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The flexible load carrying system - Vide

Development of a load carrying system that fits every car and allows for spontaneous use.

Bachelor thesis in Design and Product Development

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Cover: Picture illustrating the developed concept Vide in context.

PREFACE

The thesis is executed at Chalmers University of Technology as the last step of the engineering program of Design and Product development, 180 hp. It takes place in the spring of 2019 and is limited to 15 credits per person. The thesis is carried out together with Escenda Engineering AB.

We would first of all like to thank Escenda for giving us the chance to write our Bachelor Thesis at your company, and especially thanks to David Lundgren at Escenda for giving us guidance throughout the project.

We would also like to thank Pontus Wallgren, our supervisor and examiner at Chalmers, for sharing your knowledge around the subject and for helping us get forward when we did not know how to proceed.

Furthermore, a big thank you to;

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- all who participated in our focus group and survey.

Gothenburg, June 2019.

Matilda Broberg

Emma Wallin

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ABSTRACT

Today there are many different load carrying systems (LCSs) on the market, but many of them are designed for a very specific use, like transporting a kayak or bike. And even if a there is load carrying systems that can carry and transport different types of loads the attachment and length of them does not allow them to be attached to any car. Therefore, the purpose of this thesis is to identify problems and unfulfilled needs regarding today's load carrying systems and use that information to design a concept that meet these needs and solve these problems.

Initially, a research of the current marked helped with finding out what current load carrying systems there are. Alongside this, a series of user studies were executed. During the user studies the participants contributed with information that led to the identification of different problem areas. The data collected from the research and user studies was then used to compile a list of requirements.

Further, ideas were generated in several steps to create subfunctions which later were combined into concepts through a morphological matrix. These concepts were then tested with the help of prototypes and evaluated, which resulted in one concept to proceed with in the project.

Lastly this concept was developed further to optimize it so that it fulfilled the identified unmet needs, which generated the final concept that is called Vide. Vide consists of two foldable roof racks and four suction cup devices.

Keywords: load carrying system, transport solution, design process, roof rack, suction cups

NOMENCLATURE

CAD	Computer Aided Design
CATIA	Computer Aided Three-Dimensional Interactive Application
Iteration	When stages in a process are repeated
LCS	Load carrying system

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1

INTRODUCTION

This introductory chapter includes the background to the thesis work, the purpose of it, the delimitations that have been made and the objectives for the thesis. A brief description of the disposition of the report is included.

1.1 Background

Sometimes the storage ability of a car is not enough and an external LCS attached to the car's exterior must be used. Today there are a large number of external LCSs on the market that can be attached to a car's exterior to facilitate the transportation of various things and to create extra space for storage. The LCSs can be attached on either the roof, towbar or boot and are often designed for specific types of equipment such as bikes, skis, kayaks or surfboards etc. But because of this, the LCSs of today are not perceived as flexible in terms of being designed for specific loads and by not fit every car. Many LCSs are difficult to mount and demount. The mounting has to be planned ahead and often require two people. This results in that the LDS remain attached to the car even though not used. Due to these attributes, today's LCSs do not allow for spontaneous use. With this in mind, the thesis work has been formed together with Escenda Engineering AB.

1.2 Purpose

The purpose of this thesis is to investigate what LCSs that people uses today and how. By doing so, unfulfilled needs and problems regarding the LCSs can be identified. The overall purpose is to develop a concept that fulfills these needs and solves the problems, alongside encourage spontaneous use of the developed LCS.

1.3 Objectives

The objectives that the thesis will answer are the following:

- *How are things transported on the outside of the car today?*
- *What problems and unfulfilled needs regarding the transportation of objects with LCSs can be identified?*
- *How can a future LCS be designed to solve the problems and fulfil the needs?*

1.4 Delimitations

The delimitations of the thesis are described below. The thesis;

- only looks at LCSs used on cars.
- takes only Swedish laws and traffic regulations into account.
- includes no consistent economical consideration.

1.5 Disposition

The report is dispositioned chronologically, based on the order that each stage is performed. Decisions that are made will be announced when taken chronologically.

The first chapter (1) is an introduction to the project while the second chapter (2) maps the fundamental theory needed for the following chapters. Then follows a problem identification phase (3) with the goal to understand the usage of LCSs today and map conceivable problems regarding them. This results in a list of requirement that is taken into account when entering the next phase of concept development (4). Concepts are developed, evaluated and narrowed down to one winning concept. The winning concept is constructed in detail in the next phase (5) and results in modified concepts, which are evaluated against each other and the list of requirements. Based on this, the final concept can be presented in the following phase (6). The work ends with a discussion (7), conclusion and recommendations (8).

2

THEORY

This chapter presents the fundamental theory needed for the following chapters in the thesis. The theory touches areas regarding the exterior parts, load and weight of a car, along with aspects of product semiotics and semantics important when developing a product. Principles regarding sustainable development are also introduced.

2.1 Exterior of car

Presented in Figure 1.1 is a car with numbered exterior parts that are relevant to know of in this thesis, since they are commonly referred to. The parts presented are the rails, towbar and the boot of the car. Number 1 in the Figure symbolizes the rail of the car, number 2 the towbar and number 3 the boot.

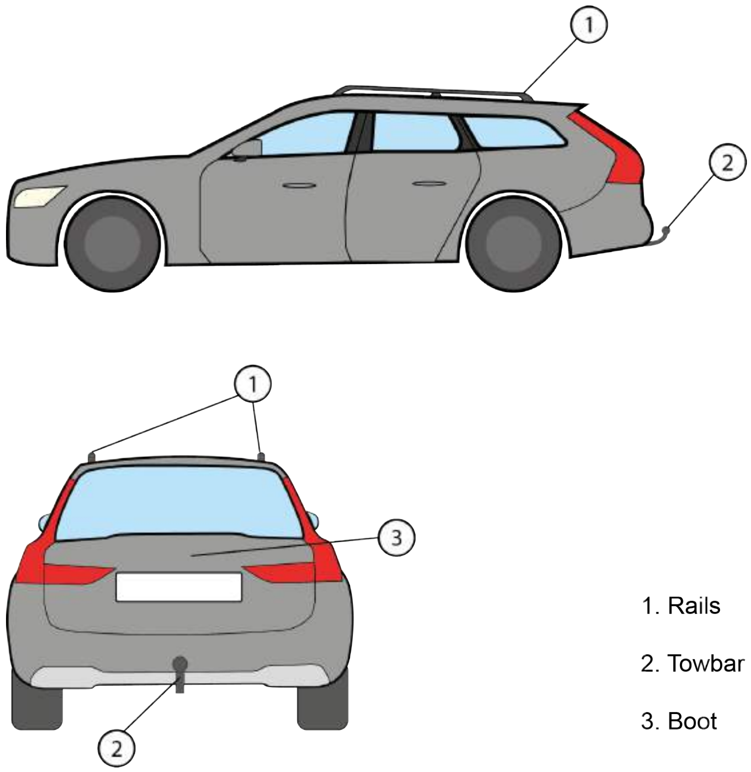


Figure 1.1. Different exterior parts of a car.

2.2 Width and length of the car with a load

According to Trafikförordningen (1998:1276), the width of a car cannot exceed 2.60 m, including the load. If loading something on the roof of the car *crosswise*, in excess of the maximum with of 2.60 m, the load cannot extend more than 0.20 m from the car and it has to be symmetrical, meaning that the load has to protrude equally on both sides. This is shown in Figure 1.2.

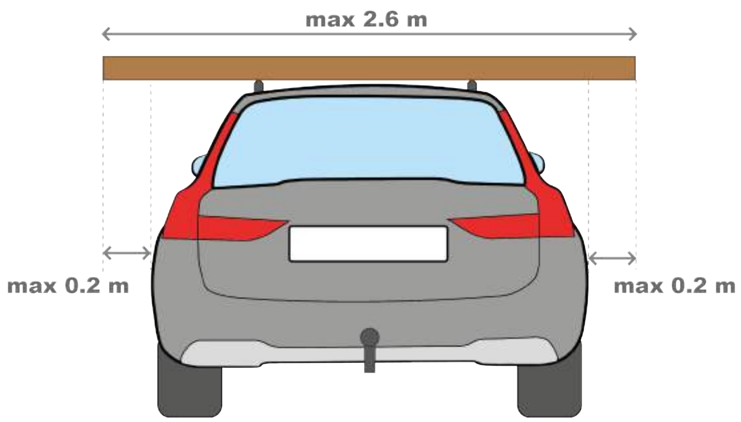


Figure 1.2. The maximum width of a car including a load.

The maximum dimensions of the car *lengthwise* are 24 m, including the load. If the load extends forward it has to be marked out, and if the load extends backwards it has to be marked out if it extends more than 1.0 m, this is pictured in Figure 1.3. If driving when it is dark outside, the load has to be marked with a white lamp and white reflectors in the front, and a red lamp and red reflectors in the back.

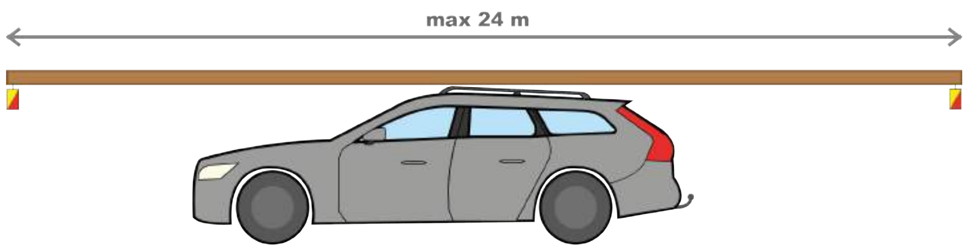


Figure 1.3. The maximum measurement of a car lengthwise including a load.

2.3 Weight terminology

According to Trafikverket (2017), the *unladen weight* indicates the unladen car with its standard setup including the driver on 75 kg. The *maximum load* states the maximum permitted load according to the car's registration certificate and therefore varies depending on the car. The *total weight* of the car indicates the maximum weight the car is constructed to handle, which is *unladen weight* + *maximum load*. *Gross weight* is the car's weight at a given time.

2.4 Correct loading

Trafikverket (2016) mentions basic rules when it comes to loading a car in the correct way. First of all, the load shall be secured with straps or something similar to prevent the load from falling off the car. Trafikverket also indicates that the greatest stress on the load and fastening happens during breaking, thus the fastening has to withstand movements in all directions.

2.5 Fuel consumption

According to Gröna Bilister (n.d.), everything that increases the air resistance or weight of the car contributes to increased fuel consumption. A rule of thumb is that every extra 100 kg increases the fuel consumption of the car by 5%. This means that all kinds of LCSs should be demounted when not used. To decrease the air resistance while using the LCSs, streamlined shapes do help.

2.6 Product semantics

According to Österlin (2016), *semantics* is the science behind the message and meaning of products. The producer of a product should ensure the semantic message of the product and in an honest and straightforward way:

- Describe the purpose of the product.
- Express the abilities of the product.
- Encourage correct use and handling of the product.
- Identify the origin of the product.

Österlin (2019) mentions that a product communicates with the user through its shape, finish, look, and sounds. E.g. a product with a wider bottom than the top, expresses stability and a ribbed finish on a cork expresses a good grip. To help communicate the semantic message, colours, icons and symbols can advantageously be used. For example, according to Color Wheel Pro (n.d.), red is a colour that draws a lot of attention and can imply warning or danger. While green, on the other hand, is a positive colour that symbolises stability and safety. According to Chheda (2017) symbols are not intuitive and we have to learn to associate them with the object that they are assigned to. Icons, on the other hand, are a direct graphical impersonation of the object that they are portraying.

2.7 Perception

Perception is about how humans see and experience their surroundings. *Perception* depends largely on the context and every individual person constructs their own *perception*. How individuals see the world differs and everyone has their own mental model (Österlin, 2016).

2.8 Sustainable Development

The definition of sustainable is *"*development that meets the needs of the present, without compromising the ability of future generations to meet their own needs". This definition was set by the United Nations in the Brundtland report, also known as our common future (UN, 1987).

According to Stena Recycling (n.d), 80% of a products' environmental impact is determined as early as in the design phase. Meaning that designers and product developers have a great responsibility. There are many different methods and principles of sustainable development, the ones that are most important for this project are described below.

2.8.1 Design for sustainable behaviour

Design for sustainable behaviour is a design process that is user-centred that enables the user to reduce the resource consumption that can be avoided. This is done by supporting the development of products, systems and services which makes this possible (Lidman & Renström, 2011).

2.8.2 Design for recycling

According to Taina Flink (n.d.) Design for recycling is a design principle that encourages product developers to design products that:

- Promotes reusing and sharing
- Enables re-manufacturing
- Promotes reparation and updating
- Enables recycling

3

PROBLEM IDENTIFICATION

The goal and purpose with this chapter is to map what types of LCSs that are used today and what problems that the users might experience when using these LCSs. Therefore, the result of the problem identification shall answer to the objectives:

How are things transported on the outside of the car today?
What problems and unfulfilled needs regarding the transportation of objects with LCSs can be identified?

3.1 Method and implementation

The methods used in this phase are presented below and the implementation of each method is described further. The purpose and goal of each method are also stated.

3.1.1 Benchmarking

Benchmarking is a type of study where the current market is analysed after products similar to yours, to get inspiration and to find out what needs that are already fulfilled. A simple way to express what benchmarking is, is "to compare" (Metodbanken, 2018).

The reason for doing a benchmarking study was to find out what products that are on the market today. The goal was to get inspiration and compare the price, quality, material etc. of current products.
It began by looking at current manufacturers. After the biggest and most interesting manufacturers were identified their product range was looked through, to list and categorize the products. Further, all of the different LCSs that the members of the project had investigated were put into main categories depending on where on the car the LCS was mounted.

3.1.2 Customer survey

A survey is a question-based method where one via a written or digital questionnaire collects information from respondents. A survey is advantageous to quickly and easily maintain quantitative data and can be designed with open and or closed questions. Closed questions mean that there are fixed options to answer the question and open questions mean that the respondent can freely answer the question. A mixture of open and closed question is preferable.
(Karlsson, 2007).

The project group compiled a survey to collect data about what people usually transport on the outside of the car and what type of LCSs that are used. Opinions regarding the experience when using the LCSs were also collected through the survey. The survey was distributed digitally and the number of respondents to the survey were 58 persons between the ages of 21 and 68, with different occupations.

The survey contained nine questions. The questions were both open and closed ones. Four questions were closed questions where there were fixed options to answer the questions. An example of a closed question in the questionnaire: "*If you/your family is/are transporting things with the help of a car, what things do you usually transport?*", where there were twelve options to choose from. Eleven of these were fixed and expressed through mediating pictures. The twelfth option was an open one, where the respondents were given the opportunity to write their own answer. Several options could be selected. Five out of the nine questions of the questionnaire were open questions where the respondent could answer freely. An example of an open question: "*How do you experience using these LCS and why?*"

3.1.3 Interview

Interviews are part of the question-based methods and are a technique to collect information about how customers and users feel and think about a product. An interview means that a number of questions are asked orally to an interviewee where the answers are registered. In connection with product development interviews are a good way to generate problem understanding and requirements (Karlsson, 2007).

To increase the project group's understanding of LCSs and to retrieve information about what users look for when buying these, the project group did an interview with an employee named Olof at Mekonomen Backaplan in Gothenburg. The interview was unstructured, which means that the interview was more of a discussion around the subject.

The project group was the interviewers and asked the questions. Probing was used to help the interviewers reach deeper within the subject by asking supplementary questions. The result assumed a qualitative form. The interview was recorded, in order to make it possible to go back and listen to important emerged information. The questions and the transcription can be found in Appendix 1.

A selection of questions for Olof:

> *"What kind of LCS do you sell the most?"*
> "*Can you use any LCS for several things?"*
> *"Do you experience that customers are missing some particular function to a LCS?"*

3.1.4 Observations

An observation is used to study the behaviour and handling of products. This helps to clarify how the products are used along with possible problems during the operation (Karlsson, 2007).

There are different levels of structure but also various sorts of observations. An observation can be constructed, semi-constructed or natural. A constructed observation means that the user situation has been arranged while a natural observation is made in a real user situation. Hence, a semi-constructed observation means that the user situation has been arranged while the usage occurs naturally. Further, an observation can be open or hidden, which means that the user is aware or unaware of the observation. If an observation is direct it means that it is happening in front of the observer's eyes and if the observer participates himself it is known as a participant observation. The different levels of structure and sorts, means that data collected via observations can be both qualitative and quantitative (Karlsson, 2007).

An observation was made at Mekonomen Backaplan alongside the interview with Olof. It is beneficial to combine observations with i.e. interviews where complementary questions can be asked to get a more comprehensive and true picture (Karlsson, 2007). The observation was semi-constructed, open and direct and generated qualitative data in terms of how products are used.

Three direct, natural and hidden observations were executed in February at parking lots at IKEA, Bauhaus and Ica Maxi in Gothenburg. The purpose was to register quantitative data in terms of how many cars that have LCSs mounted to the car, what types and what objects that are transported by the LCS. The observation did not include vans and trailers.

3.1.5 Focus group

A focus group interview is a question-based method which results in qualitative data (Karlsson, 2007). The 27th of February the project group did a focus group interview at Escenda's office. This was made to capture perceptions, requirements and attitudes towards the subject. Five participants with different backgrounds and interests, whereof two men and three women between the ages of 23 - 57 were invited. The participants were chosen based on their different characteristics and that they could contribute with different opinions and knowledge to the focus group. See table 3.1 for more information about the participants.

Table 3.1. *The table over the participants of the focus group and their characteristics.*

Participant	Gender	Information about participants
Participant 1	Female	Large bike interest and uses several different bike racks. Does not own a car.
Participant 2	Female	Has knowledge of transporting horses. Would preferably rent a LCS instead of owning one. Does not own a car.
Participant 3	Male	Interest in skiing, with good knowledge in roof racks and roof boxes. Owns a car; SUV model.
Participant 4	Female	Has not used any external LCS before. Does not own a car. Curious.
Participant 5	Male	Owns a car without rails and towbar. Usually rents a car when transporting larger things.

To create a relaxed atmosphere the project group offered the participants coffee and cake. The focus group lasted 2 hours, with a 15-minute break included. It was recorded and transcribed. One of the members of the project was the moderator and therefore the leader of the discussion. A PowerPoint with essential information was compiled and displayed during the interview. The focus group followed a beforehand created interview guide, that can be found in Appendix 2.

When all participants had arrived, the project members did a short presentation of the thesis work, agenda and purpose of the focus group. All participants presented themselves. Then, as an ice-breaker, four mediating pictures were shown, picturing situations where people have transported various things on the outside of the car. This was followed by introductory questions with the purpose to map the participants' usage of external LCSs.

Because it was hard to get access to external LCSs as mediating objects for the focus group, we decided to use six describing scenarios instead. By doing so, the participants could try to identify oneself with the scenario and express opinions around it. To each scenario, there were related questions asked by the moderator. A short description of each scenario:

Scenario 1:	Corner desk does not fit into a rented Volvo V70
Scenario 2:	Ski holiday with family and roof box mounting
Scenario 3:	Stand up paddle boarding weekend with partner with a shoulder injury
Scenario 4:	Pick up a bike on the way home from work
Scenario 5:	Road trip where external LCSs shall be mounted off due to fuel consumption
Scenario 6:	Spontaneous flea market bargain with a car without towbar

Further, the participants got to rank the scenarios on a scale from least problematic to most problematic. Then followed questions about what the participants thought were the biggest problem and what needs that are not yet fulfilled regarding the situation of transporting things with external LCSs. Lastly, the participants had the chance to generate own ideas. Based on this, both qualitative and quantitative data could be obtained as a result.

3.1.5 KJ-analysis

The KJ-method was developed by the Japanese anthropologist Jiro Kawakita to structure large amounts of data from the user studies (Karlsson, 2007). The quotes and comments retrieved from the user studies were gathered and printed out on paper and placed on an empty wall. When several comments touched the same area, the comments were placed together. In that way, different categories were created, which generated an overall picture of the collected data for the user studies.

3.1.6 List of requirements

According to Johannesson, Persson and Pettersson (2013), a list of requirements is a compiled list of identified requirements and desires that are imposed on a product, based on the wishes and information from users. In product development, the list of requirements is used as a governing document for how existing or new products should be designed.

From the information gathered in the benchmarking and the user studies (compiled in the KJ-analysis) requirements could be formulated and placed in different categories. When later evaluation concepts, they were evaluated against the list of requirements to confirm that the requirements were met.

3.2 Result

The result retrieved from the previous mentioned methods are presented in the following chapter. First, the products of the current market and the usage of them are presented. Using this alongside with the user studies, six problem areas could be identified. The resulting problem areas are; *flexibility, placement, spontaneity, storage, mounting and demounting* and *safety.* The data retrieved from the user studies was also compiled in a KJ-analysis. The result from the KJ-analysis together with the result of the benchmarking were used when creating the list of requirements.

3.2.1 Today

This section is divided into two parts. First different products on the market are presented, then follows the result of when investigating the usage of the LCSs today.

3.2.1.1 Products

When investigating the different LCSs that are used today, the LCSs found on the market were compiled into main categories depending on where on the car they were mounted. These main categories are; *roof mounted LCSs*, *towbar mounted LCSs* and *boot mounted LCSs*. A selection of different products from each category are presented more thoroughly below.

Roof mounted LCSs

The core product of the roof mounted LCSs is the roof rack, seen in Figure 3.1. Usually, the length of the rack is fixed, so manufacturers make them in different lengths. If looking at Thule's products, their racks are produced in a length-span between 108 to 220 cm. During the interview with Olof at Mekonomen, he told that the customer normally has to buy two products to make a functioning roof rack. First, the rack, then the load carrier feets that fit the specific car. These can be mounted to the car body or to the rails. Other LCSs can be attached to the roof racks, e.g. a cargo box, bike rack, roof boxes, kayak and canoe carriers. Many of these LCSs were developed to transport a specific object on the roof and therefore not very flexible in use. If transporting something using only the roof racks, some ratchet tie-downs or similar will be needed to hold the load in place, Olof from Mekonomen mentioned.

Figure 3.1. Roof racks from Thule (Thule, n.d.). Used with permission.

There are a few roof racks on the market that are more flexible, in terms of fitting different car models. These racks are usually made of fabric and are inflatable or have a foam core. Winterial is a manufacturer of inflatable roof racks called Rakapak, presented in Figure 3.2. The length of these racks is 96 cm, which is shorter than the average traditional roof rack. Rakapaks can carry up to 81.6 kg and are strapped under the roof with integrated ratchet tie-downs. The way that these racks are mounted, combined with the fact that they are soft and short, makes them a universal rack that can be mounted to almost any car model (Winterial, 2019).

Figure 3.2. The inflatable roof rack Rakapak (Winterial, 2019). Used with permission.

Towbar mounted LCSs

This product group is smaller than the roof mounted products. When looking into mounting a LCS on the towbar of the car, different bike racks are the most common LCS found.

The scissor bike rack is the simplest and most well-known version of a towbar bike rack and can carry 1-2 bikes. The bike rack is presented in Figure 3.4.

Figure 3.3. The scissor bike rack (Jula, n.d.). Used with permission.

Another type of bike rack is the platform rack illustrated in Figure 3.4. This rack can carry 2-4 bikes depending on the size of it (Thule, n.d.).

Figure 3.4. Platform bike rack from Thule (Thule, n.d.). Used with permission.

There is also a LCS called towbar cargo box, which is a cargo box mounted to the towbar. The cargo box is presented in Figure 3.5. Towbar cargo boxes come in both hard-shell and fabric. If it is made of fabric it is called a cargo bag (Thule, n.d.).

Figure 3.5. Cargo towbar box from Thule (Thule, n.d.). Used with permission.

Boot mounted LCSs

Boot mounted LCSs is the smallest product group of the three main categories. These LCSs are useful if the car used does not have a towbar. However, today there are only bike racks that can be mounted to the boot and an example is shown in Figure 3.6.

Figure 3.6. Boot mounted bike rack from Thule (Thule, n.d.). Used with permission.

3.2.1.2 Usage

From the survey and an observation, the project members could map the usage of LCSs today. In the survey, the respondents got to answer the closed question "*If you/your family are transporting things with the help of a car, what things do you usually transport?* As seen in Figure 3.7, luggage got the highest quantity of answers, followed by groceries. Waste is also common to transport by car, along with some types of sports equipment. The result also shows that the respondents are more frequently transporting unassembled furniture by car than assembled furniture. A few of the respondents filled in their own options which were; car tires, dog in a cage, horse equipment, boat equipment, musical instruments, outdoor stuff and interior decor.

The result indicates that a variety of different things with different dimensions are transported with the help of a car. When investigating the loading capacity of different car models during the benchmarking, Volvo (2019) stated that the maximum roof load of a Volvo V90 usually is 100 kg and according to Car Info (2018), the maximum roof load of a Kia Ceed is 75 kg. With this in mind, a decision was made that the final concept developed in this project shall be dimensioned to withstand a load of 65 kg.

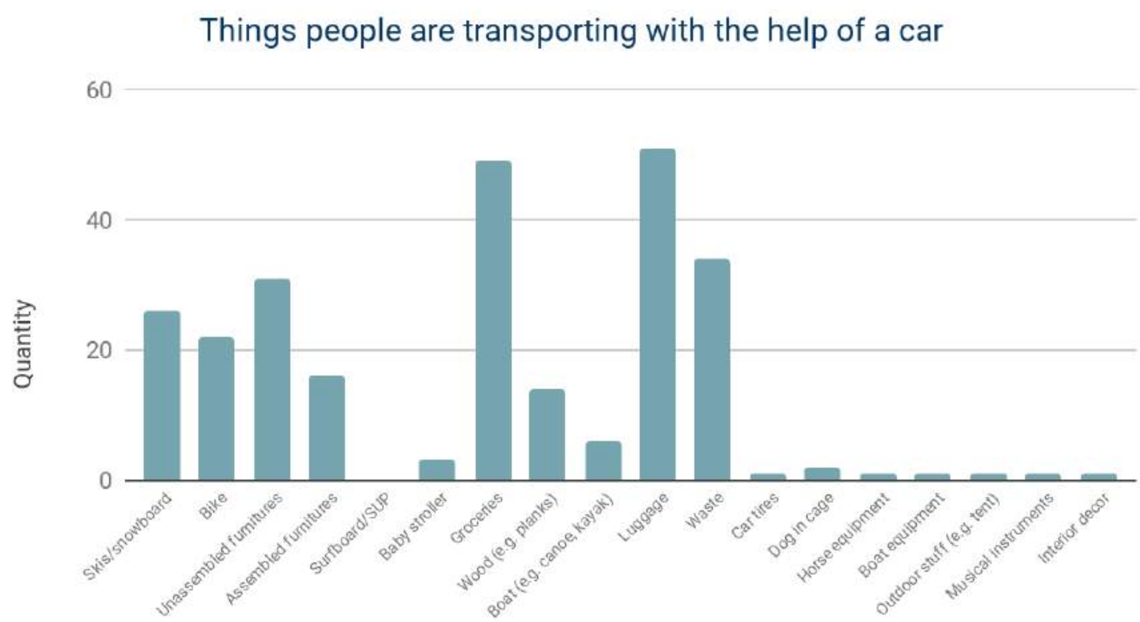


Figure 3.7. Things the respondents are transporting with the help of a car.

Next question in the survey was “*Which of the alternatives would you consider transporting on the outside of the car, e.g. on the roof? NOT with a trailer.*” The result of this question is shown in Figure 3.8. The same twelve options as the previous questions were used and several options could be selected. The responses to this question varied compared to the previous question where luggage, waste and groceries got the highest quantity of answers. On this question, these options got the lowest quantity, along with the baby stroller. Instead, Skis/snowboard is the most popular to transport on the outside of the car, closely followed by bike. A possible reason for this might be that these are things that are normally used outside and therefore it does not matter if they get dirty when being transported on the outside of the car. Wood, boat and surfboard/SUP are also preferably transported on the outside. The result also shows that the respondents are more willing to transport unassembled furniture outside of the car, than assembled furniture.

The observation made at IKEA, Bauhaus and Ica Maxi in Gothenburg showed that at IKEA, flat packages were commonly transported with the help of LCSs and at Bauhaus, planks, or other lumber. Frequently observed at both IKEA and Bauhaus were that people transported the bought objects with an open boot, secured by straps attached to the towbar. At Ica Maxi, the majority of roof boxes were spotted.

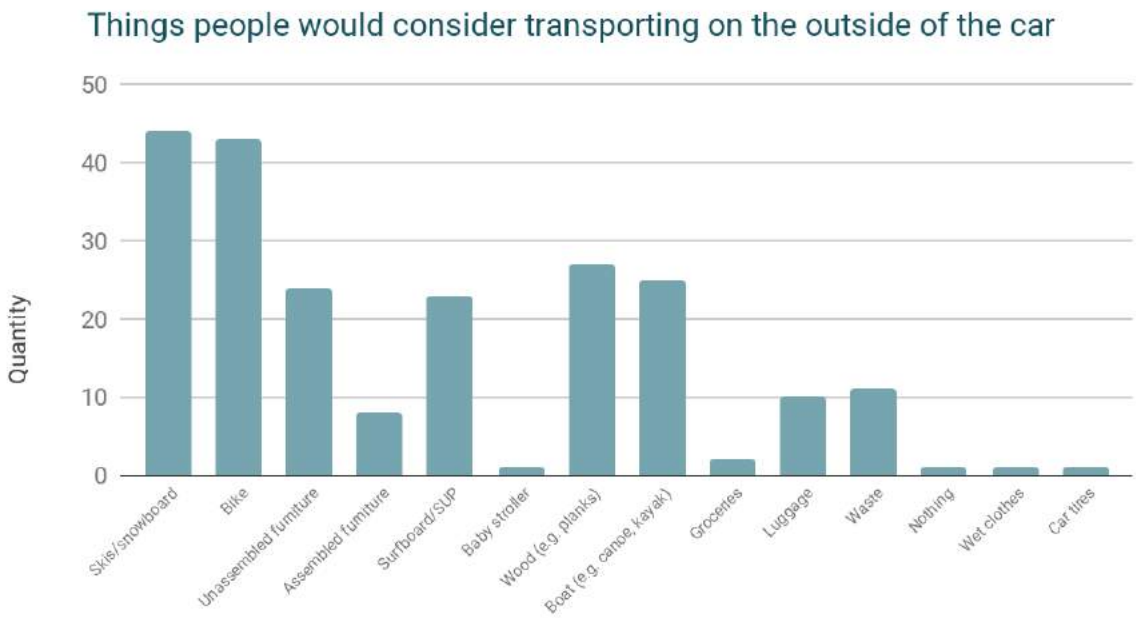


Figure 3.8. Things the respondents would consider transporting on the outside of the car.

The result of the question “*What external LCSs do you/your family use when transporting things on the outside of the car? Trailers NOT included.*” is presented in Figure 3.9. Towbar hang-on bike rack is most commonly used by the respondents, followed by roof racks, roof box and straps. Noted should be that both roof racks and straps are commonly used together with other LCSs.

When doing the observation at parking lots, the result showed that the majority of cars observed with a LCS had roof racks mounted. In total, 465 cars were observed, whereof 156 cars had an external LCS attached to the car. Thus, 34 % of the observed cars had an external LCS attached. Of these 156 cars, 18 of them had a towbar bike rack mounted whereof 8 had bikes attached. One car had a cargo box mounted to the towbar. 131 cars had roof racks mounted, and as stated in the survey some of the cars only had roof racks mounted and others had other LCSs attached to the roof rack. Of the 131 cars with roof racks, 74 of them only had roof racks mounted and 51 of these cars had a roof box mounted to the roof rack, where the sizes of roof box varied. Three Jeeps had a roof basket attached to the roof rack. Two cars were registered to have kayaks/canoes loaded on the roof with the help of kayak/canoe racks in assembly with roof racks. Out of the 131 cars with roof racks, 5 cars had roof bike racks mounted.

The result of the observation indicates more use of roof mounted LCS than towbar mounted LCSs. No boot mounted LCSs were observed. Since the observations were executed in February, that could be a possible reason for the many roof mounted LCSs observed. For example, the use of roof boxes is significantly larger during winter than summer, thus if the observations would have been performed during summer the result would most likely have been different.

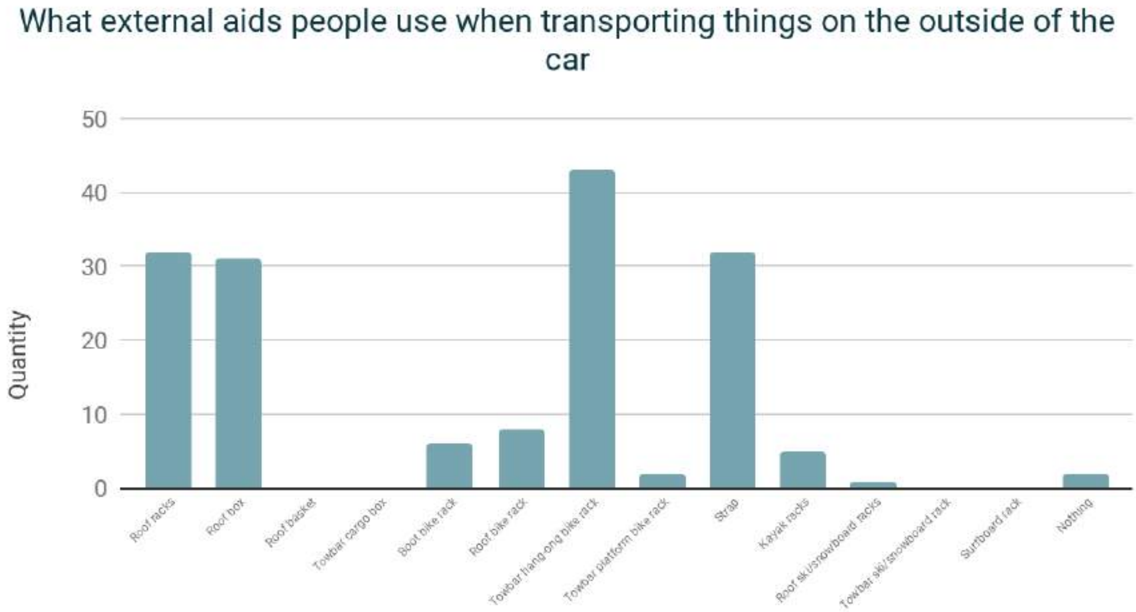


Figure 3.9. What external LCSs the respondents use when transporting things on the outside of the car.

3.2.2 Flexibility

Flexibility was a repeatedly touched problem area. With flexibility, the project group aims at the flexibility of the usage of a LCS, thus, several different products could be transported with the same LCS. Participant 2 of the focus group argued that there are two different groups of users. One where they have a hobby and therefore own a LCS that suits the hobby, and another where they do not have a specific hobby, hence do not want to own a LCS. In conclusion, some people do not want to buy a separate LCS for all different types of products they use. This was also expressed in the answers to the survey. When asked the question "*Can you use any external LCS for several things?"* to Olof at Mekonomen he refers towards the flexibility of roof racks.

> "If you want to have bikes on the roof and do not have a towbar then you must have a roof rack. If you want a roof box, you must have a roof rack. So, the roof racks may well be the basic product that fits several things."- Olof at Mekonomen

> "Versatility. All LCSs are only geared to manage a specific job on a specific car." - Respondent to questionnaire

> "I find it strange to have several different LCSs for different things, that cannot be sustainable for most people." - Respondent to questionnaire

Participant 2 came with the idea of a "sockiplastbag" which awoke interest from the other participants. The idea was a bag with one side rubber anti-slip and the other side very slippery, that could be attached to the roof of the car and be flexible in a matter that many different objects could be transported with it, either by laying and strapping the object on top of the bag or by putting it inside of the bag. The slippery side would help to get the object up on the roof. When discussing this idea further, participant 4 mentioned that it feels unrealistic that one could load e.g. a bookshelf and a bicycle with the same LCS, which the other participants agreed with.

3.2.3 Placement

Much information was compiled regarding the placement of the LCS. As mentioned previously roof mounted LCSs, towbar mounted LCSs and boot mounted LCSs have been analysed in this thesis and also the ones that were taken into account when creating the scenarios for the focus group.

Regarding the placement on the roof, the participants of the focus group indicated that they feel most safe loading things on the roof, safer than loading on the towbar and boot. One interesting point of topic concerning the roof mounted LCSs were the height. It is hard to reach when loading and mounting the roof racks and roof boxes. Participant 3 of the focus group owns a SUV and due to the height of the car, he stands on the doorframe when mounting and loading the roof mounted LCSs. This dilemma was recognized by several of the other participants as well, and in agreement, they stated that a small ladder would be preferable in this situation. Participant 1 and 3 both had the idea that the roof box could be moved laterally by the means of adjustable arms with tracks, and in that way lower the box to the side of the car for easier loading.

As mentioned in chapter 3.2.1.1 boot mounted LCSs are a good option when not having rails or a towbar on the car. Some boot mounted LCSs limits the use of other functions of the car. For example, prevent opening the trunk. Both boot mounted LCSs and towbar mounted LCSs have a better loading height than the LCSs on the roof. Nevertheless, placing the load on the towbar and tailgate are perceived as troublesome, unstable and less safe according to the respondents to the survey and the participants in the focus group. When talking about how much the towbar can handle, participant 2 convey that it can handle a horse transportation with two horses, but she is still not convinced that it is trustworthy.

> "The platform towbar bike rack does not look good, but it may be good. But when I look at it, I do not feel safe. It looks too wobbly." - Participant 2 of focus group

When discussing scenario 3 (SUP-scenario) in the focus group, the participants talked about if the SUP could be transported on the side of the car instead, since the couple in the scenario had difficulties with the attachment to the roof. Participant 4 suggested a rack with large hooks that were connected to the rails and placed on the side of the car. That would mean a more ergonomic height for the users when loading the SUP. Whereupon this, the moderator asked a complementary question about the safety with having LCSs on the side of the car. The participants discussed if the board might obscure the sight for the driver if placing it on the side of the car. They came to the conclusion that it depends on the length of both the car and board. Another aspect was if the car would be obliquely loaded if the LCSs are located on the side of the car, but in consideration of the weight of the board that would not be of influence. Participant 5 said that he would avoid loading heavier objects on the side though.

3.2.4 Spontaneity

When the participants of the focus group got to rank the scenarios, scenario 6 with the spontaneous flea market bargain was experienced as the most problematic scenario by four out of five participants. Many of the participants found the scenario complicated due to the fact that it did not include a LCS they could use to transport the flea market bargain and the car used did not have a towbar. The moderator of the focus group asked if they thought about bringing roof racks on an occasion like this. Whereupon, participant 4 said that it would have been stupid to leave them at home. Participant 3 disagreed and said that he would never have mounted today's roof racks for just a spontaneous trip.

> "It works to put the roof racks on the car from time to time, but you do not do it because you have to spontaneously go somewhere." - Participant 3 of focus group

When asking the focus group participants what equipment they would wish for in a scenario like this, they were all united that it would have been great to have a smaller LCS stored in the car that could easily be assembled and therefore used whenever needed. Other solutions also came into the topic, such as leaving the car at the flea market and rent a van nearby that would fit the bookshelf. Participant 5 mentioned that he had been in this situation before and he had then skipped buying the object.

Scenario 4 of the focus group was perceived as the least problematic by the majority of the participants. Scenario 4 describes a parent that shall spontaneously pick up the child's bike when driving home from work, and the participant all agreed that the scissor bike rack is perfect in a scenario like this and not to complicated to mount and use, hence it is manageable when spontaneously picking up a bike. Although, it takes up much space in the trunk and one might not want to always have it stored there.

3.2.5 Storage

Another noted problem was the storage abilities of LCSs, as stated in the ending of the previous paragraph. According to respondents of the questionnaire, the LCSs are often perceived as big and unwieldy to store. Participant 1 of the focus group owns several different bike racks and expressed that she stores the platform bike rack in her apartment with the bikes mounted to save space. Her scissor bike rack was sometimes stored in the trunk of the car, for spontaneous pickups of bikes (as in scenario 4), which takes up a lot of storing space inside of the car.

> "If you have several different external LCSs, you have to have a really large storage or a garage to manage to store everything. And if you live in an apartment that is not common to have." - Participant 2 of focus group

The storage abilities of roof racks also got mentioned in the focus group. If the roof racks should be stored in the trunk they would probably have to lie diagonally or be inserted in the hatch in between the rear seat. Noted should be that this depends on the size of the racks since the sizes vary. Participant 3 explained that he stored the roof box in the ceiling of the carport.

> "I have got a thing where you winch the roof box up in the roof of the carport. You just drive the car inside the carport and put the loops around each end of the box and then wind it up and lock it. It is very smooth because it is just to wind down and lay the box on the racks when wanting to mount it."
> - Participant 3 of focus group

When idea generating at the end of the focus group and when asked the question if they had any last thoughts regarding the subject in the questionnaire, ideas about that the LCS should be able to fold came into discussion, thus it would take up less space when stored. Further, if it is folded small enough it would be possible to always have it stored inside of the car. With soft material, it would be achievable by rolling or folding it together.

> "I would like them to be folded together in some smart way when they are stored and so that you can carry everything in one hand when taking it up again." - Respondent to questionnaire

3.2.6 Mounting and demounting

The mounting and demounting of the LCS were also frequently taken into debate. Scenario 5 in the focus group was about removing the external LCS from the car due to fuel consumption. Participant 1 told that she would at least have taken the bikes off from the bike rack. Participant 3 reacted strongly that he would have let them be, because of the complicated mounting and demounting of roof racks with a roof box on top.

Several answers to "*How do you experience using these external LCSs and why?*" in the questionnaire, indicated that the mounting and demounting of a LCS is experienced hard and time-consuming, especially if it is mounted by one person. None of the participants of the focus group saw the mounting and demounting as an easy process. A wish from participant 5 was that no rare tools would be required to mount or demount, even better would be if no tools were needed. Participant 4 requested fewer steps and indications that it is mounted correctly.

The observation executed at Mekonomen showed us the different parts needed for mounting a roof rack. Olof presented the part of the roof rack that connects to the rails. When observing Olof attach it, it was visible that he used a tool to screw down a small screw which made it grasp around the rail. Olof also demonstrated the use of the T-track in the roof racks. He inserted kayak racks in the T-track and attached them on the desired location by screwing with an Allen wrench on each kayak rack. The kayak rack was then pressed down towards the T-track and fixed. During this operation, we witnessed Olof using two different tools.

> "Circumstantially to mount and demount the LCSs from the car when you no longer have to use it." - Respondent to questionnaire

> "I know my mother drove around with the LCS for several weeks, just because she thought it was hard to remove it." - Participant 2 of focus group

3.2.7 Safety

As a result of the methods used in the problem identification phase, safety was a recurring area. For example, it shall be safe for the user to mount and demount the LCS with no risk of pinching. Both the participants of the focus group and respondents of the questionnaire expressed that it would be favourable with an indication that the LCS is correctly attached. This indicator could, for instance, be a clicking sound or visual hint. Then the driver and the passengers in the car can feel safe that the LCS will not fall off while driving. Many pointed out that scratching the car is a big fear when dealing with external LCSs, a bigger fear than scratching the transported object.

When talking about existing LCSs in the focus group, it got mentioned that many roof boxes are perceived as insecure because of the wobbliness of the box. Several participants also indicated that it does not feel safe when the transported object sometimes sway when driving e.g. bikes on roof mounted bike racks. One of the participants uttered that the amount of felt insecurity depends on the transported object and how it is attached.

> "I think of the time when we were moving and there was someone who moved at the same time and they put a sofa on the roof of the car. They saw that we looked at them, so they said: "it is lucky that we are just going two blocks"."
> - Participant 1 of focus group

When speaking about different materials the aspect of safety got mentioned again. One participant expressed that soft materials feel safer using than hard ones, considering that the hard ones are more likely to damage the car and the soft ones are not perceived as that difficult to use as hard ones. Other participants argued more for the strength and reliability of hard materials. To increase the safety of the transported object, the idea of friction came to attention. Friction between the transported object and the LCS would help to prevent the object from moving or sliding.

> "I think that a soft product is not complicated and unpleasant like a hard one, because you have interacted with socks throughout your life. Then you can understand and accept that the product is safe in some way, if you succeed with a good design." - Participant 2 of focus group

3.2.8 KJ-analysis

Based on the information and data retrieved from the result of the user studies, a KJ-analysis were compiled to structure the data into categories. The different categories were; *price, functions, usage, weather conditions, safety, fears, stability, flexibility and spontaneity, mounting, demounting, services, availability and ownership, weight, height, size, load distribution, storage* and *innovations.* Further, these were divided into larger main categories, which are symbolized in Figure 3.10. The sizes of the circles symbolize how much information that was retrieved from each main category. The bigger the circle, the more information.

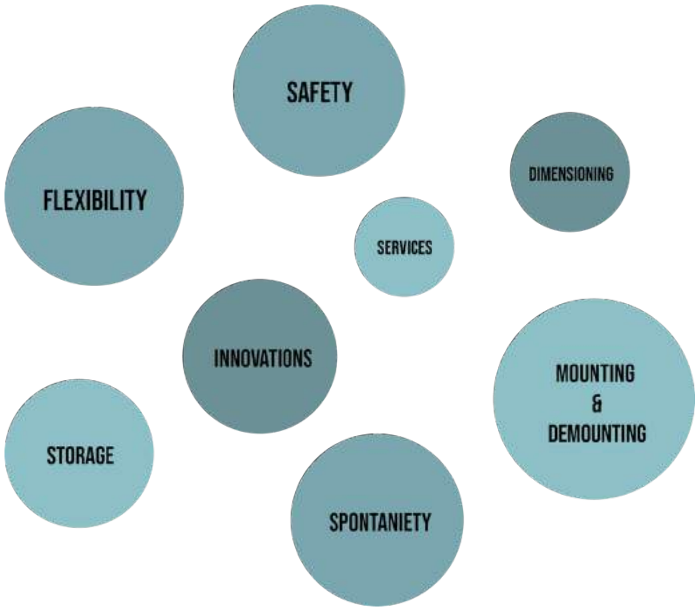


Figure 3.10. KJ-analysis with categorized information from user studies.

3.3 List of requirements

A list of requirements could be compiled based on the collected information from the problem identification phase. The requirements were sorted under various headlines based on the requirements area. The different areas were; *product requirements, safety requirements, material properties, rules and laws, mounting and demounting, dimensioning, ergonomic requirements, environmental and sustainable requirements, storage abilities, flexibility, spontaneity* and *visual aspects.*

The list contains 52 requirements which were evaluated to be necessary (N), desirable (D) or unnecessary (U). The different requirements were weighted from 1-5, where 1 is a low priority requirement while 5 is a high priority requirement. See the entire list of requirements below in table 3.1.

Some examples of necessary (N) high priority requirements (5):

- *External aid must be attached securely to car.*
- *Follow laws of traffic.*
- *Adjustable to several different car models.*

Table 3.1. *List of requirements.*

Specification of requirements	Measurement	Comment	N/D/U	Weighting				
				1	2	3	4	5
Product requirements								
Contain few components	amount	1-3 different components	D					
Shall be easy to understand		Intuitive	D					
Should not prevent using other functions on the car		E.g. opening the boot	N					
Safety requirements								
External aid must be securely attached to car		Shall not fall of while driving	N					
Lock on aid		Avoid theft of load	D					
External aid shall not damage the car		Scratch surface etc.	N					
Be stable when using		E.g. Manage heavy wind	N					
Material properties								
All materials shall withstand the weather		E.g. Not rust	N					
Materials shall be strong	Yield strenghts	Evaluate in CES Edupack	N					
Materials can be recycled or reused		Enable separation of different materials	D					
Rules and laws								
Follow laws of traffic		Swedish trafic laws	N					
Follow rules regarding car measurements	m	Not be wider than 2.6 m, aids included	N					
Follow rules regarding the cars total weight	kg	Load weight + unladen weight.	N					
Mounting and demounting								
Easy to mount/demount			D					
Indicate correct mounting/demounting		Interaction with user	D					
Few tools needed	amount	0-1 pts	D					
Common tools used		If tools are needed, these should be common	D					
Minimize time for mounting/demounting	minutes	Not take more than 5 minutes in total to mount	D					
One person mounting/demounting		One person can mount by himself	D					
Dimensioning								
Compatible with measurements of the car	m	Different measurements on different cars	N					
Manage load of 65 kg	kg	Fixed maximum weight of load	N					
Ergonomic requirements								
Allowing one person to lift aid	kg	Not too heavy	D					
Facilitate an ergonomic mounting position		Decrease the strain on body	D					
Environmental and sustainable requirements								
Ability to exchange components of aid		If a component brakes	N					
Minimize increased fuel consumption	liters	By easier removing the external aid	D					
Allow recycling or reuse		Of components or materials	D					
Storage abilities								
Possibility to store aid in car		Without taking up too much space	D					
Minimize area when stored	m^2	For a smaller storing area	D					
Flexibility								
Ability to carry more than one type of product		Not a product specific aid	D					
Adjustable to several different car models		Requires a point of adjustment on aid	N					
Spontaneity								
Have easy access to aid			D					
Have quick access to aid			D					
Encourage spontaneous use of aid		By not appearing cumbersome to use	D					
Visual aspects								
Express safety		Through shape, size, colour	D					
Express trust		Through shape, size, colour	D					
Express simplicity		Through shape, size, colour	D					
Express stability		Through shape, size, colour	D					

4

CONCEPT DEVELOPMENT AND EVALUATION

The problems identified in the previous phase and the list of requirements acted as a foundation for the idea and concept generation. Before starting to generate ideas, the project group made the decision to make the project narrower and only focus on concepts attached to the roof. This decision was taken based on data from the focus group where it was stated that the roof is the place on the car that is perceived as most trustworthy regarding transporting a load on the outside of the car. Regarding the flexibility of the concept focus will lie on the ability to mount the concept on many different types of car models and the concept should not be bound to loading one specific product. When asking the question *"What type of products should be able to be loaded on the concept?"* we decided to limit it to products, with a weight less than 65 kg, that a person might want to transport spontaneously, without having to plan ahead. This along with the requirement that the concept shall be easy to mount and demount adds to the spontaneity of the concept.

4.1 Method and implementation

The methods used in the concept development and evaluation are together with the implementation of them, presented in this chapter.

4.1.1 Brainstorming and brainwriting

According to Johannesson, Persson and Pettersson (2013), brainstorming is a method mainly used in the idea generation stage of a product development project. It is used in a group of people where the goal is to generate as many ideas as possible, without judging the results. The participants should inspire and be inspired by each other's ideas and generate new ideas by associating to the ideas of the other participants. Idea quantity goes before idea quality. There are four ground rules in brainstorming:

1. No criticism
2. Aim for quantity
3. Think outside the box
4. Combine ideas

Alongside brainstorming the method brainwriting was used. Brainwriting works similar to brainstorming, except when brainwriting the participants are sitting by themselves generating and documenting their ideas by writing or drawing. After a while, if the number of ideas is decreasing the participants can look at each other's ideas for inspiration (Johannesson et al., 2013).

To get the creative thinking going and to brainstorm and brainwrite around how a LCS can open up for more spontaneous and flexible usage, a series of questions were asked:

- "*In what ways can a LCS like this be made smaller?*"
- "*In what ways can a LCS be fastened to a car?*"
- *"In what ways can a product be fastened to the LCS?"*
- *"What material can be used between the car and the LCS?"*
- *"What shape can the LCS have?"*.

To allow for a more spontaneous usage the LCS has to take up a small amount of space when not used. This because one wants to be able to store it inside of the car and always have access to it. This opened for the first question, "*In what ways can a LCS like this be made smaller?"*. A timer was set to six minutes and during this time size-adjustable functions were written down and/or quickly sketched.

Another thought that came up was that it is not just the fact that a LCS is easy to bring that makes for flexible and spontaneous usage. During the focus group, the participants talked about the need for easy mounting and demounting, so in another brainwriting session, Ideas were generated on how a LCS can be fastened to a car. While thinking about "*in what ways can a LCS be fastened to a car?"* the project members realised that another valid question is *"in what ways can a product be fastened to the LCS?"*. This question was asked since quick and easy fastening of the load is another way to increase the spontaneity.

"What material can be used between the car and the LCS?" was the fourth question asked when thinking about if the LCS should be attached to a car without rails and therefore had to lie e.g. on the roof of the car. Further, to increase creative thinking, the product members asked: *"What shape can the LCS have?"*.

4.1.2 Morphological matrix

A morphological matrix is a method used to combine different ideas and partial solutions to create new ideas and concepts that otherwise would never have been thought of. The goal is to generate a number of concepts that all meet the requirements set in the list of requirements, all of them should be reasonable concepts and they should all contain physically and geometrically compatible partial solutions. Start with adding subfunctions to a morphological matrix, to every subfunction all the good partial solutions are added. Then create concepts by combining different partial solutions by drawing a line between the partial solutions. Sort out the concepts that, for obvious reasons, are impossible (Johannesson et al., 2013).

After using brainstorming and brainwriting to generate subfunctions, the subfunctions were put into a morphological matrix. Initially, the subfunctions were numbered and then a random generator was used to combine subfunctions into five different concepts. The morphological matrix with the generated concepts can be found in Appendix 3.

4.1.3 SCAMPER

The method was originally created by Alex F Osborn and the letters of SCAMPER each stands for a word that can be used to help revive the creative thinking regarding an idea or problem. The words can be used on their own or together with the existing ideas or problem (Johannesson et al., 2013).

S - Substitute
C - Combine
A - Adapt
M - Modify
P - Put to other use
E - Eliminate
R - Reverse

SCAMPER was applied to the five concepts generated through the morphological matrix to develop and increase their potential. Mostly, subfunctions were substituted to other subfunctions from the morphological matrix, subfunctions were eliminated and concepts combined. When asking questions like "*can any subfunction be substituted to optimize the concept?*" and *"can any of these concepts be combined to optimize one of them?"* it ended up with a sixth and seventh concept.

4.1.4 Prototyping

To visualize ideas in a product development project prototyping is crucial. According to Wikberg Nilsson, Ericson och Törlind (2015, s. 154) it is made to develop an understanding of different and possible solutions, and what the solution needs to cope with. There are different types of prototyping and the ones used in this stage of the thesis are; sketch prototyping and physical prototyping.

Early in the design process, simple models are commonly created. Sketching is a way to prototype and communicate, both internally with the designer himself or externally with the user or clients. A sketch is a visual demonstration of the designers reasoning that is easier to understand than a long description in text. Physical prototypes are used to demonstrate and test a solution. It is a creative method for exploring what is possible for the specific context and for presenting a design and getting feedback from clients and users. The prototypes can be built in any size, material and difficulty wanted (Wikberg Nilsson et al., 2015).

During the project, sketching was used when idea generating to visualize and generate more ideas, since one idea leads to another etc. The project members sketched the generated concepts by themselves and then showed each other to see if they had different pictures in mind. Simple physical prototypes were also built of each concept to evaluate functions.

4.1.5 PNI

PNI stands for Positive, Negative and Interesting. Using this method, concepts can be described in a similar way. All concepts are written down and presented through describing what is positive, negative and interesting about them. This method helps with getting a view of how well the concepts meet the requirements (Wikberg Nilsson et al., 2015).

When composing the PNI matrix in the project, the project groups perception regarding each concept was also taken into account. The PNI matrix was used to evaluate the seven concepts to see which concept met the requirements the best and therefore, further developed.

4.2 Result

The methods and implementation described above generated seven early concepts. The questions asked when idea generating resulted in a variety of subfunctions. The questions and subfunctions are listed in table 4.1. A solution to each subfunction is listed to each concept. The concepts are described in the following chapter and presented through the sketches and prototypes created.

Table 4.1. *The questions that generated different subfunctions.*

Question	**Subfunction**
“*In what ways can a LCS be fastened to a car?”*	Fastening LCS on car
“*In what ways can a LCS be made smaller?”*	Size adjustment
“In what ways can a product be fastened to the LCS?”	Fastening product to LCS
“What shape can the LCS have?”	Shape of LCS

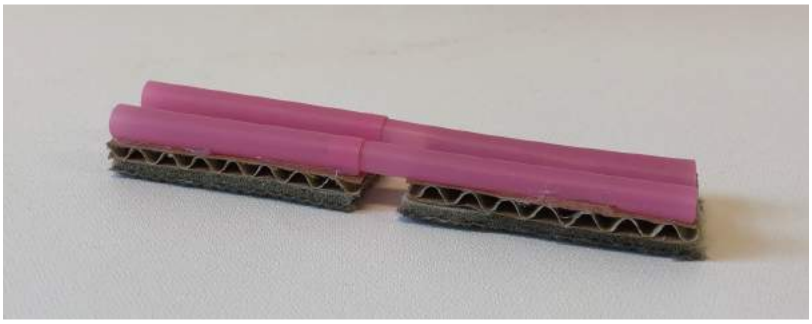
"What material can be used between the car and the LCS?"	The material between LCS and car

4.2.1 The early concepts

Concept 1: Mickey

Subfunction	**Solution**
Fastening, LCS on car:	Helmet buckle
Size adjustment:	Tent stick
Fastening, product to LCS:	Elastic bands with holes
Shape of LCS:	Double semi-circle
Material between LCS and car:	Soft material

Mickey is a concept where the roof rack lies directly on the roof. The racks are mounted to the roof with the help of wide straps that are pulled through the door openings, one rack by the front doors and one rack by the back doors. The straps are then fastened with "helmet buckles" and will lie against the car ceiling. The straps are adjustable which makes the racks tighten to the roof. The racks have a shape similar to half a dog bone. The racks are made of hard material and are foldable through the help of a "tent stick function". This means that the racks are divided into two parts where the end of one of these parts has a smaller diameter which makes it fit into a hole at the end of the other part. The two parts are connected through an elastic band so that the rack can fold but the two parts will not get lost from each other. Since the racks are hard and lie directly on the roof, they are supported with foam rubber underneath. This will both act as scratch protection and help the racks follow the convex shape of a car roof. The foam rubber is covered in a water repellent fabric and has high friction dots underneath to prevent the racks from sliding. Products are fastened to the LCS with the help of high friction elastic bands with holes in it. Between the two elevations, there are hooks where the holes in the elastic band are attached. The attachment points are placed between the elevations to decrease the risk of damaging the load. The prototype of Mickey is shown in Figure 4.1.



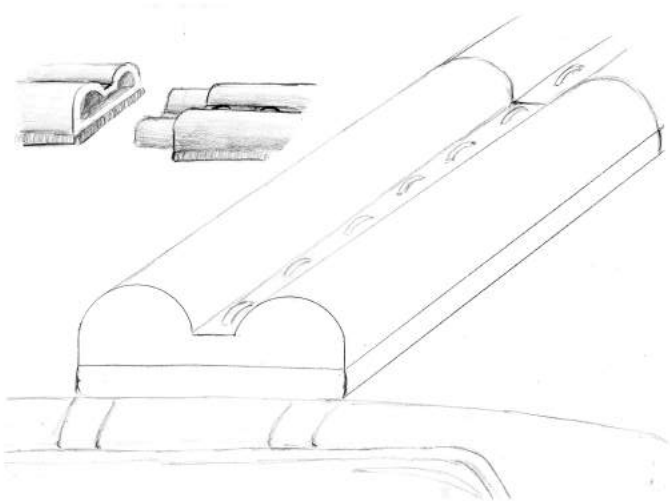


Figure 4.1. Picture of the prototype and sketch of concept Mickey.

Concept 2: Aladdin

Subfunction	Solution
Fastening, LCS on car:	Ratchet tie-downs
Size adjustment:	Soft material
Fastening, product to LCS:	Friction and net
Shape of LCS:	Rectangular
Material between LCS and car:	Soft material

Aladdin is a concept that is all made of soft material, presented in Figure 4.2. It is a rectangular foam rubber mattress that is mounted to the car roof with the help of ratchet tie-downs. The ratchet tie-downs are integrated into each corner of the mattress and then pulled through the front and back doors of the car and are attached under the car ceiling. When the ratchet tie-downs are tightened the mattress will tighten to the roof. Products are then fastened to the mattress with the help of a net, the net is made of some kind of rubber-like material so that has high friction. The mattress has many attachment points for the net. The foam is covered in a water repellent fabric and has a high friction surface underneath to prevent the mattress from sliding. Foam rubber contains a lot of air, so to make the concept take up less space when stored it is tightly rolled up so that the air is pressed out. The fact that it is made of soft material prevents the roof from being scratches and it gives some support to the products that are being transported. The foam rubber mattress has a protective border around the edge that helps to prevent the load from falling off.

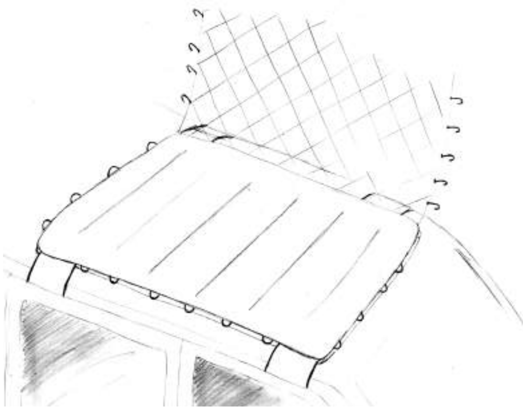


Figure 4.2. The sketch of concept Aladdin.

Concept 3: Hexagon

Subfunction	**Solution**
Fastening, LCS on car:	Clamps
Size adjustment:	Umbrella
Fastening, product to LCS:	Elastic bands with holes
Shape of LCS:	Hexagon
Material between LCS and car:	Hard material

Concept Hexagon is a hard roof rack that attaches to the car with the help of clamps that are mounted to the rails of a car. A sketch of Hexagon is shown in Figure 4.3. These clamps are lined with a soft high friction material so that they clench tightly around the rails. As the concept name implies, this rack is in the shape of a hexagon. Hexagon uses an "umbrella function" to adjust the size. The rack has a button and if that button is pressed down, the rack becomes longer. To make it short again you have to use your own muscle power to press the smaller rod into the bigger one. Products are fastened with the help of integrated elastic rubber bands. These bands have holes so that they can be attached to the rack. The material of these bands is high friction which makes for an even more secure fastening.

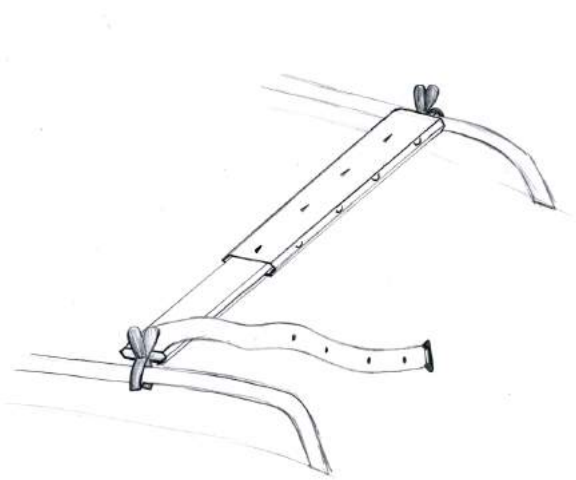


Figure 4.3. The sketch of concept Hexagon.

Concept 4: Zipper

Subfunction	Solution
Fastening, LCS on car:	Zipper
Size adjustment:	Vacuum cleaner
Fastening, product to LCS:	Elastic bands with hooks
Shape of LCS:	Oval
Material between LCS and car:	Soft material

This concept is made of both hard and soft material, as shown in Figure 4.4. The rack itself has an oval shape and its length is adjusted with the help of a "vacuum cleaner function". The basic function of a "vacuum cleaner function" is one of a telescopic arm. It has one smaller rod that is inserted into a bigger one. The smaller rod has notches where a lever on the thicker rod attaches. If a button on the thicker rod is pressed the lever can switch to another notch and the length is thereby adjusted. The bottom of the thicker part of the rack has a piece of fabric attached to it. The part of the fabric that lies underneath the smaller part of the rack has loops where the smaller part of the rack is pulled through. This fabric is water repellent and has a high friction surface underneath. The fabric will be quite thick, like neoprene, and will be padded to act as a shock absorber and to prevent the rack from deforming. The fabric is pulled through the front and back doors and a zipper connects the two fabric ends of each rack. Since not all cars are the same size the fabric has "backpack buckles" attached to it to help tighten the fabric around the car roof. The rack has small holes on the sides as attachment points for elastic bands with hooks, this is the way products are fastened to the LCS.

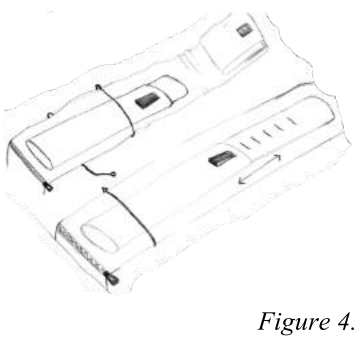



Figure 4.4. Picture of sketch and prototype of concept Zipper.

Concept 5: Inflatable

Subfunction	Solution
Fastening, LCS on car:	Ratchet tie-downs
Size adjustment:	Inflatable
Fastening, product to LCS:	Ratchet tie-downs
Shape of LCS:	Double triangle
Material between LCS and car:	Soft material

This concept is an inflatable one and the prototype is presented in Figure 4.5. The outer layer is made of water-repelling fabric and it comes with a small pump. The shape of Inflatable is that of two triangles with their tops cut of, the shape is similar to the shape of a Kit-Kat candy bar. The concept has two vents and the two triangles are separately inflated. Both the top and bottom of this concept have a high friction surface to prevent the LCS to slide on the roof and to prevent the loaded product to slide on the LCS. Inflatable is mounted to the car with the help of integrated ratchet tie-downs that are pulled through the front and back doors and then tightened. The ratchet tie-downs will lie against the ceiling when the racks are mounted. Products are fastened to the LCS with the help of integrated ratchet tie-downs as well. Between the two triangles are some loops that can act as attachment points for the ratchet tie-downs if needed.

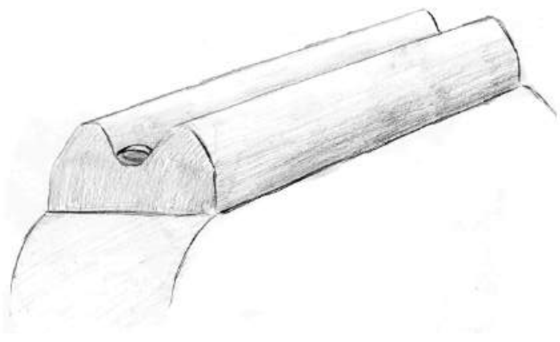



Figure 4.5 Picture of sketch and prototype of concept Inflatable.

Concept 6: Tetris

Subfunction	**Solution**
Fastening, LCS on car:	Ratchet tie-downs
Size adjustment:	Tetris
Fastening, product to LCS:	Elastic straps with hooks
Shape of LCS:	Rectangle
Material between LCS and car:	Soft material

2-3 foam blocks are held together with fabric as seen in Figure 4.6. The fabric between the foam blocks acts as hinges making it possible to fold the rack in half/in thirds so that it takes up less space when stored. The foam should have a fairly high density so that it has good shock absorption abilities. The fabric has a high friction surface underneath, where it lies against the car roof, to prevent it from sliding. The top of it has a high friction surface as well, to prevent the loaded product from sliding. The products should be fastened with straps as well. Products are fastened with the help of elastic straps with hooks that attaches to loops in the rack. The rack is fastened to the car with integrated ratchet tie-downs that are pulled through the front and back doors and fastened to the handles near the ceiling.

Figure 4.6. The prototype of concept Tetris.

Concept 7: Seven

Subfunction	**Solution**
Fastening, LCS on car:	Suction cups
Size adjustment:	Crutch function
Fastening, product to LCS:	Elastic bands with hooks
Shape of LCS:	Streamlined
Material between LCS and car:	Soft material

Concept seven is a roof rack that is fastened to the roof with the help of suction cups. The concept is visualised through a sketch in Figure 4.7. The suction cups are permanently fastened to the ends of each rack. Each suction cups have a screw that when twisted creates a vacuum in the suction cup. The length of the racks is adjustable with the help of a "crutch function". This function is a telescopic arm with holes in the bigger rod and a button on the smaller rod that attaches to the holes to fix the rack at a specific length. The shape of the rack is streamlined to decrease air resistance. The support against the car is accounted to be soft because of the rubber material in the suction cups. Concept Seven has elastic straps with hooks to fasten the load with, and hard loops on the rack that act as attachment points if needed.

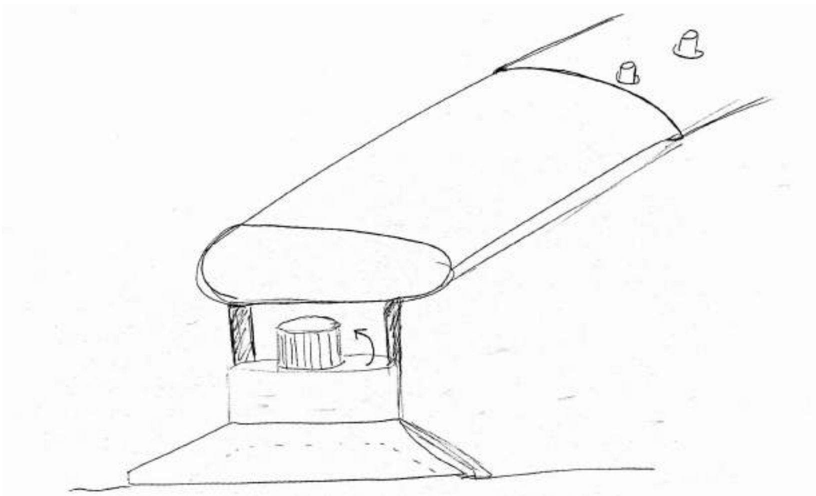


Figure 4.7. The sketch of concept Seven.

4.2.2 Concept testing

To validate how credible the developed concepts actually were, the project group did simple testing of functions that we were uncertain would work. This was executed with the help of different means, explained further in each testing. Some of the concepts have similar uncertainties, but it is only one uncertain function for each concept that has been tested.

Concept 1: Mickey

The uncertainty regarding Concept Mickey was if the “tent stick” would separate if the concept were to be tightened hard around the car. This was tested with a tent stick. The two project members pulled in the tent stick from different directions to see if the parts would separate. The parts did separate.

Concept 2: Aladdin

To validate that the car doors can securely attach Aladdin, the project group did a test with a ratchet tie-down on a car. The ratchet tie-down was wrapped around the roof of the car through the open front doors. The ratchet tie-down was tightened underneath the roof and then the car doors were closed. One of the members of the project sat inside the car and pulled in the strap of the ratchet tie-down, while the other one pulled from outside. It was securely attached.

Concept 3: Hexagon

The “umbrella function” of concept Hexagon made the project members hesitant. This because of the different cross-sectional diameters of the two parts of the hexagonal rack that might make the transported object unstable on the roof. By using two smaller umbrellas, this was tested. The umbrella sticks were folded out and placed on the floor in opposite directions and a flat object was placed on the sticks, presented in Figure 4.8. The object was not affected by the two different diameters, with a difference of 1 mm. Noted should be that the object tested was light, if a heavier object should have been tested it might have acted differently. For minimal impact on the stability of the transported object, the difference between the cross-sectional diameters must be as small as possible and still handle a maximum weight of 65 kg.

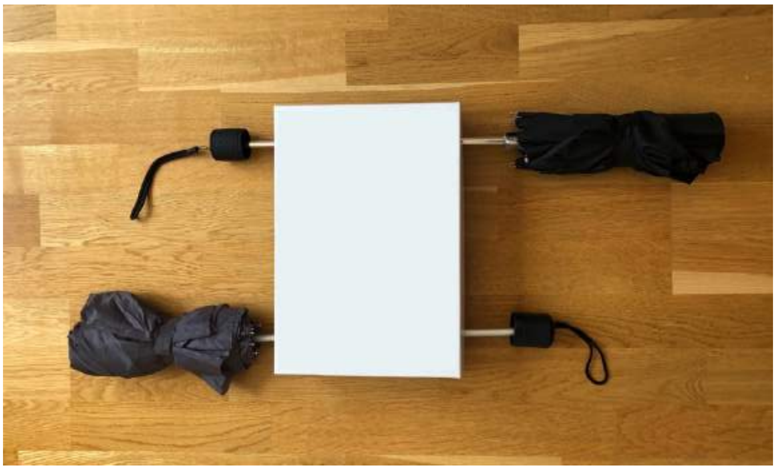


Figure 4.8. Testing the stability of Hexagon.

Concept 4: Zipper

Due to the "vacuum cleaning function" the same aspects regarding the difference in cross-sectional diameters as the Hexagon, must be considered. Another uncertainty regarding the Zipper was if the car door could prevent liquids from spreading in the fabric and leak inside of the car. This was tested with the help of a functional sweater, water, and a car. The car door was closed on the sweater so it was half inside and half outside. Water was poured on it from outside. After 14 minutes the part of the sweater inside of the car had gotten damp. This could easily be fixed with a water repellent fabric.

Concept 5: Inflatable

Concept 5 is inflatable with vents of best kind preventing air leakage, which originally was the biggest concern. The most uncertain function of Inflatable then became the rubber anti-slip bottom and how securely that is when wet on the roof. A piece of rubber was found and tested on a wet surface. The friction was reduced and the rubber piece slipped. Therefore, the surface would preferably be dry when attaching the LCS. Noted should be that the friction is an additional function to increase the safety of Inflatable's attachment to the car.

Concept 6: Tetris

A consideration regarding Tetris was the space it takes when folded together. In an unfolded position the volume is 0.00102 m^3, which is the same as the volume in a folded position. By this, it was ensured that the volume did not change when Tetris was folded but it does get shorter and also wider.

Figure 4.9. Tetris in folded out position

Figure 4.10. Tetris in folded position.

Concept 7: Seven

The concern about concept Seven was if the suction cups could be securely attached to the roof of the car. To test this, we used a hook with a suction cup with a diameter of 5.4 cm, shown in Figure 4.11. The suction cup was attached to a flat surface by turning the oval screw on the top of the hook. After a while, the suction cup arose from the flat surface and created a vacuum in the cavity. Then, the project group tested how it handled different forces by pulling vertically, horizontally and by rotating. When trying to pull only the round part of the hook, nothing happened from neither direction. But when pulling very hard in the hook, it was released from the surface. It was also tested on the roof of a car, which is slightly curved, and it stayed in place even when exposed to forces.

The created concept does not have a protruding part that enables grasping. The concept shall also have a bigger suction cup than 5.4 cm, which means that it can handle bigger forces. If concept Seven ends up as the final concept, more testing and investigation must be made to determine the size of the cup so that four suction cups can manage to sit securely with a load of 65 kg and so that the suction cups can manage to handle forces created when driving.

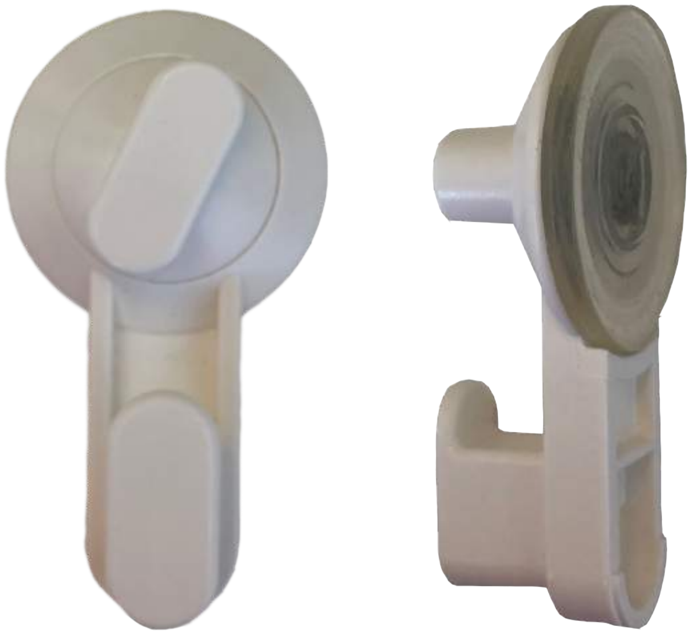


Figure 4.11. The hook used to test the suction cups on concept Seven.

4.3 PNI

The results from the concept testing, alongside with the perception of the project group, were taken into account when doing the PNI. The result of the PNI is presented in table 4.1.

Table 4.1. *PNI matrix for all concepts.*

Concept	P - Positive	N - Negative	I - Interesting
Mickey	• The attachment point for the transported object lies in between the two half circles, so it is possible to place something on top of it without scratching the object. • The transported object will not be affected by the shape of the roof = stability. • Friction against the roof. • The object lies on a wide surface and creates stability. • Requires no tools for mounting/demounting on the car.	• Only has one length mode when used. • The shape of Mickey makes it take up more space than a "regular" roof rack. • Requires a dry surface for the friction against the roof to be ultimate.	• The friction might act differently when wet outside. • The "tent stick function" slides apart when the LCS is fastened too tight around the car. • The "tent stick function" might make it less durable and the rack might truckle.

Aladdin	• The fabric protects the roof from scratches. • Friction against the roof. • Friction against fastened objects. • Requires no tools for mounting/demounting on the car. • Aladdin is the only concept that it only requires one of. • The fact that Aladdin follows the shape of the roof of the car, reduces the air resistance.	• It has a fix width and length which makes it hard to adjust to different car models. • May create instability for the product when the “mat” follows the cars roof curvature. • If no product is loaded on the LCS, it can be grabbed by the wind. • The net requires many fastening points to secure the transported object. • If Aladdin is going to be stored in a small space it requires the fabric of the LCS to be very thin = less shock absorption. • Requires a dry surface for the friction against the roof to be ultimate.	• The friction might act differently when wet outside. • How small Aladdin can be stored depends on the material of the fabric.
Hexagon	• Fastened outside of the car. • The LCS is “floating” and therefore no risk of scratching the roof. • Can be stored smaller than when used. • The transported object will not be affected by the shape of the roof = stability. • Requires no tools for mounting/demounting on the car.	• Can only be used with rails. • Only has one length mode when used. • The “umbrella function” requires the racks to have two different cross-sectional diameters which affect the stability of the load.	• The diameter difference depends on the material and the thickness of it. • The “umbrella function” might make it less durable and the rack might truckle.
Zipper	• Adjustment of the length of the LCS is possible via the “vacuum cleaning function”. • Friction against the roof. • The loose fabric inside of the car can be tightened with backpack-straps so it is not in the way. • The transported object will not be affected by the shape of the roof = stability.	• The fabric has one length and leftover fabric takes up space inside the car. • The “vacuum cleaning function” requires the LCS to have two different diameters. • If the fabric is not water repellent it might leak inside the car. • Requires a dry surface for the friction against the roof to be ultimate.	• The fabric inside the car can be further developed to create more storage abilities in the car, with e.g. hooks and pockets. • The diameter difference of the racks depends on the material and the thickness of it. • The friction might act differently when wet outside. • Can the fabric be water repelling?

<table>
<tr><td></td><td>Can be stored smaller than when used.
Requires no tools for mounting/demounting on the car.</td><td></td><td></td></tr>
<tr><td>Inflatable</td><td>Friction against the roof.
Can be stored smaller than when used.
Requires no tools for mounting/demounting on the car.</td><td>If the vent opens while driving, the air will seep out and the product will lie directly on the roof of the car.
Only has one length mode when used.
In need of a pump to inflate.
Requires a dry surface for the friction against the roof to be ultimate.</td><td>Possible to have different inflatable sections.
It might act differently when wet outside.</td></tr>
<tr><td>Tetris</td><td>Hinge function due to the fabric connecting the foam blocks - rack can be folded into half
Requires no tools for mounting/demounting on the car.
Friction against the roof.
Friction against the product.
Shock absorption due to foam.</td><td>Only has one length mode when used.
The safety of the fastening depends on the size and shape of the handle inside of the car.
While it does get shorter when folding it, it also becomes wider.
Quite big - more air resistance.
Requires a dry surface for the friction against the roof to be ultimate.</td><td>The friction might act differently when wet outside.</td></tr>
<tr><td>Seven</td><td>Fastened outside of the car.
The streamlined shape of the rack reduces the air resistance.
The only concept that can be fastened anywhere on the roof of the car.
The rack is “floating” and therefore no risk of scratching the roof.
The transported object will not be affected by the shape of the roof = stability.
Adjustment of the length of the LCS is possible via the “crutch function”.</td><td>Requires a clean and dry surface for the suction to be ultimate.</td><td>How large must the suction cup be to handle the load and forces that might occur when driving?</td></tr>
</table>

Concept Seven had the least negative aspects and was found interesting to investigate further. The project group also saw potential in concept Seven and therefore it became the chosen concept to develop further in the project. Some positive aspects that were considered highly weighted was that concept Seven was the only concept that could be attached anywhere on the roof of a car and the streamlined shape of the rack reduces the air resistance. The interesting aspect ”*How large must the suction cup be to handle the load and forces that might occur when driving?”* felt like it could strengthen the concept and give it credibility if answered. Answering this felt manageable within the frames of the project.

5

CONSTRUCTION OF DETAILS

The first step in the continued development of concept Seven was to gain a bigger understanding regarding suction cups and their characteristics. This was executed both with a further research and an experiment. Afterwards, the development process continued with the collected information in hand. Concept Seven was divided into different parts that were developed further. The parts were the rack, the suction cup device and the knob mechanism. This generated three new concepts, that were evaluated against each other and the list of requirements in a Pugh-matrix.

5.1 Method and implementation

This chapter presents the methods that are used to develop the details of concept Seven. Furthermore, the implementation of the methods is described and the purpose and goal of each method.

5.1.1 Research

Researching is a way to study a subject in order to gain new information and understanding about it. This was done to gain a deeper understanding of suction cups and vacuum and their characteristics. The research was both digital and analogue (Karlsson 2007).

5.1.2 Experiment

An experiment can be carried out with the purpose of e.g. identify problems related to the design of the product or product series. When doing the experiment, one can compare the properties of different products (Karlsson, 2007). With a suction cup, a vacuum pump and two different valves, the project group experimented with vacuum and how the pump and valves work. The arrangement of the experiment is shown in Figure 5.1.

Figure 5.1. The arrangement of the experiment.

5.1.3 3D modelling

CAD, computer-aided design, are a tool used by designers to create 3D models (Wikberg Nilsson et al., 2015). 3D modelling is useful especially during the detail construction stage in a product development project, where the degree of details is carefully thought out e.g. the location and possible movement of parts of the product (Johannesson et al., 2013). There are various programs for 3D modelling, in this thesis, CATIA has been used. CATIA stands for computer aided three-dimensional interactive application (Technia, 2019). CATIA was used to accurately reproduce complicated forms and present the dimensions of the parts of the product and its functions.

5.1.4 Pugh-matrix

According to Burge (2009), a Pugh-matrix is also known as a decision-making matrix. In a Pugh-matrix, a number of different design concepts are set against a reference product and a number of criteria. Each concept is then given a value depending on how well they meet each criterion compared to the reference product. The value that is given to each concept is usually the values -1, 0 or 1. These numbers are then summed and the concept with the highest value is the one that meets the criteria best.

In this thesis, no reference product was used when evaluating the further developed concepts in the Pugh-matrix since this project is not about increasing the performance of an existing product. Instead, the concepts were put against the list of requirements and each other and then given values -1, 0 or 1, where -1 indicates that the requirement is not fulfilled, 0 indicates that it is neutral and +1 indicates that the requirement is well met.

5.2 Result

The result from the above-mentioned methods could be divided into three different stages. In the first stage suction cups, different valves and vacuum pumps are explained and the result from the experiment is presented. This stage ends with a compiled list with important aspects for a suction cup. In the second stage, the development of the different parts of concept Seven continues, which results in three new concepts. The concepts are in the last stage evaluated in a Pugh-matrix and a final concept is determined. The result of each stage is presented more thoroughly below.

5.2.1 Explanation of suction cups

A suction cup is pressed against and attached to a surface when the surrounding pressure, atmospheric pressure, is higher than the pressure inside the suction cup, illustrated in Figure 5.2. The lower the pressure inside the suction cup, the greater the force that presses down the suction cup against the surface (Piab, 2004).

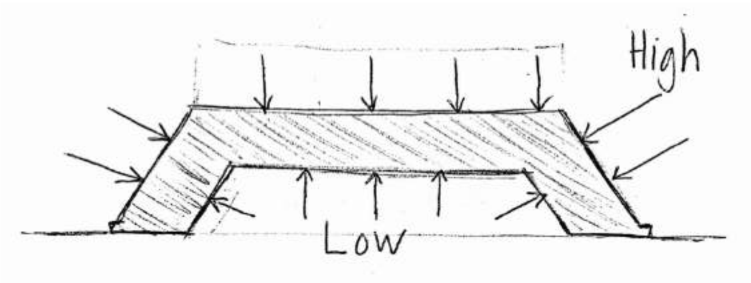


Figure 5.2 High atmospheric pressure and lower pressure inside the cup creates a force attaching the cup against the surface.

To create lower pressure inside the suction cup, different methods can be used. As seen in chapter 4.2.2 a suction cup with a screw was tested. The suction cup was flat, but when turning the oval screw the cup arose and created a lower pressure inside the cup, hence attached to the surface. By using a connected pump this can also be achieved. When pumping the pump, the air inside of the suction cup is sucked out and creates a lower pressure (Piab, 2004).

Suction cups are made out of extensible materials, most likely rubber, which gives a sealed grip surface and therefore a secure grip. If the surface is uneven, this can result in leakage and the suction cup releases. At higher vacuum levels, more energy is consumed for the work and the suction cup will wear out fast. Preferred would be to lower the vacuum level and use a suction cup with a larger grip surface and diameter instead (Piab, 2004). This is because the lifting and gripping capacity of a suction cup is defined by the following formula:

$$F = \Delta p \cdot A$$

F = Lifting force

Δp = Pressure difference between the atmospheric pressure and pressure inside the suction cup

A = Area of the suction cup

5.2.1.1 Experiment with vacuum

When doing the experiment, various suction cups were first investigated. Characteristics such as shape, diameter, grip surface, hardness and height varied, shown in Figure 5.3. According to Ekered (2019), a suction cup is constructed to manage a specific task, therefore an infinite number of various executions of suction cups can be found on the market today.

Figure 5.3. Various suction cups.

When experimenting with the process of creating lower pressure inside the suction cup, the arrangement was connected to an air flow, which generated pressure by the vacuum pump. The vacuum pump lowered the pressure inside the suction cup by sucking out the air from it. This result was obtained because a pump consists of two check valves, which allows the flow of air in one direction and prevents the flow in the opposite direction. In this case, one check valve is connected to the outside air and the other to the suction cup. When a pump is pushed inwards, the air is pushed out through the valve connected to the outside air, while the valve to the suction cup is closed. When the pump is returning to its original position, the pressure inside decreases, which opens the valve to the suction cups and air from the suction cup is being sucked out. At this point, the valve to the outside is closed. This procedure is done until the pressure inside the suction cup has reached the desired vacuum level and the suction cup attaches to the surface. The valve to the outside is then permanently closed. In this experiment, the vacuum pump was automated but the same procedure was obtained.

The project group also experimented with a throttle valve attached to the arrangement, presented in Figure 5.4. When the throttle valve was closed the vacuum was created as before and the suction cup was sucked towards the surface. Furthermore, by opening the throttle valve, the air was sent into the suction cup and it was released from the surface. It opens by screwing on the blue vent on the left side of the throttle valve, shown in the right circle in Figure 5.4.

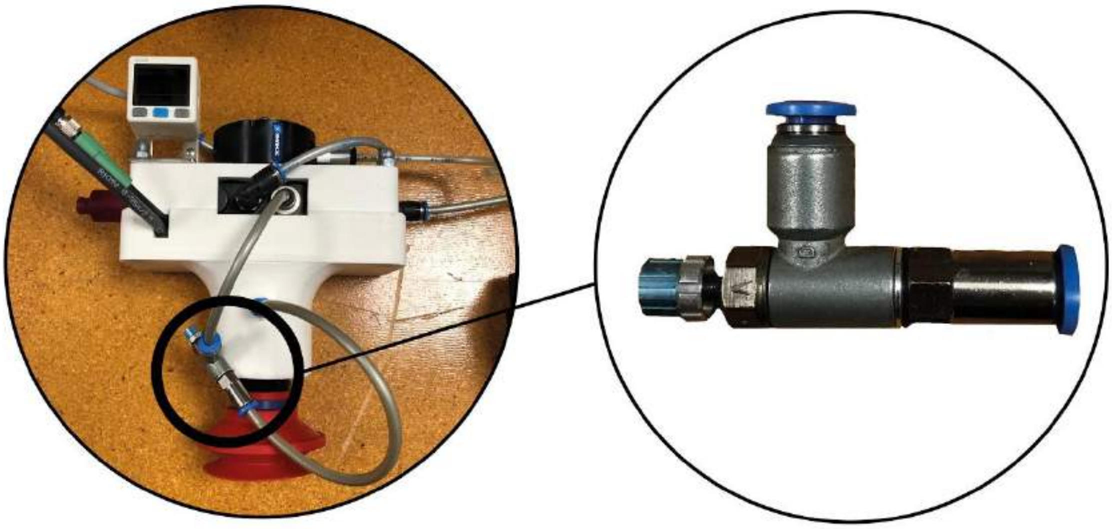


Figure 5.4. The throttle valve attached to the pump.

5.2.1.2 Significant aspects of suction cups

Based on the collected information in the thesis, crucial aspects of suction cups have been listed. They should;

- obtain a high vacuum level for best force
- manage the specific task they are constructed for
- manage lateral forces
- not damage the roof of the car
- be removable from the attaching surface
- manage environmental stresses e.g. heat, cold and liquid
- be able to be attached to a slightly curved surface
- be made of an elastic and airproof material

5.2.2 Development

After collecting further information about suction cups, valves and both their characteristics the development process of concept Seven continued with the information as underlying support.

First the suction cups were dimensioned, then the roof rack of concept Seven was analysed and lastly three mechanisms to fasten the suction cup device to the roof rack were created. This stage generated three new concepts with suction cups. CATIA was used to visualize the different parts of the concepts and its functions. At last, the concepts were evaluated in a Pugh-matrix against the list of requirements and each other.

5.2.2.1 Dimensioning of the suction cups

As stated in chapter 4.2.2, more testing and investigation had to be made to determine the size of the suction cup. Based on this and the information from chapter 5.2.1, the suction cups could be dimensioned. The four suction cups shall manage lateral forces due to acceleration, braking and turning when driving, and a load of 65 kg. If a product is placed on another surface and affected by lateral forces it also means that friction is a factor that impacts.

When calculating the number of g-forces that the load is exposed to during a break from 120 km/h - 0 km/h in 2s, the result was a number of 1,7 g-forces. Although to be on the safe side, further calculations were made with 3 g-forces. After calculating the number of g-forces an approximate coefficient of friction, μ, was calculated. With the help of the number of g-forces, a lateral force on the load could be calculated. Using the force and the coefficient of friction an approximate diameter of the suction cup could be calculated. The calculations resulted in an inner diameter of 0.16 m. All calculations are shown in Appendix 4.

5.2.2.2 Roof rack development

In concept Seven, the length of the rack was adjustable through a telescopic arm function and the suction cups fixed to the ends of the racks. A telescopic arm demands two different diameters which makes the rack less stable, tested in chapter 4.2.2. We asked the question *“Is it possible to position the suction cups wherever on the roof without the use of a telescopic arm?”*. While discussing this the realisation was made that the length of the rack does not have to be adjustable to fit different car models if the suction cups position on the racks is adjustable instead. This was done by adding a track to the bottom of the rack where a knob on the suction cup device can be slid in. The track can be seen in Figure 5.6.

Figure 5.6. The track where a knob on the suction cup device can be slid in.

5.2.2.3 The knob mechanism

A follow-up question was *"How should the suction cups attach to the rack?"*. To do this the knob on the suction cup has to be pushed against the top of the track. Three different mechanisms were generated.

The first mechanism was based on a suction cup that arises with the help of a screw, such as concept Seven. The suction cup would then be attached to a threaded screw that is connected to a handle. Between the handle and the knob is another screw that is threaded in the opposite direction. When turning the handle, the suction cup arises and the knob lowers towards the roof rack and attaches. The mechanism is presented in Figure 5.7.

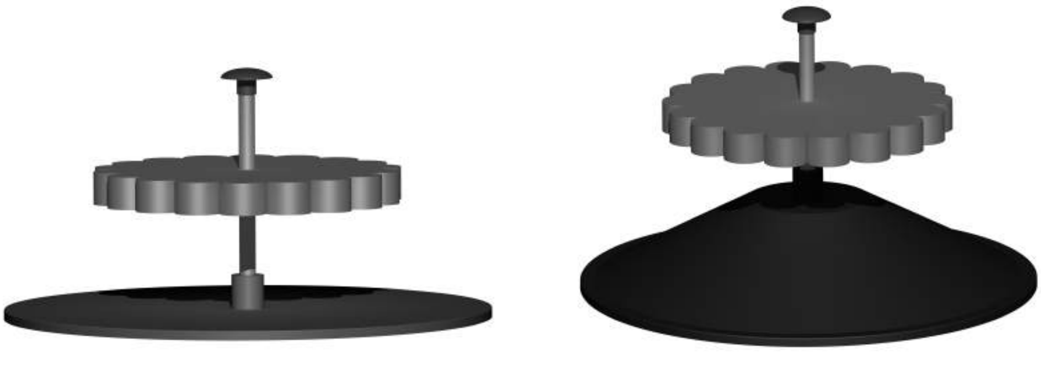


Figure 5.7. A mechanism to lower the knob.

The second mechanism created is shown in Figure 5.8. Here, the knob is attached to a horizontal axis with a wedge at the bottom. Another wedge in the opposite direction is attached at the end of a threaded vertical axis with a handle on the other end. By screwing on the handle, the horizontal axis moves inwards, thus the wedge presses against the wedge on the vertical axis and results in that the axis with the knob lowers. Hence, the knob presses down against the track on the roof rack.

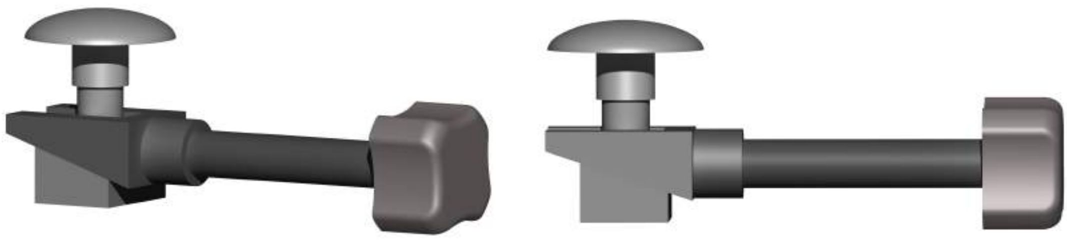


Figure 5.8. A mechanism with wedges that lowers the knob.

The third mechanism and its parts are presented in Figure 5.9. This knob mechanism is constituted by two components. The first component is the axis that the knob attaches to, and the second is a lever. When pulling the lever sideways, the angled surfaces presses down the axis and causes the knob to lower. The wings on the vertical axis prevent it from turning when the lever is pulled sideways. This mechanism is used to attach the suction cup device to the desired location on the roof rack.

Figure 5.9. The components that constitute the third mechanism.

5.2.3 Further developed concepts

The result from chapter 5.2.2 generated three concepts, with different knob mechanisms. Concept Seven got modified to Concept Seven 2.0 and since the project members had gained knowledge about suction cups and pumps, two concepts with a pump were created, TP and VaQ. The three concepts are presented below.

Concept Seven 2.0

Concept Seven was modified, now called concept Seven 2.0. Concept Seven 2.0 is presented in Figure 5.10. The first knob mechanism was used and when turning the handle on top, the suction cup arises and the knob lowers towards the roof rack and attaches. The length of the rack is adjustable with the help of a tent stick function instead of a telescopic arm function. The tent stick function makes it possible to separate the rack into two parts which halves the length. The rack also has a track underneath where the suction cup devices are slid in.

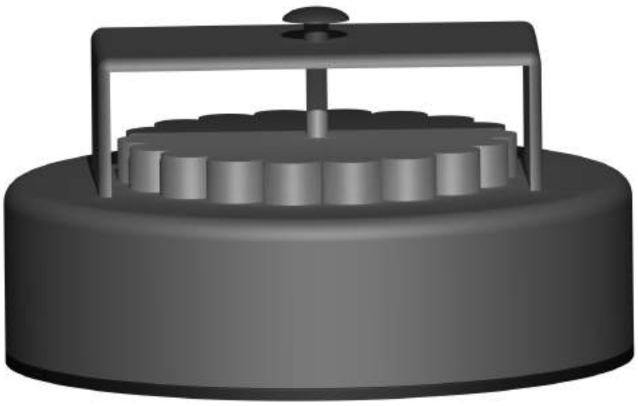


Figure 5.10. Concept Seven 2.0.

Concept TP

A concept called TP with a pump was created and is shown in Figure 5.11. TP stands for *Twisting Pump.* Here the second knob mechanism was used, with the two wedges. By screwing on the handle, the two wedges are met and pressed against each other which results in that the knob lowers and is fastened to the roof rack. The TP has the same rack as Seven 2.0.

Figure 5.11. Concept TP.

Concept VaQ

The second concept with a pump became VaQ which is illustrated in Figure 5.12. VaQ has the third knob mechanism which consists of two axes attached to each other. By pulling the lever sideways the knob lowers and attaches to the roof rack. The roof rack is the same as Seven 2.0.

Figure 5.12. Concept VaQ.

5.3 Pugh-matrix

A Pugh-matrix was compiled were concept Seven 2.0, TP and VaQ were weighed against the list of requirements and each other. The concept that met the list of requirements the best was concept VaQ and therefore the final concept. The Pugh-matrix is shown in table 5.1.

Table 5.1. *Pugh-matrix.*

Specification of requirements	Seven 2.0	TP	VaQ	Comments
Contain few components	0	0	0	All concepts has the same number of components
Shall be easy to understand	-	0	+	The bar of VaQ indicates that the lever can be pulled sideways
Should not prevent using other functions on the car	+	+	+	
External aid must be securely attached to car	0	0	0	
Lock on aid	-	-	-	No lock
External aid shall not damage the car	0	0	0	
Be stable when using	0	0	0	
All materials shall withstand the weather	0	0	0	
Materials shall be strong	0	0	0	
Materials can be recycled or reused	0	0	0	All concepts have the same materials
Follow laws of traffic	0	0	0	
Follow rules regarding car measurements	0	0	0	
Follow rules regarding the cars total weight	0	0	0	They all withstand a load of 65 kg based on calculations
Easy to mount/demount	-	+	+	The arch over the screwhandle covers the access to it
Indicate correct mounting/demounting	-	0	+	On VaQ the lever is pushed to the end of the bar. The screws on Seven 2.0 and TP is harder to know when correct
Few tools needed	+	+	+	No tools needed
Common tools used	+	+	+	No tools needed
Minimize time for mounting/demounting	+	+	+	
One person mounting/demounting	+	+	+	
Compatible with measurements of the car	0	0	0	Not an adjustable length of rack
Manage load of 75 kg	0	0	0	
Allowing one person to lift aid	0	0	0	
Facilitate an ergonomic mounting position	+	+	+	Short time to mount
Ability to exchange components of aid	+	+	+	Can update components
Minimize increased fuel consumption	+	+	+	By making it easy to demount the aid and a streamlined shape of rack
Allow recycling or reuse	0	0	0	
Possibility to store aid in car	+	+	+	
Minimize area when stored	+	+	+	
Ability to carry more than one type of product	+	+	+	
Adjustable to several different car models	+	+	+	
Have easy access to aid	+	+	+	
Have quick access to aid	+	+	+	
Encourage spontaneous use of aid	+	+	+	
Express safety	0	0	0	
Express trust	0	0	0	
Express simplicity	+	+	+	
Express stability	0	0	0	
Sum 0	17	19	17	
Sum +	16	17	19	
Sum -	4	1	1	
TOTAL	**12**	**16**	**18**	

6

PRESENTATION OF VIDE

Some modifications were made to VaQ to make it even better. The final concept is therefore called Vide and the name comes from the French word for vacuum. In this chapter, the final concept Vide is presented thoroughly.

6.1 Vide

Vide consists of two suction cup devices and one roof rack. Two pairs of Vide is required on a car. Vide is presented in Figure 6.1. The different components will be described further in the following chapters, alongside expression, manufacturing and chosen materials for the concept. In addition to this, sustainable development for Vide is presented.

Figure 6.1. The final concept Vide.

6.1.1 Suction cup device

The suction cup device is shown in Figure 6.2 and is made up of a suction cup, lid and a knob mechanism. The suction cup is the core component and made in rubber. It has a diameter of 16 cm, decided based on calculations in chapter 5.2.2.3. An aluminium ring is embraced by the rubber to enable mounting it to the lid, see Figure 6.3. When mounting, the aluminium ring and lid are first assembled by eight screws, then the suction cup is placed around the aluminium ring.

Figure 6.2. The suction cup device of Vide.

Figure 6.3. Top view of the suction cup.

The lid has a round shape. On top of the lid is a hole for an axis attaching a knob and on the side, is a bar with a lever. This is shown in Figure 6.4. On the inside of the lid, there is the mechanism which adjusts the height of the knob. It is constituted by the lever and the axis with the knob, shown in Figure 6.5. When pulling the lever sideways in the dog-shaped bar, the angled surfaces presses down the axis and causes the knob to lower. This is used to attach the suction cup device to the desired location on the roof rack.

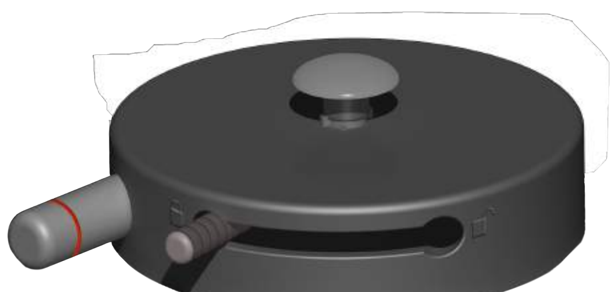


Figure 6.4. The lid to the suction cup.

Figure 6.5. The knob mechanism on Vide.

The lever has two sections with diverse diameters, larger in front and smaller in back. Since the bar is dog bone-shaped, the large part prevents the lever from gliding sideways and releasing the suction cup device from the roof rack. It is locked in place. If wanting to move the lever sideways, the lever must be pulled towards you so that the smaller part of the lever can pass through the narrow part of the bar, shown in Figure 6.6. The reason that the lever has to be pulled towards you is because it has a spring holding it back.

Figure 6.6. The lever pulled out so that the narrow part can pass through the smaller part of the bar.

The cylinder contains the pump used to create the vacuum in the suction cup. This is done by repeatedly pushing the pump inwards until the red line can no longer be seen, seen in Figure 6.7. The desired vacuum level is then reached. When the red line reapers, the pump should be pushed again. The system contains two check valves and one throttle valve. The two check valves are used to create the lower pressure inside the suction cup to attach the suction cup to the surface. When wishing to release the suction cups the throttle valve is opened and the air is sent back into the suction cup releasing it from the surface.

Figure 6.7 A sequence of the pump being pushed inwards.

6.1.2 Roof rack

The roof rack of Vide is shown in Figure 6.8. The rack has a streamlined shape to decrease the air resistance and thereby minimizing the increased fuel consumption when used. Since a tent stick function results in more loose parts, a hinge was added to the end of the two parts of the rack developed in chapter 5.2.2.2. The two halves are prevented from separating completely by an edge on both parts. This since one of the requirements was for the concept to contain as few loose components as possible. This makes it possible to fold the rack while it is still in one piece, which is presented in Figure 6.9.

Figure 6.8. The roof rack in pulled apart position.

Figure 6.9. The roof rack in folded position.

To prevent the hinge from folding while the rack is used, one of the parts is pulled over the joint, this shown in Figure 6.10. One part of the rack has a small hole in it while the other part has a small button that fits in the hole, similar to how crutches work. This is to prevent the two halves from sliding apart and exposing the hinge while using Vide. The button is easily pressed down to pull the two halves apart to fold the rack for easy storage.

Figure 6.10. The hinge and the part of the rack that is pulled over the joint.

The outer ends of the rack have a removable rubber lid to prevent dirt in the track, see Figure 6.11. These lids are opened when the suction cup devices are to be inserted into the track. Vide does not have integrated fastening straps, instead it has separate ratchet tie-downs will be used to fasten the load to the rack.

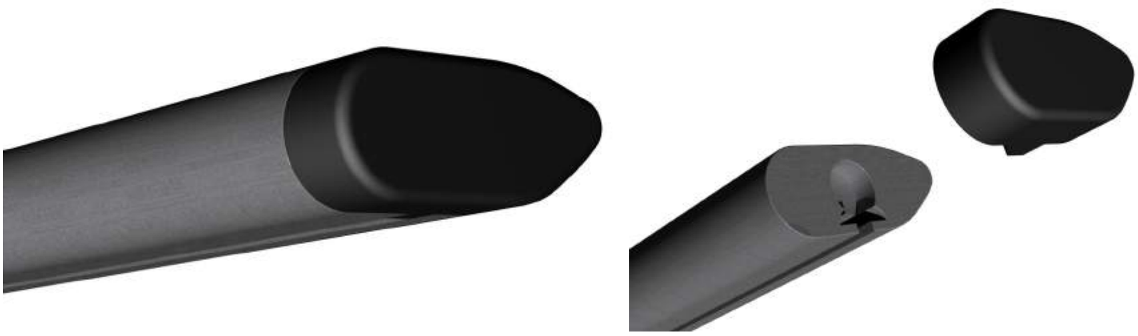


Figure 6.11. The rubber lids on the outer ends of the rack.

6.1.3 Other necessities

In chapter 4.2.3, we saw that the friction between a rubber anti-slip bottom and a wet surface lowers the friction. Furthermore, if attaching the suction cup to a dirty surface, it is not attached properly. To avoid this, a microfiber-cloth comes with the product. The cloth can be used to wipe the roof clean from dust and liquids before mounting the suction cups. The cloth can be washed in the washing machine. In addition to this, a bag is included. The purpose of the bag is to use it to store the different components of Vide when it is not mounted on the car.

6.1.4 Expression

Vide was shown to 14 people to see if they understood the overall manoeuvring of the concept. Most functions proved intuitive and easy to understand but some of them were not as obvious. Therefore, the symbols, icons and colours were applied to the suction cup device of Vide to increase the understanding and semiotic message. Vide was shown to the same people to confirm if the semiotic message was clearer with symbols, which it was. The used symbols, icons and colours are described further below and why they were applied to the final concept.

A locked lock icon was applied to the left side of the bar to show that the suction cups are securely attached to the roof rack and an unlocked lock icon to the right side of the bar to show that the suction cups are loosened from the rack and can be slid or removed. This is shown in Figure 6.13.

Figure 6.13. The unlocked and locked symbols on Vide.

A bright red line around the pump indicates the correct vacuum level, illustrated in Figure 6.14. The pump shall be pumped until the line no longer shows, as mentioned previously. The red colour is used since it symbolises warning, as described in chapter 2.4. If the red line begins to show it indicates that the vacuum level is becoming too low. The pump then has to be pumped until the line is not showing.

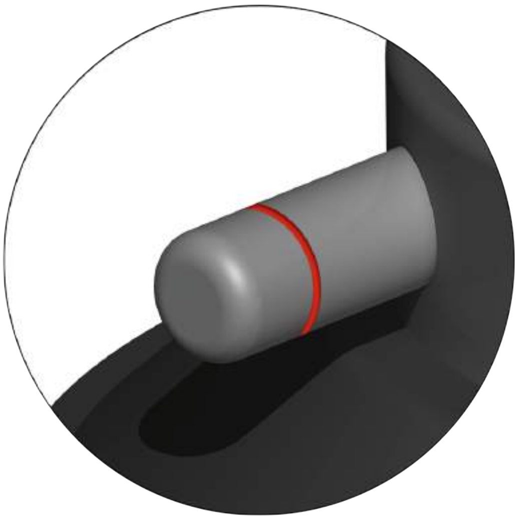


Figure 6.14. The red line on the pump.

To help users understand that the lever shall be pulled out in order to be able to move it sideways, the top of the lever is covered in matte rubber with vertical elevated lines, visible in Figure 6.15. This to indicate a good grip horizontally, hence indicating that the lever shall be pulled out.

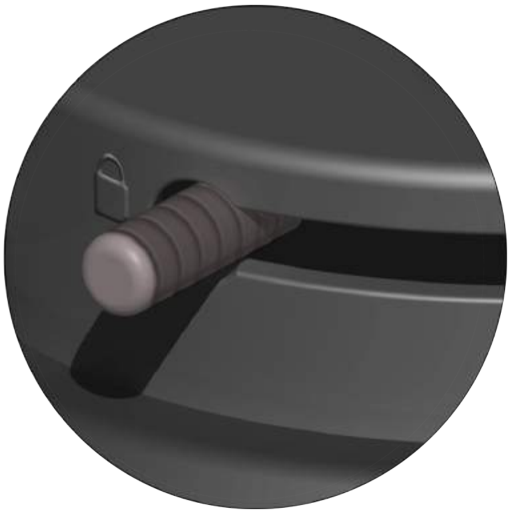


Figure 6.15. The lever with vertical elevated lines.

6.1.5 Manufacturing and material

Suitable methods of manufacturing for each component are suggested and presented below, alongside the justification of choice of material.

Roof rack

A fitting method of manufacturing for the aluminium roof rack is extrusion. Aluminium has a low density, it is ductile and reusable. If aluminium is mixed with other metals, the material gets light with high strength. The re-melting of aluminium requires only about 5 % of the energy required for new production, which makes aluminium parts to a very valuable raw material (NE, 2019).

Suction cup

The suction cup is preferably manufactured by moulding. The suction cup must be elastic because of its characteristic of returning to its original shape when being released from the surface, therefore the material chosen was rubber. Rubber is a common name for different substances that are elastic and extensible. Today, people have learned to manufacture artificial rubber from oil and natural gas, since natural rubber is depleted. The artificial rubber can be recycled and reused (NE, 2019).

Lid

A suitable manufacturing method for the lid is compression moulding. The material chosen was thermoplastic. Thermoplastic is ductile and has a low density. It can also be recycled (NE, 2019).

6.2 Sustainable Development

The principles of sustainable development described in chapter 2.8 have been analysed with respect to concept Vide. It is described in the following text.

The most critical component of concept Vide is the suction cups. The importance of having the right properties of the rubber is great for a suction cup, which was established in 5.2.1.2. They have to be in perfect shape to attach to the car properly. To keep the rubber of the suction cups elastic as long as possible, they must be maintained. This can be done with various rubber treatments in store.

If the suction cup, or any other component of Vide, is damaged, it can easily be detached and exchanged since the components can be separated. This means that one does not have to buy a whole new product if only a part of it is damaged.

The components of Vide make for a quick and easy mounting and demounting. Apart from contributing to a more spontaneous usage, this also prevents the risk of Vide not being demounted when not used. This is something that contributes to a more sustainable behaviour since driving with extra weight and air resistance increases fuel consumption. The roof rack is streamlined which also decreases the fuel consumption while using Vide and answers to the design process of Design for a sustainable behaviour.

An aspect for the future is to develop a rental service for Vide, where you can rent the product in whole or specific components. Another idea is to develop a subscription service for e.g. the suction cups. Furthermore, new suction cups could be sent out when the recommended end time for use begins to approach. The user then sends back the old suction cups, which can be recycled. The suction cups can also be sent to the manufacturer for maintenance. This could change the mindset of users and enable them to reduce their consumption of things and resources.

Another aspect of the future is to make the manufacturing of the components more effective so that the waste material generated during the manufacturing process shall be minimized. The waste material could be used in other processes or recycled. Regarding the material, natural rubber could be used for the suction cups in the future and re-melted aluminium for the roof rack.

7

DISCUSSION

In this chapter, the identification of problems and how Vide answers to these, is discussed and concluded. Aspects such as the dissemination of participants of the user studies and the future development of Vide are mentioned.

7.1 Identifying problems

This chapter discusses and concludes the outcome of the objective *"What problems and unfulfilled needs regarding the transportation of objects with LCSs can be identified?"* and the process to obtain the result.

Based on the information retrieved from the problem identification phase, an abundance of unfulfilled needs was mapped. These unfulfilled needs were categorized into different problem areas; *flexibility*, *placement*, *spontaneity*, *storage*, *mounting and demounting* and *safety*.

To identify unfulfilled needs, a series of user studies were executed. An aspect that can be discussed is if the same result would have been obtained if other participants would have participated in the user studies? For instance, the result from the focus group might not have been exactly the same if five other participants had participated since opinions always differ. For instance, participant 3 has good knowledge in roof boxes, while participant 1 has good knowledge in bike racks. Their previous experiences might have made them a bit narrow-minded towards the well-known LCS, but their good knowledge also provided with great thoughts about what could advance. Furthermore, participant 4 had no previous experiences of external LCSs, had no preferences and therefore was not biased which contributed with a neutral mindset during the discussions. Since the participants were chosen on the terms of them together having a wide background with different interests and opinions, hence the discussions of the focus group reached a broad level. The members of the project therefore believe that the retrieved result is credible and covers a wide picture.

The idea of interviewing Olof at Mekonomen was to gain a neutral view of the current LCSs on the market. Although, while performing the interview, we learned that Mekonomen mainly sells products from Thule, and we felt that he was a bit biased towards their products. For example, he expressed; ”other brands than Thule, when it comes to LCSs, does not really exist on the market.”. If interviews would have been made with experts from a specific brand, e.g. Thule, the person would most likely have best knowledge in the products of the specific brand and would not have provided us with a neutral picture of different external LCSs. To gain a wide range of knowledge, the optimal situation would have been to interview several specialists from different manufacturers as well as someone with knowledge about LCSs in general.

The survey was distributed digitally through the social medias Facebook and LinkedIn and through Escenda's weekly newsletter. The age of the respondents was between 21 – 68 where the quantity of respondents with a younger age were higher than the quantity of respondents with an older age. Distributing the survey on social media might have attracted a certain type of respondents, e.g. people our age (21 – 27 years) and from our acquaintance. One might argue that people of an older age have more experience in using LCSs and therefore it would have been preferable to even out the age ratio. To increase the quantity of respondents with an older age we could have distributed the survey through the newsletter at an earlier stage so that it could have circulated for a longer period of time. Furthermore, avoid the use of Facebook might have decreased the quantity of younger respondents, but at the same time, the overall number of respondents would have been lower.

The importance of different aspects regarding a product varies based on a person's perception and mental models. Cultural, religious and social aspects influence how a person perceives a product. There is a strive to design for everyone, but based on people's perception and different opinions, it is hard to do so. The identified problem areas might have been different if the project focused on another country than Sweden, due to the aspects mentioned above.

7.1.1 Conclusion

The conclusion that can be drawn from the discussion above is that, even though the age and knowledge of the participants of the user studies varied, the information they contributed with covered a wide spectrum. Therefore, the identified problem areas mapped in this thesis are trustworthy and relevant to the subject.

7.2 How Vide solves the identified problems

This chapter discusses and concludes the outcome of the objective: *"How can a future LCS be designed to solve the problems and fulfil the needs?"*.

How does Vide answer to the identified problem areas; *flexibility*, *placement*, *spontaneity*, *storage*, *mounting and demounting* and *safety*? Vide can be attached to every car with a roof which allows for a flexible use. In terms of safety, calculations have been made to dimension the suction cups and the red line on the pump indicates when the right vacuum level has been reached for the suctions cups to be securely attached to the car. It was also expressed that roof mounted LCSs are perceived to be the most secure when it comes to placement. Vide also enables spontaneous use since it consists of few components and is easy to mount and demount with no tools needed. The fact that all components can easily be separated and the rack is foldable allows for small storage. As stated, one can see that many of these problem areas are fulfilled by crossing each other. This was not something that was planned, but gave a positive outcome since we did not have to apply a bunch of redundant functions just to solve the problem areas one by one.

Most people's mental model of a suction cup is that they are not very safe, the first thing that comes to mind is e.g. those suction cups used in the bathroom to hold soap which tends to fall down after a while. We were not convinced about the safety of suction cups until we had done the research. Vide has symbols and such to increase the intuitive manoeuvring and to create trust, but the expressions of Vide might still not convince potential users that has not been in contact with vacuum suction cups earlier. To ensure trust in this kind of suction cup, further work has to be done to establish the semantic message and thereby eventually change the mental model of suction cups.

When this is reached, Vide could potentially be developed further with additional components which could be used together with the components of Vide and allow transportation of a wider range of things. This could form a product series where Vide is the core product. Noted should also be that, as products develop over time and trends shift, the current needs vary. Something that is very coveted right now might not at all be in 10 years. Or another manufacturer might fulfil a need in a better way. With this in mind, a product that is adaptable and can be updated over time without having to buy a whole new product might be most optimal. This so that the product can easily adapt to and follow varying trends and such, without putting too big of an effort on the manufacturer or the user.

7.2.1 Conclusion

Concept Vide is a trustworthy concept that fulfils the identified problem areas regarding a spontaneous and flexible use of an external LCS. In the future, more associated components can be developed that attaches to the components of Vide.

8

RECOMMENDATIONS

The final result of this project is a concept which is perceived as trustworthy and fulfils the unmet needs and identified problem areas. Although, continued work with calculations and dimensioning of the suction cup is recommended, hence create a suction cup for the only purpose of being attached to the roof of a car that can manage a greater load and thereby larger forces.

Another recommendation is to construct a working prototype that can be tested and validated in various situation of usage. This so that the concept can be developed into a working solution with the potential of being produced.

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APPENDIX 1

INTERVIEW AT MEKONOMEN

2019-02-11, Backaplan

Matilda: Vi kollar på det man sätter på utsidan av bilen för att frakta t.ex. cykel, skidor, och sånna saker. Vilket sånt tillbehör/hjälpmedel säljer ni mest?
Mekonomen: Ja det borde vara takräcken och liknande, och cykelhållare och sånt. Det blir ju Thule produkter är ju det som folk mest behöver extra så att säga, för semestrar och fritid och liknande. Det finns ju dekorationer och sånt också men det säljer vi absolut inte lika mycket.
Matilda: Är det Thule ni säljer mest av? Har ni några andra märken här?
Mekonomen: Andra märken när det gäller takräcken och sånt finns ju nästan inte.
Emma: De är ganska ledande?
Mekonomen: Absolut!
Emma: Är det något specifikt hjälpmedel som du anser vara mest populärt, t.ex. takbox eller cykelställ eller något annat? Handlar det om säsong?
Mekonomen: Ja men många behöver ju takräcken bl.a. om du vill ha cyklar på taket och inte har dragkrok så måste du ju i grunden ha ett takräcke. Vill du ha en takbox måste du ha ett takräcke. Så takräcken blir väl kanske grundprodukten.
Emma: Det behöver de flesta?
Mekonomen: Ja. Sen är det ju så att cykel har ju blivit en stor del för många människor, det är ju väldigt mycket folk som har cyklar nu för tiden, så har de dragkrok så köper de ju andra cykelhållare för att sätta på dragkroken för det är ju enklare givetvis.

Matilda: Vi har väl kanske lite fått svar på detta, men finns det något som man faktiskt kan använda till flera ändamål?
Mekonomen: Ja men takräcken kan du ju, det kan ju användas till vad du vill nästan.
Matilda: Vad är de vanligaste frågorna ni får kring de här hjälpmedlen, säg takräcken då? I.o.m. att det är det ni säljer mest.
Mekonomen: Det är ju inte så mycket mer än att det ska passa deras bil för det finns väldigt många olika räcken idag till bilar. Förr i tiden hade man bara ett par räcken och så täckte man hela bilparken. Idag finns det flera hundra olika sätt att greppa runt taket, det är ju det som är helt annorlunda för konstruktionerna på taken är ju helt annorlunda än vad de var för 20 år sedan. Så det är lite svårare att köpa räcken idag kan man säga.
Emma: Men hur många olika delar behövs idag för att t.ex. takräcket ska passa en specifik bil?

Mekonomen: Thule har ju gjort så att de gör det i delar, man köper tre produkter normalt sett. Man köper stängerna för sig, foten för sig och det som gör att det passar bilen. Och det som är så specifikt är ju, det skiljer ju givetvis på fötter och stänger, men inte så mycket som det skiljer på det som passar bilen. För det är ju det som är den stora grejen, att hitta det som gör att räcket sitter kvar på bilen.

Matilda: Är det något du upplever som många *kunder* känner saknas, någon funktion gällande dessa hjälpmedel?
Mekonomen: Nja, inte så egentligen, takräcken har ju sin funktion om vi talar om takräcken, det är ju så. Man kanske tycker det är dyrt, men det är ju ingen funktion. Men det är ju så i.o.m. att de har blivit så specifika räckena, just det här med att greppa tag runt bilen, så är det ju bara stora tillverkare som kan tillverka takräcken till alla bilar. Och produktionen blir ju såklart mycket mycket dyrare när du ska ha flera hundra olika specifika kit som ska vara formanpassade efter olika bilar, än vad det var för 25 år sedan när det räckte att du hade 5 räcken och så täckte du 95% av bilbanken (?) Och kunde vem som helst öppna en fabrik då och tillverka takräcken, idag är det inte lika enkelt.

Matilda: Har du någon personlig favorit kring, om vi säger liksom olika hjälpmedel?
Mekonomen: Nja, man skaffar ju inte personliga favoriter så egentligen man är ju här för att hjälpa kunderna. Det är ju deras favoriter som blir det.
Mekonomen: Jag har inget takräcke, men jag har inget behov av att ta med mig cyklar och sånt heller. Ibland finns det olika lösningar, som att hyra ett cykelställ eller takbox. Min fru ville ju ha en cykel på landet och då ville hon ta med sig sin cykel till landet, men det var billigare att köpa en cykel och ställa på landet för 3000 kr än att släpa cykeln fram och tillbaka. Då tog jag beslutet att vi köper en cykel istället. Jag tog beslutet att vi köper en cykel till istället. Så slipper vi hålla på och kånka den om det är bara dit vi vill ha den. Aaa visst hade man haft den till massa olika ställen, ja då hade man behövt skaffa något för att frakta den i ekipaget. Men i det läget var det enklare att köpa en ny cykel.
Matilda: Är det någon särskild finess som du hade uppskattat om du hade haft ett hjälpmedel?
Mekonomen: Ja men alltså de har utvecklat takräckena rätt mycket idag faktiskt. De nya aluminiumrören är som ett sånt där T-spår. Köper du en cykelhållare idag så är ju den färdig med de här T-spårsadaptrarna satt i så du skjuter egentligen bara in cykelstället i adaptrarna och sätter fast det. Så Thule är ju långt framme med att göra det användarvänligt.

APPENDIX 2

INTERVIEW GUIDE FOCUS GROUP

När? 27/2 kl. 17.15

Var? Escenda; grupprum Nobel

Hur? Fika och kaffe i grupprum

Inledning

- Hälsa välkomna vid dörren, visa vart de kan hänga av sig och bjud på fika och kaffe. Fika ca 5-10 min.

- Dagens agenda!

- Presentera oss och **exjobbet** kortfattat
    - Vi undersöker hur man transporterar saker utanpå bilen med hjälp av externa tillbehör, som t.ex. taxbox, cykelställ. Målet är att utveckla en produkt som uppfyller något behov, som dagens produkter inte uppfyller.

- Fokusgrupp
    - **Hur går det till?**
        - berätta att vi spelar in!
        - beskriva våra roller: moderator och sekreterare.
        - handlar om att diskutera fram saker, väcka tankar! Var inte rädda att komma med åsikter
    - **Syftet med fokusgruppen:** "*Vi vill ha er hjälp med att hitta dagens ouppfyllda behov, och därmed komma fram till ett antal problemformuleringar som vi sedan kan jobba vidare med i projektet.*"
    - **Varför ni är här:** Anledningen till att just ni är här är för att ni har olika bakgrund och olika mycket erfarenhet av detta och vi vill gärna få synpunkter från lite olika perspektiv. Vi vet att inte alla har sånna här hjälpmedel hemma, eller ens en bil, men vi kommer måla upp lite scenarion och ni kan också tänka tillbaka på hur din familj gjorde/gör, eller andra i din bekantskap.

- Alla i gruppen presenterar sig!

Ice-breaker:

Vi kör igång med ett par bilder på olika lösningar bara för att få igång era tankar. Ni kan berätta vad ni tänker på när ni ser dessa bilder.

Inledande frågor:

Laget runt:

- Brukar ni personligen eller i familjen använda externa hjälpmedel för att transportera saker med bil? Vilka typer?

Lämna ordet fritt:

- Till er som har hjälpmedel: Hur länge brukar de sitta på? Varför?

- Är det något hjälpmedel som ni alltid har med er? Eller hade önskat att ni alltid hade med er?

Diskussionsscenarion

Scenario 1.

Tänk att du har varit på Ikea med din kompis, ni har hyrt en bil via SunFleet och denna gång blev det en Volvo v70. Din kompis ska köpa ett nytt hörnskrivbord till sin nya lägenhet. När ni kommer ut från affären inser ni att denna går inte in i bilen.

Känner ni igen detta/har ni varit med om något liknande?

Hur går ni tillväga nu?

Om ni inte skulle ge upp hoppet på skrivbordet, hur skulle ni bära er åt för att lyckas med att transportera hem det?

Vad hade ni önskat ha tillgång till vid detta tillfällen?

Scenario 2.

Det är dags för skidsemester med familjen. Ni är två föräldrar och två tonårsbarn. Alla har sin egna skidutrustning som skall med till fjällen så ni har rivit fram er takbox från källaren. Du tar på dig att montera takboxen samt packa bilen kvällen innan så att ni kommer iväg snabbt på morgonen.

Känner ni igen detta/har ni varit med om något liknande?

Hur känner du när du tänker på att du ska montera takboxen? Vad får du för känslor?

Hur känner du när du tänker på att du ska packa takboxen? Vad får du för känslor?

(Vad ser du som omständligt när du tänker på detta scenario?)

Känns det som om du i verkliga livet hade monterat och packat takboxen helt själv eller hade du föredragit att få hjälp?

Hur säker känner du dig med att lämna skidutrustningen i takboxen? Säg att ni ska åka långt och behöver stanna över natten, eller ska på afterski osv. Är det någon skillnad mellan olika situationer?

Finns det något som du upplever att takboxen saknar idag?

Scenario 3.

Du och din partner har båda en ledig helg. Ni har spanat in vädret och det ska bli soligt, perfekt för lite SUP tänker ni! Ni brukar lasta brädorna på taket på bilen. Du är i det kortare laget och din partner har en axelskada som har börjat värka igen, vilket gör det problematiskt att få upp dem och fästa ordentlig på taket.

Känner ni igen detta/har ni varit med om något liknande?
Med detta i åtanke, vad hade kunnat underlätta lastningen av SUP-brädorna?
Hur hade man kunnat skapa en bättre arbetshöjd

Scenario 4.

Du ska ta bilen till jobbet på morgonen, precis innan du åker säger ditt äldsta barn att hen glömde sin cykel på stan igår och undrar om inte du kan ta hämta den på vägen hem.

Känner ni igen detta/har ni varit med om något liknande?
Visa bilder på olika cykelställ och fråga vad de har för tankar kring de olika varianterna?
Hur skulle ni säga att de här fungerade/monteras? (dvs förstår de hur de funkar?)
Vilken av cykelställen hade ni föredragit att snabbt montera eller ta med i bilen, innan ni åker till jobbet, i detta scenario?
Om ni istället skulle åka en längre sträcka, vilket cykelställ hade du då föredragit?
Vilket upplever du vara det bästa och mest säkra?
Om man nu tänker att barnet har en elcykel, ändrar detta något kring situationen? BILD på elcykel?
Finns det något som du upplever att cykelställ saknar idag?

Scenario 5.

Ännu en semester med familjen (samma som innan; två föräldrar, två barn) men denna gången en bilsemester i Europa under sommarlovet, där ni har packat i både bilens bagageutrymmet, takbox och box på dragkrok (lasthållare). Tanken är att ni ska bo i stugor på olika campingar och sen göra dagsutflykter med bilen. Men då bränsleförbrukningen ökar med de externa tillbehören (vikt, form etc) vill ni helst ta av dessa när ni gör utflykterna.

Känner ni igen detta/har ni varit med om något liknande?
Vilka krav hade ni velat ställa på tillbehören för att enkelt kunna montera och demontera?
Hur hade ni fördelat packningen/lasten mellan bagage, takbox och box på dragkrok?
Hur skulle ni förvara hjälpmedlen när de inte är på?
Hur hade ni förvarat dem hemma?
(Finns det något bättre sätt än så ni förvarar det idag?)

Scenario 6.

Du och en kompis “spontanåker” med din bil (lånebil/föräldrars bil/kompis bil?) till en loppis en bit utanför stan. När ni gått runt ett tag ser du en bokhylla som skulle passa perfekt i ditt sovrum. Du vill verkligen ha denna bokhylla!!!! Bilen har ingen dragkrok så att hyra släp är uteslutet.

Känner ni igen detta/har ni varit med om något liknande?
Hur hade ni löst det här problemet?
Vad för hjälpmedel hade du velat ha i detta läge?
Om du hade haft takräcken hemma, vad är anledningen till att du inte tar med dem, bortsett från glömska? Tänk “ta med egen påse till Ica”.

Ranka scenarion

Återberätta och sammanfatta de olika scenariona och låt deltagarna ranka dem. Dela ut rankningspapper och låt de fylla i enskilt. Skala: minst problematisk → mest problematisk

Frågor

- *När ni tänker på situationen att lasta saker med externa tillbehör, vad ser ni som det största problemet idag?*
- *Vad finns det för behov som ännu inte är uppfyllda vad gällande detta ämne? Vad saknas idag?*

Idégenerering

Nu tänkte vi att ni skulle få spåna på egna idéer utifrån det ni har diskuterat tidigare. Ni får 5 minuter att prata med er granne och sedan får ni presentera era idéer.
*(*Låt de diskutera och rita om så önskas)

Presentationen skall innehålla:
- *Hur hade era lösningar sett ut?*
- *Vad inkluderas i lösningen?*
- *Vilka behov skulle då uppfyllas?*

Övrigt:
Har ni några övriga funderingar eller åsikter?
Hur tyckte ni det var?

Tack för er medverkan!

APPENDIX 3

MORPHOLOGICAL MATRIX

Functions	Solutions														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Fastener on car	"Classic" on rail	Crutch lock	Magnetism	Snowboard binding - Ladder straps	Skiboot buckle	Zipper	Trousers belt	Ratchet tie-downs	Elastic bands	Buttons	Drawstring	Helmet buckle	Helmet adjustment	Clamp	Suction cup
Foldable/extendible	Telescopic arm with snap	Origami	Net	Ladder	Inflatable	Umbrella	Telescopic arm - mop	Soft material	Tetris	Telescopic arm - binocular	Tent stick/sond	Crutch	Bathroom mirror	Vacuum cleaner	Lightweight jacket
Fastener for products	T-Slot	Friction	Hooks	Net	Ratchet tie-downs	Elastic bands	Drawstring	Trousers belt	Elastic strap with hook	Helmet adjustment	Helmet buckle	Screw			
Shape cross section	Round	Streamlined	Square	Rectangle	Triangle	Hexagon	Octagon	Semicicle	Cross	T-shape	Bone				
Support against car	Soft material	Hard material													

APPENDIX 4

CALCULATIONS

a = acceleration

v = velocity in m/s = 33,3 m/s

V_0 = velocity at t_0 = 33,3 m/s

V_1 = velocity at t_1 = 0 m/s

t_0 = start time = 0 s

t_1 = end time = 2 s

X = number of g-forces that the load is exposed to (unknown)

g = gravity = 9,82 m/s² in Sweden

$$a = \frac{V_0 - V_1}{t_0 - t_1} = \frac{33{,}3 - 0}{0 - 2} = -16{,}67 \ m/s^2$$ (the negative value implies a deceleration)

This assumes that the car slows down with a uniformly accelerated movement

$$X = \frac{|a|}{g} = \frac{16{,}67}{9{,}82} \approx 1{,}7 \ G$$

∴ Breaking from 120 km/h (33,3 m/s) to 0 km/h in 2s exposes the load to 1,7 g-forces

$A_{tät} = \frac{\pi}{4}(D_y^2 - D_i^2)$

$F = p \cdot A_{tät}$

$D_y = 153\ mm = 0.153\ m$

$\Delta p = p_{atm} - p_o \quad (1)$

$D_i = 150\ mm = 0.150\ m$

$F_L = 425\ N$

$\uparrow: F - (p_{atm} - p_o) \cdot A_i = 0 \Rightarrow$

$\Rightarrow p \cdot A_{tät} - (p_{atm} - p_o) \cdot A_i = 0 \Rightarrow$

$\Rightarrow p = (p_{atm} - p_o) \cdot \frac{A_i}{A_{tät}} \quad (2)$

Colombs lag $\Rightarrow \tau < \mu \cdot p$

$\rightarrow: \tau_{medel} \cdot A_{tät} - F_L = 0 \Rightarrow$

$\Rightarrow F_L = \mu p \cdot A_{tät} \Rightarrow \mu = \frac{F_L}{A_{tät} \cdot p} = [\text{insättning av } (2)]$

$= \frac{F_L \cdot A_{tät}}{A_{tät} \cdot \Delta p \cdot A_i}$

insättning i (1) $\Rightarrow \mu = \frac{F_L}{\Delta p A_i} = \frac{425}{0.6 \cdot 10^5 \cdot \left(\frac{\pi \cdot 0{,}15^2}{4}\right)} = 0.4$

$\underline{\underline{\mu = 0.4}}$

F_L = lateral force [N].
μ = coefficient of friction = 0.4
A = area [m^3]
D = diameter [m]
g = gravity $\approx$ 9.82 m/s^2 in Sweden
m = mass = 65 kg (weight of load)
x = number of g-forces the load is exposed to = 3

$\Delta p = 0{,}6 \cdot 10^5$ Pa
F_V = vertical force [N]

$$F_L = m \cdot x \cdot g = 65 \cdot 3 \cdot 9{,}82 \approx 1915 \text{ N}$$

$$A = \frac{F_L/4}{\mu \cdot \Delta p} \quad (1)$$

[F_L is divided by 4 since the load is distributed over 4 suction cups]

$$(1) \Rightarrow A = \frac{1915/4}{0{,}4 \cdot 0{,}6 \cdot 10^5} \approx 0{,}02 \text{ m}^3$$

$$D = \sqrt{\frac{A \cdot 4}{\pi}} = \sqrt{\frac{0{,}02 \cdot 4}{\pi}} = 0{,}1596 \approx 0{,}16 \text{ m}$$