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EXPLORING SUN VISOR CONCEPTS

Using the C-K Theory

Master's Thesis in the Master's Programmes
Industrial Design Engineering and International Project Management

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Cover: Illustration of the Roll-down Curtain concept (p.33).

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ABSTRACT

The project has been carried out by the two master students Lina Engström and Andreas Samuelsson at Chalmers University of Technology in collaboration with Volvo Cars. Volvo Cars had initiated a sun visor development project to examine the possibilities of updating the current sun visor that has been looking almost the same in all cars since the invention of interior sun visors in the 1930s. The Volvo sun visor project had to either improve the coverage of outside light in the driving compartment of a car, improve roominess or create a sun visor that is compatible with a sky roof. An important delimitation was to only work with the interior part of the car. A design and innovation theory called the C-K theory was chosen to be implemented during the project at Volvo Cars and the aim was to investigate the different steps and challenges of a product from idea to finished product and to use the C-K theory in practice and assess the use for innovating new products.

A thorough research phase where the C-K theory was studied was followed by an investigation of the current sun visors on the market today. Using the information gained, the concept generation of new solutions for shielding light from the driving compartment of a car was conducted. The use of the C-K theory enabled more innovative solutions due to the new way of thinking that the C-K theory inspires to. Knowledge was collected during interviews and meetings with people with different areas of expertise. This generated innovative concepts that were further analysed using concept selection methods.

The final concepts are the Roll-down Curtain and the Two-part Sun Visor, as well as a vision for the future of sun visors. The Roll-down Curtain concept was made into a physical prototype installed in a Volvo XC90. The Two-part Sun Visor was visualised using CAD. The final concepts and other ideas produced during the thesis will act as inspiration for the further development in the area of sun visors.

Keywords: sun visor, C-K theory, product development, prototyping, innovation, Volvo Cars

PREFACE

This report is the result of a 30 ECTS Master Thesis at the department of Technology Management and Economics at Chalmers University of Technology in Gothenburg, Sweden. The thesis was carried out in cooperation with Volvo Cars during March 2016 to September 2016.

The thesis has been executed by the project team consisting of Lina Engström, Master student at Industrial Design Engineering and Andreas Samuelsson, Master student at International Project Management at Chalmers University of Technology.

The examiner and supervisor of the thesis is Kamilla Kohn Rådberg, Researcher at Technology Management and Economics at Chalmers University of Technology. The project has been externally supervised by Carl-Johan Kaudern, System Responsible at Overhead Systems at Volvo Cars.

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At last we would like to thank our family and friends for the support during our five years of study at Chalmers University of Technology.

TERMINOLOGY

A-pillar	The pillar between the windshield and the first door of the car.
B-pillar	The pillar between the first and second door of the car.
CAD	Computer-Aided Design.
Volvo	Volvo Car Corporation.
WEM	The black box on top of the windscreen containing sensors etc.

The dimentional reference system of a car, explaining the axises X, Y and Z, can be viewed in the figure below.

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1. Introduction

This chapter introduces the master thesis project behind this report. It describes the background of the project, problem statement, project aim and goal and delimitations that formed the basis for the project, but also outlines the different sections of the report.

1.1 Innovation and Design

The invention of new products is going on all the time and the strive is strong for coming up with better products that help us in everyday life. The design of a product is important for the intended user to feel comfortable with it; with its looks, to understand the functions etc. How can innovation and design be managed in a project to come up with a viable product in the end?

Innovation can happen by itself but oftentimes there is a need for tools that help the mind break habitual patterns for innovation to happen. Several methods for innovation have been developed for different industries, to aid in the work with developing products. One of these methods is called the C-K theory and is known to be a good method for managing innovative product development. The researchers has chosen to work with the C-K theory and evaluate it during this project by applying it to the development of a new sun visor for Volvo Cars.

1.2 The project

Volvo Cars has been making cars in Gothenburg since 1927 and is working towards becoming the most progressive and desired premium car brand in the world (Volvo Car Corporation, 2016). As one of the most innovative car brands Volvo Cars is driven by making life less complicated for people, with safety, quality and the environment as core values.

The passenger car is one of the most complex products there is, with approximately thirty thousand parts (NAPA Auto Parts, 2015). The parts are developed all the time, since the only way to be ahead of the competitors is to develop innovative products.

The exterior and interior of a car is what the user interact with. It is important that the design of these parts are done with the user as top of mind, and that it is easy for the user to use the car. Interior parts are what the driver will interact with when driving the car, and it is vital that everything works with ease, without disturbing the driving. The interaction with the different parts is important and the parts are therefore further developed all the time to make the driving experience better.

One part of the car that has not been as developed through the years is the sun visor. It has been looking almost the same since the 1930s, when the first interior sun visor was introduced on the market (Berger, 2001). The current sun visor is located on the inner ceiling above the front seats in the driving compartment of the car. The function of the sun visor is to increase visibility by protecting the driver from light that can disturb the driving, regardless of where the light is coming from.

At the moment Volvo Cars are using sun visors (see figure 1.1) that can be folded down to cover light coming from the front and also be turned around an axis to protect from light from other directions. Some cars have a mirror with a lid and

Figure 1.1: Sun visor on a Volvo (A2Mac1.com, 2016).

a light source in the sun visor, which means that there are electrical components in the product.

The current sun visor is manually adjusted and can be tricky to fold and turn, while at the same time maneuvering the car. The sun visor design is outdated and the sun visor construction and position is limiting the possibilities of developing the driving compartment and roof of the car. Since Volvo Cars strive to be a premium brand, there is a need to explore the possibility of developing the sun visor into something new and better.

1.3 Problem Statement

The sun visor in passenger cars have been looking the same for decades, with only minor changes in looks and material use. Volvo Cars are interested in exploring how a sun visor could be developed and improved. Volvo Cars have three main areas of improvements for sun visors in Volvo passenger cars.

Improve coverage, especially from sun coming from the side, is an important area for improvement for a more convenient and safe drive. Reduce packaging in Z-direction is important to be able to improve the spacious feeling in the car. Volvo is also interested in extending the current sun roofs of the car to become as big as possible, and the sun visor is at the moment a limitation since it is too long in the X-direction. Developing a sun visor that does not intrude on the area of the bigger sun roof, so-called sky roof, is desired.

1.4 Project Aim and Goal

The aim and goal in this project is two-folded. It is mainly to investigate the C-K theory and to adapt the theory to Volvo Cars methods from idea to finished product. The aim is to:

- Investigate the different steps and challenges in the development of a product with the C-K theory.
- Use the C-K theory in practice and assess the use for innovating new products.

The C-K theory will be implemented during the development of innovative sun visor concepts for Volvo Cars. The different concepts should be able to be implemented in the car today, or in the following years. Volvo Cars have identified three areas for development. The sun visor concepts should fulfill one or more of these demands:

- Improve the coverage of outside light in the driving compartment of a car
- Improve roominess by effective package of the sun visor in Z-direction
- Create a sun visor that is compatible with a sky roof

The goal is to gain a greater understanding of the C-K theory and use it in practise, as well as evaluate it for further use in product development, and investigate if Volvo Cars can implement the C-K theory. The goal is also to deliver the different concepts and visualise one of the concepts as a prototype implemented in an existing car.

1.5 Delimitations

The project is an interior project at Volvo Cars and will not deal with concepts and solutions where other parts of the car are affected, such as the windshield. The project is carried out by two students, which means that the research must be focused to prevent the project from becoming too extensive. The project will be carried out during 20 weeks as a 30 hp Master Thesis and will need to be finished within the stipulated time frame.

1.6 Report Outline

The first chapter introduces the project by describing the background, problem statement, project aim and goal and delimitations.

Chapter two describes the theory behind the project. The historical development of the sun visor, a perspective of design, what dominant design is and how the C-K theory works.

The third chapter presents the project's methodology. The chapter describes the chosen methods and tools to achieve a successful project.

Chapter four presents the pre-study of the project. The parts of the sun visor, the objectives tree, competitor analysis and the production visit is described in this chapter.

The fifth chapter describes the concept generation from the C-K theory in practise throughout the development from idea to the chosen concepts.

Chapter six presents how the final concepts works and how the prototypes were made. The future of sun visors in cars is also discussed.

The content of chapter seven is the discussion where the process of the project, the final result, the research questions, lessons learned, recommendations and further development is discussed.

Chapter eight is the final chapter which contains the conclusions of the project.

2. Theoretical framework

The second chapter is about the theoretical studies that form the basis for the project; information and history of the sun visor, the definition of design, dominant design and the C-K theory.

2.1 The Sun Visor

Sun visors have for long time been an important part of many vehicles, not least the car's interior. The first sun visors were developed in the early 1920s and placed on the exterior part of the car, above the windshield (Collins, 2007) (figure 2.1). The first interior sun visors were firstly developed in 1931 (Berger, 2001). Interior visors were an option on the 1931 Dodge Brothers DH6 which had both inside and outside sun visors (figure 2.2). The interior sun visors were first a luxury alternative which were much easier to reach and adjust than the exterior sun visors.

A sun visor is a component in an automobile (vehicles, airplanes, boats etc.) which main purpose is to shield the sun from the driver's and passenger's eyes. The sun visor is traditionally located in the ceiling above the windshield and folded down when the sun disturbs the driver or the passenger. The modern passenger car has one sun visor for the driver and one sun visor for the passenger. The sun visor is mounted on an axis to allow the sun visor to turn and partly block the sun from shining into the car from the side window.

The typical sun visor is made out of a plastic or metal skeleton with Styrofoam padding and vinyl or fabric as the surface material. Sun visors can also be made of a plastic case and a surface material on top. Nowadays sun visors also have additional functions, except for sun shading, such as providing vanity mirrors, lights and ticket holders. The mirrors can be located on the driver side, the passenger side or both. The vanity mirror usually has a lid cover or a slideable cover. The light sources are either located in the mirror or in the ceiling, if they are

Figure 2.1: A Ford Model T 1922 with an exterior sun visor (Collins, 2007).

Figure 2.2: 1931 Dodge Brothers DH6 (Keiser, 2011).

present. The ticket holders can be either clips in different sizes or a band around the sun visor.

From a safety point of view it is important that the sun visor follows the legal requirements. This includes requirements regarding for example "Free Moving Head" which is a requirement where a sphere is launched in all directions in the car to see where it hits. Requirements for the current sun visor regulates for instance the placement of the attachment foot and the edge radius. If a new sun visor would be developed, new regulations matching the new visor would have to be made.

2.2 A Perspective on Design

Design is a wide term and can signify a variety of things. Design can mean everything from construction of a product, the process of developing something, to the aesthetics and the modeling of a product so that the user will understand, appreciate and use it. Klaus Krippendorff defines design as:

> *"The etymology of design goes back to the latin de + signare and means making something, distinguishing it by a sign, giving it significance, designating its relation to other things, owners, users or gods. Based on this original meaning, one could say: design is making sense (of things)." (Krippendorff, 1989)*

A common distinction is made between engineering design and industrial design. Engineering design often refers to construction and the engineering part of a development process (Johannesson et al., 2004). Industrial design is the styling of a product, product identity and user customisation, the perceived qualities of a product.

When referring to design in this project, design as a work process is intended. Design is not only the look of a product but the whole process of product development based on customer needs, often with a user perspective (Swedish Industrial Design Foundation, 2016).

It has often been the case in producing companies that the construction part and the designing part of a development process has been separated, even though they are more or less interdependent (Johannesson et al., 2004). In modern companies it becomes more important to collaborate cross-functionally and parallelly to achieve success.

2.3 Dominant Design

Since the sun visor has been looking almost the same since the 30s, the sun visor design has become a dominant design. A product have a dominant design when its performance and/or design has become an accepted market standard and is hard to change (Suarez and Utterback, 1995). All developers and innovators must adapt their new similar products to the dominant design. A dominant design is not always the best solution possible nor the best looking for a product, but the market has developed the product to a market standard which is very difficult to change (The Open University, 2016). Figure 2.3 shows the Ediswan carbon-filament lamp from 1884 (Thomas Edison and Joseph Swan's company). The lamp design became a dominant design and the light bulbs today look very similar 132 years later.

Figure 2.3: The Ediswan carbon-filament lamps from 1884 (The Open University, 2016).

Baker (2010) describes that products with dominant design are often in need of improvements but that they are hard to alter due to the design having been accepted by the market. The technical solutions today entails many improvements but the dominant design is often too strong to adapt. One example is Christopher Sholes Qwerty keyboard from 1870 (Qwerty is the first six letters on the keyboard). The Qwerty keyboard is the most common keyboard standard but it is far from the best solution in today's market. The Qwerty keyboard was developed by Sholes so that the user would write as slow as possible (Baker, 2010). The typing machines back then would often clash and stick if the writer wrote too fast and the Qwerty keyboard was made to slow the writer down. In today's market we do not have the clash and stick problem but the Qwerty keyboard is still an international standard due to its dominant design. Many inventors has developed keyboards which are faster to write on but the dominant design of the Qwerty keyboard has been too strong to overcome.

2.4 The C-K Theory

Since many product designs suffer from being dominant, it is important to find ways to break through the barriers of dominant design. Several design and innovation methods have ways of doing this. One method that has come a long way in breaking the barriers is the C-K theory.

The C-K theory is a theory that further defines design and also embeds creativity into the definition (Hatchuel and Weil, 2003). It was first drafted by Armand Hatchuel in 1996 (Agogué et al., 2014) and then further developed by Hatchuel and his Mines ParisTech colleague Benoit Weil, along with contributions from several others. C-K theory was developed from practical issues as guidance to innovation design teams in a multitude of industries (Hatchuel et al., 2004). C-K theory has been proven useful in innovation situations where the usual design methods have been difficult to use (Agogué et al., 2014). It is designed to avoid the traps that other design theories and methods often fall into when using them in design processes (Hatchuel et al., 2004). C-K theory is a theory that unifies other existing design theories, since it was developed to meet the challenges and limitations of these design theories. The challenges and limitations consisted of not having a clear definition of design and not having a design theory that also addressed creativity as well as innovation during a design process (Hatchuel and Weil, 2003). Another challenge is that design theories are often tailored for a specific context, such as an industry or a specific application. The C-K theory has aimed to be a theory that encourages a common language among different industries, to close the gap between dissident competences (Agogué et al., 2014). It has also proposed a clear definition of design that is independent of the different industrial languages and that encompasses both creativity and innovation. The latter is a very important aspect of C-K theory since creativity and innovation are rarely addressed in other theories, but are very central in C-K theory (Hatchuel et al., 2004).

There exist several design theories that aim to concretise design. Some theories, like the German Systematic Model, are process oriented and organised in stages that need to be passed to complete a design task (Hatchuel and Weil, 2003). Design theories of this sort are seen as recursive and the stages are often overlapping, since the transition between every stage is contingent. They have not been able to adjust to the fast-moving technologies and expectations of consumers of this time (Hatchuel et al., 2004).

One design approach that can be compared to C-K theory is Design Thinking, a human-centered method that is based on how designers think and act. It is said to be a quite generic problem-solving approach as it can be applied to almost any situation, be it organisational renewal or product development (Carlgren, 2013). Design thinking is a broad notion, and is described in some literature as a user-centered step-by-step method with extensive understanding of user needs, especially in the beginning of projects, but are also described as the individual designers mindset when solving problems (Carlgren, 2013). Design thinking is most commonly described as a method following the

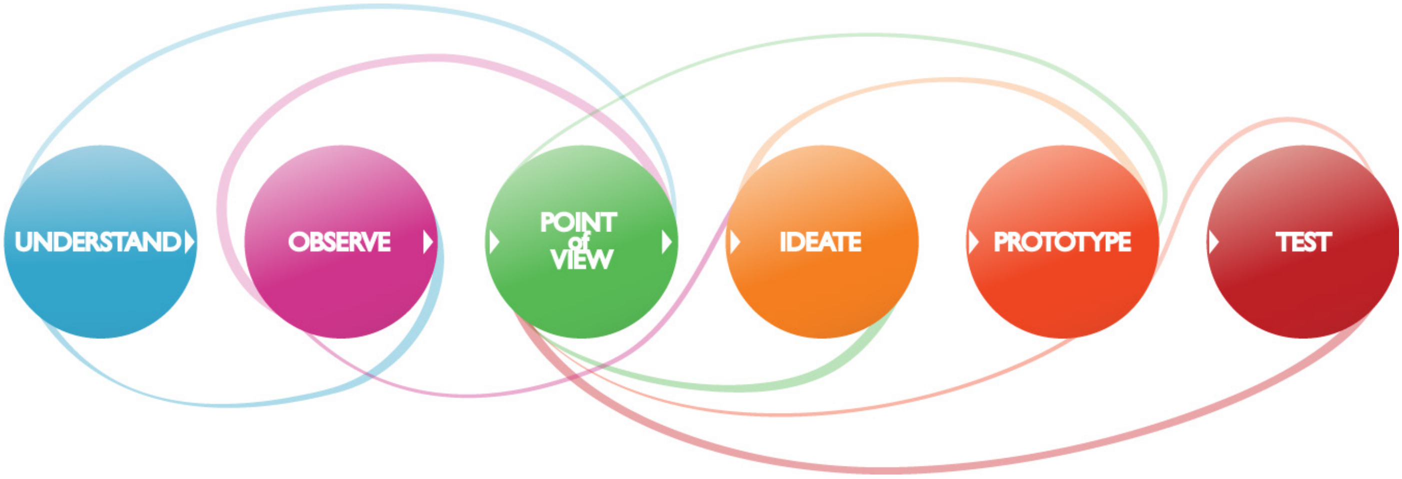

Figure 2.4: The Design Thinking Process (Stanford d.School, 2009).

steps understand, observe, point of view, ideate, prototype and test, with iteration between the steps (see figure 2.4). It is important to somehow include the user in the steps.

Design thinking is, as opposed to C-K theory, a more straightforward method for design practice, whereas C-K theory is an innovation theory. They are both problem-solving methods and can both be applied to either upscale organisations or smaller projects, but have differing approaches. Where design thinking takes extra care of the user, C-K theory focuses on the importance of innovation and expansion of knowledge and concept.

The C-K theory is based on the two spaces C, the concept space, and K, the knowledge space, and the interaction and expansion of these. The

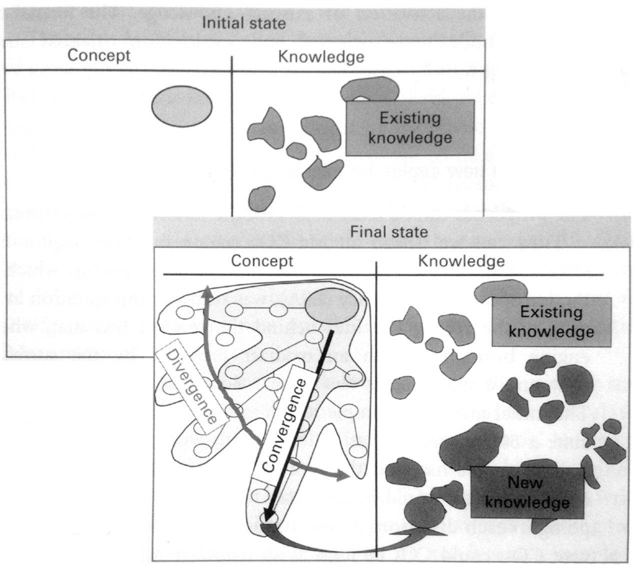

Figure 2.5: Summary of The C-K process (Le Masson et al., 2010).

knowledge space, K, is what is known today. The knowledge space is logical, a proposition that can be true or false. The concept space, C, on the other hand, is one or more propositions that are impossible to determine whether they are true or false, which means that they are not logical in K space (Hatchuel and Weil, 2003). The C space is defined by the K space which means that the two spaces are inseparable, and it makes C-K theory "K-relative" (Agogué et al., 2014). This means that everything that happens in the C-space have base in the K-space.

When developing the C-K theory the creators defined design as a co-evolution and expansion of the spaces C and K. The design definition in C-K theory have been formulated in different ways, but focus on evolution and the connection between concepts and knowledge.

"Design is the cognitive process by which a concept will generate other concepts and turn at some point into knowledge." (Agogué et al., 2014)

"Assuming a space of concepts C and a space of knowledge K, we define Design as the process by which a concept generates other concepts or is transformed into knowledge, i.e. propositions in K." (Hatchuel and Weil, 2003)

When designing, the designer seeks to expand the C space of concepts by using the K space of knowledge (Le Masson et al., 2010). When the C space has expanded, the need for new knowledge often arises, and the designer goes back to the K space to explore and get more knowledge - the

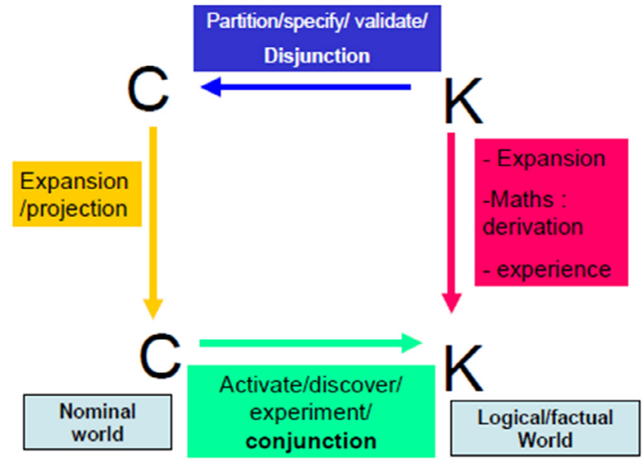

Figure 2.6: The four operators of C-K theory (Hatchuel et al., 2004).

K space is thus also expanded. By going back and forth between the two spaces, they are both expanded gradually (see figure 2.5).

Thousands of studies in creative thinking have struggled to overcome the so-called fixation effects, which are mind-sets, or rules in the mind that are difficult to change (Hatchuel, 2010). The key to being creative is to be able to resist these fixation effects. Expansion of the mind is a way in C-K theory that overcomes fixation effects. Armand Hatchuel (2010) describes the expansion of the mind as the new meaning of an existing object, or the creation of a new object. Expansion means selecting and adding attributes to an object to get the desired properties.

There are two ways of expansion in the C space; by vertically adding properties to specify the concept is called convergence, and by variating the concept horizontally in one level is called divergence (Le Masson et al., 2010) (see figure 2.5). The expansion of the C space creates a tree structure whereas the knowledge is sorted into groups in the K space.

The actions that take place during the design process of C-K theory are called operators (Agogué et al., 2014) (see figure 2.6). The K→C operator is when a proposition, or an attribute, is added (or removed) from K space to C space. So-called "disjunctions" are created when a proposition turns into a concept. Disjunctions operate from known to unknown. The initial concept is thus created by using the K space to expand the C space.

The C→K operator finds properties from K that can make a concept reach logical status, which means that the concept could become a finished design. This is called conjunction, going from unknown to known, and when conjunction happens, the design process is done (Agogué et al., 2014). The process keeps going if there is no conjunction, i.e. when new knowledge or concepts are developed.

Going from C→C is the most innovative operator. If a new proposition has a natural relationship to the concept in question, the process is considered restrictive (Le Masson et al., 2010).

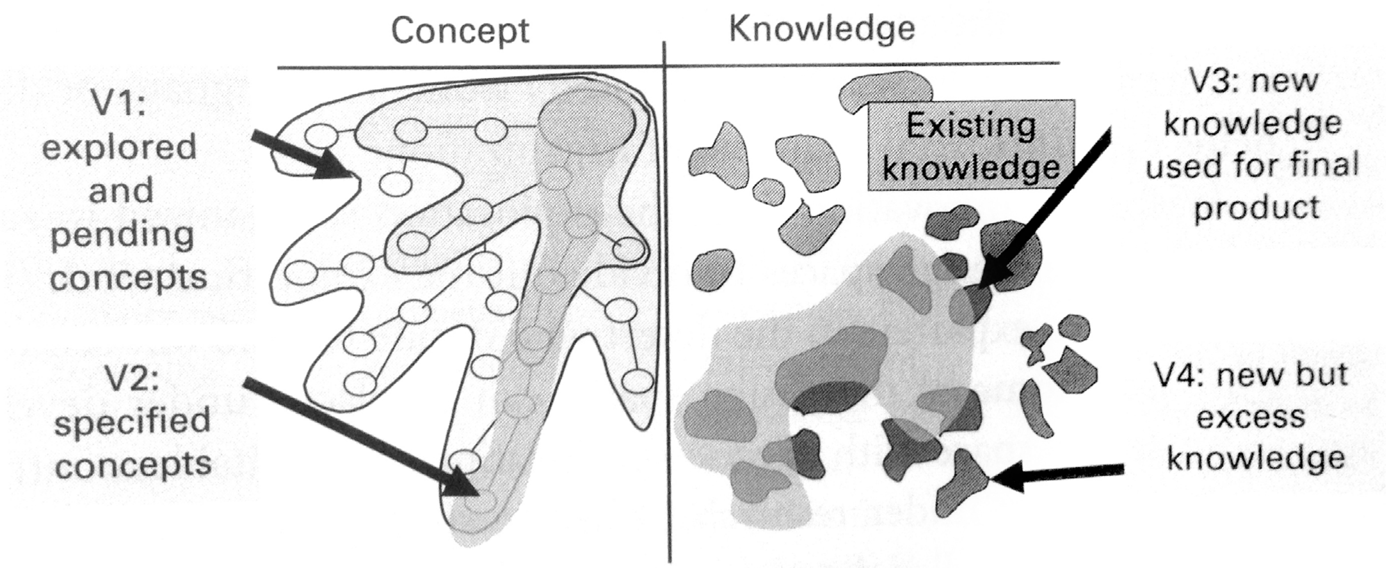

Figure 2.7: Four types of values (Le Masson et al., 2010).

If the proposition adds unexpected attributes and changes the core meaning of the concept, the process is creative. The new part-concept is thus considered expansive. This is the operator in which breakthrough innovation can be made (Agogué et al., 2014).

The last operator is the K→K operator, which refers to the learning process that is the expansion of the K space, by for example demonstration of new theorems (Agogué et al., 2014).

When the C-K process is done it has typically produced four types of "values" (see figure 2.7). V1 are explored concepts that were rejected due to time and resource shortage, but saved for another time. V2 are the other explored concepts that become products (conjunction). The new knowledge that was used is called V3 and the unused knowledge is called V4, and both can become valuable in another project.

To be able to efficiently use the C-K theory there is need for structuring the two spaces C and K. The use of colour codes works to highlight different levels of knowledge within the K space; validated knowledge, on-going learning or missing knowledge (Agogué et al., 2014) (see figure 2.8). In the K space the knowledge has an archipelagic structure (see figure 2.7).

There are three colour codes for the C space as well, describing the concepts with known technical solutions with conjunctions to the K space, the concepts with attainable solutions that are being investigated, and alternative concepts, the so-called crazy ideas, which are unexplored (Agogué et al., 2014) (see figure 2.9). As said before, the C space has a tree-structure (see figure 2.7).

When using the C-K theory the designer needs to figure out what strategy is going to be used. The two strategies in C-K theory are called "breadth

	Industrial implications	Theoretical foundations
Validated	Knowledge and validated in-house	Stabilized knowledge base (including dominant design)
On going learning	Knowledge being acquired (there is an on-going research program on the issue)	K identified, conditions of validity and evaluation to define
Missing	Absent or non-actionable knowledge in-house	Identification of a need for K (expansion of the knowledge base)

Figure 2.8: Colour codes K-space (Agogué et al., 2014).

	Industrial implications	Theoretical foundations
Known	The concept refers to a set of known technical solutions, whose performance is also known	There are many conjunctions
Attainable	The concept is to be deepen but attainable	Restrictive partition
Disruptive	The concept is far from the dominant design and can be a dedicated design approach	Expansive partition

Figure 2.9: Colour codes C-space (Agogué et al., 2014).

first" and "depth first" and can be used separately or together, depending on factors such as time and goal. "Breadth first" is the exploration of many different design paths, divergence, and "depth first" is to explore one path more deeply, convergence (see figure X1). "Breadth first" is good to use when many different solutions are sought, and better for reaching more original concepts, though it is resource consuming. "Depth first" will find out quickly if a path has potential value, but fewer paths will be explored which reduces the possibility to find originality.

C-K theory is good to use in both science-based and creativity oriented projects, as the two following examples can testify.

In a European Space Agency (ESA) project designers were trying to develop a new better engine for a known mission on Mars. They did not succeed in creating the desired engine for the intended Mars missions, but found a completely new functional space for the Mg-CO2 combustion engine in new missions (Hatchuel et al., 2004). C-K theory had been used in the process and got the designers to realise that the new Mg-CO2 combustion engine that they had developed would fit perfectly for other missions on Mars. The use of the C-K theory enabled the team to ease up on the constraints of the products needs and the use of the product. In C-K theory the concepts often contain both constraints and solutions.

In another project by Avanti, a nail holder was developed using C-K theory for structuring the work (Hatchuel et al., 2004). In the case of the nail-holder, the large amount of ideas needed to be well-structured and there were little previous knowledge needed. C-K theory helped as a controller of creativity in this case, to identify the best options for further exploration. When the solution for a nail-holder was found, C-K theory could be used in the further development of the whole product series, and worked well as a structuring tool for the series growth strategy.

The C-K theory has both advantages and disadvantages. The C-K theory has advantages against other existing design methods and creative theories. The fact that C-K theory can be used in different industries is one of its biggest advantages. It is mostly used in engineering design and management (Agogué and Kazakçi, 2013). Many other theories are limited to one profession since they are developed to be used in a specific context.

C-K theory helps overcoming the fixation effects that trap the mind and prevents it from being creative, from expansion. According to Hatchuel (2010), thousands of studies in creative thinking have struggled to overcome the fixation effects, but C-K theory claims to have addressed these issues with the expansion effect in C-K theory.

There exist some limits and disadvantages to the C-K theory. One critique against it is if it can be considered as a scientific theory. According to Choulier et al. (2010) it can better be described as "a descriptive theory of the interaction between knowledge and the early design stage". This is linked to the disadvantage that C-K theory lacks decision criteria of what to do next for the designer. Another disadvantage is that C-K theory does not include the previous research in the design science area. Social aspects, functions and architecture are not considered in the theory. Choulier et al. (2010) states that these disadvantages can be eliminated by a clear scope of the theory.

Choulier et al. (2010) describes that "the links between design and knowledge are clarified and draw fundamental interdependencies". The user of the C-K theory needs some sort of knowledge to develop concepts. The user must have good knowledge in the specific area to reach to the best results possible. Another example is if there are no concepts, no knowledge is possible and without the knowledge there will be no new concepts developed. The theory does not offer a theory of knowledge.

The C-K theory does not help the user in which direction of the K-space or the C-space it is required to push to go further (Choulier et al., 2010). It does not offer which kind of specific knowledge is required to reach the best result in the specific area. There is no description how to guide the process in the theory to go further in the development.

There is no doubt that C-K theory is a good theory for concretising what happens in the innovation phase when new ideas spark, and the reason for why they become viable. C-K theory makes it more apparent when new knowledge is required. The C-K theory can be of good help when innovating as a tool for understanding and also breaking barriers in the mind. There still exist some uncertainty in some parts of the method that can be developed through research. C-K theory was chosen as a method in this project because it has advantages in the area of breaking through mindsets, for example when overcoming a dominant design. During the project the C-K theory will be further evaluated for use in concept development projects at Volvo Cars.

3. Methodology

The methodology chapter introduces the research methodology used during the project, as well as the methods for planning, data collection, concept development, concept choice and prototyping. The setup of the process can be seen in figure 3.1.

3.1 Research Design

Research design is the framework for the procedures of inquiry, the plan for carrying out and accomplishing a project (Maxwell, 2012). It is essential in a project that the plan is thought through to get a well working process and a good result. The research design is decided in the beginning of a project. The reason for having a thought-through research design is to be able to address the problem effectively. Maxwell (2012) proposes a five component method for research design (figure 3.1).

- Goals. This includes why the project is of importance.
- Conceptual framework. Earlier findings, theories and literature study that will help understanding the project.
- Research questions. What specifically is being studied during the project?
- Methods. The methods that will be used in the execution of the project.
- Validity. Discussions and conclusions after the project.

The research questions are the center for the research design, to which the other components of the model are connected (Maxwell, 2012). The research design needs to be specified before

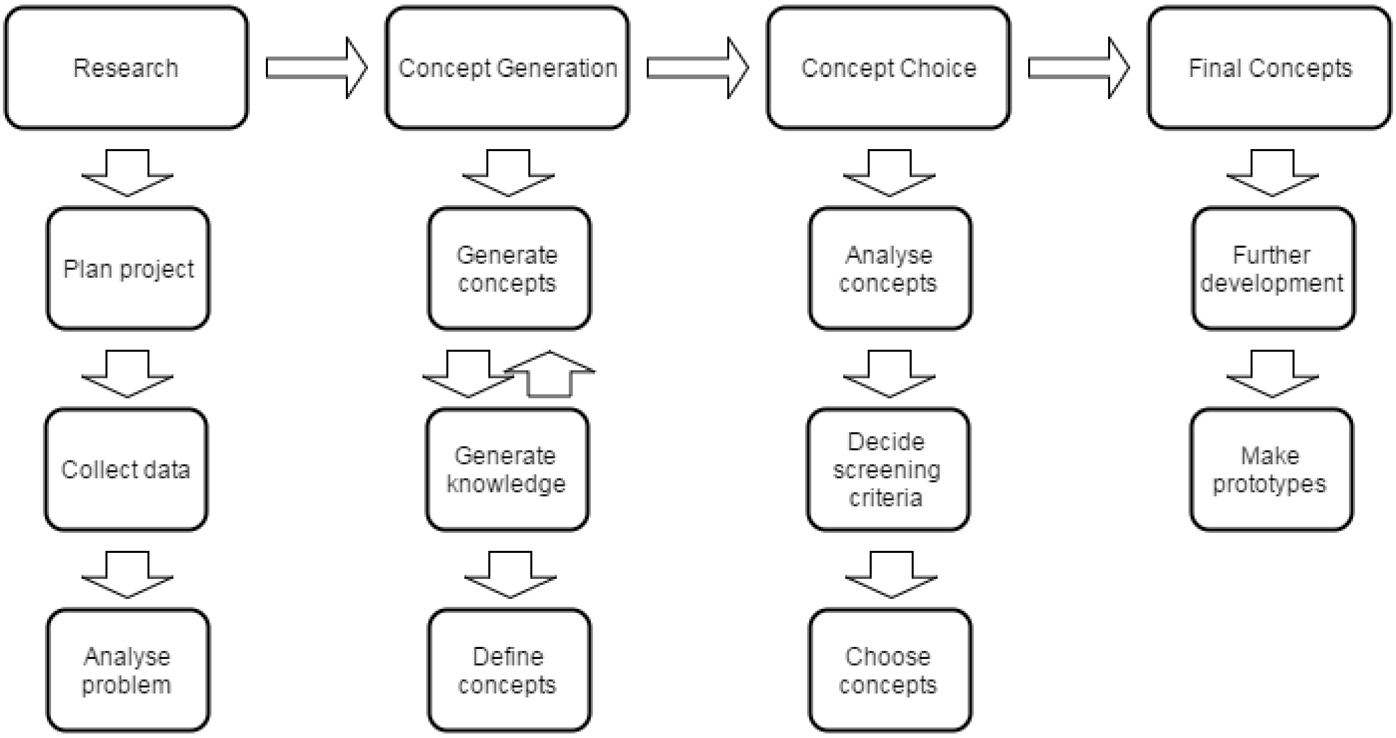

Figure 3.1: Project process.

the start of the project, but can also be modified because of information learnt when the research is being conducted.

There exist both quantitative and qualitative research. In short, quantitative research put emphasis on numbers, things that can be measured or experimentally examined, such as quantities, amounts, intensity, frequency, etc. (Denzin and Lincoln, 2000). It is often used to generalise or explain phenomenons, through for example statistical data. Examples of quantitative methods are questionnaires, polls and surveys. Bryman and Bell (2015) explains that a quantitative research has a deductive approach between the theory and the research. It is common for the research to test a hypothesis from the theory.

Qualitative research on the other hand is about words rather than numbers. Qualitative research concerns the understanding of different areas and the intimate relationship between what is being studied and the researcher (Denzin and Lincoln, 2000), and there are a number of different qualitative research methods. Ethnography/participant observation is when the researcher observe and listen in on a social setting and collect data (Bryman and Bell, 2015). It is called qualitative interviewing when the researcher is somehow conducting interviews. Focus groups is another qualitative method, as well as the language-based approach, which includes for example conversation analysis. There is also collection and qualitative analysis of texts and documents. Qualitative research is often a study of people in one way or another. A critique of qualitative research is that it can become too subjective, since it is based on the researcher's own views (Bryman and Bell, 2015). It is also hard to replicate a qualitative study, there exist problems with generalisation and a lack of transparency within qualitative research. This can be managed by being clear and transparent in the research and show exactly what has been done. It is also good to have discussions and involve other people in the research, which will minimise the

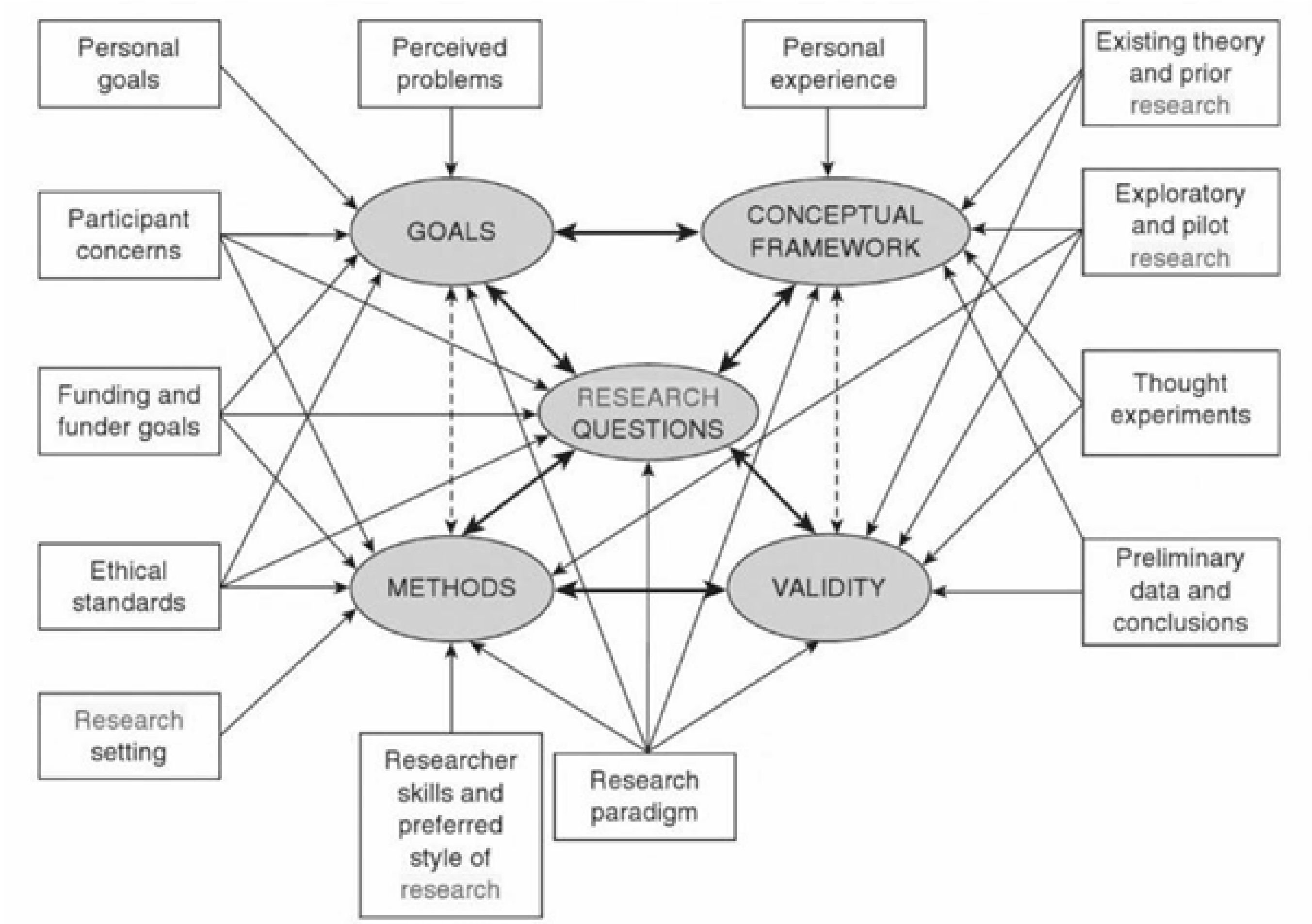

Figure 3.2: Contextual factors influencing research design (Maxwell, 2012).

subjectiveness.

Qualitative research design was chosen for this project because of the nature of the project; product development, narrative research, case study and qualitative data such as interviews are the basis for this project. There was a need to gain a deeper understanding of the subject.

3.1.1 Action Research

Action research is a form of qualitative research where the researcher collaborates with the client to solve a problem and reach a solution (Bryman and Bell, 2015). Action research was firstly introduced in the 1940s by the German-American social psychologist Kurt Lewin (Education Reform, 2015). Kurt Lewin's principles for action research are still the same today 76 years later. Action research is a method where the researchers get involved, evaluate, investigate and analyse an existing problem and finally reach a solution which is better than the current. Ferrance (2000) highlights that action research is not a method where the researchers just study a problem but take action and solve the real problem. The action can for example be to identify any problem in an existing product in a company and solve the problem. The involvement of researchers that action research requires often leads to re-education of the client, they start thinking differently and, as the goal is, take action (Bryman and Bell, 2015).

Action research is also called "cycle of action" since the method is following a process. A simple cycle of action often contains (Education Reform, 2015):

- Identify the current problem
- Collect the data needed
- Organize and analyse the data collected
- Develop a plan to execute the research
- Implement the plan
- Evaluate the result of the plan.

It is important that action research does not only contribute to practical action when the researchers intervene, but that there is a theoretical contribution as well (Bryman and Bell, 2015).

Action research is when the researchers intervene and do the work, not only in theory but in practice. In this project, to intervene means that the researches interacts with employees at Volvo Cars where the project is carried out. The researchers are taking action and developing new research for the company and delivers both new concepts and ideas and are contributing to new mindsets in the area of product development.

3.2 Planning of the Project

After having established project goals, research questions etc., the project needed to be planned. As stated before, planning is crucial for the success of the project. Volvo Cars follow well prepared guidelines when planning projects with new research. By using a GANTT chart, the different activities were determined and the time frames estimated.

3.2.1 Projects at Volvo Cars

Volvo Cars have well prepared R&D frameworks for how to act when delivering new technology and research. The method is a structured, data driven, holistic and failure avoidance focused process for delivering products with success. The first part of the process is the pre-study (FU), where the potential for a certain project is investigated. If the pre-study shows that the project should proceed, the project will pass through a gateway and continue on to becoming part of a program at Volvo Cars. This projects works as an FU at Volvo Cars.

3.2.2 GANTT

The first GANTT-chart was originally developed in the mid-1890s by Karol Adamiecki. 15 years later Henry Gantt developed Adamiecki's idea to his own version of the chart and named it as we know today as the GANTT-chart (Gantt, 2016).

A traditional GANTT-chart is most common in project management. The GANTT-chart is the most popular way of illustrating a project's activities against the project time for each activity (Gantt, 2016). Each activity in the project is vertically listed to the left and all activities are illustrated by a bar. The position and the length of the bar shows the time when the project should start and end the specific activity. The GANTT-chart allows an organisation to become efficient, to show when the project start and end and is a visual way to illustrate where the project is and if more resources are needed to catch the time frame (Tech Advisory, 2013).

3.3 Data Collection

As a basis for the project, different kinds of data was collected. The purpose of data collection is to broaden the knowledge in specific areas in a project. As much necessary information as possible on the time given should be collected for a wide and informative research. This project's data collection includes product analysis, function tree analysis, competitor analysis, semi-structured interviews, meetings and production visits. The strategy is to involve as many important contacts as possible in the beginning of the project to be able to discuss and evaluate the project throughout the whole process.

3.3.1 Sun Visor Analysis

An analysis of the different parts of a product is good to do to get an overview of the parts and why they are important in the product. It can be helpful in a product development process to know what the exiting product consists of. A break-down of the product is done and the parts are analysed in terms of material, use, etc.

An objectives tree takes into account the objectives of a product instead of specifying its material, parts or design. It is important to keep track of the objectives, what the product must be able to accomplish. To solve a design problem one must be aware of the product goals, and an objectives tree is a helpful method in that matter (King, 2015). The method is to start with the top-level goals and break them down into criterias for the product. The criteria is then organised into a tree-structure. A method for making the criteria clearer is to ask what is meant by the statement.

3.3.2 Competitor Analysis

A competitor analysis is a tool to explore and analyse the competitors products and the product properties (Bergman and Klefsjö, 2011). It is a tool to meet the requirements of the customers and to develop products in the right direction. A competitor analysis can be done in the beginning of a project to explore the market and it should be done continuously to keep the products up to date. A competitor analysis should discover different properties which gain high values for the customers. The weaknesses of the competitors can be used as advantages for the next product (Bergman and Klefsjö, 2011).

3.3.3 Semi-Structured Interviews

A semi-structured interview is a unique method which allows the researcher to have a clear structure of the questions asked during an interview, but still the flexibility to leave space for new topics mentioned by the participant (Galletta, 2013). The semi-structured interview gives the opportunity for the researcher to open the interview with a question but still be open to the participants ideas and interests which can gain new knowledge for the researcher. The researcher must prepare a few main questions which are open for discussion. The questions can be rather strict to fully opened. A fully opened question allows the participant to address the topic in his or her direction of interest (Galletta, 2013). The benefits of the semi-structured interview is that the method is very simple, efficient, answers can be very detailed and it allows freedom for both the researcher and the participant. The weaknesses of the method are that the interviewer needs to be skilled to get the full potential of the interview, it is time consuming, it is hard to predict for the researcher what the result of the interview will be and the experience and knowledge that the participant have is very important.

3.3.4 Observations

The observations during this project has been mainly meetings, but also production observations.

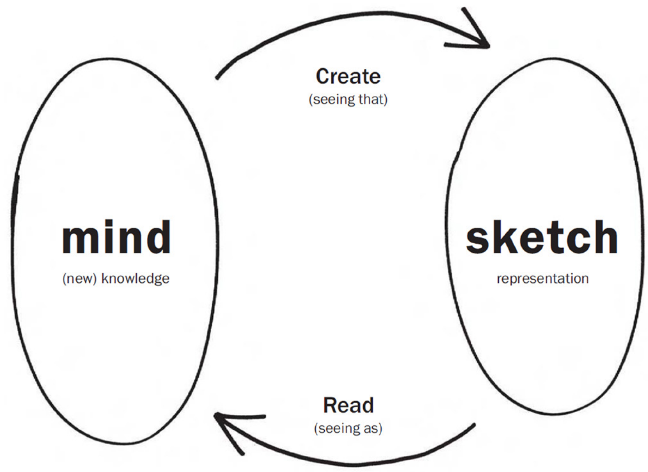

Figure 3.3: Sketching (Buxton, 2007).

Meetings are defined as:

"Formal or informal deliberative assembly of individuals called to debate certain issues and problems, and to take decisions. Formal meetings are held at definite times, at a definite place, and usually for a definite duration to follow an agreed upon agenda" (Business Dictionary, 2016).

Meetings helped the project to gain information in every important aspect that a new product needs to fulfill. A big company as Volvo Cars have many regulations and standards that needs to be followed.

3.4 Concept Generation

When all the necessary data had been collected, the concept generation could begin. By using the C-K theory and sketching, several concepts could take form.

3.4.1 C-K Theory

C-K theory is a theory but it is also a method used to generate ideas and to overcome fixed mind-sets. C-K theory helps to overcome difficult mind-sets to enable the designer to be innovative and create new solutions from concepts. The original concept will be expanded with additional attributes to get the desired properties. As the concept space C is expanded, new knowledge is needed and thus the knowledge space K is expanded (Le Masson et al., 2010). The method goes back and forth between the C space and K space to expand both spaces and come up with more creative ideas with dual expansion. When enough knowledge is collected for a concept in C space to become viable, the concept generation can come to an end.

3.4.2 Sketching

Sketching is a great communication tool during the ideation process. As a complement to other methods, it serves to visualise and communicate ideas but also to explore ideas and come up with new ideas. When visualising an idea, the sketch is made from existing knowledge in the mind (Buxton, 2007). When reviewing the sketch new knowledge is created. This way, sketching can be a tool for developing ideas (see figure 3.3).

3.5 Concept Selection

To choose between the concepts developed, concept selection methods were used. By evaluating the concepts through the Pugh matrix, criterion assessment method and the comparison method, the number of concepts were reduced.

3.5.1 Pugh Matrix

The Pugh matrix is a decision-making method, developed by Stuart Pugh. The number of choices is reduced by sorting out the least viable choices (Johannesson et al., 2004). A number of criteria represent the requirements of the product. The potential concepts are compared to the original solution (baseline) and scored in the matrix. The scores are better (+), equal (0) or worse (-) than the baseline. The weighted Pugh matrix has ranked criteria from 1 to 3 depending on the importance of the criteria. Each score is multiplied with the importance of the weighted criteria in the calculation. This method is the first step to evaluate all concept and finally to eliminate the concepts with the least potential (lowest score).

3.5.2 Criterion Assessment

The existing ideas are evaluated based on a number of criterion (Johannesson et al., 2004). The criterion chosen are important for the performance of the final product. The criterion are weighted so that the more important criteria will receive higher points in the score. Each idea is evaluated against each one of the criteria and is given points as following:

3 = Meets criterion very well
2 = Meets criterion fairly well
1 = Meets criterion modestly
0 = Does not meet criterion

The total weighted score provides a ranking for the ideas.

3.5.3 Comparison Method

Ideas are evaluated based on pairwise comparison (Johannesson et al., 2004). Each idea is compared to all other ideas, concerning different criterias. In each comparison the best idea gets a point, and if both ideas are similar in the current aspect they get half a point each. The ideas are scored on each criteria and the assembled total score provides a ranking.

3.6 Prototyping

A prototype is a representation of the final product (Banerjee, 2014). The purpose of a prototype is to test the product functions before finalising the product. The prototype simulates how the final product will work, but can be very simplistic. It is important to emphasize that the prototype is not the final product. A prototype can be made is several different ways, for instance a physical prototype or a CAD prototype. The prototypes at Volvo Cars are made by the Concept Center (FU-verkstaden).

3.6.1 Documentation

The prototypes were documented using photos and film, to use during presentation and in the report.

4. Pre-study

This chapter presents the outcome of the data collection; the sun visor was taken apart and analysed and an objectives tree was done, the competitors were assessed and a visit to the production line at Volvo Cars was made.

4.1 The Parts of a Sun Visor

An analysis of a sun visor was conducted in order to produce a list of the components in a typical sun visor. A sun visor was disassembled and documented (see figures 4.1-4.5). The analysis gained information on how a sun visor is made, assembled and how the mechanics work inside.

4.1.1 Component Overview

a. Skeleton	plastic or metal
b. Axis	plastic and metal
c. Ceiling mounting	plastic and metal
d. Electric cable	wire with plastic cover
e. Padding	Styrofoam
f. Surface material	fabric or vinyl
g. Glue	-
h. Mirror frame	plastic
i. Mirror lid	plastic
j. Mirror	glass
k. Lens	frosted polycarbonate
l. Light electronics	plastic and metal
m. Screws / clips	metal
n. Screw covers	plastic

4.1.2 Component Analysis

a. Skeleton
The skeleton is the base on which the other parts of the sun visor are mounted (see figure 4.1). Its main function is to make the sun visor stable. There are clips on the skeleton on which the mirror case can be mounted. The skeleton is usually made of plastic with metal parts but can be fully made of metal. The plastic colour usually matches the colour of the ceiling.

b. Axis
The axis is mounted to the skeleton and its function is to be able to rotate the visor around the y and z axis (see figure 4.1). The axis usually has a metal core with plastic cover. The plastic often has a colour matching the ceiling.

c. Ceiling mounting
The ceiling mounted foot is what mounts the sun visor to the ceiling. It is fastened to the axis (see figure 4.1). Holes in the part enable screws (or clips) to mount it to the ceiling. Clips on the sides of the part make the visor stay in place during assembly. The foot is made of plastic of the same colour as the other plastic parts.

d. Electric cables
The electric cables go through the axis to the skeleton and ends where the light electronics will be fastened. The other end is later connected with the car's power system. The cable is made of wire and plastic isolation (see figure 4.2).

e. Padding
The padding is a cover for the skeleton and for protection. It is made of moulded Styrofoam to fit the skeleton (see figure 4.3). The padding can also be a plastic cover, but then the sun visor does not need a skeleton.

f. Surface material
The surface material can be either in fabric or vinyl (see figure 4.4). Fabric is often used in premium cars and vinyl is the more common

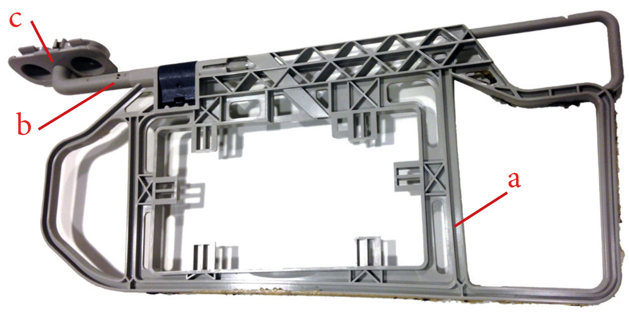

Figure 4.1: a. Skelleton and b. Axis and c. Ceiling mounting foot.

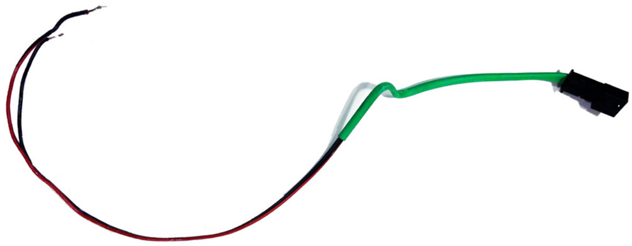

Figure 4.2: d. Electric cable.

Figure 4.3: e. Padding in Styrofoam.

Figure 4.4: f. Surface material in fabric.

material. It is fastened with adhesive and glue.

g. Glue
The glue is used to attach the skeleton to one side of padding and then to glue the pieces together with the surface material.

h. Mirror frame with ticket holder
The mirror frame is the base of the mirror case sub-assembly (mirror frame, lid, mirror, electrical parts and lens), which is then attached to the clips on the skeleton (see figure 4.5). The mirror frame with integrated ticket holder is made out of plastic.

i. Mirror lid
The function of the mirror lid is to shield the light when it is not in use (see figure 4.5). The lid is also the switch for the light, which is on when the lid is open and is switched off when the lid is closed.

j. Mirror
The mirror is attached between the frame and the light electronics (see figure 4.5). The mirror's main function is for the user to be able to look themselves in the mirror. It is made of glass.

k. Lens
The lens is mounted to the electrical part. The lens is used to spread the light from the LED lamp. It is made of frosted polycarbonate (see figure 4.5).

l. Light electronics
The light electronics have the function of powering the LED lamp. The electronic part is attached to the frame with four clips. It is made of plastic and metal, a circuit board and a LED lamp (see figure 4.5).

m. Screws / clips
The function of the screws and clips are to fasten the sun visor to the ceiling. The screws are made of metal and the clips of either metal or plastic.

n. Plastic covers
The plastic covers cover the screws and clips when the sun visor has been installed in the car.

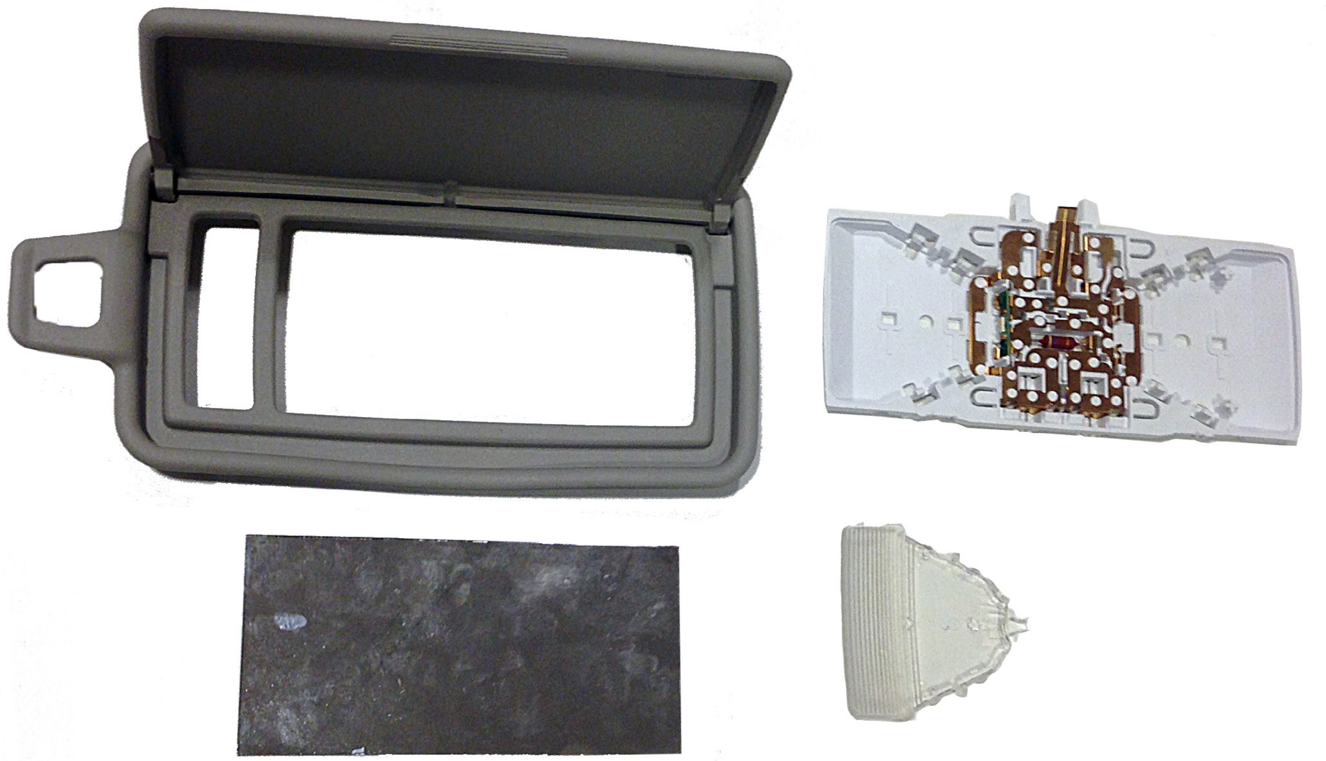

Figure 4.5: h. Mirror frame, i. Mirror lid, j. Mirror, k. Lens and l. Light electronics.

4.1.3 Assembly

The axis and ceiling mounting are assembled with the electric cable, and then mounted to the skeleton. The Styrofoam padding and surface material are then mounted to the previous parts with glue.

The mirror frame and lid are assembled together with the mirror, lens and light electronics. The mirror case is mounted to the rest of the sun visor.
The sun visor is mounted to the ceiling during the production of the whole car (see Appendix 1). This is done by firstly attaching the sun visor provisionally to the detached ceiling, by fastening it with clips on the sides of the ceiling mounted foot part. The ceiling is placed in the car and the sun visor and ceiling are mounted to the roof by screws (or clips). The screw covers are attached to hide the screw heads.

4.2 Objectives Tree

The objectives tree analysis was made on the sun visor to investigate what objectives of the existing product are important (see figure 4.6). Volvo Cars' standard sun visor functions were taken in consideration when the objectives tree analysis was made.

A sun visor's most important function is to cover light, so that the occupant do not get disturbed by light, for example blinded by sunlight or irritated by flickering streetlights. To be able to fulfill this function the sun visor needs to be able to cover light both from the front and the side, to rotate and it needs to stay in the desired position.

The current sun visor is often the provider of a vanity mirror. The mirror needs to reflect image and there is also a need for a mirror cover, to eliminate the risk of reflecting light when the mirror is not in use.

The sun visor often has a light source to illuminate the face when a mirror is present. The light source needs to have the ability to be turned on and off.

The sun visor is also the provider of information about airbag safety, which by current law regulations is located on the sun visor.

To be able to be as innovative as possible when developing a new sun visor, a decision was made

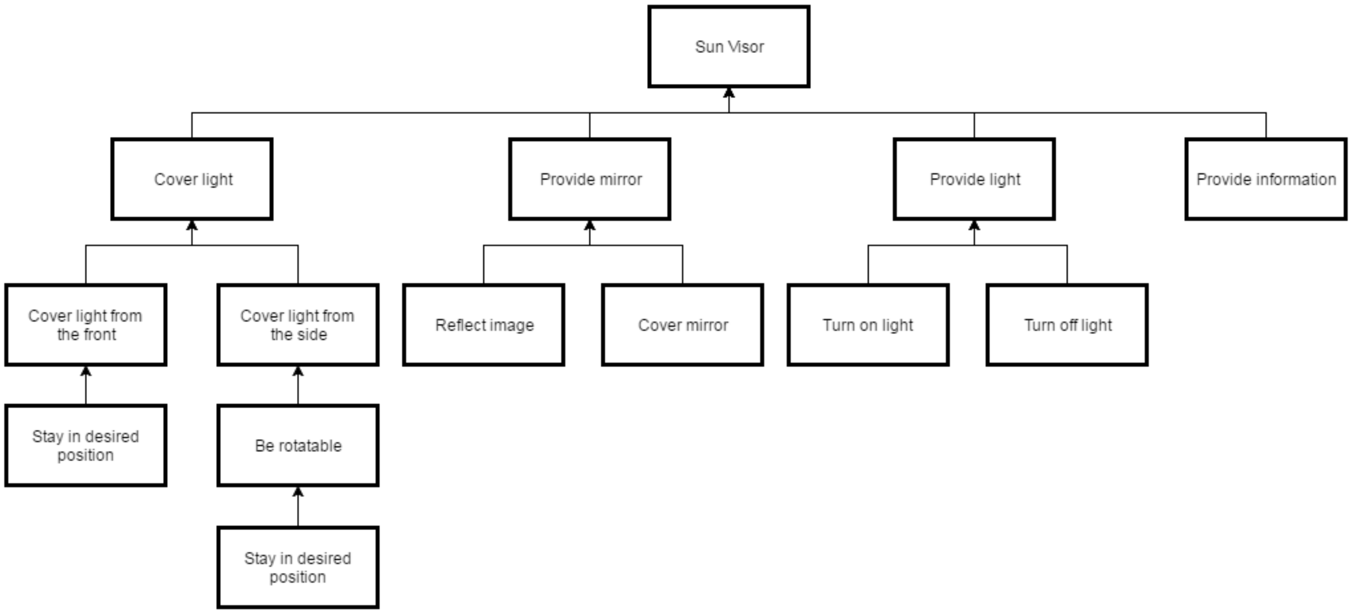

Figure 4.6: Objectives tree.

only to focus on the objective of cover light, since the other objectives would be too restrictive. They were kept as objectives that "would be nice" to fulfill.

4.3 Competitor analysis

When the sun visor components had been analysed and the functions investigated, the next step was to compare the current solution to other car manufacturers' sun visors. A competitor analysis was made to gain information about the range of sun visor solutions on the market today. The market analysed can be considered a European market since the car brands and models analysed were found at car dealers in the Gothenburg area. Volvo Cars competitors were examined to detect the strengths and weaknesses and Volvo's own car models were analysed to see potential improvements and to see their performance compared to other brands. In the competitor analysis 35 different car models at Audi, BMW, Citroën, Mercedes-Benz, Peugeot, Tesla, Toyota, Volkswagen and Volvo were analysed. Volvo's closest competitors were mainly focused on but other brands were also a part of the competitor analysis because of their interesting approach and sun visor solutions (such as Tesla, Peugeot and Citroën). The analysis only contained new cars from 2016 (except from the inspiring roof solution in Citroën DS 4 from 2012), from one of the competitors' smallest car models to one of the largest car models. It was interesting to investigate both smaller and larger cars, since roominess in the driver compartment and difference in price affect the sun visor. The marginal on the larger cars are higher and the sun visors are often more equipped. The competitor analysis is summarised in Appendix 2.

The main focus of the competitor analysis was on the exterior part of the sun visors since there were no possibility to take the sun visors apart. The aim was to gain a feeling for the market, see the different standards and to see possibilities for improvements for Volvo. It is important to explore Volvo Cars' strengths and weaknesses today to be able to develop a new sun visor that can be a future competitor advantage for Volvo. Aspects examined were surface material, mirror


Figure 4.7: Volvos small plastic clip ticket holder.

size, type of mirror cover, ticket holder size and type, number of lights, position of light, the position of the sun visor, if there was any extra sun protection solution available and additional observations. The research method was to take pictures and then analyse the differences between the brands and models. All data was summarised in Excel (see Appendix 2) but both significantly good and bad solutions were prioritised. The competitor analysis gained further knowledge and information that could be used in the further research. The different factors were analysed on some car models from each brand, to finally be compared with Volvos car models (see chapter 4.3.10). Every brand's sun visors are described below in the following segments.

4.3.1 Volvo

For comparison during the market research the Volvo car models V40, V60, S60, XC70, XC60 and XC90 were analysed (see the whole analysis in Appendix 3). All Volvo sun visors are mounted in the ceiling. Volvo has large mirrors with lid covers and lights on each side of the mirror in every model except in the XC90, which have a

Figure 4.8: Edge of sun visor sticking out.

smaller mirror with only one light source. Four cars had fabric and two had vinyl and no extra sun protection is offered on any car model. Ticket holder, a very small plastic clip (figure 4.7) is only available in the XC90.

4.3.2 Audi

The Audi car models analysed were A1, A6, Q5 and Q7 (see the whole analysis in Appendix 4). Every Audi car model had medium sized mirrors with sliding mirror covers. All sun visors had medium sized plastic clips as ticket holders on the driver's side. A1 and Q5 had vinyl material and A6 and Q7 had fabric. A1 had no light at all but all other models had one light source in the ceiling. Audi did not provide any extra sun protection.

4.3.3 BMW

The BMW car models 118i, M4 cab, 520d Sedan, X3 xdrive 20d and X5 edrive were analysed (see the whole analysis in Appendix 5). BMW have small mirrors and bands as ticket holder in the smaller models and medium mirrors with a medium sized clip as ticket holder in the larger models. The ticket holders are on both sides

Figure 4.9: Extra sun protection on BMW.

Figure 4.10: Roof slided back vs. in the original position.

Figure 4.11: The axis is placed in an ineffective position.

Figure 4.12: The protruding edge.

in every model. All cars had vinyl material and sliding mirror covers. BMW offers one light in the ceiling except in the M4 cab which had no light. Both 118i and M4 cab had very small sun visors and in the cabriolet the sun visor edge was sticking out in X direction (see figure 4.8). The larger models had an effective extra sun protection solution, in the form of a telescopic axis, to cover the sun from the side window (see figure 4.9).

4.3.4 Citroën

Citroën DS4 was analysed because of the innovative solution for the windshield, roof and sun visor. It is possible to move the sun visor backwards in X direction to gain a bigger windshield which gives a more spacious feeling in the car (see figure 4.10). The sun visor was mounted on the sliding roof panel. The mirror was medium sized with a lid cover. The ticket holder was a pocket in the plastic on the side of the sun visor and Citroën had not prioritized any light sources. Better sun protection on the side was possible due to the sliding roof solution, which enabled the sun visor to slide back to cover sun from the side better. See the whole analysis in Appendix 6.

4.3.5 Mercedes-Benz

The Mercedes-Benz car models analysed were A 200d, C 350e Kombi and GLA 200 CDI (see the whole analysis in Appendix 7). Mercedes-Benz had very similar sun visors in all their models. All models had vinyl surface material, one light in the ceiling, medium mirrors with lid covers. All models had plastic clips as ticket holders on

Figure 4.13: smooth transition between the roof and the sun visor.

both sides and they had no extra sun protection. The only difference was that the largest model had a slightly bigger mirror. When the sun visor was removed from the original position to the side the light was turned off automatically. The sun visor axis was placed in an ineffective position (figure 4.11) which resulted in poor side coverage, since part of the coverage from the sun visor cannot be used in the turned position.

4.3.6 Peugeot

The Peugeot models 208, 308 Sport Wagon, 508 SW GT and 5008 Allure were analysed (see the whole analysis in Appendix 6). All sun visors had vinyl surface material, large mirrors, except the smallest model, with lid covers and very small plastic clips as ticket holders, except the biggest model which had a diagonal band. Peugeot offered one light on each side of the mirror except on the smallest model which had no light. No extra sun protection was provided. All models except 308 Sport Wagon had a protruding edge

Figure 4.14: Good side sun protection on Model S.

Figure 4.15: Innovative solution on Model X.

to the panoramic roof, see figure 4.12. 308 had a slightly smaller roof visible in figure 4.13.

4.3.7 Tesla

The Tesla car models studied in this analysis were Model S and Model X (see full analysis in Appendix 8). The Tesla Model S has a very long sun visor (in Y direction in its original position in the ceiling). The long sun visor gives good protection against light coming from the side (figure 4.14). The light source is positioned in the overhead panel directed at the mirror. The mirror is large and has seamless edges. The Tesla Model X has a different sun visor solution than any of the other car manufacturers. The sun visor is positioned in the elongated A-pillar and can be manually mounted to the overhead console with magnetic fastening when used. The mirror is large and has one light on each side of the mirror (figure 4.15). Both models had fabric, no ticket holders and no additional sun protection solutions.

4.3.8 Toyota

Toyota Verso, Auris Touring S and RAV 4 were analysed (see whole analysis in Appendix 9).

Figure 4.16: Ugly edge.

Figure 4.17: Telescopic extension.

All Toyota cars had vinyl surface material and medium sized mirrors with both sliding covers and lid covers. The light is positioned in the ceiling and Auris Touring S had a switch to turn on and off the ceiling light. Only the smallest model had a band ticket holder.

4.3.9 Volkswagen

The Volkswagen car models analysed were Beetle cabriolet TSI 105, Golf 1,6 TDI 110, Passat 120 SC TDI, Touran TSI 110, Tignan Premium R and Touareg TDI 204 (see full analysis in Appendix 10). Volkswagen have sun visors with vinyl material (with soft padding on the biggest

Figure 4.18: Poor side sun protection of an XC70.

Figure 4.19: Difference in ticket holder size between Volvo (top picture) and Audi (bottom picture).

Figure 4.20: Using the sun visors with and without extention in Volkswagen cars.

model) and medium size mirrors with sliding lids. They mix both bands and clips as ticket holders. The cabriolet had no light but the other models had one light positioned in the ceiling. The biggest model had light around the mirror. The cabriolet had aprotruding edge in X direction (figure 4.16). Extra sun protection was an option with telescopic extension (figure 4.17).

4.3.10 Summary of the competitor analysis

The result of the competitor analysis was that Volvo has a lot of improvements to make but they also have strengths. Their strengths are that they had more models with fabric material, which feels more premium than vinyl. Volvo also have on average the largest mirrors. Volvos biggest problems are that they only got one ticket holder on all models analysed (on the XC90), which was the smallest one and that Volvo had the worst side sun protection which is not good enough, see figure 4.18. The difference in size of the ticket holder in Volvo and Audi can be seen in figure 4.19.

The general analysis shows that all models except one position their sun visor in the ceiling. Vinyl is the most popular surface material and the most used mirror size is medium. The mirror cover is even between sliding covers and lid covers. The majority of the models had some kind of ticket holder. To have one light in the ceiling was most popular but one light on each side of the mirror was common as well. No extra sun protection dominated the research but three out of nine brands (including Citroën) offers extra sun protection on some models. The analysis can be seen in Appendix 2.

The telescopic extension was the most popular solution for additional sun protection and the result was impressive. The difference between two Volkswagen models with and without the telescopic extension can be seen in figure 4.20.

Another factor that the research showed was that all cabriolets and all models with large panoramic roofs have problems with protruding edges in X direction (see figure 4.13 and 4.16). The sun visors are not made for large panoramic roofs. The only model with innovative mirror lights were Volkswagen Touareg TDI 204 which had the mirror light around the mirror, which created a backlit feeling (figure 4.21).

Tesla and Citroën was part of the market research due to their innovative solutions for the sun visor, even though they are not main competitors to Volvo. The Tesla Model S had a very wide sun visor in Y direction (in the original position) which solved the problem when the sun is shining from the left side of the driver. The problem with that solution is that the driver has to basically duck to dodge the sun visor hitting the head when turning it to the side. The Tesla Model X offers the customer an extremely large windshield which gives an open and comfortable feeling. The difference from an original windshield and Tesla Model X can be seen in the red rectangle in figure 4.22. Because of the large windscreen they cannot have a normal sun visor positioned in the ceiling and have one that is positioned on the elongated a-pillar instead. Figure 4.23 shows the interesting sun visor in use on the large windscreen.

Volvos weakness is that they do not offer any extra solution for shielding the sun from the side. Other car brands have solutions in the form of for example telescopic extensions. Volvo have the biggest average mirrors, but only a ticket holder on the XC90. The competitor car models have a ticket holder on almost every car model, even the smallest cars. The ticket holder on the XC90 is also the smallest on the market, which is bad especially for the chinese market. Volvo have fabric material on most of the sun visors, but in general vinyl is the most used material, even on the competitors premium cars. As a conclusion on the competitor analysis, there are very few interesting sun visors on the market today and Volvos weaknesses were easy to identify.

4.4 Problem identification

A compilation of the problems of the current Volvo Cars sun visor was made.

- The sun visor is inconvenient to use. When turning the sun visor to the side the visor often hits the head of the occupant, which can lead to the occupant having to dodge the sun visor while driving.
- The sun visor, and especially the attachment foot, poses a security risk in case of a crash.
- The lack of spaciousness in the car that the sun visor contributes to is an issue when wanting a more premium feeling.
- The current sun visor is too long in x-direction for the future large panoramic roofs.
- The sun visor form inadequate coverage. Light can leak through the gaps and blind the occupant. This problem is especially evident with light coming from the side, where the sun visor does not cover well enough.
- The sun visor can block the visibility during for example low sun.
- The sun visor design has been looking almost the same for decades and is generally

Figure 4.21: Light around the mirror on Volkswagen.

Figure 4.22: View of the windshield on Tesla Model X.


Figure 4.23: Tesla Model X windshield.

regarded as unattractive.
- Manual components are becoming outdated, and the industry is moving towards more automated products.

4.5 Production Visit

A production visit is recommended the get a helicopter view of the project and to understand the whole product process from idea to finished product. A visit to the production at Volvo Cars was made to gain an overall understanding on how the production process of a car works as well as to see the installation of the current sun visor in a car (see Appendix 1).

The visit started with a walk through the production plant, watching several different parts of the assembly of the different car models that are built in Torslanda. A longer stop was made at the inner ceiling assembly point, where among other parts, the sun visors was put together with the ceiling. The sun visor, which is already assembled from a supplier, is provisionally mounted to the ceiling by small clips on the attachment parts. The ceiling is sent forward to be mounted to the car body. The screws in the sun visor are also what is partly holding the ceiling to the body. When the visor is screwed to the ceiling, the ceiling is also fastened. The visit ended with watching the finished cars rolling onto the factory floor.

5. Concept Generation

This chapter tells of the process from early ideas to the final concept choice, through the use of the C-K theory and concept selection methods.

5.1 C-K Theory in Practice

C-K theory was used as a framework for how the whole process of concept development was organised. The process followed during the project was that when an idea sparked in C-space, information was sought. The information could then bring up new issues that needed new knowledge in K-space, spark new ideas in C-space or confirm that an idea worked, conjunction, meaning it was a viable concept. The process thus went back and forth between the two spaces until a conjunction was made. The information gathering during the process mainly consisted of meeting people with knowledge and having semi-structured interviews with them (see Appendix 15).

5.1.1 Coming up with ideas

The hardest part in an idea generation process is to actually come up with novel ideas. Most ideas in this project sparked through association, often from existing products in other markets. A lot of research was done to see what other products existed that had similar functions as sun visors in cars. Many interesting future innovations were taken into consideration, even though the technology might be too far off in the future for the current project.

When an idea sparked, sketching was used to explore the idea. As the method of C-K theory states, new knowledge needed to be gathered to proceed with the idea. The new knowledge could either verify some part or the whole concept, generate a new concept or produce new questions that needed new knowledge to be answered.

5.1.2 Gathering of knowledge

The use of semi-structured interviews was very successful for the project at Volvo Cars. Many people in the extended project team had knowledge in specific areas which could extend the research further. Semi-structured interviews were used during meetings throughout the whole project to gain information in different areas during different stages of the project.

The knowledge gathering were conducted during meetings held by the researchers. By letting the meetings be quite open, with only the main area of discussion explained, the participants could have more spontaneous comments and get the chance to be more elaborate. The meetings could take unexpected turns if interesting information came up. The meeting time would vary but often be around an hour or more, to give time for contemplation and discussion between researchers and participants.

The outcome of the meetings were often that a lot of new information had come up, which broadened the perspective of the research area. Unfortunately most of the knowledge gathered were not useful for the concept generation process and did not lead much further into the C-K process. The information often consisted of limitations in the project, that the participants considered ideas to be impossible to implement because of the current car structure.

In this part of the research, it was important to realise that the limitations brought up should not limit the concept generation process, but be seen as additional knowledge that did not need to be taken into consideration during this part of the process.

5.2 Early Concept Definitions

After a thorough concept generation process a first draft of ideas were made. The following concepts are the concepts that were put through the elimination process later on.

A. Foldable Sun Visor
The sun visor is wider than a conventional sun visor and the same in length, but folded in half to fit on the side roof (see figure 5.1). The foldable sun visor is placed in the cavity where the roof handle is placed today. The cavity is extended to fit a sun visor. The sun visor can be used both on the side and the front, by turning it.

B. Two-part Sun Visor
This sun visor concept is made of two flat parts that are slidable against each other (see figure 5.2). It has the same width as a conventional sun visor but is half in length. It can be extended to full length by sliding one of the visor parts down, and can also be extended in width by sliding one part to the side. It is fastened to the roof in the same way as the current sun visor and can be turned to the side.

C. Bent Axis
The sun visor looks like a conventional sun visor but has an elongated bent axis that accommodates for placing the visor further forward, which works well with a skyroof (see figure 5.3). The axis also makes it possible to have the sun visor cover the sun more from the side window.

D. Moveable Sun Visor
The sun visor is detachable to be able to move it where it is needed, with attachments on carefully chosen spots in the car. It has one attachment

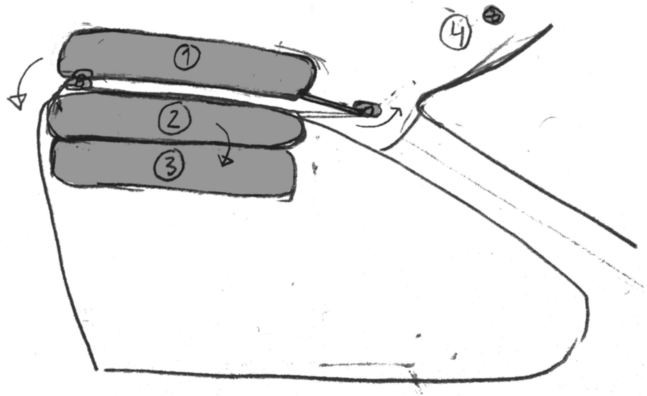

Figure 5.1: Foldable sun visor.

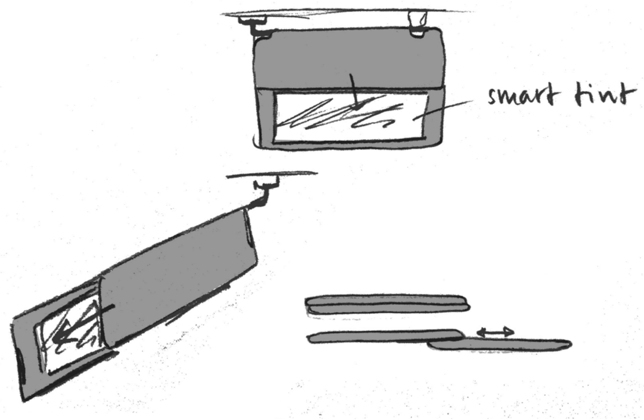

Figure 5.2: Two-part sun visor.

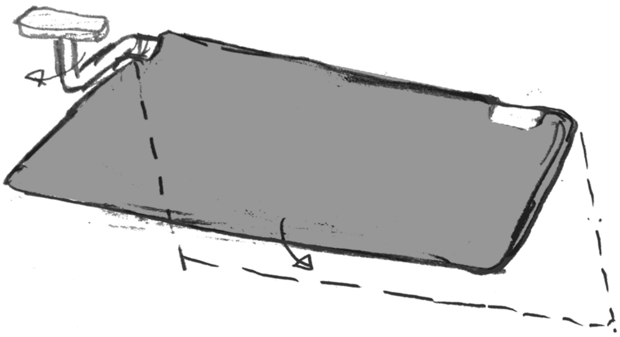

Figure 5.3: Sun visor with an elongated bent axis.

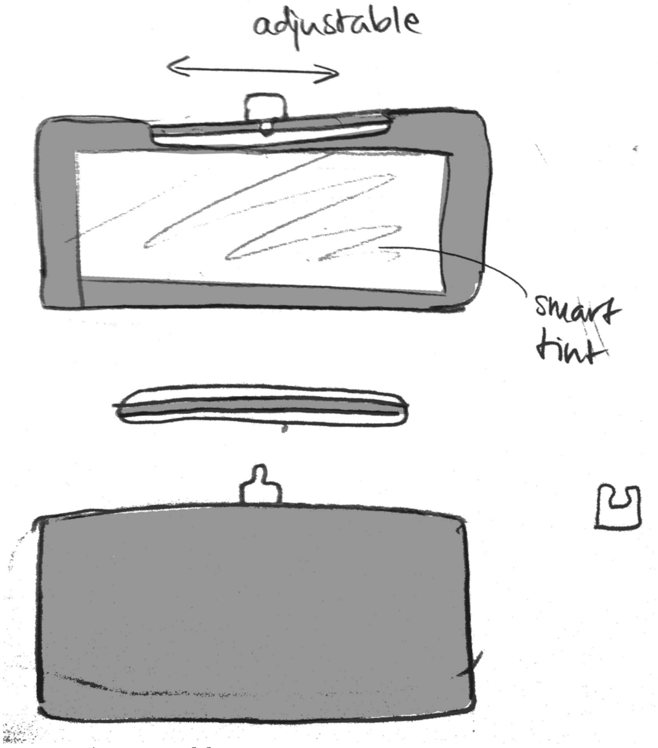

Figure 5.4: Movable sun visor.

that is fastened to a rod in the ceiling, which makes it possible to slide the visor sideways, both in the front and the side (see figure 5.4).

E. Panel Curtain
A manually slidable panel curtain obscures the sun from the side window. The panel curtain is attached to the upper and lower part of the window in the door (see figure 5.5). A conventional sun visor obscures the sun from the windscreen.

F. See-through Sun Visor
The sun visor is made out of a see-through plastic material that obscures the sun, like the glass in sun glasses. It is designed like a conventional sun visor with an extension to be able to cover sun from the side (see figure 5.6).

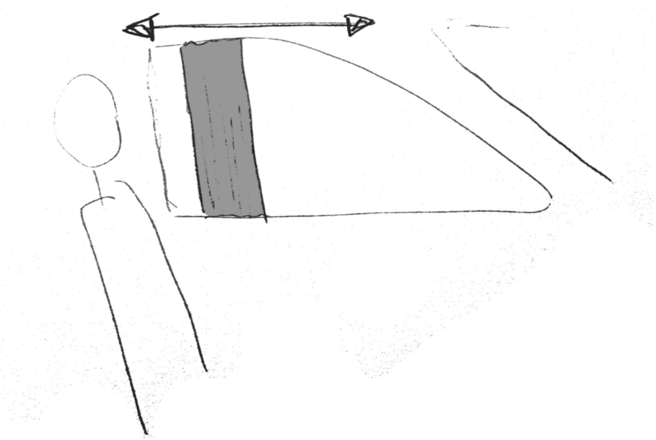

Figure 5.5: Panel curtain.

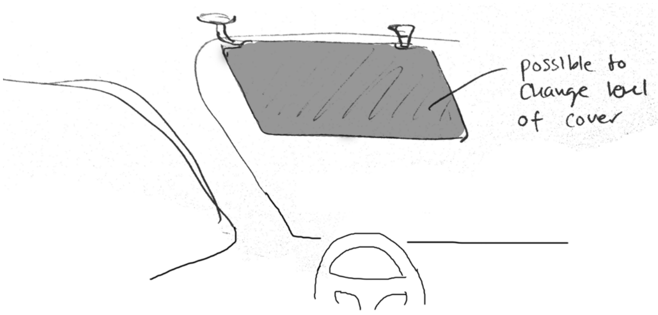

Figure 5.6: See-thorugh sun visor.

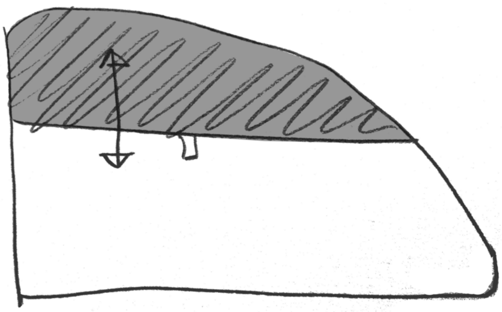

Figure 5.7: Manual pull-down curtain on the side window.

G. Manual Pull-down Curtain on Side Window
A pull-down curtain placed in the side of the roof shades the sun coming from the side window. It is operated by pulling a tab and dragging the curtain downwards (see figure 5.7). A conventional sun visor with only one attachment point covers sun from the front.

H. Roll-down Curtain
The roll-down curtains between the A pillar- B pillar and A pillar- WEM are button controlled from the door armrest, similar to the controlling of the window (see figure 5.8). The curtains are made of a material that is see-through but still obscures sun.

I. Manual Horizontal Curtains
A see-through fabric or film is contained in a roll placed in the B and A pillar respectively. The fabric can be manually pulled out over the window and fastened with magnetic attachment (see figure 5.9).

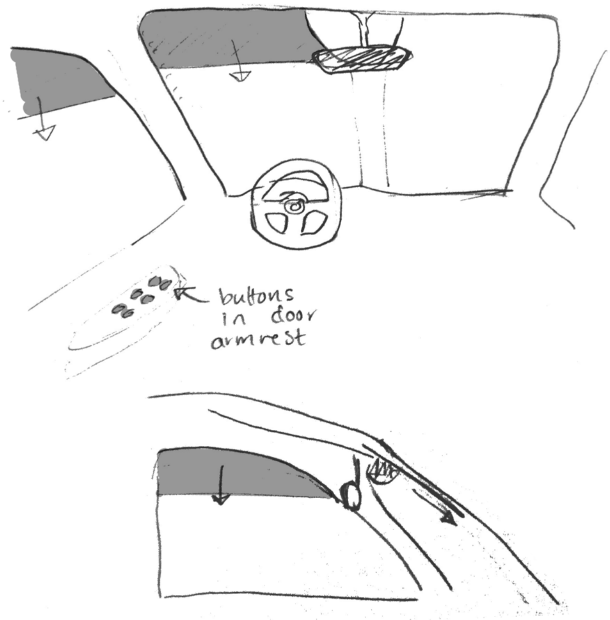

Figure 5.8: Roll-down curtain.

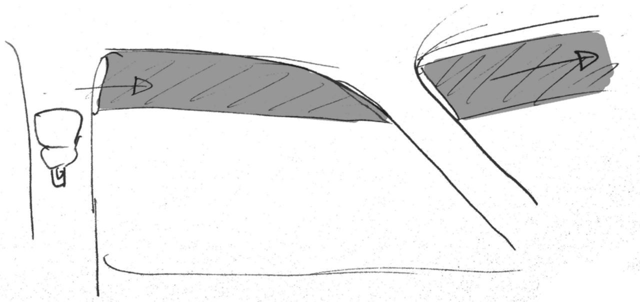

Figure 5.9: Manual curtains that pulls out horizontally.

J. Eyetracking and sun sensors
Thin blade made of OLED which blacks down on the part of the visor where the sun is shining. Otherwise it looks like a conventional sun visor with the turning axis but with the additional extension possibility to account for sun coming from the side window.

K. Blackdown
Whole car gets blackened by curtains to accommodate for sleeping in cars with autonomous drive. The curtains can be both see-through and not, so that the driver can still see the road when it is pulled down. When the driver is driving the car the curtains can be removed or be halfway down to shade sun.

L. Extention and B-pillar Attachment
A sun visor with a more attractive design and an extension to be able to shade sun from the side window. There is also a B-pillar attachment to stabilise the sun visor (see figure 5.10). The visor can be made thinner by having a mirror without casing, which also makes it look more like the rear view mirror.

5.3 Pugh Matrix

A weighted Pugh Matrix was used to compare the concepts against different criteria's. The criteria were selected as requirements of a new sun visor. A scale from one to three was used as levels of importance for the criteria. Four of the concepts were eliminated (33%) in this first stage, see Appendix 11. The concepts that advanced to the next stage were A, B, F, G, H, I, J and K.

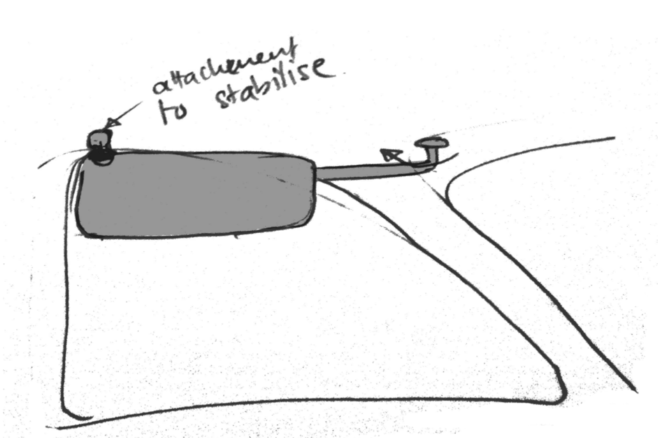

Figure 5.10: Sun visor with telescopic extension.

5.4 Criterion Assessment

The eight remaining concepts after elimination by the Pugh Matrix were now further eliminated to five concepts by using the Criterion Assessment method. The criterions used were the same as in the Pugh Matrix. By giving the concepts points between 0-3 depending on how well criteria's are met, the best concepts could be distinguished. The concepts that scored the highest points were kept for the next elimination step. The concepts H, I , A, B and F (in that order) were kept in favor for G, J and K (see Appendix 12). K was eliminated because it was judged to be too advanced and made for future cars, even though it scored high.

5.5 Comparison Method

The concepts A, B, F, H and I were compared with respect to coverage, z-direction package, adaptability to sky roof, visibility, ease of use, ergonomic adaption, crash safety and realisability. The concepts were ranked from first to last in the order H, F, I , A and B (see Appendix 13 and 14).

5.6 Concept Choice

The choice to go forward with only two concepts was made in consultation with the Volvo Cars supervisor Carl-Johan Kaudern. After discussion about opportunities, risks, safety, etc. an agreement was made on which concepts should be investigated further. The concept that scored the highest score in most concept choice methods, concept H, was chosen to go forward with. Concept B was chosen in favor for A, F and I. A was considered too complicated for actual implementation and I is actually a variation on concept H. It was later on decided to include ideas for future solutions that had not been included in the concept generation because of the delimitations.

6. Final Concepts and Implementation

In this chapter the final concepts and the prototyping of them will be presented.

6.1 The Concepts

The project resulted in two new sun visor concepts and one vision for the future of sun visors in cars.

6.1.1 Two-part Sun Visor

The two-part sun visor consists of one thicker part attached to the ceiling and one thinner part that can be pulled out to increase the coverage (see figure 6.1). The sun visor is attached to the ceiling in the same way as a conventional sun visor, and can be turned to the side. A backlit mirror is attached to the thick front-part, and the wires connecting the light goes through the foot of the sun visor. The mirror is covered by Smart Tint, a black plastic film that becomes transparent when connected to power. The Smart Tint makes it possible to switch on the mirror when in use, by lightly touching a conductive lower part of the mirror.

The thin back-part of the sun visor is the part that can be moved to increase coverage, both to extend the sun visor in length and in width. By moving the part downwards the coverage to the front is increased. By turning the sun visor to the window side and then extending the back-part sideways the side coverage is increased.

A variation of this concept is to have the thin back-part made of a sun-shielding plastic that works

Figure 6.1: Illustrations of the Two-part Sun Visor in a car with old sun visor present.

like sun glasses. This way the driver will be able to see the road through the lower, see-through part of the visor, while still being shielded from low sun. In this variation increased coverage to the side by pulling out the see-through part is not possible, but will be possible with an extendable axis instead.

The two-part sun visor solves the issue with a large sky roof and increases the overall coverage. It does not solve the issue with roominess because of package in z-direction.

6.1.2 Roll-down Curtain

The Roll-down Curtain sun visor is a concept consisting of two separate curtains, one for the front window and one for the side window, operated by the buttons on the door armrest. The sun visor is fully integrated in the interior of the car and is not visible to the user when the sun visor is not in use. When in use, the button is pushed and the front and/or side sun visor is lowered in a stepless fashion until desired coverage is reached (see figure 6.2).

The sun visor curtain is mounted on a cylinder that is motor driven and rolls the curtain up

Figure 6.2: Illustation of the Roll-down Curtain concept.

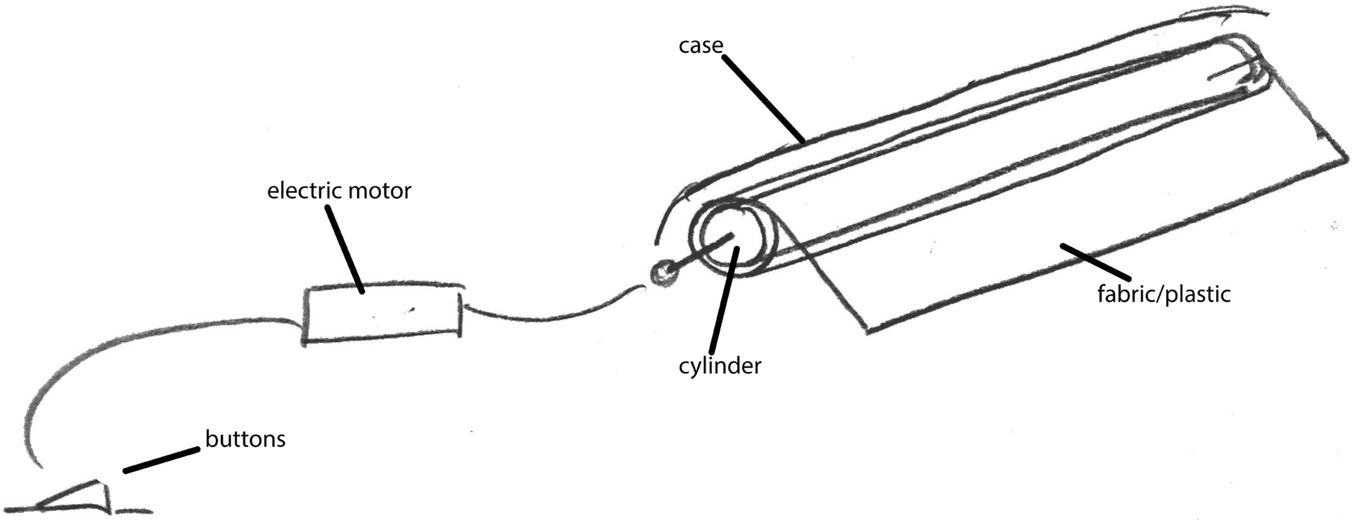

Figure 6.3: Sketch of the Roll-down Curtain concept.

and down (see figure 6.3). The sides of the front curtain goes through paths in the A-pillar and WEM to keep it in place and secured. Telescopic arms help keep the sun visor in place against the windshield. The side curtain goes through paths in the B and A-pillar. The sun visor curtains can be lowered to a coverage corresponding to that of a conventional sun visor.

The curtain is made of a sun-shielding plastic film that is lightly tinted.

6.2 Implementation

The two concepts were implemented in different ways, one by making a physical prototype and one by CAD.

6.2.1 Physical Prototype

The physical prototype of the Roll-down Curtain was made in collaboration with the Concept Center at Volvo Cars. Jan Davidsson helped during the prototyping process. The front curtain was made using an electric motor driven roof curtain. Even though the part is wider than the actual concept is meant to be, it effectively shows the intentions of the concept.

The ceiling of the car was removed to make it possible to install the new concept. The rear view mirror, the sun visors and overhead panel was also removed. The front of the ceiling was cut off to fit the prototype in the roof. The curtain was mounted to the ceiling close to the windshield (figure 6.4).

Figure 6.4: Installation of the prototype.

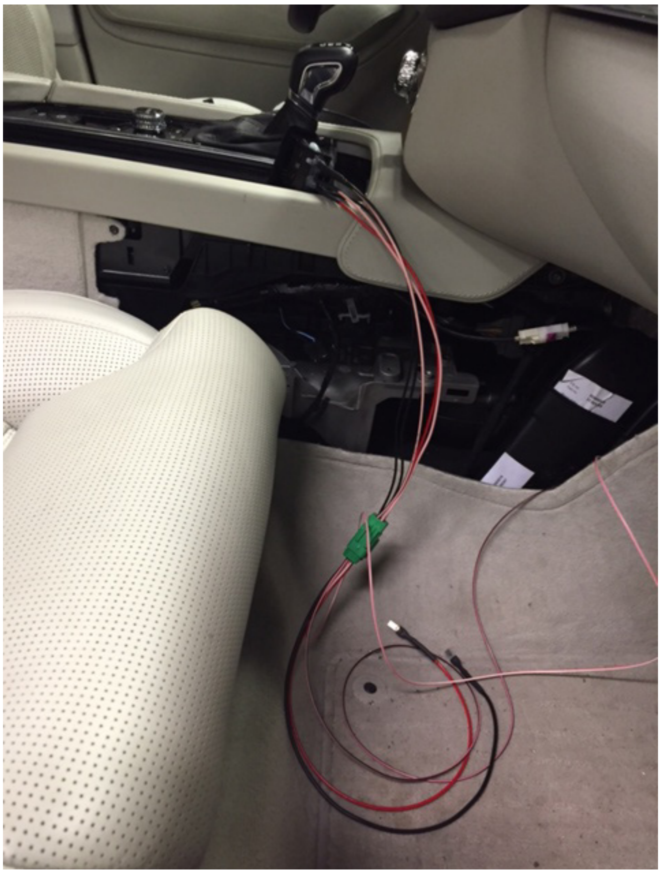

Figure 6.5: Electric cables.

Figure 6.6: Final installation of prototype.

Figure 6.7: Installation of the buttons.

Figure 6.8: Prototype seen from the outside, left - not in use, right - in use. .

Cables was later on attached to the motor on the prototype and pulled through the ceiling, down through the A-pillar to the floor and up through the mid console (figure 6.5). The cigarette lighter socket was removed and the cables and the button for the motor was mounted where the cigarette lighter socket was before.

The prototype was covered in blond fabric to camouflage it against the ceiling and the main part of the overhead console was installed again (figure 6.6). In a final product, the tracks on the windshield will be installed inside the A-pillar and inside the WEM. The curtain will be stabilized with a telescope solution protruding from the WEM.

The button to roll the curtain up and down is finally installed in figure 6.7. In the final product the button will probably be placed in another place.

The prototype have a solid non-see-through fabric but the actual product will have a dark transparent plastic so that the driver can have full attention on the road while driving even if the sun is low (see figure 6.8). Figure 6.9 shows a comparison between the current sun visor and the prototype.

The side curtain is not possible to prototype in a current car, but a modified version of the side curtain was made instead. The prototyped version has the curtain coming up from below (see figure 6.10). The top part is shaded and the lower part is see-through. By implementing the concept in this way it is possible to show a new solution that might be easier to implement in a car sooner.

6.2.2 CAD Prototype

A CAD prototype of the Two-part Sun Visor was made. With the help from a drawing with measurements, Marcus Malmström at Volvo

Figure 6.9: Prototype compared to the current solution.

Figure 6.10: Side window prototype.

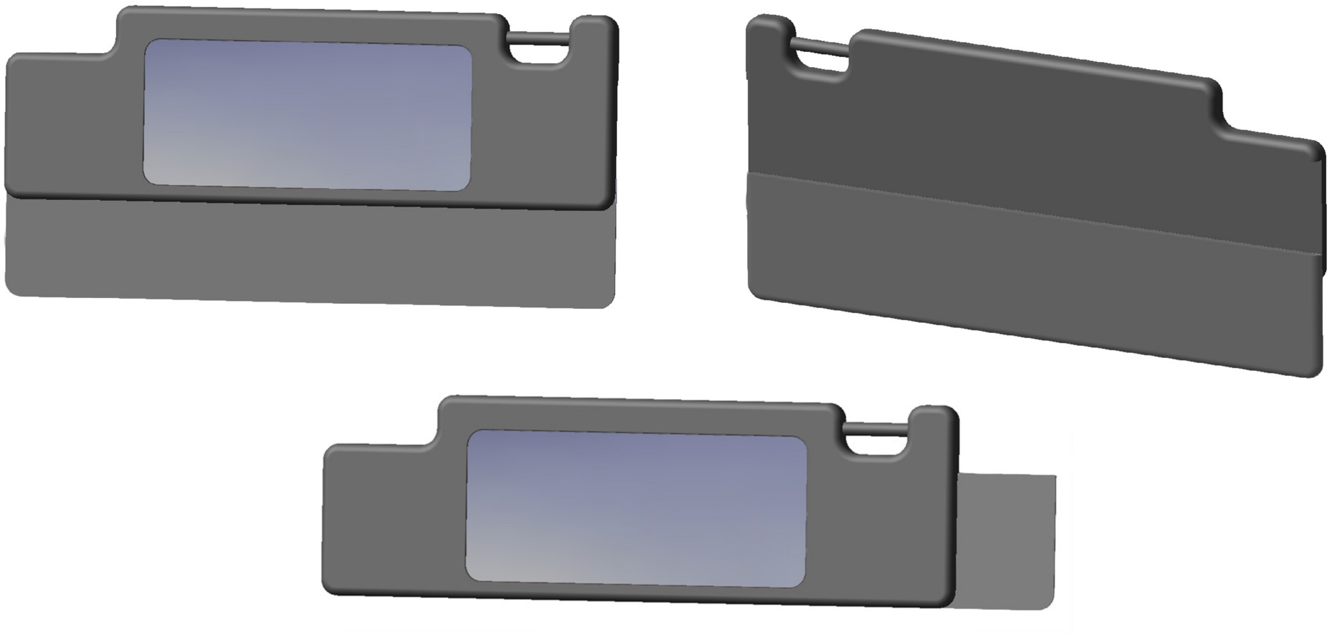

Figure 6.11: CAD illustrations of the Two-part Sun Visor.

Cars made a visualisation in Catia V5 (see figure 6.11).

Making a CAD illustration was chosen as an alternative way of prototyping the Two-part Sun Visor since there was only time to make one physical prototype.

6.2.3 Mirror Prototype

An additional prototype of the mirror with Smart Tint was made to show how the Smart Tint would work on a large backlit mirror. The reason for having Smart Tint is to be able to eliminate the lid on the mirror thus making the sun visor thinner and also more attractive. The prototype also shows an alternative band ticket holder (see figure 6.12).

The prototype was made using an existing sun

Figure 6.12: Mirror prototype.

visor as a base for the mirror. It was carved out to fit a mirror, a diffuser and the light source. The back of the mirror glass was scratched in a rectangle around the mirror to allow light to be visible. A milk-white plastic was used as a diffuser for the light. The light source used was LED strips. On top of everything the Smart Tint was installed.

6.2 A Vision of the Future of Sun Visors

One of the limitations in this project was not to deal with exterior concepts and solutions such as concepts concerning the windshield and the side windows since the project is an interior project. But even though this was a delimitation, it was impossible not to take into account the new technologies concerning screens and smart materials emerging on the market now and in the upcoming years. A lot of technology available today is still very expensive and it needs to be developed further to be able to be applicable to the car industry. But this technology could still give interesting ideas to the current project, and was therefore researched.

Another technology that will influence the future of the sun visor is the autonomous drive technology. The development in this area is moving quickly forward and will probably become an international standard in the near


Figure 6.13: Future concept (Mercedes-Benz, 2016).

future. Since self-driving cars will become a reality on the roads, this was taken into account when doing research on what a future sun visor could be.

In the future there will be affordable technology available that will make it possible to black out the whole windshield or parts of it. Parts of the windshield will automatically black down to shield the driver's eyes from sun or other irritating light when driving, so that the driver will still be able to see the road and surroundings well. The windshield will also work as a dashboard and show speed, GPS etc. When the autonomous drive is in use, the whole car can be blacked down to accommodate for sleeping, or the windshield or side windows can turn into screens to use for various applications (see figure 6.13). Autonomous drive will give the opportunity for the car users to work, sleep, watch TV etc. in the car. The window screens will be able to adjust to the user needs. Other areas of use for black-down windows is avoidance of theft and protection from strong sunlight when the car is parked.

The introduction of autonomous cars will change the use of components in the car. The sun visor will transform from an interior part of the car into the windshield and the side windows. The windows can fade from transparent to black-down and the windshield will be anything from a TV screen to a dashboard.

7. Discussion

This chapter discusses the thesis as a whole, the process and the project outcome, insights during the duration of the project and also thoughts on what could have been done differently. A list of Lessons Learned and Recommendations and Further Development concludes the chapter.

7.1 The Process of the Project

In a project with a limited time frame, the process is very important. To be able to reach the goal of making a physical prototype, it was essential that the project was well planned.

The research design chosen for this project was qualitative research, since there was a need to get a deeper understanding of the subject. A lot of effort was made on studying the theoretical framework for the project, especially the C-K theory and how it could be used in this project.

The process followed during this project was a product development process inspired by action research. It was crucial for the success of the project to be able to be involved at the company. Since one of the more important factors of C-K theory is the generation of knowledge, the presence at Volvo Cars opened up many doors. To be able to hold meetings and conduct interviews with people with a lot of knowledge and insight into the area was rewarding.

The meetings with Volvo employees, and also external experts in other fields, gained a lot of knowledge to the project, but not everything was useful in the project. Many comments from the meetings resulted in limitations for the project, that needed to be discarded because of the concept nature of the project. It is impossible to break new ground in an area if always taking into account current limitations. Very little of the knowledge gained resulted in concepts straight away. There was a need to process the knowledge and investigate further to come up with new concepts.

Since the researchers in this project were external consultants, i.e. students, there was a possibility to question procedures without being threatening, and also contribute with new approaches. The project has been a qualitative research done by external people and would probably have given another result if it had been done internally, because of different mindsets and procedures.

7.2 Final Result and Research Questions

The final result is both a sun visor that can be implemented in a car today, a new light-shielding concept with a curtain that will need to see bigger changes in the built of the car to be a reality, and a vision for the future of sun visors.

It has been rather difficult to work with the sun visor scope since it has been quite restrictive. To work only with interior concepts was hard since it was so apparent that the future solutions would be in the area of the windshield, which is an exterior part. The reason that it was not possible to work exteriorly was that the project was an interior project and the departments at Volvo Cars are separated. Adding the vision for the future was important to be able to show that work had be put into studying these kinds of concepts as well.

The Two-part Sun Visor solves two of the demands that were stated in the beginning of the project. It improves the coverage of light by being able to be pulled out to the side and thus shielding side light. It is also compatible with a sky roof since the two parts slide onto each other in folded position, thus making the sun visor shorter in X direction.

The Roll-down Curtain solves all of the demands. It has a very good and adjustable coverage, it is located on the inside of the ceiling thus not interfering with the roominess of the driving compartment, and it is therefore also compatible with a sky roof.

It is important to point out that the outcome of the project is ideas and concepts that can be further developed during longer time, and that the prototypes delivered are by no means finished products.

The aim of the project was not only to develop concepts for a new sun visor and make a prototype, but also to evaluate the use of the C-K theory. C-K theory has been helpful in this project, especially during the idea generation process. In this project is has been true that, as Hachuel (2010) claims, the expansion effect of C-K theory helps the mind in breaking free from fixation effects, and makes it easier to be creative. The guidelines that C-K theory provides have been helpful in moving forward in the ideation process and finding new ways. The cue to always look for more knowledge has lead to findings in areas that would not have been looked into without the knowledge of C-K theory. This could be a helpful tool at Volvo Cars for them to get a more innovative mindset.

In theory the C-K theory sounds very straight-forward but that has not been the case in reality. During the project there was often the need to consult the literature or the supervisor to sort out the thoughts and get a clear view of what was happening in the process. Even though C-K theory helped the project move forward in the ideation process, urging for more knowledge, it could still be hard to know what the obvious next step was. Was it expansion of C or K-space that would lead the project forward? The lack of decision criteria made the process a bit frustrating from time to time, and might have been a reason for the process not moving deep enough into ideation.

The result in this project would probably have been a bit different had other methods been used alongside the C-K theory, other than sketching and the methods for evaluating and chosing concepts. If other idea generating methods had been used during the ideation, there might have been a wider range of ideas in this step.

An attempt was made to use the visualisation methods that C-K theory provides, but this was abandoned when it felt too abstract and complex, and also stopped up the process because of this.

One disadvantage of the C-K theory was that C-K theory does not offer a theory of knowledge (Choulier et al., 2010) which means that without knowledge there is no concepts and vice versa. This could be confusing during the process, when trying to figure out where to start the concept generation. Where does the concept or knowledge come from if they generate each other? A decision was made to see previous knowledge as the generator for initial concepts, and then move forward from that and find more knowledge. It is clear that there is a need for good knowledge in the given area for C-K theory to be useful to a user.

Overall the C-K theory worked for the project, but would have been more successful in a larger project group. For this project it might have been better to mix the C-K theory with other ideation methods to come further in the idea generation process.

7.3 Lessons Learned

The following are lessons learned during the duration of this thesis:

- Used our knowledge from school in practice and learned new thing along the way.
- Experienced working with a project at a large company with many people involved in the different steps.
- Lead a project that affects several departments at a company and adjust to the different opinions.
- Planned a large project and done necessary changes when unforeseen problems occurred.
- Conducted meetings and interviews with different sorts of people.
- Developed a product in a complex area with many limitations.
- Learned about the C-K theory and used it in practice.
- Taken the steps from idea to the making of a physical prototype.
- Learned that it is impossible to listen to the opinions of all different people in a company. Instead we took the opinions into account but made up our own mind about the project.

7.4 Recommendations and Further Development

To go from an idea to developing a prototype during the limited time of only 20 weeks is hard and shortcuts need to be taken to be able to finish the project within the stipulated time frame. Projects like this often take years to fulfill and this project is not an exception. The new innovative sun visor concepts needs further work to be a standard equipment on the car market. The further developments are described below:

- The final prototype must be further investigated considering manufacturing, safety tests, durability, useability and the economical aspect.

The recommendations are:

- Plan to spend longer time in the concept generation stage. Especially when developing a complex product in an complex industry such as the sun visor in the car industry.
- The C-K theory should be used in larger groups to generate more ideas in the concept space. Other ideation methods can also be used in combination to come up with ideas easier.
- The project should engage as many dedicated people as possible in the beginning of the project to gain as much knowledge in the knowledge space as possible. It is possible to narrow down the number of people during the project.

8. Conclusion

The final result is two new-thinking sun visor concepts and a vision for the future of sun visors in the car industry. One concept that can be implemented in a car today, one that will need more invasive restructuring of the interior of the car, and the vision with technology not available to the car industry today, but that will be available in the upcoming years. The two concepts are steps towards the inevitable future of smart screens in the windshields and windows of cars. There was a need for a change in the market of sun visors and the ideas produced during the thesis are interesting new ways of perceiving what a sun visor could be.

The task to develop new concepts for shielding light from the car was not an easy one. The limitation to only work with the interior of the car was challenging. Therefore the C-K theory fit the project perfectly. The C-K theory helped us to think outside the box and to develop new concepts.

The project was performed successfully and all the demands from Volvo Cars were fulfilled. Even if the project had a satisfying result for us, the concepts needs more time to be further developed. There is a need for safety tests, manufacturing tests, durability tests and further economic research. The technology is available which means that the concepts could become a reality in the coming years. Most of all we wanted to give new ideas on what can be done in the area of sun visors in cars. The fact that a new concept can spark discussion and new ideas is very promising for the future of this area. We hope that our ideas and concepts will come to use, either as inspiration or further down the line as parts of a future car, and that we have contributed to the development.

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APPENDIX

1. Visit to the Production Line at Volvo Cars

29th of March 2016

Together with Volvo Cars supervisor Carl-Johan Kaudern

In order to get a better picture of the production of a car at Volvo Cars, a visit to the production line at Volvo Cars Torslanda was done. The visit consisted of a walkthrough through the factory and focussed on the mounting of the sun visors, but other parts of the car were also inspected. It was not allowed to take pictures during the visit due to confidentiality.

The sun visor is firstly mounted on the inner roof with clips, which makes the sun visor stay in place. Then the roof is lifted into place in the car. The sun visor and inner roof is fastened to the body of the car with screws.

The assembly personnel need to fasten the first screw, then open the sun visor to reveal the hole for the second screw and then fasten the second screw and close the visor again. The screws are finally covered by plastic covers to hide the screw heads.

The visit to the production line gave us a clear picture of how the sun visor is mounted in the car. We also got a helicopter view over the whole production from body to finished product.

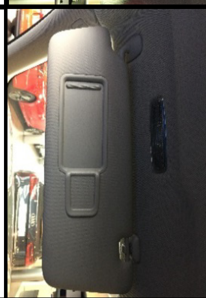
2. Summary of Competitor Analysis

Car brand and model	Volvo	Audi	BMW	Mercedes-Benz	Peugeot	Tesla	Toyota	Volkswagen
Position	Ceiling	Ceiling	Ceiling	Ceiling	Ceiling	Ceiling & A-pillar	Ceiling	Ceiling
Surface material	Vinyl and fabric	Vinyl and fabric	Vinyl	Vinyl	Plastic and vinyl	Fabric	Vinyl	Vinyl (padding on biggest model)
Mirror size	Large	Medium	Small to Medium	Medium/Large	Medium to Large	Medium	Small to Medium	Medium
Mirror cover	Lid	Sliding	Sliding	Lid	Lid	Lid	Sliding and Lid	Sliding
Ticket holder	Very Small clip (just on XC 90)	Medium clips	Band and medium clips	Small clips	Small clips and band	No	No and band on backside	Band and medium clip
No. of lights	1 on each side of mirror	0 (on smallest model) otherwise 1	1 (0 on cab)	1	0 (on smallest model) otherwise 1 on each side of mirror	1 and 2	1. Both automatic and manually lights	1 (0 on cab)
Position of light	Each side of mirror. 1 on XC90	Ceiling	Ceiling	Ceiling	Each side of mirror	Overhead panel and mirror	Ceiling	Ceiling. Around mirror on biggest model
Extra sun protection	No	No	Yes	No	No	The construction gives side protection	No	Yes
Other observations	Fabric even on the smaller models. Only ticket holder on the biggest model. Very small clip. Biggest average mirror sizes.	Same type of clips as Volvo but bigger.	Problem with an ugly edge on the cab (the sun visor is too long in X direction). Offer the customer extra sun protection (telescopeic extension).	Ceiling light turns off automaticly when turning the visor to the window side.	Problem with an big ugly edge up to the panoramic roof (the sun visor is too long in X direction). Clips very small.	Long visor in Y direction gives good protection against light coming from the side. New solution on Model X mounted on A-pillar	The manually lit mirror light keeps emitting light even when the visor is closed.	Problem with an ugly edge on the cab (the sun visor is too long in X direction). Offer customer extra sun protection (telescopeic extension).

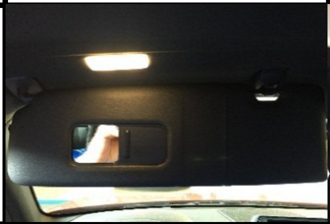
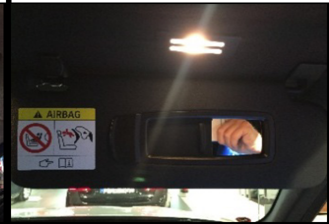
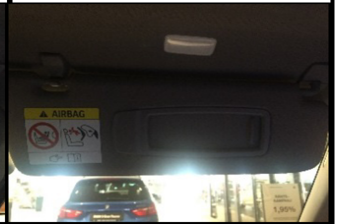
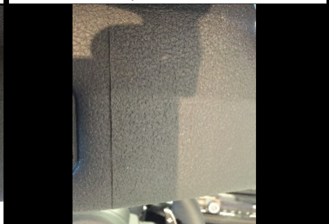
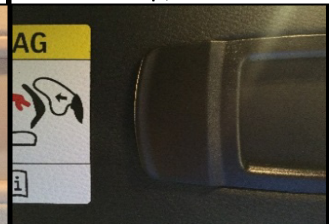
3. Volvo Analysis

Car brand and model	Volvo V40 T2, 2016	Volvo V60, 2016	Volvo S60 CC, 2016	Volvo XC 70, 2016	Volvo XC 60, 2016	Volvo XC 90, 2016
Picture sun visor						
Position	Ceiling	Ceiling	Ceiling	Ceiling	Ceiling	Ceiling
Surface material	Vinyl	Fabric	Fabric	Fabric	Vinyl	Fabric
Mirror Size	Large	Large	Large	Large	Large	Medium
Mirror cover	Lid	Lid	Lid	Lid	Lid	Lid
Ticket holder	No	No	No	No	No	Plastic clip, both sides
Picture ticket holder	–	–	–	–	–	
No. of lights	2	2	2	2	2	1
Position of light	Each side of mirror	Each side of mirror	Each side of mirror	Each side of mirror	Each side of mirror	Mirror
Extra sun protection	No	No	No	No	No	No
Other observations				 Example of the poor sun protection		One of the smallest ticket holders.

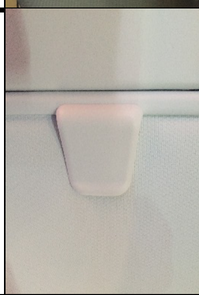
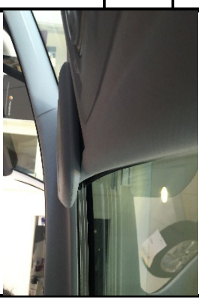
4. Audi Analysis

Car brand and model	Audi A1, 2016	Audi A6 Avant S-line, 2016	Audi Q5, 2.0 TDI quatro, 2016	Audi Q7, 3.0 TDI quatro, 2016
Picture sun visor				
Position	Ceiling	Ceiling	Ceiling	Ceiling
Surface material	Vinyl	Fabric	Vinyl	Fabric
Mirror size	Medium	Medium	Medium	Medium
Mirror cover	Sliding	Sliding	Sliding	Sliding
Ticket holder	Plastic clip, driver side	Plastic clip, driver side	Plastic clip, driver side	Plastic clip, driver side
Picture ticket holder				
No. of lights	0	1	1	1
Position of light	–	Ceiling	Ceiling	Ceiling
Extra sun protection	No	No	No	No
Other observations				

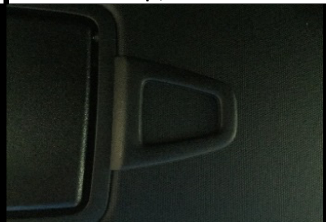
5. BMW Analysis

Car brand and model	BMW 118i, 2016	BMW M4 Cabriolet, 2016	BMW 520d Sedan, 2016	BMW X3 xdrive 20d, 2016	BMW X5 edrive, 2016
Picture sun visor					
Position	Ceiling	Ceiling	Ceiling	Ceiling	Ceiling
Surface material	Vinyl	Vinyl	Vinyl	Vinyl	Vinyl
Mirror size	Small	Small	Medium	Medium	Medium
Mirror cover	Sliding	Sliding	Sliding	Sliding	Sliding
Ticket holder	Band, both sides	Band, both sides	Plastic clip, both sides	Plastic clip, both sides	Plastic clip, both sides
Picture ticket holder					
No. of lights	1	0	1	1	1
Position of light	Ceiling	–	Ceiling	Ceiling	Ceiling
Extra sun protection	No	No	No	Telescopic extension.	Telescopic extension.
Other observations	Small sun visor.	 Very small sun visor and ugly egde.	Ticket holder looks different.		

6. Peugeot and Citroën Analysis

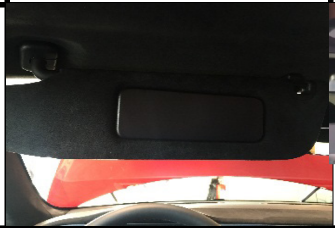
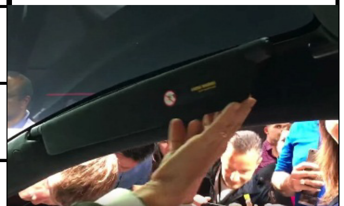
Car brand and model	Picture sun visor	Position	Surface material	Mirror size	Mirror cover	Ticket holder	Picture ticket holder	No. of lights	Position of light	Extra sun protection	Other observations
Citroën DS4, 2012		Ceiling	Plastic	Medium	Lid	"Pocket"		0	–	Yes	Roof can slide back and forth on the extra large windshield. Good adjustment and coverage for sun visor, especially when turning visor to the side.
Peugeot 208, 2016		Ceiling	Vinyl	Medium	Lid	Small clip, both sides		0	–	No	Very ugly overlap to sunroof.
Peugeot 308 Sport Wagon, 2016		Ceiling	Vinyl	Large	Lid	Small clip, both sides		2	Each side of mirror	No	Good transition to sunroof.
Peugeot 508 SW GT, 2016		Ceiling	Vinyl	Large	Lid	Small clip, both sides		2	Each side of mirror	No	Ugly overlap to sunroof, but less than previous car.
Peugeot 5008 Allure, 2016		Ceiling	Vinyl	Large	Lid	Diagonal band, driver side		2	Each side of mirror	No	Ugly overlap to sunroof.
Peugeot Sun roof problem											The sun roof models has a ugly edge

7. Mercedes-Benz Analysis

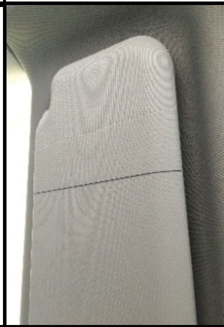
Car brand and model	Mercedes-Benz A 200d, 2016	Mercedes-Benz C350E Kombi, 2016	Mercedes-Benz GLA 200CDI, 2016
Picture sun visor			
Position	Ceiling	Ceiling	Ceiling
Surface material	Vinyl	Vinyl	Vinyl
Mirror size	Medium	Medium	Medium/Large
Mirror cover	Lid	Lid	Lid
Ticket holder	Plastic clip, both sides	Plastic clip, both sides	Plastic clip, both sides
Picture ticket holder			
No. of lights	1	1	1
Position of light	Ceiling	Ceiling	Ceiling
Extra sun protection	No	No	No
Other observations	Ceiling light turns off automaticly when turning the visor to the window side.	Ceiling light turns off automaticly when turning the visor to the window side.	Ceiling light turns off automaticly when turning the visor to the window side.

Notes for all tested cars	
	
Solution for automaticly turning off the light	Bad solution for axis. Less sun protection of the side window

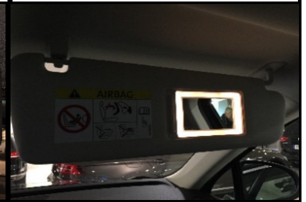
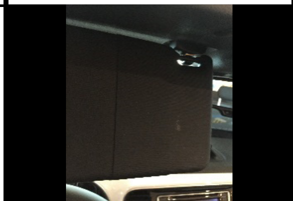
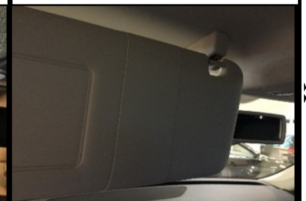
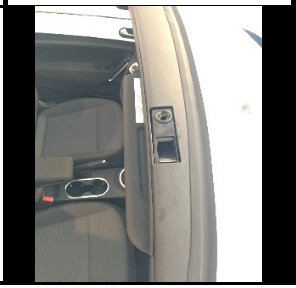
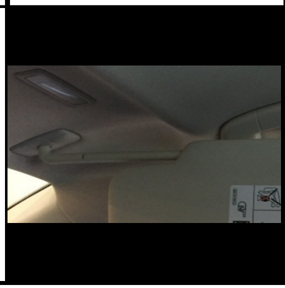
8. Tesla Analysis

Car brand and model	Tesla Model S, 2016	Tesla Model X, 2016	Tesla Model X Solution, 2016
Picture sun visor			
Position	Ceiling	A pillar	
Surface material	Fabric	Fabric	
Mirror size	Large, seamless edges	Long	
Mirror cover	Lid	Large lid	
Ticket holder	No	No	
Picture ticket holder	No ticket holder	No ticket holder	
No. of lights	1	2	
Position of light	Overhead panel, directed at face.	Both sides of mirror.	
Extra sun protection	No.	No.	
Other observations	 Long visor gives good protection against light coming from the side.	Magnetic fastening to the overhead panel.	

9. Toyota Analysis

Car brand and model	Toyota Verso, 2016	Toyota Auris touring S, 2016	Toyota Rav 4, 2016
Picture sun visor			
Position	Ceiling	Ceiling	Ceiling
Surface material	Vinyl	Vinyl	Vinyl
Mirror size	Small	Medium	Medium
Mirror cover	Sliding	Lid	Sliding
Ticket holder	Band,outside driver side	No	No
Picture ticket holder		–	–
No. of lights	1	1, manually lit	1
Position of light	Ceiling	Ceiling	Ceiling
Extra sun protection	No	No	No
Other observations		The manually lit mirror light keeps emitting light even when the visor is closed.	

10. Volkswagen Analysis

Car brand and model	Volkswagen Beetle cab TSI 105,2016	Volkswagen Golf 1,6 TDI 110, 2016	Volkswagen Passat 120 SC TDI,2016	Volkswagen Touran TSI 110, 2016	Volkswagen Tignan Premium R, 2016	Volkswagen Touareg TDI 204, 2016
Picture sun visor						
Position	Ceiling	Ceiling	Ceiling	Ceiling	Ceiling	Ceiling
Surface material	Vinyl	Vinyl	Vinyl	Vinyl	Vinyl	Vinyl with padding
Mirror size	Medium	Medium	Medium	Medium	Medium	Medium
Mirror cover	Sliding	Sliding	Sliding	Sliding	Sliding	Sliding
Ticket holder	Band	Clip	Clip	Clip	Band	Band
Picture ticket holder						
No. of lights	0	1	1	1	1	1
Position of light	–	Ceiling	Ceiling	Ceiling	Ceiling	Around mirror
Extra sun protection	No	No	Telescopic extension	No	No	No
Other observations						

11. Pugh Matrix

		Baseline	Alternative Conceps											
Criteria	**Weight of criteria (1-3)**	**Current Solution**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
Overall coverage	3	0	+	+	0	+	+	+	+	+	+	+	+	+
Side window coverage	2	0	+	+	+	+	+	+	+	+	+	+	+	+
Decrease packaging in Z direction	3	0	+	0	0	0	0	+	0	+	+	+	-	0
Solve sky roof	3	0	+	+	+	0	0	0	0	+	+	0	+	0
Visibility for the driver	2	0	0	0	0	0	0	+	0	+	+	+	+	0
Ease of use	2	0	0	0	0	-	-	0	0	+	-	0	0	0
Ergonomic adaption	1	0	0	0	-	-	0	0	+	+	-	0	+	0
Crash safety	2	0	0	0	-	+	+	0	+	+	+	0	+	0
Appearance	1	0	0	0	0	0	-	0	0	+	0	0	+	+
Complexity	1	0	-	0	0	0	-	+	-	-	-	-	-	0
Total +		0	4	3	2	3	3	5	4	9	6	4	7	3
Total -		0	1	0	2	2	3	0	1	1	3	1	2	0
Score		0	3	3	0	1	0	5	3	8	3	3	5	3
Weighted Total +		0	11	8	5	7	7	11	8	19	15	10	14	6
Weighted Total -		0	1	0	3	3	4	0	1	1	4	1	4	0
Weighted Score		0	10	8	2	4	3	11	7	18	11	9	10	6
Rank		0	3	5	10	8	9	2	6	1	2	4	3	7

12. Criterion Assessment

		Conceps							
Criteria	**Weight of criteria (1-3)**	**A**	**B**	**F**	**G**	**H**	**I**	**J**	**K**
Overall coverage	3	2	2	2	3	3	2	2	3
Side window coverage	2	2	2	2	3	3	2	2	3
Decrease packaging in Z direction	3	3	1	2	1	2	3	2	1
Solve sky roof	3	3	2	0	0	3	3	0	3
Visibility for the driver	2	1	1	3	1	2	2	3	3
Ease of use	2	2	2	2	2	3	1	2	2
Ergonomic adaption	1	2	2	2	2	3	1	2	3
Crash safety	2	1	1	1	1	3	2	1	3
Appearance	1	1	2	2	1	2	1	2	3
Complexity	1	2	2	3	2	1	2	0	0
Score		19	17	19	16	25	19	16	24
Weighted Score		41	33	33	31	52	42	32	49
Rank		4	5	5	7	1	3	6	2

3 = Meets criterion very well
2 = Meets criterion farely well
1 = Meets criterion modestly
0 = Does not meet criterion

13. Summary of Comparison Method

Comparison Score					
	A	**B**	**F**	**H**	**I**
Coverage	1	1	1	4	3
Z-Direction	3,5	0	1	2	3,5
Sky roof	2	1,5	0	3,5	3
Visibility	0,5	0,5	3,5	3,5	2
Ease of use	1	2	3	4	0
Ergonomic adaption	1	2,5	2,5	4	0
Crash Safety	1	1	1	4	3
Realisability	2,5	2,5	4	1	0
Score	12,5	11	16	26	14,5
Rank	4	5	2	1	3

14. Comparison Method

Coverage						
A	**B**	**F**	**H**	**I**	**Score**	**Rank**
A	A/B	A/F	H	I	1	3
	B	B/F	H	I	1	3
		F	H	I	1	3
			H	H	4	1
				I	3	2
				Sum	10	

Ease of use						
A	**B**	**F**	**H**	**I**	**Score**	**Rank**
A	B	F	H	A	1	4
	B	F	H	B	2	3
		F	H	F	3	2
			H	H	4	1
				I	0	5
				Sum	10	

Z-direction						
A	**B**	**F**	**H**	**I**	**Score**	**Rank**
A	A	A	A	A/I	3,5	1
	B	F	H	I	0	4
		F	H	I	1	3
			H	I	2	2
				I	3,5	1
				Sum	10	

Ergonomic adaption						
A	**B**	**F**	**H**	**I**	**Score**	**Rank**
A	B	F	H	A	1	3
	B	B/F	H	B	2,5	2
		F	H	F	2,5	2
			H	H	4	1
				I	0	4
				Sum	10	

Sky roof						
A	**B**	**F**	**H**	**I**	**Score**	**Rank**
A	A/B	A	H	A/I	2	3
	B	B	H	I	1,5	4
		F	H	I	0	5
			H	H/I	3,5	1
				I	3	2
				Sum	10	

Crash safety						
A	**B**	**F**	**H**	**I**	**Score**	**Rank**
A	A/B	A/F	H	I	1	3
	B	B/F	H	I	1	3
		F	H	I	1	3
			H	H	4	1
				I	3	2
				Sum	10	

Visibility						
A	**B**	**F**	**H**	**I**	**Score**	**Rank**
A	A/B	F	H	I	0,5	3
	B	F	H	I	0,5	3
		F	F/H	F	3,5	1
			H	H	3,5	1
				I	2	2
				Sum	10	

Realisability						
A	**B**	**F**	**H**	**I**	**Score**	**Rank**
A	A/B	F	A	A	2,5	2
	B	F	B	B	2,5	2
		F	F	F	4	1
			H	H	1	3
				I	0	4
				Sum	10	

15. Meeting and semi-structured interviews

Carl-Johan Kaudern	VCC, System Responsible Overhead system
Niclas Molin	VCC, Manager Carpets Headlining & NVH parts
Jan Davidsson	VCC, Concept Center
Jörgen Ambratt	VCC, Planning Concept Center
Johan Persson	VCC, System Responsible Interior Lighting
Hans-Olof Johansson	VCC, Attribute Leader - Ergonomics
Gustav Groth	VCC, Product Ergonomist Engineer
Victoria Olofsson	VCC, TPP/TDF leader CBP coordinator Interior & Climate
Erja Olsson	VCC, Innovation study leader
Daniel Olsson	VCC, Design Task Leader / Roof Systems (Ext).
Marcus Malmström	VCC, Graduate R&D Mechanical Engineering program
Michelle Khoo	VCC, CAE Crash Engineer 91431
Corien Pompe	VCC, Design Manager Future Lab & Innovation
Sven-Olof Persson	VCC, Interior Design Manager
Anja Lund	CTH, PhD in Chemistry and Chemical Engineering
Henrik Oxfall	Swerea IVF, PhD Researcher