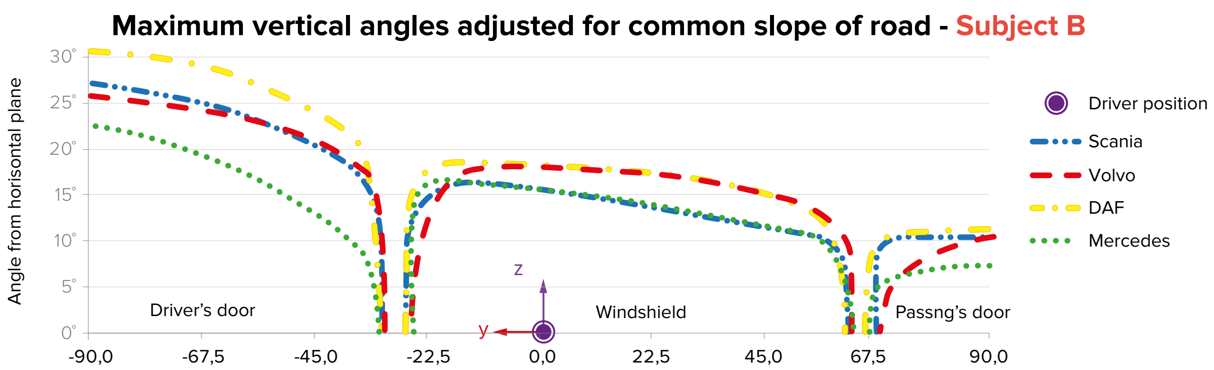
Combined graph



Subject A



Subject B



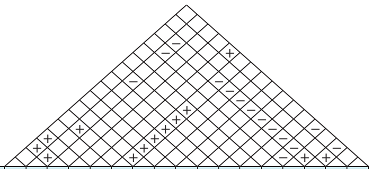
Appendix F - QFD matrix

QFD: House of Quality	
Projekt:	Solavbländning Scania 2014
Version:	1
Datum:	2014-05-02

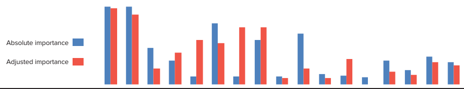
Interrelationship	
Positive	+
Negative	–
None	

Relationship	
9	●
3	○
1	▽

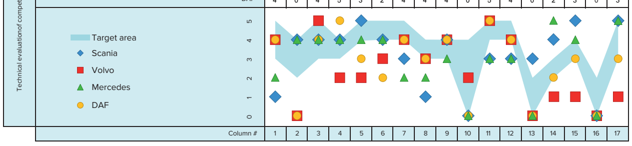
Target direction	
Maximise	▲
Precise	◇
Minimise	▼



		Row #	Relative importance	User importance	Största förhållande	User demands (explicit and implicit) / Functional demands	Activate within reach [mm]	Number of covering parts [#]	Force to activate [N]	Time to activate [s]	Experienced sense of quality [#]	Number of modes [#]	Angle driver's side front [degree]	Angle between pillars and cover [degree]	Angle driver's door vertical [degree]	Angle passenger's door vertical [degree]	Angle between covers horizontal [degree]	Angle passenger's side vertical [degree]	Number of features [#]	Number of components [#]	Cost of manufacture [kr]	Compability with models [#]	Number of cycles [#]	Scania	Volvo	Mercedes	DAF	Row#
							1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17					
							▼	◇	▼	▼	▲	▲	▼	▼	▼	▼	▼	▼	▲	▼	▼	▲	▲	Comparison between competition				
Activation	15 p	1	14%	6,8	9	Do not want to reach	●	○	○	▽														1	5	3	4	1
		2	3%	1,2	9	Cover driver's side independent of passenger side		●				○												4	0	4	0	2
		3	3%	1,3	9	Minimal force	○		●															4	5	4	4	3
		4	2%	1,2	9	Minimise time to activate	○		▽	●		▽												4	3	4	5	4
		5	2%	1,0	9	Provide a robust feel			▽		●									▽			○	5	2	4	3	5
		6	10%	4,6	9	Ability to adjust position		●		▽		●												4	4	4	3	6
Usability	15 p	7	2%	1,1	9	Front area (C)						▽	●				▽							3	4	2	4	7
		8	11%	5,3	9	Area near a-pillar (B)						▽		●										1	4	3	4	8
		9	2%	1,1	9	Driver's window (A)						▽			●									4	4	3	4	9
		10	11%	5,2	9	Passenger's window (F)	○					▽				●								0	2	0	0	10
		11	2%	1,2	9	Angle between visors (D)	▽					▽					●							5	5	5	5	11
		12	2%	1,2	9	Area in front of passenger (E)	○	○				▽					▽	●						3	4	3	4	12
Details	1 p	13	2%	1,0	9	Special features: mirror, storage, small objects													●					3	0	0	0	13
Passenger	5 p	14	5%	2,3	9	Cover frontwise independent of driver		●				○												4	0	4	0	14
		15	2%	0,8	9	Angle by a-pillar								●										2	4	3	3	15
		16	4%	1,9	9	Passenger's window										●								0	4	0	0	16
Engineer	10 p	17	1%	0,7	3	Minimise impact on roof shelf														○		○		4	2	4	3	17
		18	4%	2	9	Reduced cost														●	●	○		4	1	3	2	18
		19	4%	2	9	Modularisation, fits several cabs																●		4	2	5	4	19
		20	6%	2,7	3	Adjustable for different body heights	○		▽	○		○										○		2	4	3	4	20
		21	6%	2,7	9	Rigidity			○											○			●	5	1	4	2	21



	Activate within reach [mm]	Number of covering parts [#]	Force to activate [N]	Time to activate [s]	Experienced sense of quality [#]	Number of modes [#]	Angle driver's side front vertical [degree]	Angle a-pillar and cover horizontal [degree]	Angle driver's door vertical [degree]	Angle passenger's door vertical [degree]	Angle between covers horizontal [degree]	Angle passenger's side vertical [degree]	Number of features [#]	Number of components [#]	Cost of manufacture [kr]	Compability with models [#]	Number of cycles [#]
Absolute importance	98	97	46	55	9	76	10	55	10	64	13	10	9	29	18	34	27
Adjusted importance	120	110	25	50	70	65	90	90	10	25	10	40	0	20	15	35	30
Relative importance	15%	15%	7%	9%	1%	12%	2%	9%	2%	10%	2%	2%	1%	5%	3%	5%	4%
Largest interrelationship	9	9	9	9	9	9	9	9	9	9	9	9	9	1	0	0	3
Target (upper)	5	5	4	4	5	5	5	5	4	4	5	3	2	3	4	2	5
Target (lower)	3	2	3	2	3	2	4	3	3	1	4	2	0	2	3	0	3
Scania	1	4	4	4	5	4	3	1	4	0	3	3	3	4	5	0	5
Volvo	4	0	5	2	2	3	4	4	4	2	5	4	0	1	1	0	2
Mercedes	3	4	4	4	4	4	3	3	3	0	3	3	0	5	4	0	5
DAF	4	0	4	5	3	2	4	4	4	0	5	4	0	2	3	0	3

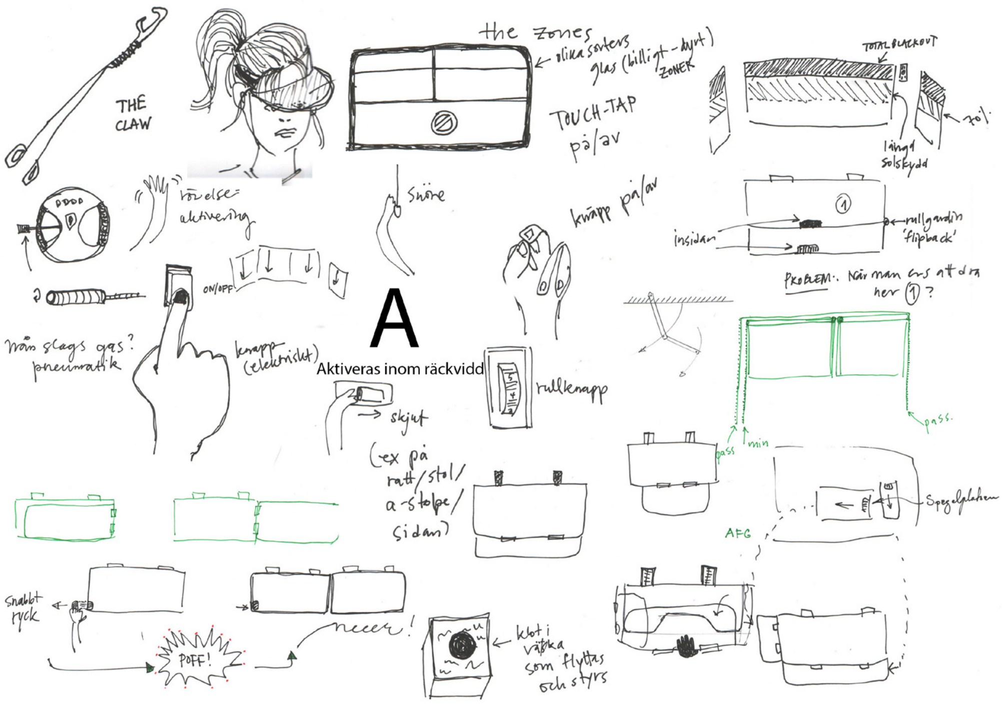


Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

Appendix G - Concept groups

There were 12 groups and 20 pages like the two shown below.

Group “Activated within reach



Group “Force required for activation”: