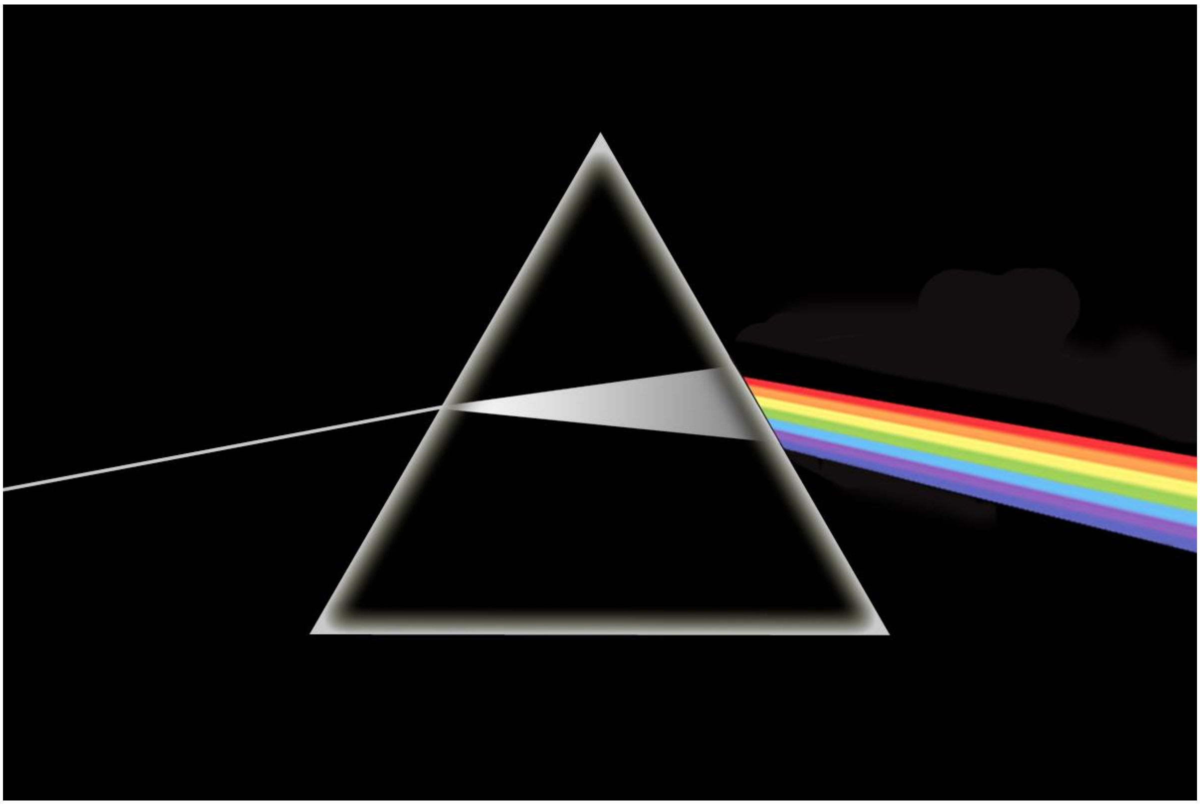

ILLUMINATION

The development and implementation of lighting concepts into a physical car

Bachelor's thesis in Industrial Design and Computer Engineering

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[The cover features Pink Floyd's "The dark side of the moon" album cover by Storm Thorgerson (Commons Wikimedia, 2013)]

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PREFACE

This bachelor thesis was conducted at the Institution of Product and Production Development and the Institution of Computer Science and Information Technology at Chalmers University of Technology and was commissioned by the Department of Body & Trim (B&T) at Volvo Cars Torslanda. We would like to start sending our thanks to Erja Olsson, Innovation Study Leader at B&T, and Magnus Lindh, Manager at B&T, for supporting us throughout the whole project and having confidence in us. Also thanks to our supervisors at Chalmers, Ralf Rosenberg at the Institution for Product and Production Development, and Sven Knutsson at the Institution of Computer Science and Information Technology for giving us advice, second opinions and helping us over bumps and obstacles along the project.

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Last but not least we would like to send our special thanks to Kristoffer Johnsson, Attribute leader of Illumination at B&T, Johan Persson, Principal Engineer at the Interior Department, and Corien Pompe, Design Manager of Identity & Innovation at Volvo. Your expertise has been priceless during the project and your ideas and thoughts has been a great source of inspiration for us.

The team in front of the Strix car

ABSTRACT

This report covers the exploration of how illumination can be used in cars to create customer value and affection. The work was conducted at the Department of Body and Trim at Volvo Cars in Torslanda, Gothenburg and featured an interdisciplinary approach that mixed computer- and design engineering. The project was launched as a step in Volvo's ambition to become a premium car brand in an industry where illumination is by many considered a forgotten area. The purpose was to generate and implement innovative interior and exterior concepts into a car that would serve as a source of inspiration and discussion for personnel at Volvo.

The work was introduced with a pilot study, aiming to narrow the scope and create a more specific theme when later generating ideas. This phase resulted in one design- and one technical vision that stated that the light in the car should express life, temper and character, resulting in a vehicle that felt intuitive, respondent and alert. The following idea generation phase included several workshops and discussions with people inside and outside Volvo and resulted in a total of 24 ideas of which 12 were built into a final demo car named Strix. These built in concepts blended small function oriented features, such as a buckle finder, with large conceptual visions that involved analysis of how future car driving would be like. The lighting techniques used in these concepts included Power LEDs, optical fibers, photo luminescent pigment and different light transporting mediums.

Looking at the final result, the Strix project was perceived as successful. While not all objectives defined at the start could be fulfilled, the general impression was that the project succeeded in its stated main purpose, i.e. creating inspiration and discussion at Volvo. The automotive industry has a long way to go when it comes to taking advantage of the possibilities with illumination, but Volvo has started the work and the concepts demonstrated in the Strix might very well develop into something that is implemented in future production cars.

Keywords: Volvo Car Corporation, Concept, Illumination, Strix, light, emotional design, Arduino, LED, Power LED, optical fibers, photo luminescent pigment

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LIST OF ABBREVASIONS AND ACRONYMS

Illumination	Holistic experience of decorative lighting
Power LED	An LED with a high intensity relative to its consumed energy
Ra-index	Describes how well the light from a lamp can reproduce colours on lit up surfaces.
Raking light	When light hits an object from the side creating shadows in the surface
FPGA	Field-programmable gate array
IAQS	Volvo's interior air quality system, filters the outside air through a carbon filter
IDE	Integrated development environment
LED	Light-emitting diode
OLED	Organic light-emitting diode
PIR	Passive infrared
PWM	Pulse width modulation
R&D	Research and development
RGBW	Red, green, blue and white
UV	Ultraviolet
VHDL	Hardware description language, programming language by IBM

1. INTRODUCTION

The following report describes an interdisciplinary project combining Computer and Design engineering. Because of this, some chapters involve more specific design subjects, while other focus on computer- and electrical matters. Also note that the report contains double sets of method and result sections. This setup is chosen so that the reader has the necessary understanding of the scope when reading the idea generation- and concept development chapters.

The project is conducted at the department Body and Trim at Volvo Cars, Torslanda, Gothenburg. The project has been assigned about 400 working hours from the Concept Workshop where a big part of the time is spent, involving about 10-15 people from the workshop personnel.

1.1 Background

Volvo Car Company is Sweden’s biggest and most commonly known car company selling over 440 000 cars a year worldwide. Since the start in 1927 AB Volvo has expanded its area of business to include aero parts, trucks, buses and marine engines. In 1999 Volvo Car Company was separated from AB Volvo and first sold to American Ford Motor Company and later, following the global economy crisis 2008-2009, to Chinese Geely Holding Group. As a part of Geely’s global strategy plans Volvo Cars is going through a transformation meaning to position the brand at the premium segment of the car market together with brands such as BMW, Audi and Mercedes. To succeed in this, the products need be improved when it comes to quality, exclusiveness and design. This is going to be achieved through Volvo’s new design orientation called “Scandinavian luxury”, referring to the Scandinavian design heritage with a neat, slimmed and often functional oriented design. Other typical Scandinavian core values such as high quality craftsmanship, natural materials, and environmental awareness are also included in the term (Isacson & Lundén, 2012). Earlier thesis work has investigated Scandinavian luxury functions and demonstrated these in an acclaimed demo car called Lynx. This report picks up where the Lynx left off and digs deeper into the field of illumination.

Light design and illumination is mainly a subject in architectural context and is by personnel at Volvo considered a ”forgotten area” in car design. Besides the obvious usage – creating general functional lighting - light can be used to set moods, create emotions, and enhance or reduce impressions. This is often the case within buildings, landscapes or cities, but rarely in cars. New lighting technology such as LED has opened new possibilities to create dynamic, living, and customized light while reducing energy consumption, heat emitting and weight. The benefits of these changes have not yet been fully taken advantage of in the automotive industry, and as a consequence of this Volvo launch the illumination project.

1.2 Purpose

The purpose of this project is to in theory and practice examine how the field Illumination interior and exterior can contribute to make Volvo cars unique and desirable for customers. The goal is to design and build new innovative lighting concepts and install them in a demo car. The goal includes finding solutions for the car to be more energy efficient by e.g. reducing the weight on components or finding less energy consuming light sources. The final demo car will be presented and shown at internal fairs as a source of inspiration and discussions for Research and Development (R&D) workers at Volvo. Focus of the work is therefore more towards innovation rather than production adapted realization. If the concepts get developed further in a later stage production aspects will then be taken into account.

1.3 Delimitations

The car assigned to this project is a Volvo V40 and main focus will therefore be to create light solutions adapted for smaller cars like the V40. The front- and back exterior headlights are not a primarily focus since these are being the subject of extensive design work at other parts of Volvo. The design and light from graphic user interfaces on displays will not be subject for development, but will be taken into account when developing surrounding lights. The possibility of future autonomous drive and how that affects the interior and exterior lighting is not treated in this project.

1.4 Clarification of the issue

To further explain the issue a number of questions have been set up. As the project proceeds these questions will be more specific and refined.

- How can one create customer affection to the car with the use of illumination?
- How can the weight of cables for lighting in the car be reduced?
- How can lighting in the car be more energy efficient?

2. THEORY

This chapter aims to provide the theoretical background knowledge needed when reading the rest of the report.

2.1 Illumination

The word illumination means "decorative lighting", and is in this project interpreted as the whole experience one gets from light. The paragraphs listed below derives from a light design lecture with Stephanie Sales of the WSP group, and describe what parameters can be altered to create different effects when designing light.

2.1.1 General- and located lighting

When designing lights it is important to consider what function the actual lamp or light source have. One way to categorize different types of lighting is to divide them into general- and located lights. The general lighting fills bigger parts of the room and describes the space within so that people can orient themselves. Located light highlights specific areas that are of importance. There can also be a combination of the two, e.g. an office area where the general lighting often is represented by fluorescent tubes in the roof, and are complemented with desk lamps at the different workstations.

2.1.2 Direct- and indirect lighting

All lights can be either direct or indirect. A direct light travels directly from the light source to the surface it is supposed to lighten up. An indirect light is first reflected on something before reaching the surface it is supposed to lighten up. Usually a light becomes more ambient and smooth in indirect light.

2.1.3 How to design light

According to Sales there are seven main principles to take into consideration when designing light. These can be mixed in differently to obtain a desired mood, fill a certain function or effect.

1. Levels: The light level is described in Lux (or lumen per square meter) where clear daylight is about 10 000 lux, normal office areas about 200-600 lux, and a candle from one metre about 1 lux (Piikkila, 2005).

2. Distribution: The light distribution describes the light level at different distances from the light source, and can be adjusted through e.g. choice of lens or by shielding off the light with the help of a luminaire.

3. Shadows: When speaking of light it is important to not forget shadows. Each light source creates one and it can be used to enhance shapes, textures and materials by adding depth and contrasts. A shadow can be sharp or diffuse depending on the distance relation between light source, light shield and surface where the shadow occur.

4. Reflection: When light bounces on materials reflections are created in the surface. Especially high gloss materials are reflective, and it's therefore important to consider what kind of materials are going to be lit up when designing light. Reflections can be both wanted and unwanted.

5. Glare: This phenomena occurs when the eye is hit by a quick intensification of light and makes the eye partially, or fully blind for a limited period of time (Bohgard et. al, 2008). There are three types of glare: direct, indirect and contrast glare. From a light designer's perspective, glare is almost always unwanted.

6. Colour of the light: Light can have different colours and different temperatures. Usually, temperature is the subject when speaking of white light, and it stretches from warm (a bit more yellow) to cold (a bit more blue). Coloured light has much more saturation to it and affects a scene in a much more obvious way.

7. Colours of the surfaces: The colour of any lit up surface affects the light that reflects on that same surface. If there is both a coloured surface and a coloured light that mix can create unpredictable visual effects.

2.2 Light technologies

Listed below are the light technologies found relevant in the project.

2.2.1 Light Emitting Diodes

Light emitting diodes (LED) offer light with a high degree of efficiency and with little or no heat radiation in the direction of the light. Heat is however radiated behind the diode but could easily be reduced with thermal grease and a heat sink. LED:s are compared to incandescent light expensive, but have a lifetime up to twenty five times as long (Belysningsbranschen, 2013). The LED emits light pulses at such a high frequency that the eye perceives this as a constant light. The light is of high intensity, has good colour reproduction and has the ability to be dimmed with the use of PWM-signals by lowering the frequency.

2.2.2 Organic Light Emitting Diodes

Organic light emitting diodes (OLED) offer the same advantages of the LED with the added advantage of being flexible and thin (see fig. 2.1). OLED:s could be arranged together in panels and because of their flexibility be used on arched surfaces as light sources or even as displays. Since OLED technology is still under development, the efficiency in relation to the cost is low.

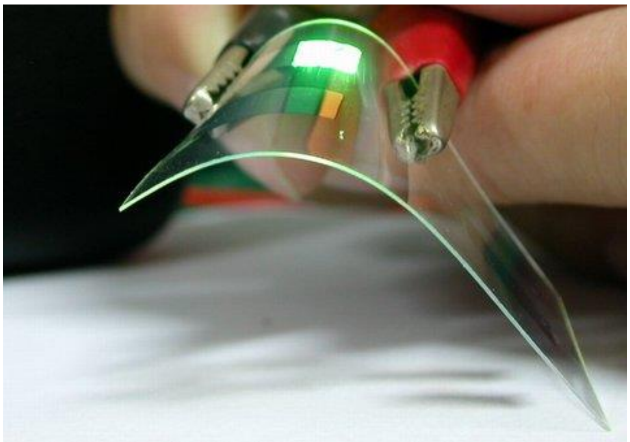

Fig 2.1. A thin and flexible OLED panel (File:OLED EarlyProduct.JPG, 2001)

2.2.3 Ultraviolet light

Ultraviolet (UV) light has a wavelength shorter than the human eye can register and is therefore not visible. However, bright surfaces hit by UV light prolong the exiting wavelengths resulting in a light within the visual field of humans and appears as a “glowing” light.

2.2.4 Photo luminescent pigment

Photo luminescent pigment absorbs and stores photons from light and radiates the energy for several hours. The results in a slowly decreasing glow. The pigment can be mixed in nearly any kind of plastic, paint or clear varnish. The weight is negligible and no energy is used but the radiation from the sun. The limitation of the pigment is the light level, the slightly greenish emitted light and the need of exposure to UV light to charge. Charging is therefore not possible during night without the use of additional artificial light sources. The light can also not be switched off at command. Eli-Chem Resins in the UK supplied the pigment used in this project.

2.2.5 Optical fibers

Optical fibers are flexible and transparent light transporting mediums made from solid plastic tubes in various diameters. The fibers transport the light from one end with an attached light source to the other. Depending on the property of the tube, light can be emitted in different amounts along the way. If the fiber is bent sharply the principle of total reflection can no longer be obtained and the light escapes in the corner where it is bent.

2.3 Other relevant technical theory

2.3.1 Sensors

A capacitive sensor works by sensing anything conductive in its surroundings, e.g. a human hand, and can relatively easy be built with a piece of metal, a high-value resistor, some wires and a programmable developer board (see chapter 6.3.6). The cost of a sensor is low, but the sensing result is not very accurate or precise.

An ultrasonic sound sensor sends out a burst of ultrasonic sound and waits for the echo to be reflected back at the sensor. The distance to an object is calculated by measuring the time from the sending of the sound to the receiving of the echo. An ultrasonic sound sensor can thus be used to accurately determine the distance to an object.

Passive infrared (PIR) sensors detect infrared radiation emitted from objects in their surroundings. The sensors can be set to react when the amount of detected infrared light exceeds a predefined value and are therefore often used as motion detectors. PIR sensors are relatively inexpensive and easy to use.

Eye tracking sensors can be used to detect movement of eyes and determine which way the e.g. driver is looking. A system consists of two or more cameras facing the driver and software developed to detect the pupils of the eye, calculating the line of sight. To be able to understand the hardware and software and to use the system instructions and courses are needed.

2.3.2 Programmable devices

Arduino is an Italian company developing microcontrollers based on Atmel processors. The boards consist of open-source hardware and can with their easily accessible input and output pins be used in endless numbers of different projects. The programs are written in C and are compiled with Arduino IDE software (Arduino, 2014).

The Raspberry Pi is a single-board computer originally developed for teaching computer science in schools but offers basically the same performance as a standard home computer. The Raspberry Pi uses an operating system optimised for its hardware, called Raspbian, and is programmed in Java, Python or C (What is a Raspberry Pi, 2014).

The FPGA Spartan 6 from Xilinx is a programmable logic device developed with the aim to be extremely cost effective when produced in large numbers and are often used in displays, routers etc. The device is programmed in VHDL using the software Xilinx ISE Project Navigator (Spartan 6 family, 2013).

3. SETTING THE SCOPE

The work at Volvo was introduced with a pilot study called "Setting the scope". The objective of this phase was to further limit the scope and produce a design- and technical guideline that could be used as a reference when later generating ideas to build into the car (see chapter 4 and 5).

3.1 Methods used to define the scope

In this section the methods used for the research that defined the scope are described.

3.1.1 Investigating different aspects of light

A few aspects of light seemed extra important when setting the scope and where therefore investigated deeper through literature studies. These aspects where the relation between light and emotions, light's physical effects on humans and different cultural aspects of light. These aspects goes beyond the usual considerations when lighten up a space, but in this project they were believed to offer a new and innovative approach. To investigate the emotional and cultural aspect of light the book *Light and Emotions* were studied. The book contained interviews with light designers working on different architectural projects all over the world.

3.1.2 Trend analysis

A number of key trends were examined in order to determine their influence when designing lighting in a car. Trends in usage of cars, human-machine interaction and the society in general were analysed through interviews, information gathering and trend spotting. Upcoming trends were of great importance since any concept generated in the project could be implemented in cars first three to five years later.

Design trends
To find out in what direction modern design evolve at Volvo, in Sweden and worldwide, design trends were spotted. This was done through interviews with people at Volvo's Design Department, literature studies, visiting furniture stores as well as the Stockholm Light and Furniture fare.

Future car usage and transportation
In order to understand the needs of future car users different trends regarding car usage and transportation were analysed. Car pools, human-machine interface, and development in Volvo's biggest market China, were investigated through literature studies, reading statistics and interviewing experts inside the industry.

Personalisation
Another key trend was personalising the car. Interviews with Volvo designers connected to China as well as teenagers during our workshops (See chapter 4.1.3) were conducted and interpreted.

3.1.3 Visiting fairs and museums

To get information about the latest lighting technologies and to find new ways of using light, Stockholm Light and Furniture Fair was visited. The fair is the world's biggest meeting point for Scandinavian furniture and lighting and consists of hundreds of exhibitors, mainly interior light design companies but also the world's leading manufacturers of light technology. One part of the fair, called Green House, allows designers, engineers and students to show their latest works and inventions.

The Volvo Museum was also visited in order to see how earlier concept vehicles had been working with light. The museum covers the development from Volvo's first car model the ÖV4 to the cars, trucks and buses of today. Old concept and demo cars were viewed and analysed.

3.1.4 Investigating Volvo's illumination strategy

To gain an understanding of Volvos current and planned work within the field of illumination, involved workers at Volvo were at several occasions interviewed.

3.1.5 Benchmarking the car market

A benchmarking was carried out to see how competitive car brands were working with illumination. Seven car sales were visited during day time. The benchmarked car brands in chronological order were: Mini, BMW, Mercedes, Jaguar, Range Rover, Audi, and Lexus. At the time of the benchmarking an understanding of Volvo's light solutions was already established. On the basis of this, attention was focused on two main areas:

- How did the competitors solve the same functions Volvo solved with light?
- Did they have any areas of light application that Volvo did not?

3.1.6 Benchmarking relevant industries

Another benchmarking was carried out in order to see how companies outside the car industry worked with illumination. Architecture, aviation, train and furniture industries were investigated. Looking at airplanes and trains, the Boeing 787 Dreamliner and the SJ 3000 high speed train were deeper investigated. The Dreamliner were studied through articles and the SJ 3000 was observed at two occasions during two-hour trips in daylight and then studied theoretically in articles.

IKEA and Svenssons Möbler were visited and different types of fixtures and lamps were observed. The furniture industry usually pick up trends quickly and has essentially shorter time from idea to product than heavy industries such as automotive.

3.1.7 Technical Research

A number of technologies relevant to the project were examined through information gathering as well as building prototypes.

Light technologies
Interviews were made with people in the light industry to gain an understanding of what light technology that would be prominent in the future. Properties such as energy consumption, heat radiation, cost, light quality, and light intensity were evaluated to see what light source would be best suited for the project. The examined light sources were:

- LED
- OLED
- Ultraviolet light
- Luminescent pigment
- Light transporting medium i.e. fiber optics

Sensors
A demand of non-mechanical switches led to investigate other possible solutions for controlling lighting in the car. A number of different sensors and their field of application were analysed. The ones found most suitable for the project and were to be evaluated further were:

- Capacitive sensor
- Ultrasonic distance sensor
- Passive infrared sensor
- Eye tracking sensor

Programmable devices
To be able to control the light dynamically with sensors and switches the system needed to be programmed. A small highly customizable programmable device that easily could be built in the car was required. The qualified devices were:

- Arduino
- Raspberry Pi
- FPGA

3.2 Results describing the scope

This section describes the result from the pilot study and in the end the results are summarized into the actual scope.

3.2.1 The different aspects of light

From the literature study a number of both well documented and subjective effects from light were discovered.

Light and emotions
Light designer Peter Andres from Hamburg pointed out the importance of how light makes people look. For instance, lights that are too diffuse or has too low RA-index could make people look pale and sick, leading to discomfort to persons in the room (Laganier & van der Pol, 2009). Another source of discomfort was, according to light designer Ray Chen of Originator Light Design Consultants in Taipei, Taiwan, too much direct lighting. Direct lighting creates a feeling of being “in the spotlight”, and thereby a feeling of vulnerability. In a car this effect could be very prominent because of the glass windows and the often dark outside. According to Chen, an indirect lighting where people get the impression of being surrounded by light rather than in the spotlight is therefore to prefer. The conclusions drawn

were that the general lighting in the car should be indirect, bring out contrasts in peoples' faces and be at such a level that people in the car wouldn't feel exposed to the looks of the outside.

Several light designers in the book also stated the fact that humans are designed for natural light, i.e. sunlight, and usually finds this kind of light to be comfortable (Laganier & van der Pol, 2009). Unlike most artificial lights, sunlight is a dynamic, moving and ever changing light source. The colour, angle and character of the light change depending on the weather type, hour of the day and location. The conclusion drawn from these assumptions were that usage of dynamic lights inspired by nature could be an effective way of creating a pleasant light that never gets boring in the car.

Physical effects of lights

It was found that light has many physical effects on people. All humans have a circadian rhythm that controls the body's need to sleep. This rhythm is to one part steered by individual factors but is also affected by light, which explains why people in the northern hemisphere often get more tired during wintertime. Scientists have showed that the surrounding light has great influence on people's circadian rhythm and by increasing the light level, people can maintain focus longer and perform better (Ljuskultur, 2013). Consequently, having a certain level of general lighting during drive was desired, since it could improve driver performance and minimize the risk of falling asleep.

Blue light that affects sleepiness were another topic that was investigated. Due to parallel research at Volvo however, this area was not further developed.

Cultural aspects of light

When the term "Nordic light" was investigated the most prominent where the Northern Lights, Aurora Borealis, that sometimes appears in the sky during winter. This phenomenon is unique for the northern hemisphere and was found to have been used by Volvo in commercial. It was also used in the Lynx, where a side window had a blasted edge that filtered the light, resulting in an imitation of the Aurora Borealis. The idea of using glass as a light transporter and forming patterns in the material were of great interest in this project.

Looking further into cultural aspects, it was found that Nordic countries perceived warm temperature lights as very pleasant and inviting, while southern countries preferred lights with a cooler light temperature (Laganier & van der Pol, 2009). Colour also had different meanings in different cultures. In China, red is the colour of fortune and luck and holds a great mythological meaning (Gao & Cousins, 2011). Red light in western world is usually associated with a warning light or danger. Blue on the other hand is usually connected to the divine and is often used in temples and holy places. Therefore red light should be used with great caution if designing lights adapted for both these cultures, which is the case with Volvo. Colour and temperature of the light could be used as a good way to customize the additional light equipment for different markets.

3.2.2 Impressions from the trend analysis

Design trends

Design trends usually come and go in high pace, but some more consistent trends were found. According to Corien Pompe, design manager identity & innovation at Volvo, the big trend at Volvo for the time being is efficiency. According to Pompe, this trend is in the coming years slowly transcending towards the idea of Wellbeing, referring to how the car interacts and influence the user in a positive way.

When looking further out in the world, the idea of wellbeing went well in hand with bigger design trends of emotional design. This far, the fast technique development has lead to an explosion of functions and choices within many products. Now, some parameters indicates that trends are moving towards reducing the number of choices and simplifying design in order to ease the usage of products. This can be seen in Apple products such as the iPhone, in car industry through reducing buttons and controls.

Future car usage and transportation

As China has developed and become richer, it has also become the world's biggest car market and Volvo's most important future market (More cars are now sold in China than in America, 2009). According to Anders Sachs, Volvo's Chief Designer Colour & Materials in China, Chinese customers buying premium cars prioritize backseat luxury since they want their friends, business associates, and customers to sit comfortable. This is most apparent in larger cars such as Volvo S80 and S60L. Sachs also points out environmental awareness as a fast growing trend, especially in larger cities where air quality is a major problem. Based on this, lights that express luxury and environmental awareness to both driver and passengers could be attractive in the fast growing China.

When looking at trends in Europe, cars are losing ground as the leading status provider for younger generations and young people therefore turn to alternatives for owning a car. Statistics from Sunfleet, Sweden's biggest car pool company, showed that the usage of car pools has quadrupled from 2009 to 2013 (Wickström, 2014), putting pressure on car manufacturers as their selling numbers decrease in these groups. This trend is most apparent in cities where parking are hard to find and where the public transportation is well developed.

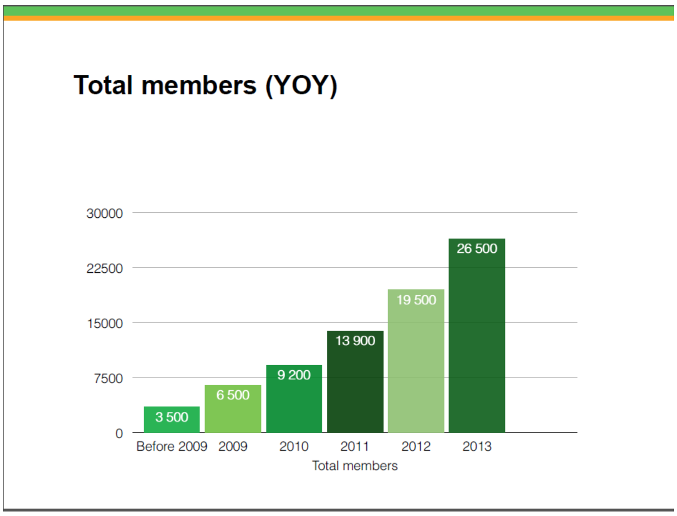

Fig 3.1. Statistics of the number of members in Sunfleet's carpool in Sweden. (Wickström, 2014)

Personalization
At Volvo personalization were described as a major feature for being perceived as premium and the company therefore made big efforts into enabling this in as many aspects of the car as possible. However, the word personalization meant different things to different persons at Volvo. Some people saw it as enabling as many options in as many aspects of the car as possible, while others saw it more as a way of making the car feel personal without creating multiple choices for every function. In a lecture published as a Ted talk renowned psychologist Barry Schwartz lifts the potential danger of having too many choices. According to Schwartz, too many choices can create apathy, anxiety and unhappiness in people. People with choices get power, and with the power follow a responsibility to make the best choice (Schwartz, 2005). If the best choice is not made, there is no one to blame but themselves. Even if the best choice is made, there is still a degree of uncertainty and worry of that another option could have been better. On the other hand, having no options make people feel trapped and forced into decisions. The conclusion, Schwartz says, is that choice is good up to a certain level, but if that level is exceeded choices become a source of unhappiness. When taking this reasoning into consideration, the car of the project was decided to have a certain degree of functional choice (e.g. light level), but other non-functional options (e.g. changing colours of the light) should be eliminated.

3.2.3 Impressions from fairs and museums

The visit at the light and furniture fair contributed to the understanding of the growing trend and interest of indirect lighting. Many exhibitors accomplished the indirect lighting by reflecting light from a completely hidden light source on a bright surface. This technique results in a highly effective general lighting that is non-glaring and pleasant to the eye. A number of connections were made with people from light manufacturing companies such as Osram and Verbatim Light. The same people contributed to the project by sharing knowledge in basic light technology and the on-going light development.

In the fair’s Green House Malin Bobeck, a student at the Swedish School of Textiles in Borås, showed one of her latest projects with optical fibers embedded in fabric. In the fabric, the optical fibers are weaved along with ordinary cotton threads and the ends of the fibers are exposed to highly intensive light. The fibers transport the light, emitting some along the way, making the whole fabric glow (Bobeck, 2014).

Fig 3.2. Fabric with embedded optical fibers, “Liquid Light” by Malin Bobeck

The visit to the Volvo Museum contributed to the understanding of Volvo's heritage. The displayed concept and demo cars gave some guidelines on how unconventional one can be when building a demo car.

3.2.4 The Illumination strategy of Volvo

As it turned out, Volvo had two specialists working in the field of illumination, Kristoffer Johnsson and Johan Persson. From interviewing Johan Persson, who was working close to production, it was understood that the current lighting in the car was thoroughly worked through in terms of technical specifications such as RA-values, light temperature etc. According to Persson, the best way to incorporate new light sources to production cars would be to create multi-functional lights, since these were easier to motivate from a cost perspective. Even though cost savings were not a priority of this project, the idea of multi-functional light was absorbed.

Kristoffer Johnsson, attribute leader of illumination at Volvo, presented an animation of different headlight sequences that could welcome the user differently depending on the car model. For instance, an R-design could light up quickly in a special sequence expressing eagerness to drive in order to appeal to its targeted group. This planted the idea of using user scenarios and light sequences to create a dynamic and interesting light.

During these interviews it was also discovered that Volvo had a standard on the colour temperature of the lights where the white lightning were 3500 Kelvin while the control buttons and glowing surfaces were 5700 Kelvin.

3.2.5 Impressions from benchmarking the car market

The benchmarking showed that few car brands separated themselves from the pack in the usage of light. The exception was Mini and Mercedes. Mini used coloured light extensively, displaying a coloured light show from the overhead light console each time the door was opened. The general lighting in the car shifted from red to blue to green and purple reminding of an amusement park.

Mercedes used LED lights to illuminate the star-logo in the grille, which made the car a stand out in darkness (see fig. 3.3). The idea of communicating the brand in darkness is usually found in head- and rear lights of the cars, so the lit up logo in the grille were an interesting and innovative feature.

Another Mercedes, the S-class, used light extensively. Light strips with changing colour were covering big parts of the interior, creating a changing mood in the coupe (see fig. 3.3). This was a good example of the big opportunities that come with new LED technology. However, the impressions were that the usage of drastically changing saturated light was the result of a sudden overenthusiasm, rather than a well considered design process. Therefore, the conclusion were that coloured light should be used carefully and in a specific purpose, since over-using could be perceived annoying, non-premium and unserious.

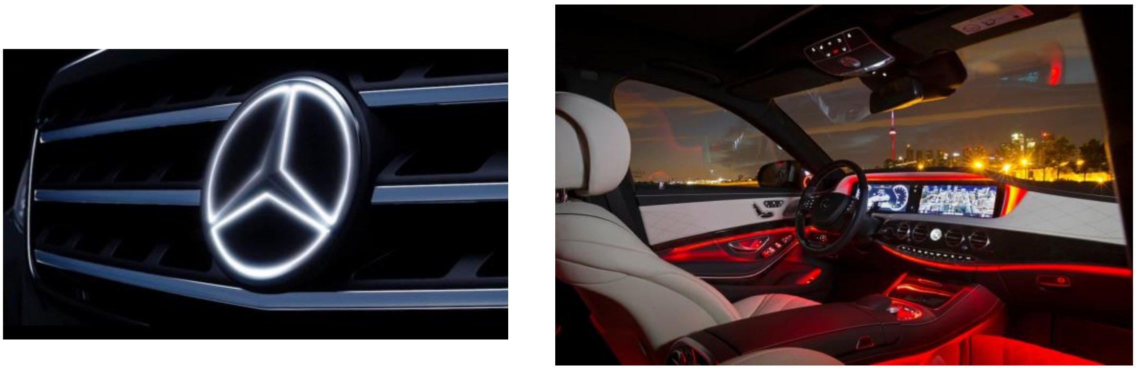

Fig 3.3. The illuminated Mercedes Star and the interior of the Mercedes S-class. (The illuminated star, 2013) (Mercedes S Class, 2013)

3.2.6 Impressions from benchmarking other industries

Architecture

Lights were often used to illuminate facades around in Gothenburg. The main entrance at Sahlgrenska University Hospital had beams of raking light directed at the facade from the bottom up (see fig. 3.4). The light created highlights and shadows that accentuated the brick structure in the wall, while making the building look taller. This showed how the use of raking light could create volume, contrasts and lift up a character in a material.

Fig 3.4. Raking light at the entrance to Sahlgrenska University Hospital

Boeing 787 Dreamliner

The Dreamliner is a lightweight, efficient, and expensive airplane designed for intercontinental long distance flights. It is the leader of the pack in a new era of carbon composite airplanes, which makes it not only influenced by trends, but also a trendsetter. It was found that the Dreamliner had an extensive interior illumination program intending to create a sense of luxury and wellbeing for its long flight passengers (Nearing, 2012). Its dynamic LED light could adapt strength and colour to create the illusion of a blue sky in the roof, imitate sunrise and sunset, and influence passengers' level of sleepiness and mood (see fig 3.5). This was thought of as an interesting feature.

Fig 3.5, The interior of the Boeing 787 Dreamliner (Commons Wikimedia, 2013)

High-speed train SJ 3000

The SJ 3000 has a top speed of 200 km/h and is used on longer distances (SJ AB). It should, just as the Dreamliner, create a comfortable, functional and relaxed environment for passengers traveling a longer time than average. In the train the general lighting were divided into spotlights with visible light source over the centre walk, and an indirect general lighting that was pointed towards the walls and the side of the roof creating a more ambient light. This created a soft and pleasant lighting effect that was thought to be suitable for the project.

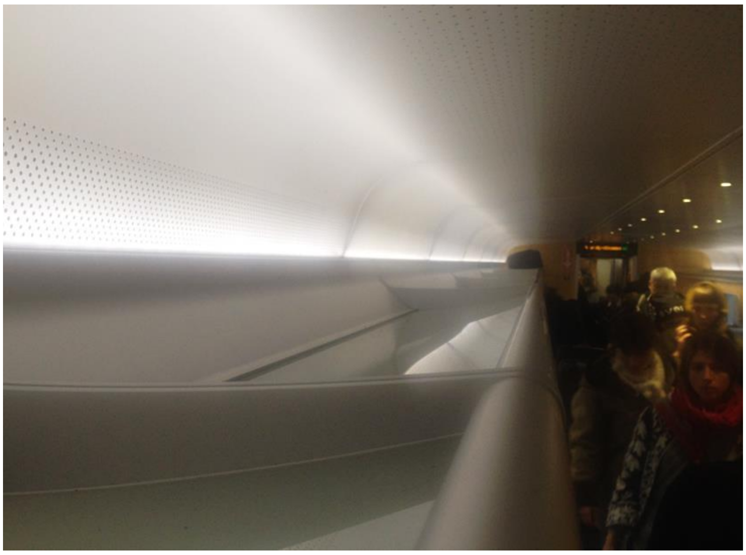

Fig 3.6, The lighting inside the SJ 3000 high speed train

Furniture stores

At Svenssons Möbler an interesting lamp were discovered. The lamp had the shape of an inverted light bulb that was enclosed in glass. This showed the effect of carving out patterns inside a glowing medium, an idea that was later used in the Spacious inner door (see chapter 5.6)

Fig 3.7. The inverted light bulbs at Svenssons Fritidsmöbler

3.2.7 Technology relevant for the project

Light technologies

Due to the low energy consumption, small size and low heat radiation LED was used as the main light source technology in the project. As fig 3.8 shows, the future efficiency of LED were estimated to be further improved, meaning this would likely be the prominent light source for years to come. The OLED was found not sufficient developed, but as shown in figure, it made an interesting alternative for future projects. Photo luminescent pigment and optical fibers were also used in certain parts of the car primarily because of their abilities to emit and spread light with no or little use of electrical assistance. UV lights was found not suitable to use in cars since even unwanted objects, such as stains and dust particles, were highlighted when exposed to the light. For detailed information about the various light technologies see chapter 2.2.

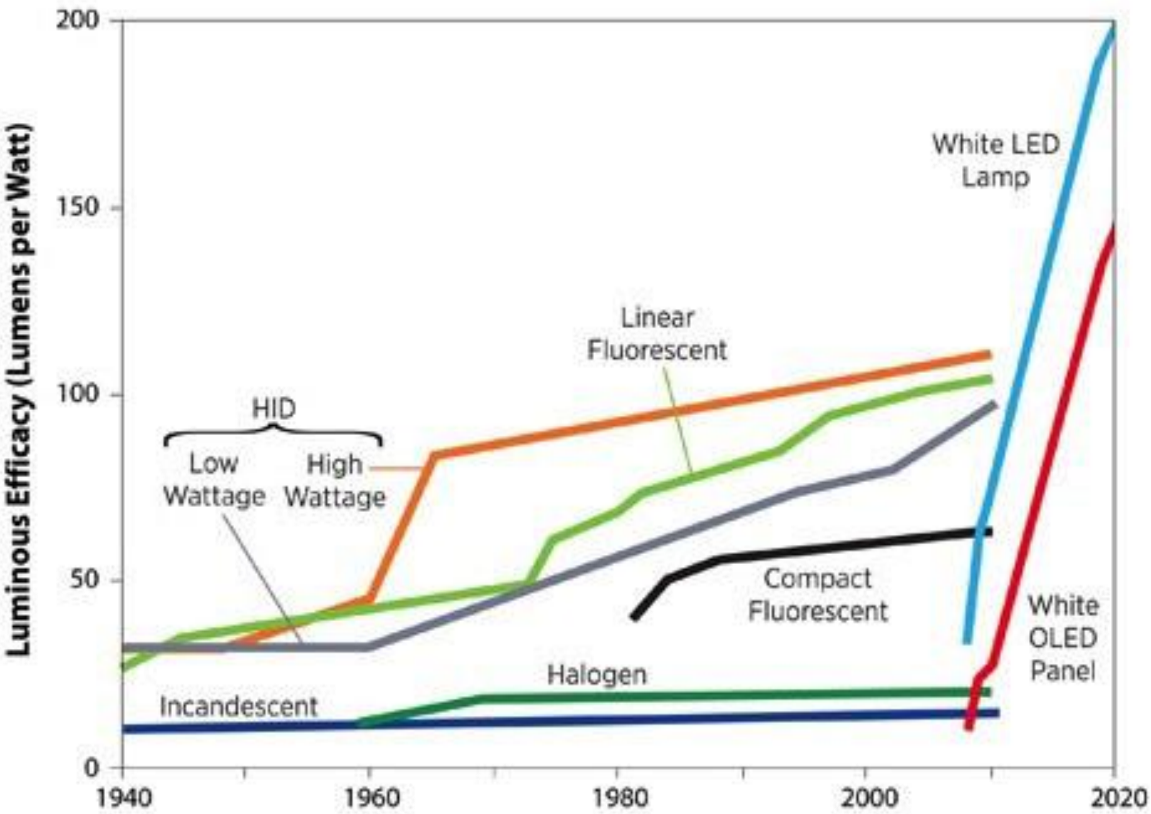

Fig 3.8. The US Department of Energy's future lighting efficiency forecast of LED and OLED (Evanczuk, 2012)

Sensors

Capacitive sensors have low weight and small dimensions compared to mechanical buttons and will be used in the project along with ultrasonic distance sensors to control some lighting. The infrared sensors are relatively inexpensive and easy to use but found too sensitive to control lighting in a car, and will therefore not be used. Nor the eye sensors will be used since it was found to time consuming to learn about the system's hardware and software. Eye tracking was, however, considered an interesting technology for future projects. For detailed information about the various sensors see chapter 2.3.

Programmable devices

Because of the simplicity of both the hardware and the software it was decided the Arduino were to be used as the programmable device in the project. The developer boards that will be used are the Arduino Uno and the Arduino Mega 2560 (see chapter 6.1). The Raspberry Pi was found too complex and overqualified for the project and the FPGA was not as user-friendly as the Arduino and had relatively low capacity. For detailed information about the various programmable devices see chapter 2.3.

3.2.8 The final scope

The pilot study was summarised with a phase called “the final scope”. The purpose of this was to create an overview of what conclusions had been drawn from the pilot study and translate these into some guidelines and visions for the project. This was done through discussions with involved parties of Volvo as well as the supervisor Ralf Rosenberg at Chalmers.

Design guideline
The design guideline was summarized as follows:

The general lighting in the car should be indirect, bring out contrasts in peoples’ faces and be at such a level that people in the car don't feel exposed to the looks of the outside. A certain level of general lighting should be possible to have during drive without disturbing the driver. All interior light sources should be hidden in order to avoid glare and the colour temperature of the interior white lamps should be 3 500 Kelvin. Saturated coloured light should only be used sparingly, and only if there is a specific purpose with the colour.

Design vision
The vision was summarised as: *The aim is to through illumination create an emotional bond between the car and the user. An efficient way to do this is to create a car that express life, temper, and character and accordingly has the ability to through light help, interact and communicate with the user. This goes in line with growing trends of emotional design as well as Volvo’s design direction with focus on wellbeing and connectivity.*

Technical vision
The technical vision was summarized as: *The aim is to in a new innovative way use already existing technologies to create intuitive control over lights in the car. By sensing variations in e.g. movement, temperature and pressure and get the car to react to these variations the car will feel alive and alert. To create these expressions of life various light sources and light transporting mediums as well as different programmed start up lighting sequences will be tested, evaluated and implemented. By reducing the amount of cables the created system will also be lightweight and energy efficient.*

The name Strix

Strix is the Latin word for owl. The Strix possess many of the attributes that were decided upon in the scope. It is a strong icon with a calm and beautiful appearance, complemented with a powerful temper that quickly can turn it into an aggressive predator. The owl is also a night animal associated with wisdom, which corresponds with the idea of a car that helps, interacts and guide the user.

Fig 3.9. The logotype of the Strix that was developed for the project

The target user

Interpreting the Volvo V40 commercial, its target buyer seemed to be a small household looking for a fun car to drive, mainly in urban environment. In addition to this, the target users for the Strix was set to be in their thirties, social, and with a habit of doing weekend trips with friends. They appreciate details and value their spare time so high that they are prepared to pay more for a comfortable car once they get out on the road, rather than being connected to a car pool. Therefore the Strix should be both sporty, and practical and offer a cosy atmosphere that appealed to the users.

4. IDEA GENERATION PHASE

As the scope was set, the next phase was to generate ideas that corresponded to the scope. This chapter describes that phase.

4.1 Methods used to generate ideas

This section describes the methods used and how they were executed in order to generate ideas.

4.1.1 Current Situation analysis

A *Current Situation Analysis* for the Volvo V40 was carried out. The analysis had the form of a functional analysis and listed all the functions of the lights in the car. By focusing on functions rather than actual design, the risk of thinking only in conventional solutions was minimised. The vehicle exterior and interior were scanned from back to front for lighting. Each light, or light group, was given a headline under which both current and desired functions were listed. Current functions were marked in green, while desired functions were marked in blue.

4.1.2 Internal discussions

Internal discussions were held continuously in the R&D workshop. The aim was to get inside information about improvable parts or functions in the car and get their view of what the customers asked for.

4.1.3 Creative workshops

Four workshops were conducted with groups of people outside the car industry. The purpose was to get ideas that were ”outside the box”, get insight to people's perception of the field illumination and to generate ideas that were from a future generation of car buyers.

The first three workshops were introduced with splitting people into groups of about five. When forming the groups peoples natural groups were preserved since acquainted people are less afraid of presenting crazy ideas to each other. The participants did not know that the project involved illumination or lights when the workshops started. Each group was given an electrical household appliance with the task to assign a given property to it. These properties were based on the objective of the project (See chapter 3.2.8) and were assigned to the machines with the help of various accessories, such as feathers, straws and paper (see fig. 4.1). After about twenty minutes of building and discussing, the groups were told to present the result. After presenting and explaining the built in features and how they contributed to the property asked for, the groups were told to discuss how to create the same features in a car through illumination. This created an open discussion where the groups debated and helped each other obtain their objectives and generate ideas. This approach was decided upon to create a wide spread of ideas and to prevent loss of ideas in an early stage due to strict directives.

Workshop 1
During the first workshop there were fifteen participants divided into three groups. The participants were all swedes, but of different genders and backgrounds. The majority were students in their mid-twenties studying design related bachelor or master's program on Chalmers University of Technology. The design objectives for the groups were:

- Group 1 were given an electric hand mixer and asked to make it communicate temper.
- Group 2 were given a toaster and asked to make it communicate personality.
- Group 3 were given a sewing machine and asked to make it communicate helpfulness.

Fig 4.1. The material used in Workshop 1

Workshop 2
The second workshop contained seven senior high school students of the Art and Form class at Peder Skrivares Skola in Varberg whom were divided into two groups. This workshop was carried out to see if the result would vary between the different targeted groups of people. The participants were about sixteen to seventeen years old and consisted of five girls and two boys. The workshop took place in their classroom in Varberg. The design objectives for the groups were:

- Group 1 were given an electric hand mixer and asked to make it reduce the user's frustration.
- Group 2 were given a toaster and asked to make it communicate temper.

Workshop 3
The third workshop also took place at Peder Skrivares skola, this time with third year students of the Art and Form program. This group contained nine women of the age of nineteen and were divided into two groups. The design objectives for the groups were:

- Group 1 were given an electric hand mixer and asked to make it communicate life, temper and character. Their target group were urban hipsters in the age of 25-35.
- Group 2 were given an iron and asked to make it communicate life, temper and character. The target group were people in the age of 55-65 with no children living at home.

Workshop 4
An additional workshop with a different approach was held with a class of 21 senior high school students at Peder Skrivares Skola. The students were in the Technology Product Development Program's second year and were 17-18 years old.

The class were first divided into two groups of ten people. As an introduction to this workshop the two redesigned household machines from Workshop 3 were displayed and the participants were to pick from the whiteboard a number of given words that they found to be prominent in the two designs. After about ten minutes the groups were asked to present their chosen words. Thereafter, the design objective from Workshop 3 was revealed and the groups were given five minutes to compare and discuss differences and similarities of their chosen words and the objectives of Workshop 3. This introduction was meant to works as a warm-up and to get the groups to think in terms of design for emotions.

Next step was to split the two groups into four groups and present the objective of the thesis work. After gaining an understanding of the area illumination and the desired features in the project, each group were assigned a part of the car and asked to brainstorm ideas involving lights.

- Group 1 were assigned the exterior roof and side.
- Group 2 were assigned the exterior front and back.
- Group 3 were assigned the interior driver environment.
- Group 4 were assigned the interior passenger environment, including the backseat.

The groups then generated ideas for about twenty minutes before being asked to present the result. Thereafter five light technologies were introduced to the groups through pictures and explanation:

1. Luminescent pigment
2. Ultraviolet light
3. Optical fibers
4. Distance sensors
5. Eye tracking sensors

See chapter 2 for further information about the various technologies.

After another fifteen minutes of discussion the groups were asked to present their final concepts. The concepts were written- or sketched down on paper.

4.1.4 Brainstorming in car

Once the current status of the car were established the idea generation phase was introduced with the most basic and straight-forward way to generate ideas - a brainstorming session in the assigned Volvo V40. This was mainly done as a warm-up and to get to know the car, but also to get as many rough ideas as possible to later be able to refine them as knowledge were exchanged with people involved in the project.

4.1.5 Elimination and solution matrix

In the cases where several different ideas competed in solving the same function, a weighted decision matrix was used. The matrix had columns with the different solutions and rows describing different important criteria. The criteria were weighted in accordance with their importance and at the bottom the total score was gathered.

4.2 Areas identified as improvable

The areas found as improvable were later used as starting points when developing ideas.

4.2.1 Current Situation analysis

During the analysis of the Volvo V40 a number of areas to improve were found (see Appendix 1 for full analysis). Starting from the back, the luggage compartment lighting was too dark. There were two light sources on the side walls of the luggage compartment, but the dark interior absorbed the light and the placing made them easy to block. Therefore, a redesigned light should not be as easily blocked and better describe the space and depth of the luggage compartment.

When unlocking the door the welcoming lights were lit up. The current welcoming lights consisted of a puddle light pointed down on the ground from the side mirror, position lightning in the headlights and rear lights and a faded general lighting inside the coupe. The sequence offers good feedback in terms of confirming that the car is unlocked, but could be improved in terms of creating a welcoming and inviting light for the user.

The interior general lighting consisted of an overhead console above the two front seats, one over the back seats, and foot lighting in all four seats (depending on the level of extra equipment). The light from this console worked as both general lighting and as located lighting. This resulted in a wider light spread with a highlight in the knee of the user. It was noticed that the interior light created reflections in the driver’s visual field, resulting in that the lights had to be switched off during drive in order to not disturb the driver. This went in contradiction with the desire to have a general lighting during drive, and therefore left an opening for improvement.

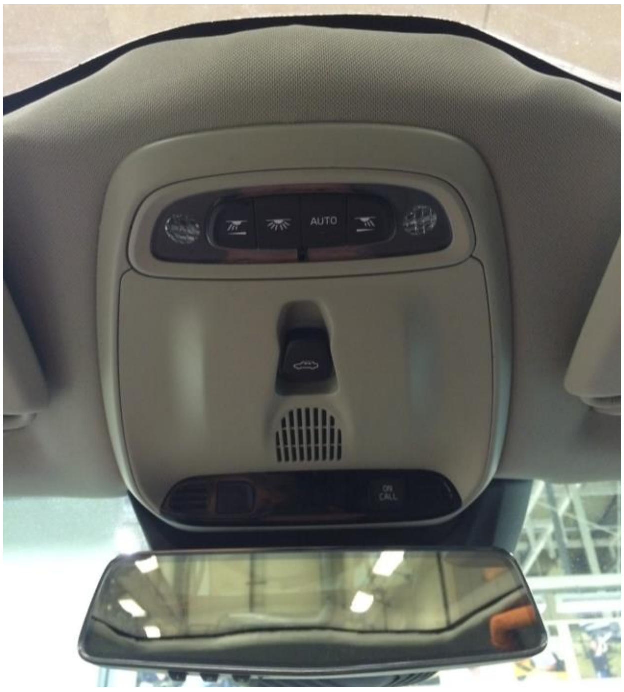

Fig 4.2. The current overhead console, containing both general and located lighting

4.2.2 Internal discussions

The internal discussions resulted in a list of problem areas and parts to improve in the car. The following problems were found to be of importance in this project:

Finding the belt buckle: In a small backseat the belt buckle often gets stuck under people, which make it hard to find. Together with bad light conditions, this creates irritation and discomfort. An easier way to find the belt buckle was therefore needed.

Reading lamp backseat: As the backseats are getting more and more important, a reading lamp that could be lit up during drive was requested. The lamp could not glare or in other ways disturb the driver and should feel premium and fresh.

Phone storage: Many people complain about having nowhere to put their smartphones in the car. In a society where the phone often is more important than the wallet this was a major source of irritation among customers.

General storage: Cars do not often keep room for general storage such as hats, gloves and napkins. Therefore, it was desired to free space in order to generate this storage space.

Insight under the car: On the American market the customers wanted to see under the car so that they could feel safe that no one was hiding there.

Clean air indicator: A request from Volvo China was to further communicate Volvo’s Interior Air Quality System (IAQS) to the Chinese customers. The IAQS consists of a carbon filter that cleans the air that enters the car through the fan system. This is much appreciated in Chinese cities where pollution is a major problem. However, nothing in the current cars shows the users that the system is activated, or even exists. Therefore, it could be a good selling advantage to accentuate the system in the car.

4.3 Impressions from the workshops

During the first workshop Group 1 used feathers and straws in fiery colours to give the impression of an angry hand mixer ready to attack (see fig. 4.3). When asked to connect this to lighting in a car the group came up with using interior light to indicate speed. This gave inspiration when developing the "Campfire Centre Stack" (See chapter 5.5). During the same workshop, Group 3 came up with the idea of using light under the sewing machine in order to create the illusion of it floating in the air. This idea was later used in the "Flying carpets" (see chapter 5.9).

During workshop number two, Group 1 dressed the hand mixer with purple toilet paper and made it look like a unicorn in order to reduce frustration (see fig. 4.3). When discussing how to make the same features with light the group expressed that the light should be soft and, depending on the outside, dimmed to an appropriate level.

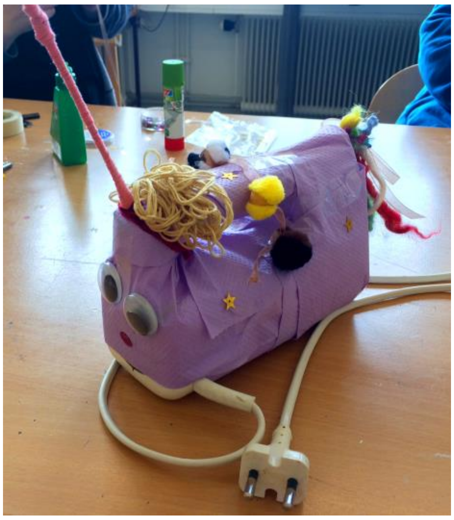

Fig 4.3. To the left: the results from Workshop 1. To the right is the purple hand mixer from Workshop 2, designed to reduce frustration

During workshop number four the groups were presented with different light technologies. Group 2 presented the idea of using fiber optics with a dynamic light in the centre stack to get it look like a waterfall. The group thought of water as fresh and clean. The idea of a waterfall centre stack has already been used by Volvo in the 2009 S60 Concept, but that time the effect was achieved with crystal glass. Never the less, using optical fibers in the centre stack in order to create a moving light were implemented in the "Camp fire centre stack".

Other ideas that were presented during the workshops were neon light in the rims, artificial star ceiling for children in the backseat, and ultraviolet light for reading making the pages bright without disturbing others.

4.4 Generated Ideas

All in all the workshops, discussions and brainstorming sessions resulted in a large number of ideas linked to the field of illumination.

Portable light in glove compartment
The light source in the glove compartment could be portable, enabling multifunctional light. If the user needs to get out of the car at night the light in the glove compartment could be removable easily, creating a flashlight to use outside. The flashlights charge when in its place in the glove compartment.

Panorama roof light
The panorama roof could be used as a light transporter. A light source could be placed in one end of the roof causing the light to be transported to the other end. This would cause some reflections, creating a general lighting in the car.

Star sky
When using the panorama roof as a light transporter, the surface could be scratched at certain places creating small dots where the light can emit from the roof. This would give an impression like a starry sky.

Motion detector to welcome user
A motion detector could be used to get the car to react when the user comes close. The car could for instance turn on the headlights or pulse the interior lighting discretely. This would give the impression of an alert and welcoming car.

Glowing handles
To guide the user to the handles in the doors, the bonnet and the trunk lid the handles could be lit up with LED-strips or luminescent pigment in the paint or plastic.

Handles communicating locked or unlocked
The exterior door handles could communicate if the car is locked or unlocked by showing green or red light in the handles. This would leave no unwanted concerns about whether the car is locked or not.

Rim signature
To get a unique Volvo signature on the side of the car the Volvo-logo in the centre of the rims could be highlighted either by using electrical lights or luminescent pigment.

ECO-drive interior light
The interior lighting in the car could help the user with eco-driving by showing the current engine rpm. Red interior lights indicate it is time to change gear.

Control light with eye movement
By tracking eye movement with sensors it could be possible for the user to control the interior lights in the car by looking at certain things. The centre stack for example could be dimmed down while driving until the user looks down at it.

Self-tinting side windows
“Smart glass” (LaMonica, 2011) in the side windows could be used to automatically tint the windows in a darker tone when passing lights annoying to the driver, for example the sun behind trees causing flickering light.

Pulsing light in gear lever
To communicate the link to the heart of the car, i.e. the engine, the gear lever could pulse with warm light in a heartbeat-like way. This pulsing could be connected to the engine, indicating when to change gear in order to drive environmentally friendly.

Lit up iron mark
A glowing iron mark in the front could make the Volvo brand a stand out in darkness.

Red Welcoming Carpet
A red carpet of light could fold out as the user unlocks the car in order to welcome the user in an elegant and fortunate way. This could appeal to Chinese costumers, since red in China is the colour for fortune and luck.

Side signature
A side signature that was visible in darkness could offer the same recognition of the brand as todays Volvo backlights do.

Lightened Volvo Letters
Lighting up the Volvo letters on the trunk could create a welcoming sign as the user approach the car from the back.

Creating a campfire feeling in the car
Integrating the wellbeing associated with sitting by a campfire into the car could make the experience of riding the car feel more inviting and cosy. This could turn the space inside the car into a room for conversation and socialising rather than just a room for transport.

Spacious inner door
If the door were made more spacious, it could be used as a platform for user oriented functions of which some are described in chapter 4.2.2.

Reading lamp
A reading lamp hidden so that it didn’t glare could be developed. This would mean that passengers could read while driving and not disturb the driver or other passengers.

Illuminated Volvo badge
The Volvo Badge in the steering wheel could be lit up in order to communicate alertness and awakening as the driver sits down in the driving seat.

Light Corridor Roof
If replacing todays overhead console with long light handles along the sides of the ceiling, this could mean a bigger light spread, less glare (since the light source doesn’t need to be as strong) and a comfortable general lighting in the car.

Lightened carpets
If putting light behind the carpets rather than just on them, the effect of flying could be achieved. This would be unique within the car market, and could create an intriguing effect on the users.

Buckel finder
In order to find the buckle in the backseat when it’s crowded and dark, a buckle finder using light could be developed.

Clean air indicator
In order to indicate Volvo’s Interior Air Quality System (IAQS), light expressing purity and freshness could be used when the system is active. This could make a strong sales point in countries where air pollution is a major problem.

Luggage compartment lighting
In order to improve the lighting in the luggage compartment and prevent blocking the light source, long light transporters could be used to spread the light. This way, even when partaly blocked, light would still be emitted in the luggage compartment.

Dim light with hand movement
Using movement to control the light could be a way to reduce the number of buttons in the car.

Using the joint knowledge gathered during the project, ideas were weekly evaluated together with people at Volvo. Based upon how well the ideas corresponded with the scope and how innovative they were, twelve ideas were implemented in the car (see chapter 5).

5. CONCEPTS IMPLEMENTED IN THE CAR

In this chapter the final concepts that were physically implemented in the car are described. Construction details such as components and actual building workflow for each concept can be found under chapter 6.

5.1 Glowing Iron Mark

With inspiration from the illuminated Mercedes logo (se chapter 3.2.5) a new Volvo iron mark was developed. By adding a “glow in the dark”-effect this Volvo trademark comes alive during night and makes the brand more easily recognizable in the dark. The idea is that it also intrigues people’s minds and make them think twice about what the light is and how it works. This touch of mystery adds to people's interest in the Volvo brand. The light emitting properties was achieved by moulding the piece in a luminescent plastic, making the iron mark clearly visible in the dark.

Unlike Mercedes the solution does not require any light sources, cables, or installation and it does not consume any energy. It is solid and withstands damage without affecting the glow. Furthermore the light is delicate and does not scream the message to the observer, but rather presents a mystery moment when the mark illuminates very discretely. Since the light is not electrically generated the glow will appear even when the car is not running.

Fig 5.1. The initial visualisation followed by the final result of the glowing iron mark

5.2 Red Welcoming Carpet

To welcome the user in an exclusive way a red light carpet was developed. The red carpet is activated when the car is unlocked. In its initial position the light is directed under the car, creating insight so that the user know that there is no one hiding, or an animal lurking under the vehicle. This was a request from American customers. After a few seconds, the light is extended out below the doors, creating an embracing welcoming carpet on the ground. The light cone that is projected on the ground concentrates the light closer to the door and expands along the sides making it weaker further out. The effect is a guiding light that draws the user in the right direction. The red carpet also shows puddles and dirt at the entrance of the car, helping the user to stay clean and dry as he or she enters the car. When the door is closed, the carpet folds in and disappears.

The use of red coloured light was an idea adapted for Chinese market, where red is the colour of luck and fortune. To be welcomed to enter the car in this sign could, according to Lars Falk, Vice President Product Design at Volvo in China, be very much appreciated by these customers.

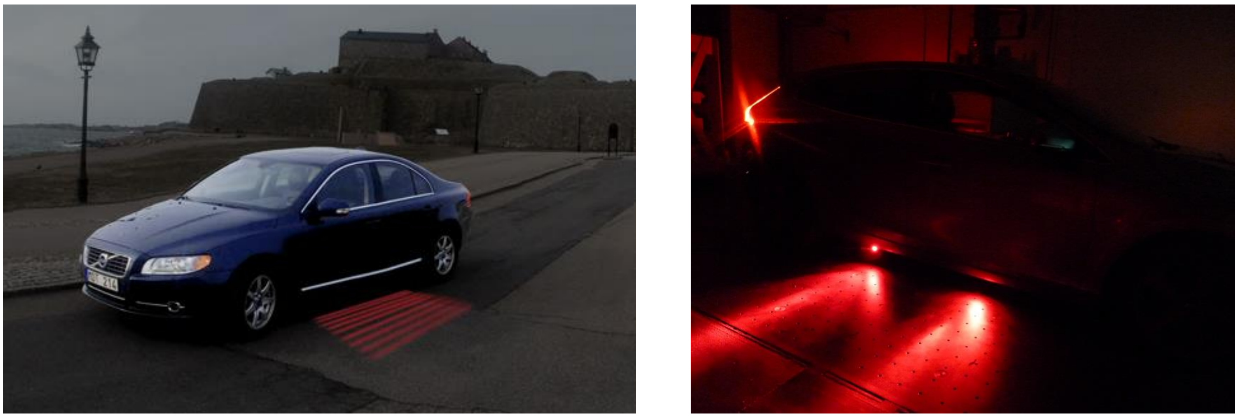

Fig 5.2. The first visualisation of the red carpet and the final result

5.3 Side Signature

The brainstorming session gave birth to an idea of a side signature inspired by the iconic Volvo P1800 and the more recent Concept Coupe. A thin line with photo luminescent pigment mixed in clear coat was drawn along the so called catwalk - a mutual design feature on the doors of these cars (see fig. 5.3). Practically invisible in daylight, this small design feature creates an unmistakable identity in darkness, relating to Volvo's heritage and making the brand stand out further in its competition. Alike the glowing iron mark, the side signature offers a discrete mystery for the viewer and tick many boxes in terms of being unique, innovative and unpredictable.

Fig 5.3. The Volvo P1800 followed by the sketch of the Side Signature.

5.4 Glowing Volvo Letters

During discussions with the people in the concept workshop the idea to illuminate the Volvo letters on the trunk occurred. The idea was to make the car answer as it was unlocked and to add to the welcoming effect when approaching the car from behind. Three different lighting alternatives were evaluated, resulting in one final solution. The chosen solution where to attach light sources on the backside of the letters and make the light "spill" out on the sides of the letters.

In a using scenario the letters are lit up as the user unlocks the car and are then turned off as the engine starts, due to legislative demands.

Fig 5.4. The Glowing Volvo Letters

5.5 Campfire Centre Stack

The Campfire Centre Stack takes the wellbeing emotions associated with a campfire and transfers these into a car, creating a space to socialize, relax and enjoy the company of friends. It finds inspiration in fire and changes pace, colour, and light level accordingly which creates a pleasant dynamic general lighting that reminds of a camp fire. The dynamic light is accomplished through use of textile with large numbers of fiber optics embedded, leading out in the backend resulting in foot lights in the backseat.

Fig 5.5. The mood board created for the Campfire Centre Stack

The Scenario

When entering the car the centre stack lights up in sections, starting from the inside going out in order to communicate the awakening of the car. The colour of the light is connected to the outside temperature. If cold outside the centre stack has a warm orange light and vice versa. As the driver enters the car and starts the engine the colour of the light slowly fades towards a 3500 Kelvin white light. Once the car is running, the pace of the unsynchronized pulsing is dependent on how much the driver presses the gas. When going fast, the asynchronous movement in the centre stack increase in pace which leads to a faster moving light that enhance and connects the user-car experience.

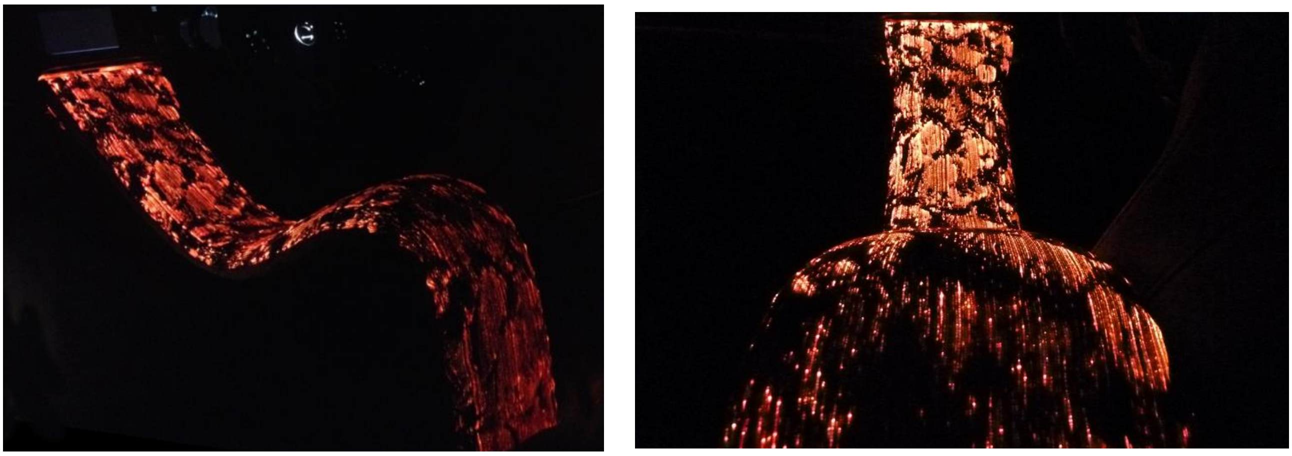

Fig 5.6. The final Campfire Centre Stack

Limitations
Since the physical Strix car is not drivable due to mechanical work that has been conducted, the scenario that is demonstrated were limited to a parked car in cold weather. For the Campfire Centre Stack, this meant that the light sequence of starting the car and driving away were not physically visualised in the Strix.

The shape
The initial shape of the Campfire Centre Stack had a conventional vertical connection to the dashboard. Because of uncertainty of how well the optical fibers could transport light in sharp corners, the design was later developed to its more fluent and soft final shape (see fig 5.6). This form freed space below and felt thin and light. The height was adapted so that the driver could lean the elbow comfortably.

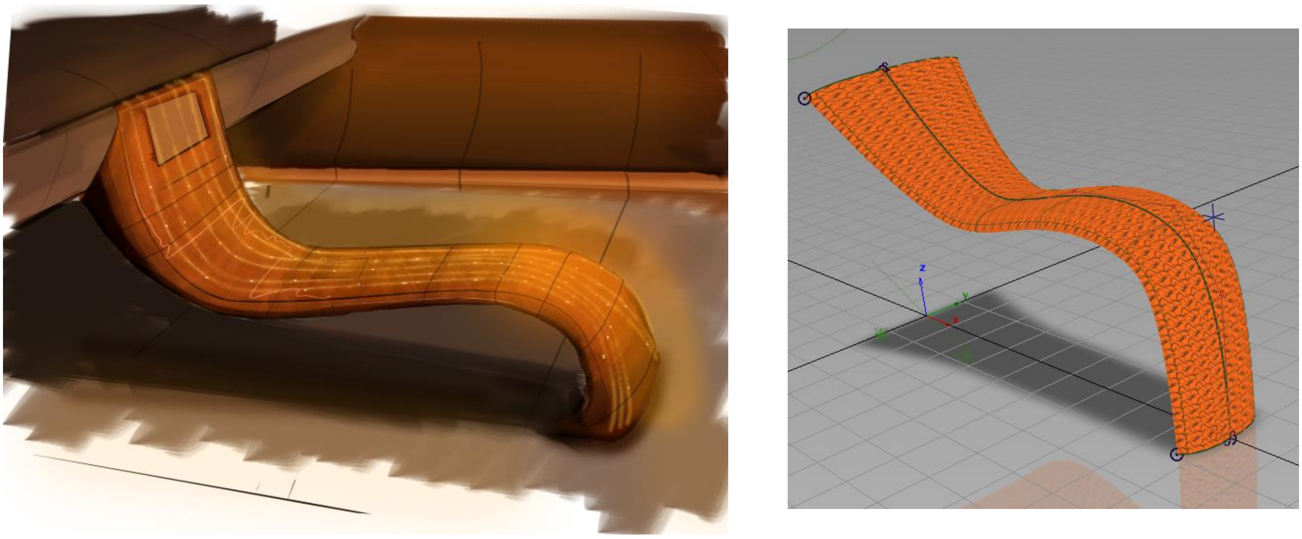

Fig 5.7. The first sketch of the Campfire Centre Stack, followed by a CAD model of the further developed shape

5.6 Spacious Inner Door

To get a more exclusive experience while sitting in the backseat the inner door was made more spacious and luxurious. The door combines several functions such as bigger storage, reading lamp and elbow rest. The size of the storage space where increased through the removal of the loudspeaker and window regulator. With a storage wall shape that enables improved down sight, combined with an added motion-activated lighting, it is easy to see what lies in the storage space. The motion sensor also makes the inner door more functional and less energy consuming (see chapter 7). The inside of the door were covered in an orange fabric that went well in line with the Campfire Centre Stack. The textile had a rough texture that was highlighted through a raking light from a LED-strip attached on the backside of the elbow rest. Inspiration to this was found in Sahlgrenska University Hospital where raking light were used to enhance the structure of facades (see chapter 3.2.6).

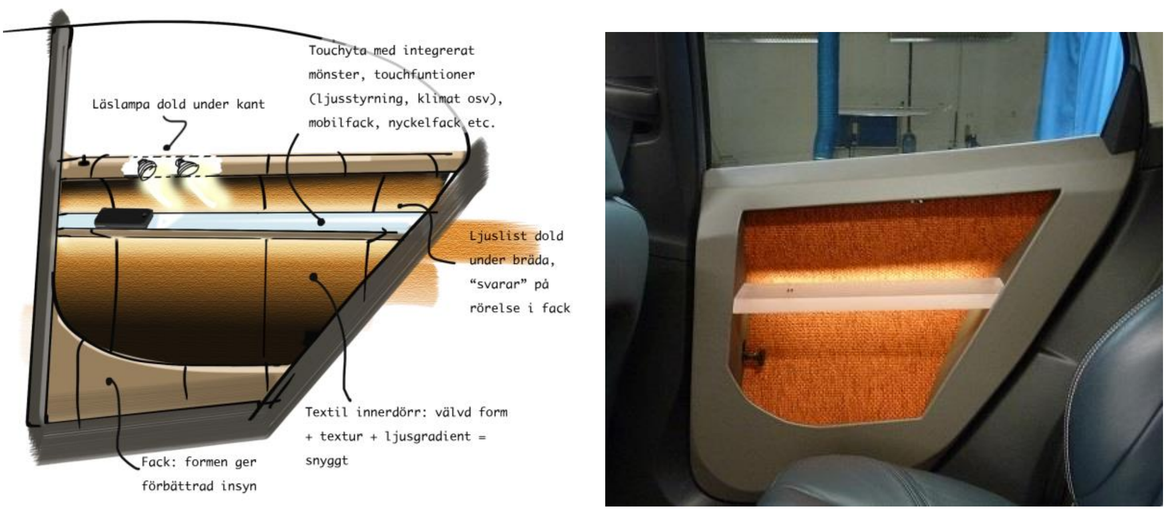

Fig 5.7. The sketch of the Spacious Inner Door followed by the final result

The armrest was made in semi-transparent Plexiglas that further communicated the spaciousness in the door, and was fitted with touch controls to turn on and off the reading lamp, the heated seats, the electrically operated windows and opening the door. The armrest also offered storage of a smartphone. The touch control demonstrated how one could avoid having mechanical controls.

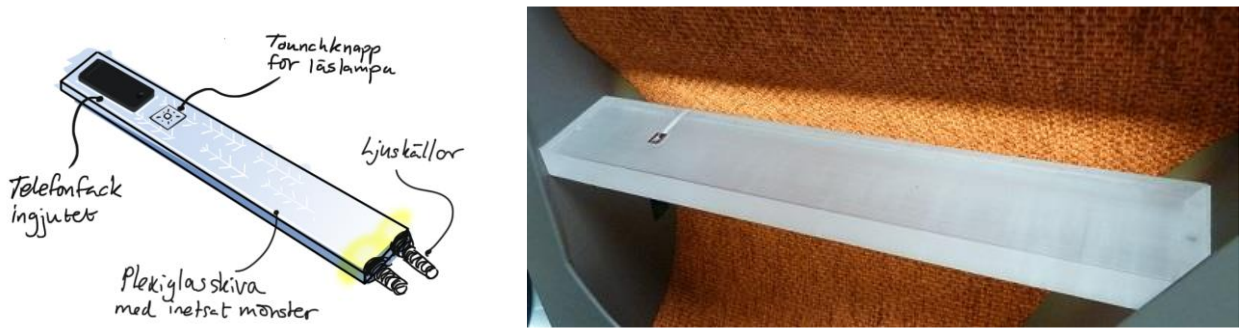

Fig 5.8. To the left: the sketch of the armrest. To the right: the final result

When deciding a new reading lamp for the back seat, four different placings were assessed. The assessment showed that the most suitable placing for the lamp would be in the door, using the ledge below the window as a light shield to avoid glare and unwanted reflections. This solution scored well in all categories except "quality of light", meaning that some risks of shadows and blocking the light occurred (see fig. 5.9).

Weighted Decision Matrix - Reading Light

Decision Factors		Snabellampa	Roof spotlight	Door spotlight	Front seat light
Criteria	Weight	1	2	3	4
Do not distract driver	2,0	3	-3	5	5
Quality of light	2,0	4	-2	-1	3
Hidden light source	1,0	0	-5	5	2
Premium feel	1,0	-3	0	4	1
Easy to control	1,0	1	3	4	-4
Weighted Scores		12,0	-12,0	21,0	15,0

Criteria	Definition
Do not distract driver	How strongy glare, reflections, and other light caused problems distract the driver
Quality of light	How good is the light for reading? In terms of shadows, light level, spread, contrasts etc.
Hidden light source	How well hidden is the light source? Is there low risk of glare?
Premium feel	Does the solution as a whole feel premium?
Easy to control	Does one understand how to use the light correctly?

Explanation: Score goes from **-5 to +5** for each criteria. The score is multiplied by the weight to arrive at the total weighted score. The winning solution is marked in blue at the bottom

Fig 5.9. The Weighted Descision Matrix describing the selection process when deciding the position of the reading lamp

5.7 Illuminated Volvo Badge

To enhance the feeling of an alive and alert car the Volvo badge in the steering wheel was added with a cold white light. The light were designed to pulse in a heartbeat-like way together with the light in the Campfire centre stack, creating a feeling that the car is eager to drive off. As the engine starts the pulsing fades away in order to not distract while driving.

Fig 5.10. The sketch of the illuminated Volvo badge, followed by the final result

5.8 Light Corridor Roof

The standard handles in the roof sides were replaced with a long handle, stretching from front to back, increasing possibilities to grasp the handle from different angles. The handle is made out of transparent plastic with attached light sources at both ends, making the whole handle conduct light and light up.

To avoid glare the handle was covered with the same fabric as the Spacious Inner Door. However, some bare plastic was spared, not visible for neither passengers nor driver, creating a stretched out indirect general lighting in the side ceiling of the car. This indirect lighting created side light in the face of the people riding the car, which enhance contrasts and creates soft shadows.

Fig 5.11. The Light Corridor

5.9 Flying Carpets

With inspiration from the workshops (see chapter 4.1.3) the standard floor carpets were modified with downward directed light to give the impression of them hovering a few centimetres over the floor. This gives an exclusive and futuristic feeling, but also connects with fairy tales from the Middle East in a playful way. In order to demonstrate the full potential of the light, a thin veneer of walnut were placed under the carpet. This wood base picked up the colour from the carpets in a beautiful way and added to the flying effect.

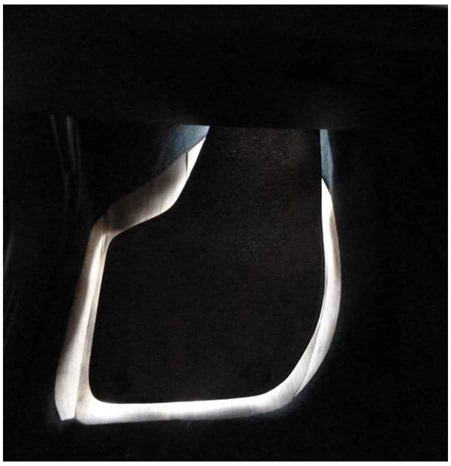

Fig 5.12. Picture of the left Flying Carpet with the wood veneer beneath

5.10 Buckle Finder

To be able to easier find the safety belt buckle a thick guiding seam with a thread covered in photo luminescent coat were sewed into the backseat. The thread charges from sunlight during day, and emits the light during night, resulting in a glowing seam that points out the direction towards the buckle and has such a thick profile that even when not charged with light it still guides the hand to the right place.

Fig 5.13. The buckle finder in daylight

5.11 Clean Air Indicator

Based on the requests from the Chinese market, a Clean Air Indicator was developed. When Volvo's Interior Air Quality System (IAQS) is active, a clean air-text situated below the air vents on the dashboard is lit up from behind. The light has a cool colour temperature of 5700 Kelvin in order to communicate freshness and purity.

Fig 5.14. The Clean Air Indicator when the IAQS is switched on

5.12 Luggage Compartment Lighting

Several performed methods indicated the need of improved luggage compartment lighting, and consequently this was developed. To better communicate the form and depth of the space, light transporting tubes were connected to hidden LEDs and attached along the sides, lighting up the flat loading surface. The light emitted from the sides serves as a low level general lighting, while the light that runs out in the end of the light transporters serves as a stronger, located light. The located light from the ends of the light transporters comes out in the back, lighting up the luggage compartment from behind. Light from behind is desirable since it is not as easily blocked and do not glare.


Fig 5.15. The new luggage compartment lighting

5.13 Extra - dim light with hand movement

As an option to mechanical switches and touch controls a completely non-touch control was developed. By moving a hand closer to a light source the light will turn on and increase in intensity until the hand stops or is removed. With this technique it is possible to intuitively control lighting in the car. This feature was not implemented in the car, but was shown as a stand-alone feature.

6. THE CONSTRUCTION OF THE CONCEPTS

6.1 Components

In order to build the various concepts a number of components where used, these are listed below. This chapter excludes small electrical units e.g. resistors and transistors (see Appendix 2).

6.1.1 Arduino Uno

Arduino Uno is a microcontroller board based on Atmel's 328 processor. The Uno operates at a voltage of 5 Volts and has 6 analog input pins and 14 digital pins for output or input. PWM signals to control LEDs e.g. can be used from 6 of these digital outputs (Arduino Uno, 2014). In this project the board was programmed with Arduino software v.1.0.5.

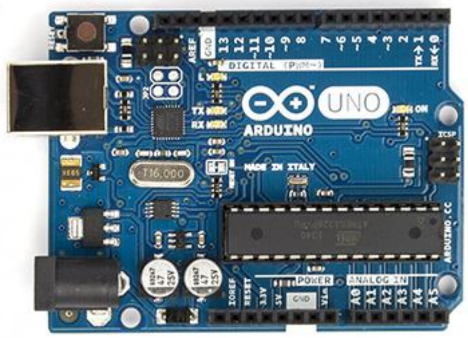

Fig 6.1. Arduino Uno board

6.1.2 Arduino Mega

Arduino Mega is a microcontroller board based on Atmel's 2560 processor. The Mega is Arduino's biggest board and offers 16 analog input pins and 54 digital pins for output or input, 15 of the digital output can be used as PWM-outputs (Arduino Mega, 2014). In this project the board was programmed with Arduino software v. 1.0.5

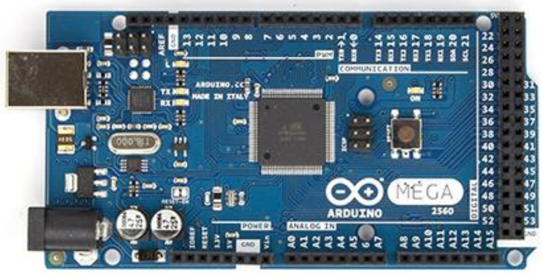

Fig 6.2. Arduino Mega 2560 board

6.1.3 Ultrasonic sensor

The PING))) Ultrasonic Distance Sensor from Parallax provides accurate distance measurements to objects as close as 2 centimeter and as far as 3 meters. The sensor works by sending out a wave of ultrasonic sound and listening for the echo as the sound hits an object and reflects back. The duration from sending to receiving the sound is measured and can be used to determine the distance to the object (PING, 2013).

Fig 6.3. Ultrasonic PING sensor

6.1.4 Voltage regulator

To reduce the voltage from the car's battery down to 5 volts the voltage regulator L78SO5CV from STMicroelectronics was used. The regulator takes a voltage of 7 to 25 volts as input and converts it to a 5 volt output and is protected from thermal overload and short circuit.

6.1.5 Light sources

The main light sources used in the project are listed below.

Power LED star RGBW
The RGBW power LED from Barthelme consumes a current of 350mA, offers a maximum light intensity of 100 Lumen and has a high rate of energy efficiency. By combining the different diodes, red, green, blue and white and their intensity it is possible to get every color in the visible light spectra. The four different colored diodes are all encapsulated in one module, enabling good color mixing and easy installation. The light source radiates no heat in the direction of the light but all the more backwards, therefore, to prevent damages the LED needs to be cooled with a heat sink (Elfa Distrelec, 2014).

Fig 6.4. Power LED with integrated red, green, blue and white diodes

Osram Golden Dragon
The Golden Dragon is a high power LED available as both warm white with a color temperature of 3500 Kelvin and a cold white with a color temperature of 5700 Kelvin. It has a high luminous efficiency with 76lm/W and is supplied with a heat sink and can therefore manage the radiated heat well (Osram Opto Semiconductors, 2014).

12V LED strip
The strip is manufactured by the company Sloan and consist of 60 single LED:s arranged in a row. The strip has a length of one meter but can be cut every five centimeters without affecting the ability to emit light. It is driven by a voltage of 12 Volts with makes it possible to connect directly to the battery in a car. The strip has a built in protective resistor of 130Ω to prevent damaging the LED:s.

6.2 Current amplifier

Since the Arduino boards put out a maximum current of 80mA and the power LED:s require 350mA the current had to be amplified. This was done by using NPN Darlington transistors. A solution of this kind also enables the use of PWM, which is necessary to be able to dim LED:s. A resistor of 1kΩ was connected to the base to protect the Arduino's digital pins from the high current. The emitter was connected to ground and the collector via another protective resistor to an LED (resistor not shown in the figure). A current amplifier of this kind was used in all solutions involving an Arduino board to control power LED:s.

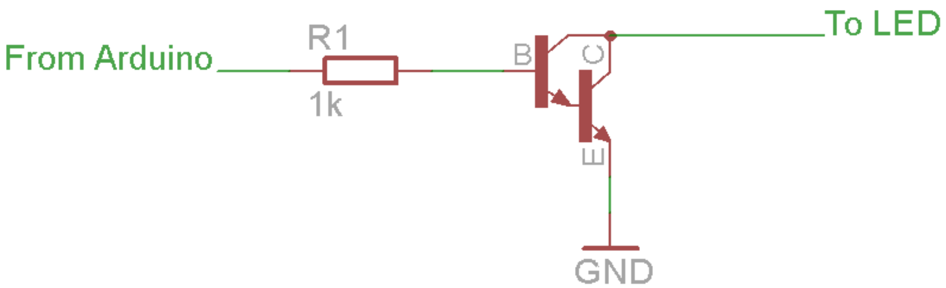

Fig 6.5. Current amplifier schematics

6.3 Construction

The following chapter describes the construction phase more thoroughly.

6.3.1 Glowing iron mark

The iron mark was manufactured in a luminescent plastic that charge light from UV-radiation at daytime, and emit the light at night. A template in silicon was made from the original detail and a new mark was molded in plastic with added luminescent pigment (see chapter 2.2.4). The chosen pigment had an aqua blue color and made out approximately ten percent of the total substance.

6.3.2 Red Welcoming Carpet

The red welcoming carpet was constructed in a way not involving any software, instead being all mechanical. This was done to further broaden the knowledge of the different possible ways to build a system.

Hardware

Two red colored power LED:s project the light carpet on the ground. The LED:s were mounted on an rig operated by an electrical engine. The engine used was originally positioned in the car's side mirrors, making them automatically fold in as the car is locked. Switches were used to determine when the carpet had reached its end positions and when to turn on and off the lights.

Assembly

The system is controlled with a three-state switch. With the switch in one position the engine turns one way and in the other position the 12V and ground poles change making the engine turns the other way. The pole switching was accomplished with two electromagnetic relays (for further description see chapter 6.4). The system was mounted under the car and two reflectors were attached to the LED:s to make the light projected on the ground more concentrated. The system was driven directly by the car's 12V battery.

Before deciding the final way to build the light carpet several different light sources and their placings were tested and evaluated.

Fig 6.6. Testing different lighting alternatives during the construction of the Red Welcoming Carpet

6.3.3 Side Signature

The side signature was realized by mixing luminescent pigment (see chapter 2.2.4) into clear varnish and spraying the specific detail of the doors in several layers. The doors were first masked with a thin tape to get clean sharp edges of the glowing clear varnish.

Fig 6.7. Striping up the Side Signature before doing the paintwork

6.3.4 Glowing Volvo Letters

The standard Volvo letters on the trunk lid were removed and a blasted plastic were glued to the back side of each letter. Holes were drilled in the lid making room for ten cold white Osram LED:s connected in a series, two for each letter. The blasted plastic behind each letters helped spreading the light over the whole surface making the text glow out from the sides.

Another possible solution to the light sources used to highlight the Volvo text was to mould new letters adding luminescent pigment in the plastic. This would go in line with the Volvo iron mark front (see chapter 6.1) and contribute to lesser energy consumption in the car since no electrically generated light source would be used.

6.3.5 Campfire Centre Stack

The new center stack was manufactured in a sandwich construction consisting of Styrofoam covered in glass fiber to make the construction better withstand pressure. The optical fiber fabric found when visiting the Stockholm Furniture Fair (see chapter 3.2.3) was used to cover the center stack and five light sources were attached to the optical fibers' ends. The fabric was created by Malin Bobeck, from the high school of textiles in Borås, Sweden. At the front of the construction there is a polycarbonate glass with dummy buttons and the Strix logotype in relief. In the back of the center stack the optical fibers from the fabric run down towards the floor and create a foot lighting for the back seat.

To make the center stack truly feel like a campfire the light sources in the ends of the optical fibers were programmed to pulse in a pleasant way changing color as well.

Hardware

For the decided solution ten PWM outputs were needed, which in turn led to using the Arduino Mega, see chapter 6.1.2. The lights sources used were the RGBW star power LED:s, see chapter 6.1.5.

Assembly

Each of the five RGBW LED:s consist of four integrated colored diodes of which the red, green and white were used. The LED:s were arranged and connected in pairs. See figure.

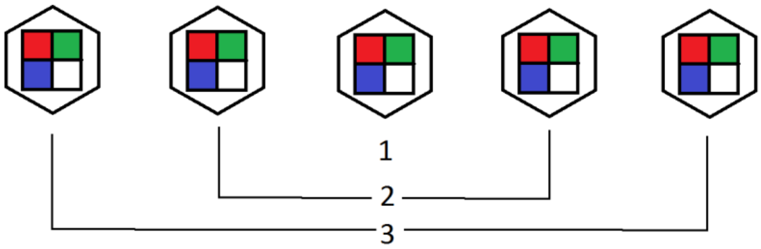

Fig 6.8. The LED:s arranged in pairs

The transistors in the schematic (see Appendix 3) are Darlington transistors and are used to amplify the current (see chapter 6.2). The 1kΩ resistors are used to protect the Arduino pins from the high current.

As seen in the schematics nine PWM outputs were needed for the Campfire Center Stack, however the tenth was used in the Volvo badge steering wheel (see chapter 6.3.7)

To protect the LED:s 33 Ω resistors were used. This was decided taking Ohm's law into consideration where the resistance is determined in regard to the current and the voltage. A current of 350mA and a voltage of 12 Volts led to the following calculation:

$R = U / I \longrightarrow R = 12 / 0{,}35 \longrightarrow R = 34{,}3\ \Omega$

It was however discovered that one resistor alone became too hot. A solution with two 33Ω parallel resistors connected in a series with two more 33Ω resistors were therefore used instead. This solution led to the same total amount of resistance but reduced the produced heat.

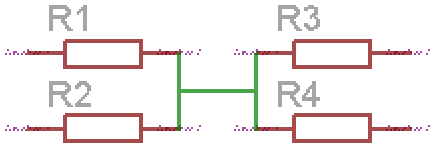

Fig 6.9. Parallel resistors connected in a series

Software

The light sources were programmed in their pairs and made to pulse asynchronous and change color from a warm orange to a colder white. By combining the red and the green diode an orange color was accomplished. For program code, see Appendix 4.

6.3.6 Spacious Inner Door

To be able to make the new inner door truly spacious the mechanism for the electrically operated window and the loudspeaker were removed. A new panel was manufactured in plastic covered in a brown synthetic foil. The arched surface was covered in a warm orange fabric with rough structure.

Hardware

To make the storage compartment in the door light up when an object is detected an ultrasonic distance sensor was used (see chapter 6.1.3) to determine when a 12 volts LED strip would dim up. A capacitive touch sensor was used to turn a power LED on, serving as a reading light. All components were connected to an Arduino Uno.

The capacitive sensor

To be able to control the reading light with a sleek, non-mechanical switch a capacitive sensor was developed. The sensor follows the same principle of a basic resistor-capacitor circuit (booksofscience, 2012), with a high value resistor and a piece of metal, in this case copper, as a capacitor when touched by anything conductive.

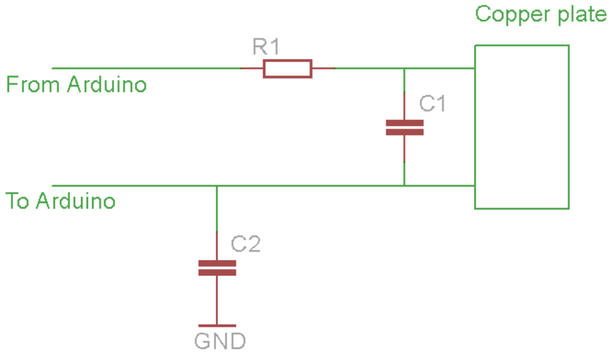

Fig 6.10. The capacitive sensor schematics

The resistor R1 in the schematics (see fig 6.10) had a high resistance of 4.3MΩ. The high resistance causes a slow drain time and makes the sensor more sensitive. With a 4.3MΩ value the sensor reacted to objects even one centimeter away. A 200pF capacitor (C1) and a 100pF capacitor to ground (C2) improved the stability of the sensor readings. The values of the resistor and capacitors were tested and found suitable for the purpose.

The sensor works by changing the send pin to a high state and waiting for the receive pin to change to a high state as well. The time for this is measured and it is possible to determine if someone has touched the sensor by looking if the send-receive time is longer than normal.

When developing the sensor it was found very important with separate groundings for the sensor and the power supply for the reading lamp. This was accomplished by splitting the ground cable from the car's battery to the Arduino into two.

The software for the sensor was created with parts from a pre-built Arduino library called CapSense (Badger, 2012).

Assembly
The ultrasonic ping sensor was placed in the bottom of the storage compartment, not visible for passengers in the back seat and connected to the Arduino for 5 Volts supply, ground and sensor reading. The LED strip was attached on the backside of the armrest in the door and connected directly to the car's battery and via a transistor to the Arduino.

The capacitive sensor consisted of a copper plate covered in a 2 mm plastic and was connected to one send and one receive pin. To reduce the voltage and thereby the heat radiated from the protective resistor to the power LED the voltage was converted from 12 Volts to 5 Volts with the voltage regulator L78SO5CV (see chapter 6.1.4).

Calculating the desired resistance to the power LED using Ohm's law resulted in a resistance of approximately 14Ω. To further reduce the heat radiated from the resistor, two parallel 33Ω resistors were used instead. This resulted in a total resistance of 16,5Ω and a pleasant light intensity from the LED. For schematics, see Appendix 3.

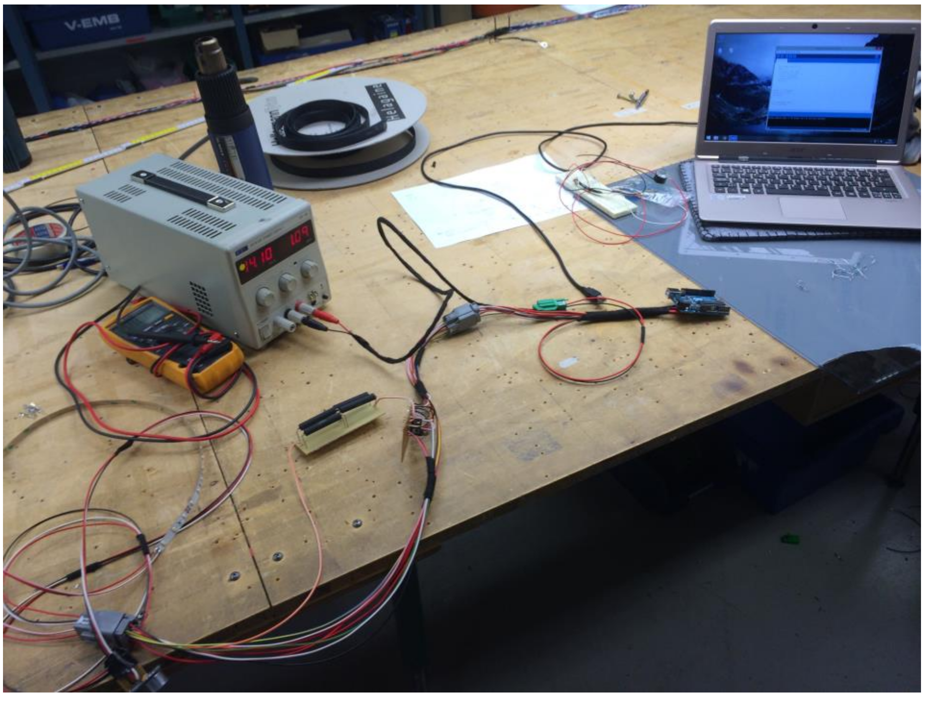

Fig 6.11. Testing the system of light sources and sensors before mounting into the Spacious Inner Door.

Software
By constantly checking the ultrasonic sensor for motion detection and the capacitive sensor for touch it was possible to know when to turn the different light sources on. The sensor was calibrated to only detect absolute touch of the plastic covering the sensor's copper plate, and the intensity of the LED strip was as well tested in the car to achieve the best result. For program code, see Appendix 4.

6.3.7 Illuminated Volvo Badge

The Volvo badge steering wheel is controlled by the same Arduino Mega used in the Campfire Center stack. The Arduino controls one cold white Osram LED mounted behind the badge in the steering wheel. The badge itself it made using the same technique as in Volvo letters back (see chapter 6.3.4) with added transparent blasted plastic on the backside. The light is made to pulse in the same pace as the center stack.

6.3.8 Light Corridor Roof

The standard handles in the inner roof were removed and replaced with a long plastic tube with two warm white Osram LED:s connected in a series in both ends of the tube. The plastic tube was covered in an orange fabric making the emitted light more pleasant and communicating a warm car.

6.3.9 Flying Carpets

Two light transporting tubes were attached around each floor mat and warm power LED:s were connected to the tubes' ends to make the light emit all around the carpet. To better reflect the light a walnut veneer was placed under the carpets.

6.3.10 Buckle Finder

The backseat was dissembled and small holes were made with a sewing machine in the leather covering the backseat. Luminescent thread was then sewed by hand into the leather in a pattern developed to guide the user to the belt buckle. This solution required no external light sources and no wires were drawn.

6.3.11 Clean Air Indicator

The original air vent was removed and a new air vent was manufactured in a tinted black semi-transparent plastic. A text "Clean Air" was left transparent and a cold white LED was placed behind the text. The cold white light gives a feeling of freshness and clean air. To actually look like a real air vent tracks were milled through the plastic.

Fig 6.12. Milling tracks through the plastic of the Clean Air Indicator

6.3.12 Luggage Compartment Lighting

To either complement or replace the two standard LED:s found in the luggage compartment two light transporting tubes were attached along the sides. Power LED:s were connected to the tubes' ends making the whole tubes light up and communicate the space and depth of the compartment. The ends of the tubes serve as light sources and direct light at objects stored in the boot.

6.3.13 Extra - dim light with hand movement

This concept was built as a stand-alone feature since the effect was better shown when not put inside a car. It was left to the observer to imagine the various fields of application.

Hardware
An Arduino Uno, an ultrasonic ping sensor and a white power LED was mounted inside a plastic box. The Arduino was programmed and then simply driven by the voltage from a computer's USB port.

Software
The ping sensor returns the time it takes from sending the ultrasonic sound to the response. This time was converted to a distance and used to determine when to turn on the light. To achieve the dimming of the light a directly translated scale was developed. The current distance to an object was multiplied with a factor and used directly as a PWM signal to the LED. This made the light intensity increase as an object moved closed to the sensor and decrease when the object moved away. For program code, see Appendix 4.

6.4 Controlling the light

To easily be able to control the different light concepts individually and in combined sequences a control system was built.

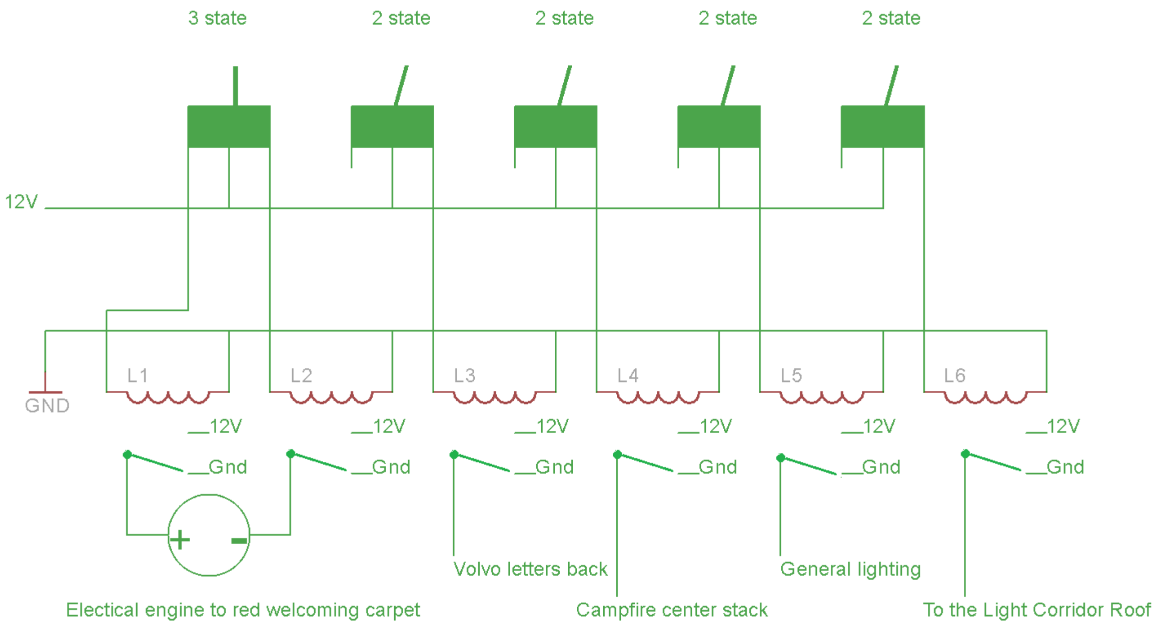

Fig 6.13. Control system schematics

The control system involved four 2-state switches and one 3-state switch. The switches controlled relays that in turn turned on or off the various light functions in the car. The relays were used to enable bigger currents, which the switches alone would not have managed.

When a 2-state switch is flipped a voltage is directed to the inductor in a relay. This causes an electromagnetic field which in turn pulls another switch from ground to 12 volts and on to the desired light source, se figure.

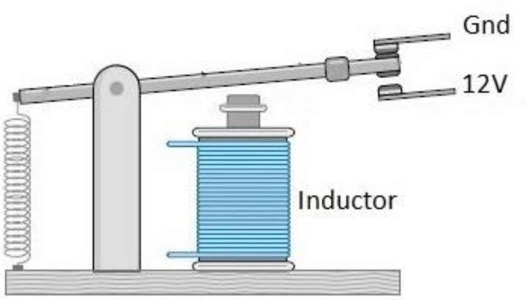

Fig 6.14. An electromagnetic relay

A 3-state switch was used to control the Red Welcoming Carpet (see chapter 6.3.2). The switch works in the same way as a 2-state switch but is connected to two relays instead of one. One relay makes the electrical engine go one way, and one makes it go the other.

7. ENERGY EFFICIENCY

The energy consumption of the lighting was taken into consideration in several aspects. Using the photo luminescent pigment compared to an electrical driven light source eliminated all electrical energy consumption, and also made drawing cables, constructing circuits etc. obsolete. The downside were that this light source were not as easy to control as ordinary light sources, and therefore could not be used in more critical applications such as warning lights. In this project however, this “unpredictable” side of pigment added to the desired temper of the car.

Other examples of energy efficient light technologies used were the power LED:s, light transporters and motion sensors. A power LED produces more lumen per watt than a regular LED. In combination with a light transporter it distributes the light over a large volume and makes it even more effective. In the case with the Flying carpets, two light sources produced the light of two to three LED strips containing multiple diodes, and spread the light more smoothly over the lit up surface. In the case with the Camp Fire Centre Stack, five power LEDs gave light to the whole fabric, resulting in an effect that would have taken hundreds of small LEDs to accomplish otherwise. The pulsing in the centre stack also saved energy compared to if the light would have been constantly on full effect.

Another example of how energy efficiency could be used was found in the Spacious inner door (see chapter 5.6). Here, the responding character of the light leaves the light on low effect when it is not needed, adding to the general lighting in the car. Compared to having it lit up all the time, this saves a lot of energy. The idea of having lights switched off or turned down when not being used could easily be translated to other functions in the car.

8. DISCUSSION

The Strix project had few existing guidelines from start. These can basically be summarised as “exploring how lighting in a car can create customer value”. It might sound odd that a couple of students get so much resources coupled with so few injunctions, but from Volvo’s perspective this is a way to get new, “fresh” input without steering the outcome in a certain direction. The aftermath of the project is much larger than just a car with a number of concepts built in if considering the objectives of the project, i.e creating new ideas for either direct implementation, further development, or creating discussions. These objectives are also important to remember when assessing each concept. Focus for the work has not been to create models with perfect finish or production adapted design, but rather point out possibilities with different functions, technologies and effects, raising interest and discussion. Therefore there are a wide spread among the final concepts in terms of how “conceptual” they are. Some ideas, such as the “Side signature”, are basically ready for production, while others such as the “Campfire Centre Stack” is more conceptual ideas of how future car riding could be experienced. Opinions about the concepts were basically only gathered from workers at Volvo, meaning that how the concepts are perceived in other countries and cultures remains uncertain.

Looking at the structure of the work, a few things are worth mentioning. Since the initial instructions were so few it was natural to start the project with a phase that defined what the work should be about. The scope states that the car should have a temper, a word often associated with anger. In this context however, the word means a car that replies immediately, changes mood from calm to alert quickly and changes behaviour depending on the user. To actually define how this should be represented in lighting and implement these qualities into the car proved to be very hard. Therefore, some of the functions are only presented in text or described to the viewer, not actually implemented in the physical concept. One example of this is the connection between velocity of the car and the speed of the pulsing light in the centre stack. However, this is possible to achieve if developing the concept further.

Another thing worth mentioning with the work is how the interdisciplinary affected the workflow. Usually the design phase in a project runs far ahead of the construction phase. In this computer- design interdisciplinary project, the two workflows went much closer, almost parallel. For instance, two days after the idea of the spacious door with lights that responded to movement was born a prototype was built. The prototype confirmed the hope that controlling the light with a motion sensor worked, meaning the design process could continue reassured and enriched of this knowledge. The downside of this way of working is that it is more dependent on the workshop personnel to take initiatives since all specific details in the design are not fully specified as they start their work. Sometimes this leads to unexpected misunderstandings, however, all in all this proved to be an efficient way of working for this specific project.

Looking at the original technical aims of the project, some of them proved to be too comprehensive to fit in. Ways to reducing weight and the mount of cables were investigated briefly, but when developing the concepts these objectives were subordinated the bigger aims of displaying new ideas, creating discussion etc. Perhaps one can say they were a bit forgotten, since the other aspects stole so much attention. This focus led to not fully optimised electrical construction with many cables and relatively large components. However, if the concepts would proceed to production, the size, weight and number of the electrical components and circuit boards can be reduced substantially. This due to the possibility to order resistors, transistors, circuits etc. from external providers that exactly matches the desired properties.

8.1 Conclusion

The area of illumination has a long way to before its fully taken advantage of in the automotive industry, but at Volvo they have started paying attention to the potential of light. As this project shows, this puts Volvo in a rather unique position within the automotive industry, and gives them a card up the sleeve when competing with other premium car brands in the future.

Looking at the Strix project, the main purpose was to generate innovative illumination concepts that could be used as a source of inspiration and discussion for personnel at Volvo. The twelve concepts implemented in the Strix are in many ways unconventional, innovative and mix small details with large visions. The mix of function, design and technique creates impressions for a wide spread of different professions looking at the car. While not all objectives defined along the way could be fulfilled, the general impression based on the feedback amongst personnel at Volvo, is that the project succeeded in the stated main purpose. The results of this project might very well develop into something that is implemented in future production cars.

8.2 Future work, further development

Looking at the future of the automobile industry, a big and upcoming trend is the autonomous drive. This trend was deliberately left out of the project since it was thought to influence every aspect of the illumination strategy, and thereby would be more suitable as a project of its own. If one would investigate this trend deeper, the next level would be to analyse the whole car from the point where reflections in windows and outside view is not a problem. With self-driving cars the inside of a car will likely transform to a “living room” - a place to socialize with friends and family. This will likely move the focus of illumination towards how people see each other inside the car, rather than how the driver see the outside of the car. Even though this were not a topic of the current project, traces of this idea is found in the Campfire Centre Stack that were developed with the idea of making the car more of a social gather point in mind.

Another thing that was briefly looked into was the physical and emotional effects of blue light. It was found that blue light at a wavelength of about 470 nm had an extra strong effect on people’s alertness. This effect occurred when light hit the eye with about 20 lux for at least an hour, which then resulted in a reduction of the sleeping hormone melatonin (The Lighting Research Center, 2010). The use of blue light during night driving could reduce the risk of falling asleep, and thereby improve safety. This area was, as earlier mentioned, already explored at Volvo so future work should sync with that project.
New light sources could also be an interesting future work. The possibilities with the thin and flexible OLED technology seem endless once the price has come down. Audi has made a small demonstration with very dynamic light at the rear, scratching the surface of the possibilities with this new technology.

An area that possibly could reduce the energy consumption is to investigate if the start-up energy peaks in the car could be lowered. As a car starts up all lights turn on at the same time together with the ignition, causing large sudden energy peaks. This means that the electrical components need to be dimensioned after these peaks. A dynamic start-up lighting sequence that turns on the lights in a certain order would lower energy peaks and thereby enable smaller and lighter components. This combined with thoroughly investigating the entire electrical system of a car could likely minimize weight.

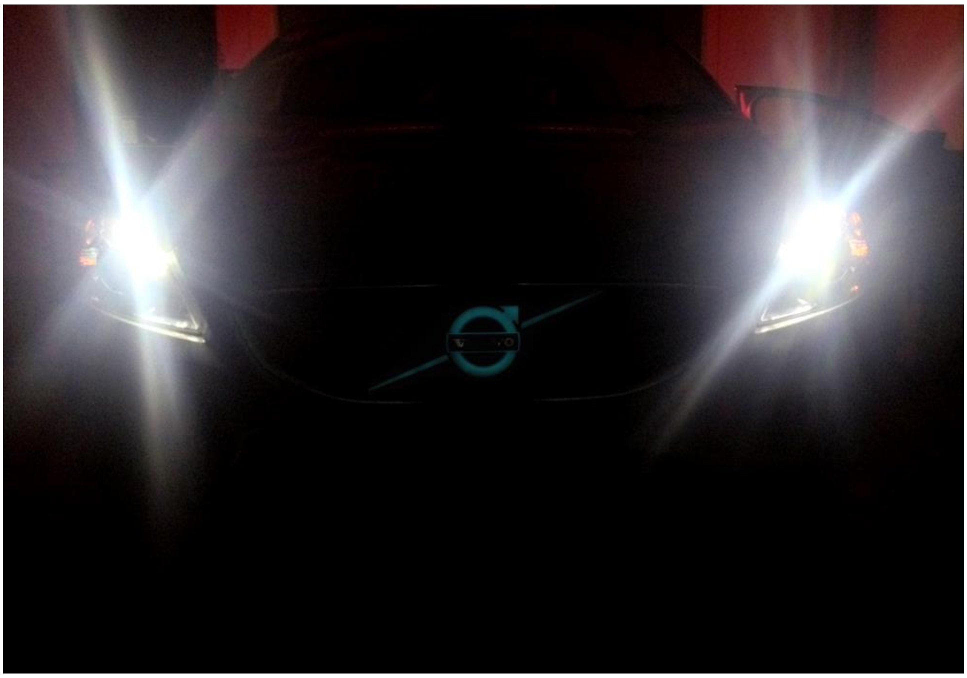

Fig 8.1. The Strix looking forward

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APPENDIX

Appendix 1: Current Situation Analysis

Functions for current lights (marked in green)				
Desired additional functions (marked in blue)				
NR	Function		Type	Remarks
	Verb	*Substantive*	HF= Head Function N= Necessary D= Desirable U= Unnecessary	
1.0	*Overall head functions*			
	Create	Visibility	HF	
	Create	Life	HF	*We want to make the car feel alive*
	Express	Harmony	N	*All lights should create a harmonized impression*
2.0	*Luggagestore lights*			
	Describe	Space	N	*Improvable, easy to block the lamp*
	Communicate	Interior	N	*Improvable*
	Not	Blind	D	
	Warn	mud	D	*Warning for mud outside the car*
	Communicate	Luxury	U	
	Allow	customizing	D	
3.0	*Interior mood lights while parked*			
	Welcome	Users	D	
	Communicate	Space	N	
	Not	Blind	D	
	Allow	Customizing	N	*Only functional customizing*
	Create	Insight	N	*When approaching the car, safety matter*
	Maintain	Integrity	D	*No "glass cage" when standing still*
	Ease	Communication	D	*So passengers can talk and look at each other*
	Create	Harmony	N	*Holistic view*
	Create	Well being	D	
	Create	Volume	D	*Increase perceived space*
4.0	*Interior mood Lights while driving*			

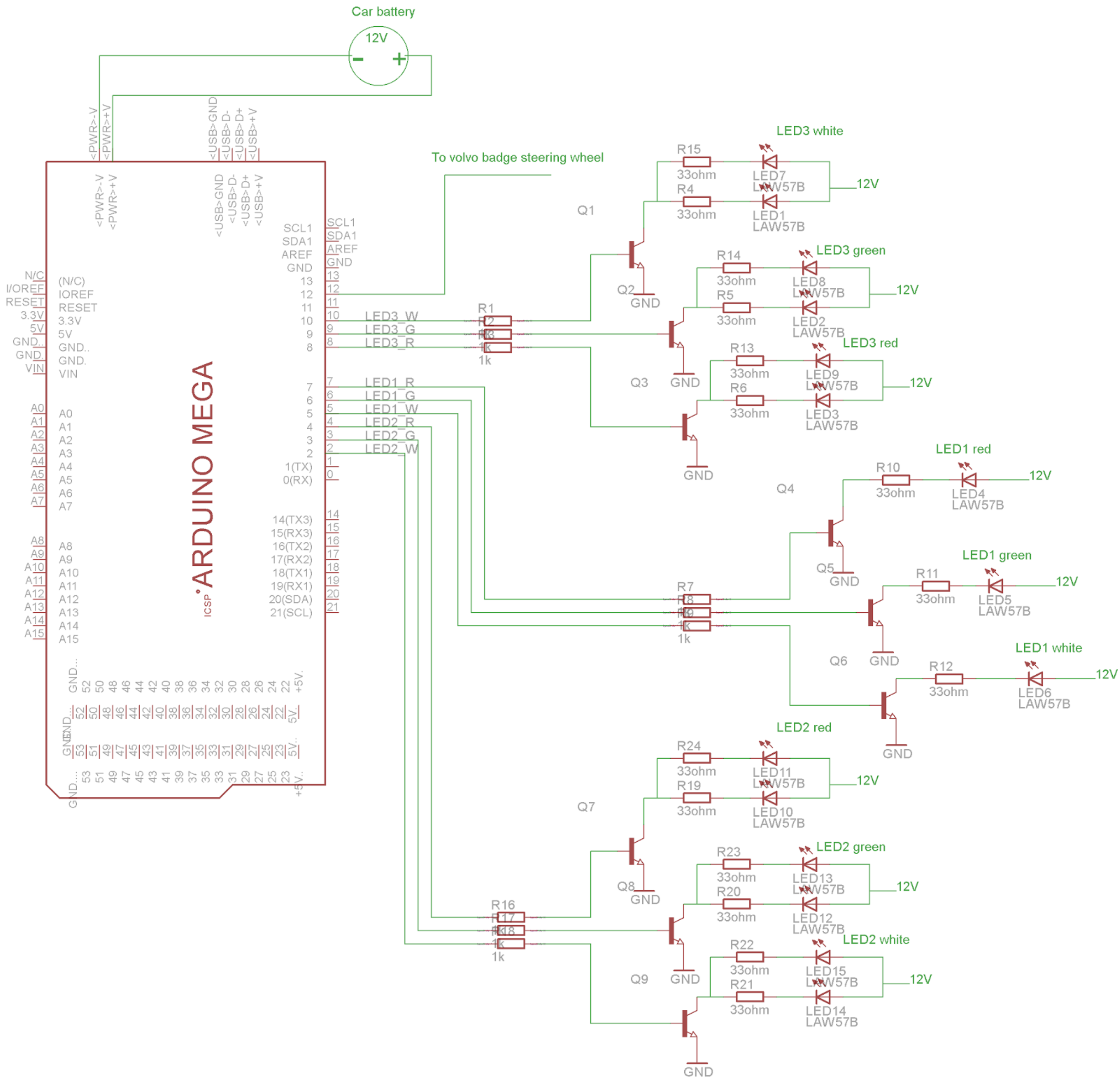
	Allow	Customizing	D	
	Not	Blind	D	*Including people on the outside*
	Not	Reflect	D	*In an unpleasant way*
	Decrease	Loneliness	D	*While driving alone*
	Maintain	Reality	D	*Maintain the drivers focus on reality and surroundings while driving*
	Decrease	Sleepiness	D	
	Decrease	Loneliness	D	*While driving alone*
	Communicate	Car	D	*What is happening with the car, engine etc. Not in regard of emergency*
	Communicate	Outside	D	*Either enhance, or lower what happens outside, depending on the situation*
	Create	Well being	D	
5.0	*Interior Functional Lights (dashboard etc)*			
	Help	User	HF	*Can be expanded to more functions*
	Communicate	Functions	N	*Can be expanded to more functions*
	Not	Disturb	D	
	Interact	User	D	
	Guide	User	U	*Predict users next move*
6.0	*Interior Spot Lights*			
	Focus	Light	HF	
	Not	Blind	N	*Goes for both passenger and driver*
	Utilize	Details	N	*The light needs to be strong enough to read in*
	Allow	Pointing	D	*Pointing the light in different angles*
	Allow	Customize	N	*Dim up and down f.i*
7.0	*Exterior Welcoming Lights*			
	Create	Welcoming	D	*Improvable*
	Prevent	Accidents	D	*Help user discover mud, holes in the ground, objects under the car etc.*
	Create	Insight	N	*Lit up the car, safety matter*
	Communicate	Position	D	*Show where the car is*
	Express	Eagerness	D	*The car (especially a R-design) should express that it is ready to go*

Appendix 2: Components

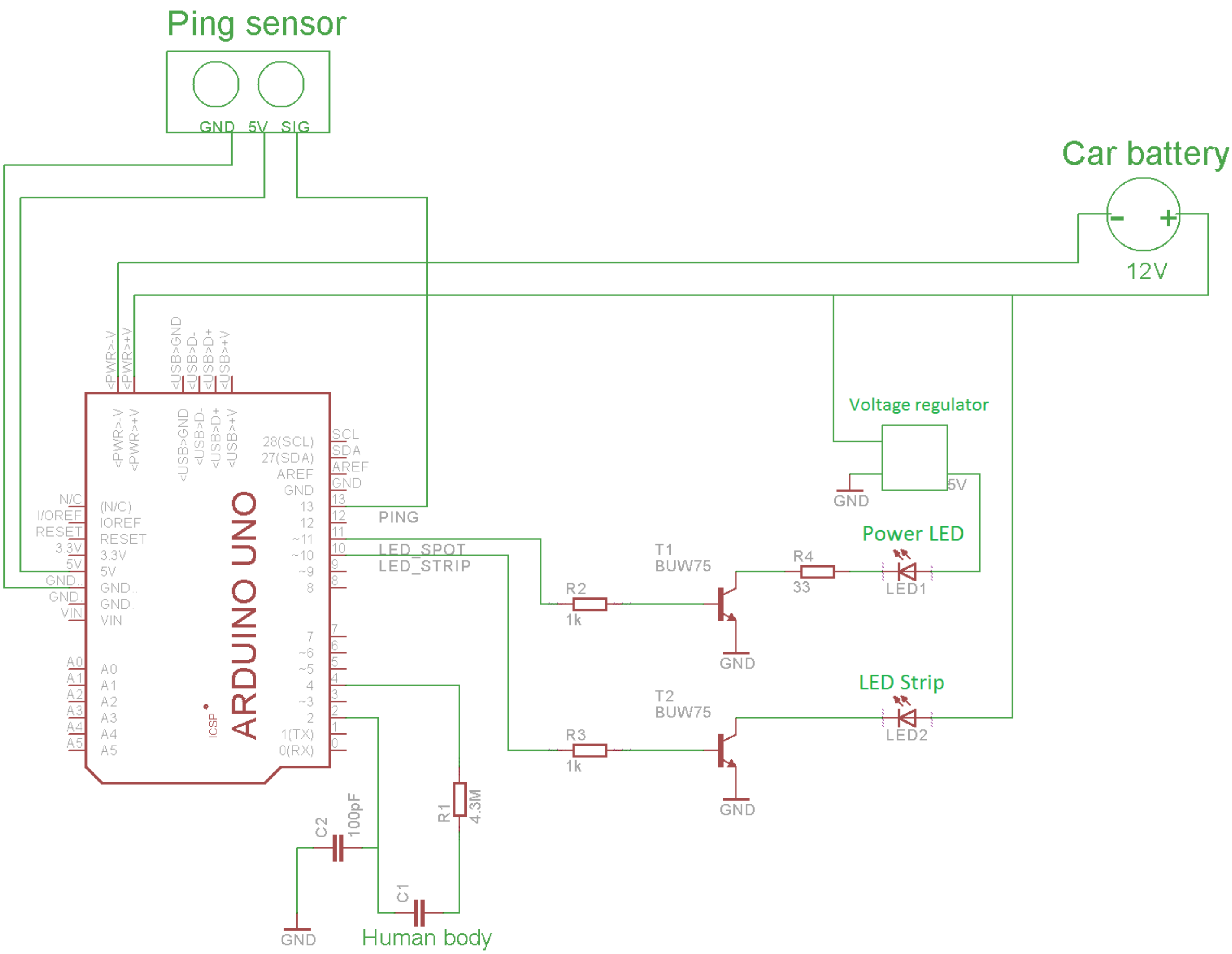
Arduino Uno	x 2
Arduino Mega 2560	x 1
Ultrasonic ping sensor	x 2
Voltage regulator, L78SO5CV	x 1
Power LED RGBW	x 5
Osram Golden Dragon LED	x 21
12V LED strip	x 1
NPN Darlington transistor	x 11
Electrical engine	x 1
1kΩ resistor	x 11
33Ω resistor	x 17
4,3MΩ resistor	x 1
100pF capacitor	x 1
200pF capacitor	x 1
Electromagnetic relay	x 5
2-state switch	x 4
3-state switch	x 1

Appendix 3: Schematics

Campfire centre stack



Spacious inner door



Appendix 4: Program code

Campfire centre stack

```
int LED1_G = 6;
int LED1_R = 7;
int LED1_W = 5;
int LED2_G = 3;
int LED2_R = 4;
int LED2_W = 2;
int LED3_G = 9;
int LED3_R = 8;
int LED3_W = 10;
int LED_steering_wheel = 12;

int counter = 0;
int i, j, k;
boolean color;

void setup(){
 Serial.begin(9600);
 pinMode(LED1_G, OUTPUT);
 pinMode(LED1_R, OUTPUT);
 pinMode(LED1_W, OUTPUT);
 pinMode(LED2_G, OUTPUT);
 pinMode(LED2_R, OUTPUT);
 pinMode(LED2_W, OUTPUT);
 pinMode(LED3_G, OUTPUT);
 pinMode(LED3_R, OUTPUT);
 pinMode(LED3_W, OUTPUT);
 pinMode(LED_steering_wheel, OUTPUT);

 color = true;
}

void loop(){

 //Pulse in orange 10 times
 for(j=0; j<10; j++){
   for(i=10; i<250; i++){ //Dim up

     analogWrite(LED1_G, i * 0.3); //With the green diode at 0.3 of the red diode makes a orange color
     analogWrite(LED1_R, i);
     analogWrite(LED1_W, 0);

     analogWrite(LED2_G, i * 0.3);
     analogWrite(LED2_R, i);
     analogWrite(LED2_W, 0);
```

```
    analogWrite(LED3_G, i * 0.3);
    analogWrite(LED3_R, i);
    analogWrite(LED3_W, 0);

    analogWrite(LED_steering_wheel, i);

    delay(10);
  }

  for(i=249; i>9; i--){  //Dim down
    analogWrite(LED1_G, i * 0.3);
    analogWrite(LED1_R, i);
    analogWrite(LED1_W, 0);

    analogWrite(LED2_G, i * 0.3);
    analogWrite(LED2_R, i);
    analogWrite(LED2_W, 0);

    analogWrite(LED3_G, i * 0.3);
    analogWrite(LED3_R, i);
    analogWrite(LED3_W, 0);

    analogWrite(LED_steering_wheel, i);

    delay(10);
  }
}

//Pulse in white
for(j=0; j<5; j++){
  for(i=10; i<250; i++){  //Dim up

    analogWrite(LED1_G, 0);
    analogWrite(LED1_R, 0);
    analogWrite(LED1_W, i);

    analogWrite(LED2_G, 0);
    analogWrite(LED2_R, 0);
    analogWrite(LED2_W, i);

    analogWrite(LED3_G, 0);
    analogWrite(LED3_R, 0);
    analogWrite(LED3_W, i);

    analogWrite(LED_steering_wheel, i);

    delay(10);
  }

  for(i=249; i>9; i--){  //Dim down
```

```
    analogWrite(LED1_G, 0);
    analogWrite(LED1_R, 0);
    analogWrite(LED1_W, i);

    analogWrite(LED2_G, 0);
    analogWrite(LED2_R, 0);
    analogWrite(LED2_W, i);

    analogWrite(LED3_G, 0);
    analogWrite(LED3_R, 0);
    analogWrite(LED3_W, i);

    analogWrite(LED_steering_wheel, i);

    delay(10);
   }
 }
}
```

Spacious inner door

```
#include <CapacitiveSensor.h>

int ping = 13;
int led_spot = 11;
int led_strip = 10;
int duration, range, pwm, i, count;
long value, total;
boolean active;
CapacitiveSensor   cs_4_2 = CapacitiveSensor(4,2);

void setup(){
 Serial.begin(9600);
 pinMode(led_spot, OUTPUT);
 pinMode(led_strip, OUTPUT);
 active = false;   //To indicate the led_spot is turned off
 cs_4_2.set_CS_AutocaL_Millis(0xFFFFFFFF);     // turn off auto calibration, from CapSense library
}

void loop(){
 analogWrite(led_strip, 25);  //Turns on the led_strip with low intensity
 long start = millis();  //Start counting time in milli seconds

 total = 0;
 value = 0;
 count = 0;

 while(true){  //This loop calculates the average of 5 readings to get more accurate values.
   count++;
   value =  cs_4_2.capacitiveSensor(30);
   total = total + value;
```

```
  if(count == 5){
   break;
  }
 }
 total = total / count;

 pinMode(ping, OUTPUT);
 digitalWrite(ping, LOW);  //Sets the output to Low to be sure it is low
 delayMicroseconds(2);
 digitalWrite(ping, HIGH);   //Sends a burst of ultrasound for 5 milli seconds
 delayMicroseconds(5);
 digitalWrite(ping,LOW);

 pinMode(ping, INPUT);  //Switch to input, to recieve the echo of ultrasound
 duration = pulseIn(ping, HIGH);
 range = toRange(duration);  //Convert time to range

 if(range < 12){      //If an object is detected 12 centimeters or closer -> increase intesity of light
  for(i=25; i<200; i++){
    pwm = i;
    analogWrite(led_strip, pwm);
    delay(10);
  }

  delay(2000);

  for(i=199; i>25; i--){    //After delay, decrease intesity back to normal 25
    pwm = i;
    analogWrite(led_strip, pwm);
    delay(10);
  }
 }

 if((total > 400) && (active == false)){  //If capasictive sensor readings are above 400, turn the spot light on
  analogWrite(led_spot, 250);
  active = true;
  delay(500);
 }
 else if(total > 400 && active == true){  //Turn it off
  analogWrite(led_spot, 0);
  active = false;
  delay(500);
 }
}

long toRange(int sec){     //Turns time into range in inches. Sound travels one inch in 74 micro seconds
 return sec/74/2;
}
```

Extra, dim light with hand movement

```
int ping = 8;
int led = 9;
int pwm, newPwm;
```

```
float duration, range;

void setup(){
 Serial.begin(9600);
 pinMode(led, OUTPUT);
}

void loop()
{
 // The PING is triggered by a HIGH pulse of 2 or more microseconds.
 // Give a short LOW pulse beforehand to ensure a clean HIGH pulse:
 pinMode(ping, OUTPUT);
 digitalWrite(ping, LOW);
 delayMicroseconds(2);
 digitalWrite(ping, HIGH);
 delayMicroseconds(5);
 digitalWrite(ping, LOW);

 // The same pin is used to read the signal from the PING: a HIGH
 // pulse whose duration is the time (in microseconds) from the sending
 // of the ping to the reception of its echo off of an object.
 pinMode(ping, INPUT);
 duration = pulseIn(ping, HIGH);
 range = toRange(duration);

 pwm = range * 10;  //Converts the range to be able to use as PWM signal

 if(pwm < 250){
   NewPwm = 250 - pwm;    //Invert the value
   analogWrite(led, NewPwm);
  }
  if(pwm == 250){
   analogWrite(led, 0);
  }
}

float toRange(float sec){  //Converts time to range in centimeters. Sound travels one centimeter in 29 micro seconds
 return sec/29/2;
}
```