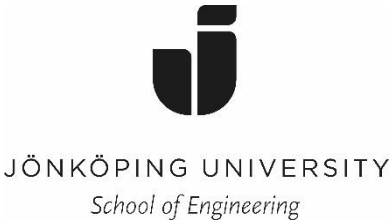

Conceptual design and development of an off-road cargo trailer for bicycles

PAPER WITHIN: *Product Development – Product Lifecycle Management (PLM)*

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Abstract

This report presents the conceptual development of an off-road cargo trailer designed for usage in conjunction with bicycles when camping. The objective of the study is to address the limitations of existing cargo trailers and thereafter create a trailer that efficiently can navigate off-road terrains while carrying various types of cargo. The research includes collecting data regarding user behaviours and desired functions an optimal trailer should obtain and was translated into user requirements. The result demonstrates the successful development of an off-road cargo trailer on a conceptual level that offers innovative solutions and improved load-carrying capacity in comparison to the available market, while considering factors such as weight, manoeuvrability, and ease of use. This research contributes to the field by presenting data, which can be used in development and a comprehensive solution that expands the possibilities for bicycle-based cargo transportation in off-road environments. Future work can include further refinements to optimise the trailer's performance and address additional user requirements based on the data presented.

Summary

Purpose - A trend that gained momentum during the pandemic is camping and spending time in the nature. A popular activity and transportation method used is often bicycling in many forms. However, combining biking and camping makes it problematic to carry the necessary packing for spending extensive time outdoors. Due to that, the company this project is in collaboration with have seen a need in the market. Therefore, the purpose of this paper is to design and develop a bicycle trailer on a conceptual level that can carry a significant amount of cargo in various terrain.

To address the purpose, three research questions have been formulated: (1) What are the needs that users have regarding a bicycle trailer when camping? (2) What are the challenges the users have with a trailer in an off-road environment? (3) How can the design of the trailer be developed to cover all these needs and requirements?

Methodology - The research in this paper required data collection using both qualitative and quantitative methods in form of survey, user journey, and different sort of tests. Knowledge about the topic was also received through the theoretical framework, where relevant topics within the area was investigated and analysed.

Findings and analysis - The survey contained both a questionnaire, which mainly stood for the quantitative data and together with that interviews were performed which represented the qualitative data. Beyond that, user journeys performed at two different occasions, with two various trailers to gain a deeper understanding for how they work practically. Two different types of tests were also performed in form of a load testing and a turn testing. This contributed with insights about limitations and facilitated the process of establishing requirements in the product specification.

Discussion and conclusions - The final concept resulted in what can be seen as the core or basis of the trailer, which enables going out in the nature and spending a few nights there on a simple level. If the customer wants to improve the experience, the idea is that they can buy accessories that makes the trailer more useable. The concept presents innovative ideas as the telescopic function to lengthen and shorten the trailer and new ways of thinking in combination with improved features that is already available on the market.

Keywords

Camping, outdoor life, off-road, cargo trailer, bicycle trailers, bike trailers, and mountain biking.

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1 Introduction

This project is carried out in collaboration with a company that sees a need for an off-road cargo trailer for bicycles. The project aims to explore a new market segment and gather data to be used for exploring ideas and conceptual work of how such a product could look like. This exam work has been carried out at the School of Engineering in Jönköping in the subject area Product Development and the work done in this report is part of the education. During the project different concepts and solutions will be examined, where functions, user needs, materials, and costs will be considered and evaluated.

1.1 Background

The use of bicycles as a mode of transportation and amusement is something that has been existing for quite some time but has increased in popularity in recent years. Bicycles are cost effective, environmentally friendly, and a healthier alternative to motorized vehicles. However, the limited cargo capacity of bicycles can be a barrier for some users, especially those who want to use the bicycles for longer adventures or for carrying heavy load. This has led to the expanding market of bicycle trailers and cargo bikes to increase the load capacity of bicycles.

Bicycle trailers have been traditionally designed for pavement use but there is a growing interest in off-road cycling and the use of bicycle trailers in off-road environments. Off-road cycling includes a variety of different terrains that can be challenging, and it is important for bicycle trailers to be designed to withstand the harsh conditions of off-road terrains.

Most bicycle trailers available on the market is aimed at carrying children or dogs in an urban environment. The design and development of bicycle trailers intended to be used in an off-road environment is a relatively new field of research, with a focus on improving the design and functionality of these trailers to meet the specific needs of off-road cycling. However, there are still many challenges to be addressed, such as weight reduction, stability, functionality, manoeuvrability, and cargo capacity.

1.2 Problem area

A trend that gained momentum during the pandemic is camping and spending time in the nature. A popular activity and transportation method used is often bicycling in many forms. However, combining biking and camping makes it problematic to carry the necessary packing for spending extensive time outdoors.

The current market offers products that are often heavy, difficult to manoeuvre, and are not constructed for rough conditions and off-road terrain. This results in limited use and poor performance, which limits the capabilities of the cyclists and restricts the places possible to travel. Therefore, a need for a bicycle trailer that is lightweight, stable, easy to operate, able to carry a significant amount of cargo, and intended to be used in an off-road environment can be identified. It should be easily attachable and detachable from any bicycle and withstand harsh conditions and rugged terrain of off-road environments. The user should be able to bring and pack their cargo in a convenient manner that does not limit their intended trip, nor make it significant more difficult.

1.3 Project purpose and aim

This master thesis aims to address these challenges by developing a bicycle trailer that can be drawn by a bicycle in an off-road environment, while carrying a significant amount of cargo. The research will focus on identifying what cargo the user brings in the trailer while camping, in what scenarios the trailer might be used, and which type of terrain and activities the trailer

might be exposed to. Final deliveries will be in form of a prototype with belonging renders to express the design language.

The purpose is to design and develop a bicycle trailer on a conceptual level that can carry a significant amount of cargo, is lightweight, stable, easy to manoeuvre, and is intended to be used in an off-road environment.

Based on exploration of different scenarios, there will be varying cargo that the users need to bring in the trailer. A target group will be chosen, and a bicycle trailer aimed for that intended usage will be developed. To address the purpose, the following research questions have been formulated:

1. What are the needs that users have regarding a bicycle trailer when camping?
2. What are the challenges the users have with a trailer in an off-road environment?
3. How can the design of the trailer be developed to cover all these needs and requirements?

1.4 Delimitations

The study will focus on the use of the bicycle trailer in off-road environments and will not address the use of the bicycle trailer in other types of terrain or environments, such as urban areas. Focus will be on designing a single bicycle trailer model, rather than a range of models or sizes. It will also only consider the use of the bicycle trailer by adult riders and will not take into account usage by children or other specific groups of users. The trailer will also be constructed with the purpose of carry cargo and will not be suited to transport children. Final deliveries will be a prototype on a conceptual level with material suggestions and material costs but will not go into further detail regarding production aspects, such as manufacturing aspects.

The development of the trailer will mostly focus on the cargo space and what terrain it will be used in. This means that the construction of the trailer will be prioritised rather than the aesthetics, but the visual appearance will also be taken into consideration. Rules and regulations will be delimited to follow the guidelines within Europe regarding what the trailer needs to fulfil, but general information may also include United States. The rules and regulations will in first case provide information from standards that are established. Since most standards costs money and needs to be purchased to be read, they will be supplemented with recommendations and guidelines from various brands that are operative within the area.

1.5 Outline

To give an overview of the report, the *Introduction* chapter has provided background about the problem area to give a general understanding and explanation why this project is carried out and what it will try to achieve. In the second chapter *Theoretical framework,* important subjects and knowledge that must be considered in the development will be presented. After that the *Methodology* chapter concerning the approach and methods used to proceed with this project and gather data will be explained. How the methods are going to be used and how they work practically can be found here. The *Findings and analysis* chapter is the generative phase of the report where the results of the methods introduced in the *Methodology* chapter will be presented and findings will be analysed. After that the *Results* chapter will show the final concept in form of renders with belonging text explaining functions it obtains. Following that, the *Discussion and conclusions* chapter will debate the results presented. Lastly, suggestions of improvements and things that needs further development will be discussed in *Further work*.

2 Theoretical framework

The theoretical framework contains important areas of subjects that needs to be considered when proceeding with the development. Examples of these subjects are rules and regulations, fundamental functions of a trailer, different attachments of trailers to bicycles, and materials used in bicycle trailers. The knowledge gained in these subject areas can be advantageous when developing the product for it to excel well within these areas.

2.1 Search procedure

The initial step of the search procedure was to find directly relevant sources. Based on those, initial keywords were identified that suited the purpose and research questions and it was possible to narrow the search further and find better suited sources. At an early stage of the search procedure, these keywords were established: *camping, outdoor life, off-road, cargo trailer, bicycle trailers, bike trailers, cargo bike, and mountain biking*.

Even though bikes have been around for plenty of years, cargo bikes, bicycle trailers and electrical bikes are relatively new on the market. Therefore, the sources included in the theoretical framework will not be older than 20 years to make sure that the information is up to date. The language used in the papers will be English and Swedish. The databases that have been used in order to find relevant literature are ScienceDirect, Google Scholar and Libris.

The search strategy that has been implemented is snowballing backwards or reference search method. By using the initial listed keywords and identifying some useful sources, it was after that possible to apply snowballing backwards to further the search of sources. As the search proceeded, the sources became more relevant and it was possible to establish more accurate keywords and synonyms like *biking*, *downhill, freight bicycles, carrier cycles, box bikes, and cycle-trucks*.

2.2 Rules and regulations

When developing a cargo trailer for bicycles there are some things to consider and integrate in the development of the product, but also things to communicate and explain for the user since there are restricted ways of using a cargo trailer for bicycles.

If the purpose is to carry two passive children that are not pedalling, which is the maximum number of children allowed carrying. Each child can weigh maximum 22 kg according to the standard (SS-EN 15918:2011+A2:2017). This implies that the maximum allowed weight for such a trailer cannot exceed 60 kg, including its kerb weight with additional cargo. That includes cargo and, or passengers (Swedish Institute for Standards, 2017).

It is important to state what the purpose is with the cargo trailer, as in some countries it is forbidden to operate trailers with certain loads or passengers at a certain age. For instance, in Germany, it is not allowed to pull a child trailer at an age younger than 16 but are allowed to pull dog and cargo trailers. Thereby it is a shared responsibility by both the company and the user to ensure that no law is crossed over. The user has the responsibility to check the laws in the country, as it can vary depending on where it is used. The company have the responsibility to clearly state what the purpose of the trailer is, so there is no misunderstanding from the user's side. This leads on to identifying the specification of the trailer. To pull a trailer safely and ensure safe braking it is important that the loads does not exceed capacity of the trailer, but also that the towing bicycle is capable of towing the trailer with that specific load (Croozer, n.d.).

Cyclists should always use bicycling lanes and paths even when pulling a trailer. If there happens to be none, one must ride on the street. It is only allowed to ride on sidewalks if there are specific signs that indicates that it is fine. Cautious should be taken on narrow paths and on

paths with two-way traffic since the trailer is often wider than the handlebars on the towing bicycle. The maximum allowed speed is 25 km/h when pulling a trailer (Croozer, n.d.).

Usage of the trailer at night, dusk or dawn requires a fully functional lighting system, where the source of electricity should come from a battery or generated from the motion of the bicycle. The bicycle and subassemblies should follow the (SS-ISO 6742-3:2021) stated at Swedish Institute for Standards (2021) as following:

- Part 1: Lighting and light signalling devices
- Part 2: Retro reflective devices
- Part 3: Installation and use of lighting and retro-reflective devices
- Part 4: Lighting systems powered by the bicycle's movement
- Part 5: Lighting systems not powered by the bicycle's movement

According to the European standard DIN EN 15918 and DIN EN 1888 the trailer must succeed with the drum test, the hitch arm test, and the ramp test to be classified as safe to use. The drum test loads the trailer with 125% of the initial load capacity of the trailer and is then placed on a drum test rigg. Obstacles with wedge-shapes are attached to the drum surface. When the drum starts rotating the trailer will be forced to ride over the obstacles with the speed of 12.5 km/h. After the pre-set number of cycles has been performed, the trailers frame and chassis need to be free of damage.

The hitch arm test locks the axle sockets and secures them. The hitch arm is then loaded horizontally with a force of 450% of the initial load capacity. After the pre-set number of cycles has been performed, both the hitch arm and the connection point must be free of structural damage.

The ramp test places the trailer on a ramp where the lower end is blocked by a steel panel. Predetermined crash tests obstacles of certain weights are placed in the trailer. The trailer is then released and rolls down to then crash into the steel panel. The trailer must be free from any visible damage after the tests, and the locking mechanisms and fasteners must still work (Croozer, n.d.).

2.3 Fundamental function

Generally, there are two types of trailers: one-wheel and two-wheel trailers. The common thing for all trailers is that they are constructed to carry loads and being towed by a bicycle.

One-wheel trailers

One-wheel trailers have been around since 1950. The characteristics of them are that their slim profile makes them a good option for narrow paths. Their typical construct makes them to some extent unaffected by headwinds and their rolling resistance is small. It is not beneficial to load beyond, or even up to the manufacturers maximum load capacity for off-road use when it comes to one-wheel trailers, since that will have an impact on the bicycle's behaviour when riding. It is beneficial to pack the heaviest items low in the trailer. If the characteristics are speed wobbling when riding, items should be moved closer to the rear tire of the bicycle and spread out the load across the bicycle. For high demanding terrain use it is beneficial to use 20-inch wheels. That follows the same reasons as for bicycles, since 20-inch wheels roll over uneven terrain such as rocks and roots in a more efficient way (Gilbert, 2022).

Two-wheel trailers

The characteristics of two-wheel trailers are that they are rotationally decoupled, which means that not only can it manage its own weight, but also have a small impact on the handling of the bicycle regardless of how heavy the load is. They typically cope with heavy loads well and the handling is at its best at slow speeds. The backside of it is that they can tilt over if one wheel is exposed to an uneven area of the surface that is significantly more disturbing than for the other wheel. Again, packing heavy items as low as possible will improve the stability. They can in most cases be folded down, or compressed in some way, to fit them into cars, busses, or other transportation options (Gilbert, 2022).

2.4 Cargo bikes

A cargo bike is a bicycle which is designed and constructed with the purpose to be able to transport loads. They also have plenty of names and are often mentioned as freight bicycles, carrier cycles, box bikes, and cycle-trucks to name a few. These kinds of bikes are offered in various shapes, sizes and are produced by several manufactures and does sometimes have assistance from electric capacity. As an example, some bicycles are capable of carrying significant amount of cargo and several children within the trailer at a front position of the bicycle. Other offers similar solutions but with load capacity at the rear. Research has highlighted that cargo bikes has an advantage in their ability to carry gear and children in the way that they become more visible and therefore becomes safer from collisions. This applies primarily to cargo bikes with the load capacity at the front, rather than the rear (Riggs, 2016).

Some studies analysed the shortcomings and limitations in relation to utilitarian trips with focus on carrying gear and, or children. These limitations were especially applicable for women, who make up a minority of cyclists in the United States but are often more likely to be responsible for transporting children. This may depend on what country is studied since in Netherlands, the use of bikes by women is higher than the average. Another factor that has influence is the age of the population, where elderly people with reduced muscular capacity for riding, may be more intrigued of the use of e-bikes. The references discussing these limitations along with other work has identified the need for evaluation of different kinds of bicycle platforms as a research priority. They are indicating the possibilities the cargo bikes offer and the potential to provide the opportunity to attract cyclists in need of a substitute mean of transport for utilitarian purposes. Some sources suggests that cargo bikes are an upcoming trend and other publications indicates that different formats or types of bicycles have the potential to offer a substitution and support the path away from cars as mean of transport (Riggs, 2016).

The availability of cargo bikes has increased in the United States. While a large portion of research continues to investigate traditional bicycle transportation. Cargo bikes make it possible to arrange trips that otherwise would have been made by car. Data gathered from a survey about cargo bike users, examined the use and mode of transportation with the hypothesis that ownership of a cargo or e-cargo bike could influence their transportation behaviour. The result from the survey showed that 68.9% of the participants changed their travel behaviour after the purchase of a cargo bike and the number of auto trips decreased by 1-2 trips per day. The two driving factors for this behaviour change was the ability of transportation with children and more gear (Riggs, 2016).

2.5 Different attachments of trailers to bicycles

Attaching the trailer to the bicycle can be done in different ways, and the bicycle itself and the trailer will allow certain ways to do it depending on their construction. When looking at the market, one-wheel trailers usually attaches from both sides of the rear wheel, since it is needed

for stability. Whereas a two-wheel trailer usually attaches only to one side of the bicycle. It can be concluded based on Usman (2022) that there are four ways of attaching a trailer to a bicycle:

1. The Tow Ball Hitch
2. The post Hitch
3. The Axle Hitch
4. The Rack Hitch

The tow ball hitch is most common on two-wheel trailers and are considered good because of its free movement, which also allows for loading heavy weight without affecting the bicycle's handling. The post hitch has a very tight turning circle, which could be beneficial. However, since the steering input and axle, which sits underneath the handlebar of the bicycle is further away from where the hitch is, it can cut corners. This can become an issue on tight and narrow paths. It has less impact on the handling of the bicycle though compared to axle hitches. The axle hitch is described to wrestle with the bicycle more than others when it is heavily loaded. This can cause tear and wear on the bushings and bearings if the bicycle has a full suspension rigg. Therefore, naturally it is more suitable for hardtail bicycles with stiff rear ends. Lastly, the rack hitch could be suitable to use if the bicycle has a rack and if it is not possible to attach the trailer in any of the previous ways explained. The rack hitch is a component, which is assembled in the rack itself that the trailer can be coupled to (Gilbert, 2022).

2.6 Materials used in bicycle trailers

Based on WIKE's experience, which are a company that develops and sales bicycle trailers for both biking and walking, there are four things that indicates the overall quality of a bicycle trailer. The four things they identified that have the largest impact of bicycle trailers performance and improves the experience are fabrics, flooring, metals, and tires. Regarding the choice of fabric, it is important to consider that the trailer will be exposed to sunlight but will also most likely be used in rain and possibly snow as well. This means that the trailer will have to withstand both dust, dirt, and rain. The trailer will also probably be used in some harsh conditions with bumpy roads and impenetrable terrain, which causes more stress on the fabric. The low-end trailers often use fabrics that fades more quickly and tears more easily. To prevent this, a good quality fabric can be used, which also makes a significant difference of the price (Bike Trailer Components You Need to Know, 2017).

When it comes to flooring of bicycle trailers, it is common that cheaper bicycle trailers have flooring that is just made of fabric and as mentioned earlier the quality and durability of the fabric may vary. As the price increases, the flooring becomes more solid and sometimes rubberized. The kind of flooring becomes more durable but at the cost of additional weight, even though the increase in weight is not significant. Regarding the use of metals in bicycle trailers, steel and aluminium is the two most frequently used. Steel is more prone to rusting while aluminium is a more lightweight choice in consideration to steel. Both are common to find within bicycle trailers and works well. What should be noted is that trailers that uses substantial amount of plastic for framing should be paid attention to, since plastic lacks the strength of metals and is more likely to warping and cracking (Bike Trailer Components You Need to Know, 2017).

The last thing that should be considered is the tires. The right tires will ensure a comfortable ride and prevents the cargo from getting damaged. Generally, the larger the tires are the smoother and faster it is possible to ride. Depending on the usage of the trailer, the material for the rims may be different. If the cargo consists of grocery, the trailer would most likely be fine with a smaller tire and plastic rims. When the cargo is heavier, a larger tire with metal rims is more suitable (Bike Trailer Components You Need to Know, 2017).

In the study made by Sen (2022), where the environmental impact assessment of bicycle trailers was investigated, the contribution of used materials in an existing bicycle trailer was examined. Materials that were used in the bicycle trailer was aluminium, steel, copper, plastic, rubber, and fabric. The materials that had the highest percentage regarding emissions of total materials was aluminium and plastic, mainly consisting of nylon 6 with glass fibre, accounting for 41% and 53% respectively for the production impacts (Sen, 2022).

2.7 Tests of materials

There are various material options when constructing a trailer of this kind, some very basic but there are also interesting new materials. One thing that all of them needs to cope with is various tests. Since the product will be used out in the nature in various weathers, temperatures, and light it needs to cope with the topics of water resistance, waterproof, UV resistance, corrosion resistance, and colour resistance.

2.7.1 Water resistance

Water resistance is the construction of materials ability to resist penetration of water to a certain extent, but not necessarily fully. An example could be of the material and construction of the product to be coated to repel water to a certain degree and time. An example could be gloves that keeps the hands dry for occasional splashes of water due to the material being coated, but that does not mean they should necessarily be used in wet conditions at all times (Scalisi, 2021).

2.7.2 Waterproof

Waterproof on the other hand, refers to the ability to not let water in at any time regardless of the time spent in water. To determine how waterproof a material is, it can be done by measuring the exposure to water through hydrostatic head. This is a method specific for fabrics. The method is about placing pillars of different heights on top of a fabric. The taller the pillar, the more water it fits. Which means that the more waterproof the fabric is, given no water leaks through the fabric. For instance, if a pillar with the inner dimensions of 1x1-inch and a height of 10 000 mm filled with water is used and no leakage can be seen, the fabric could be seen as waterproof for that pillar (Jivani, 2018).

2.7.3 Corrosion resistance

When considering other materials than fabric, it is more crucial to look at corrosion resistance rather than water resistance or waterproof. This only concerns metals and not plastics. When metals are exposed to water and salt, they tend to corrode over time, which means that the construction of the material itself deteriorate. This is something that needs to be considered if any metal is an option for the trailer. However, there are tests that can be done to see the corrosion and how it evolves over time in a more efficient way. There are accelerated corrosion tests which can include wet and dry cycles, salt spray, or humid environments. The reason for accelerating the test is to see how the corrosion evolves over the material, which is a process that takes years if it should happen naturally. Obviously, there are metals such as aluminium that is not affected by corrosion. If other metals are considered because of other desired properties, there are solutions such as zinc coated steels that prevents corrosion (Fujita & Mizuno, 2006).

2.7.4 UV resistance

UV resistance is mainly important when considering plastics or polymers as a material for the product. UV light that reaches the earth is only a portion of 3% but is enough to cause changes in the polymers mechanical and chemical properties. The effect of too much exposure of UV

light is discoloration, which means that the colours lose their glance and can gain a phenomenon of yellowing or whitening. This is also known as “chalking”. It can also cause loss of impact and tensile strength and can lead to making the polymers brittle and prone to cracking and breaking. It can also affect the materials elongation, which is its ability to allow physical changes before reaching irreversible deformation. The UV light that causes the most damage to polymers is within the range of 290-400 nm and the results could end up in deterioration and oxidation. There are polymers which handles the UV light better than others, but also weather conditions and location on earth will determine how affected the polymer will be by the UV light. These are factors that need to be considered when looking into potential polymers for the product (McKeen, 2013).

2.8 Sustainable development

Sustainable development implies the ability to meet today’s needs without jeopardizing the ability of coming generations possibilities to meet their needs in the future. A sustainable development can be divided into three different categories, which are environmental, social, and economic sustainability. Environmental sustainability means to make the earths biological and geological system to work properly and be farmed sustainable. This covers the water, air, land, biodiversity, and ecosystem services with regards to pollution, groundwater levels, salinity, temperature, and foreign species. Social sustainability is about people’s well-being, justice, power, rights, and individual needs. Economic sustainability is about promoting growth and progress without causing harm to the environment or society. It requires responsible use and management of resources, promoting efficient and effective use of both renewable and non-renewable resources to create lasting value. To achieve a sustainable development, all three categories needs to be taken into account and non can be neglected. The interaction between the categories to achieve a sustainable development can be seen in figure 1. An environmental sustainability can be considered a requirement for both social and economic suitability, whilst social sustainability is the basis for economic sustainability to be possible (Hållbar utveckling, n.d.).

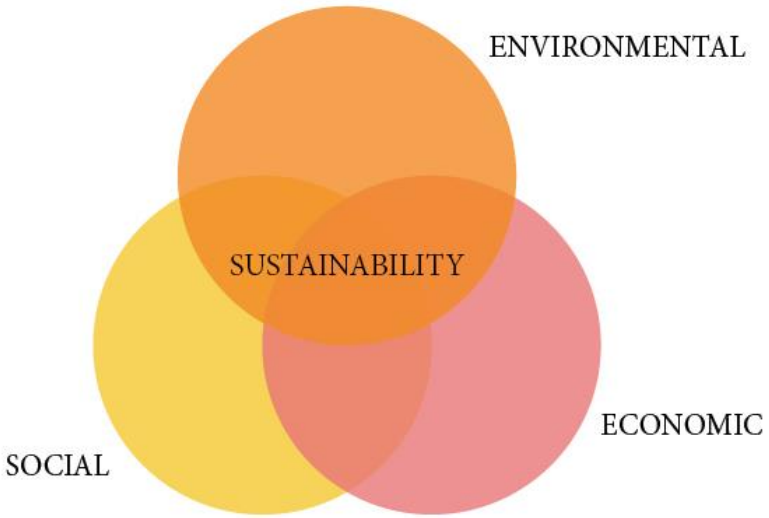


Figure 1. *Interaction between social, environmental, and economic sustainability.*

3 Methodology

This chapter explains the approach and methods used to proceed with this project. Explanation of the methods and how they work practically is found here.

Design process

Designers typically begin with thoroughly exploring the problem presented. When diverging the first time, the scope of the problem is expanded to examine all the underlying issues. Then it is narrowed down in the converging phase to a single, concise problem statement. During the solution part, it again expands the space of possible solutions, which is part of the divergence phase. Finally, it converges to present a proposed solution. This double diverge-converge pattern is called the double-diamond design process model, which can be seen in figure 2. The process can be divided into four stages: "discover" and "define" for the divergence and convergence phases in identifying the problem, and "develop" and "deliver" for the divergence and convergence phases at arriving at the right solution (Norman, 2013).

The alternating phases of divergence and convergence play a crucial role in determining the proper problem to solve and then finding the most effective solution. While this process may seem disorganized and unstructured, it adheres to well defined principles and procedures. When converging upon a solution it may be realised that the problem is inappropriately formulated and it is needed to repeat the process or parts of the process, although it can be done faster this time since much more about the problem is already known. Therefore, to find the right problem and most optimal solution it is usually required to repeat the process of divergence and convergence in an iterative way (Norman, 2013).

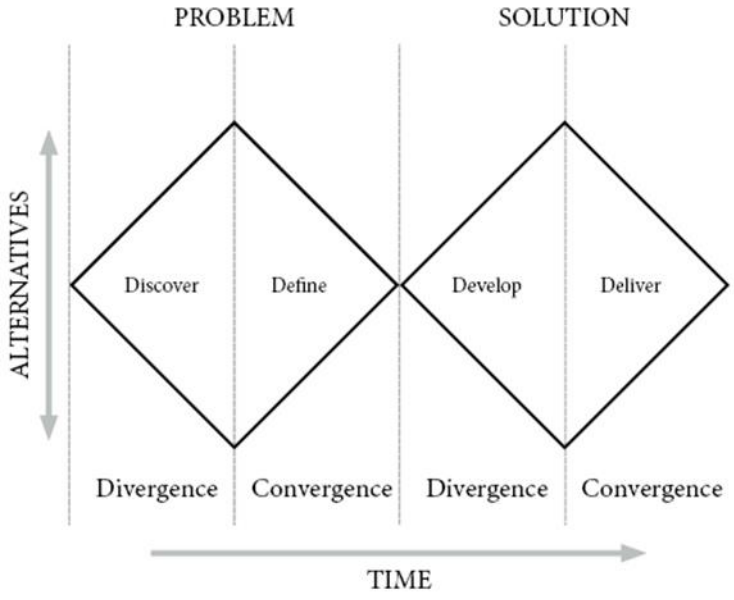


Figure 2. *Double-diamond design process model.*

3.1 Market research

It is important to know the market and how the product will be used when starting to develop it. That is why market research is used to understand and gain knowledge about the current products and solutions, but also to see pros and cons with them. This method is usually conducted in the beginning of a process in order to discover opportunities for a potential market gap to fill. It also aids the development by identifying what resources and opportunities are

available, to make the product or service stand out from the competitors on the market (Wikberg-Nilsson et al., 2015).

3.2 Scenarios

A scenario is an outline of a group of users, their work environment, and the tasks they are performing or wish to perform in the future. It also projects the facilities that will aid them in completing those tasks. A scenario combines a detailed examination of current practices with a visionary outlook on how a product or service can enhance and improve those activities in the future. The purpose of a scenario is to mediate a picture of how a human activity could be supported by the intended mean of facility. Scenarios thereby gives a good reference point for making design decisions. By indicating the actual circumstances, scenarios provide guidelines on how a facility should perform (Nardi, 1992).

3.3 Target group

A market is a collection of individuals and organisations that have a need or desire that can be met through purchasing a specific product or service. The first thing that needs to be done is to decide what target group it will serve. By dividing the market into market segmentations and selecting which segments to focus on, which is called target marketing, the individuals and organisations included make up the current and potential customer base for that product. Marketing contains managing markets to gain profitable customer relationships, which is not an easy thing to maintain. Sellers must find buyers, identify their needs, design valuable products to a reasonable price, promote them, and store and deliver them. Core marketing activities implies product development, research, communication, distribution, setting prices, service, and maintenance. Some think of marketing as finding the most potential customers as possible to increase the demand, but it is not possible to accommodate all customers in every way. Through trying to make all customers happy it may be so that it does not suit any customer at all. Instead, it is better to aspire to serve a portion of customers well and profitable (Armstrong, 2009).

3.4 Load testing

The practice of testing bridges under load, dates to the time when they were first constructed and are in some countries still a requirement prior to opening a bridge. Historically, load testing provided reassurance to the public that a newly opened bridge was secure. Today, with aging bridges and infrastructure that has been around for several years, load testing is utilized to evaluate the condition of existing bridges. Despite the advancement of analytical techniques for forecasting bridge responses, the uncertainties surrounding a bridge's behaviour increase as time goes. Therefore, load testing can be useful in gaining a deeper understanding of a bridge's behaviour in situations where the underlying mechanisms are not well understood or clear, particularly in certain types of bridges. This method is also used in other areas, as buildings for example, to ensure the buildings safety and evaluate its structure (Lantsoght et al., 2017).

3.5 Turn testing

Incorrect positioning or securing of cargo on vehicles can lead to accidents and damage to the cargo and in worst case even to human life. To ensure everyone's safety and protect the cargo from harm, it is crucial to secure it properly during transport and prevent it from sliding, tilting, or rotating depending on what cargo that is being transported. Measuring the forces acting on a vehicle and its cargo is essential to understand their behaviour. This can be done by using suitable devices and method, such as studying the average accelerations acting on a vehicle and cargo during cornering (Jagelčák et al., 2022).

3.6 Mood board

Mood boards is usually a collection of found or made images fixed to a board, either physically or digitally, with the purpose of presenting something with intention. It can also contain bits of fabrics or colour swatches, drawings, physical objects that are either natural or industrial, and colours in general. Shayal Chhibber states that "A mood board collates colours, textures, images and material samples as a starting point prior to creating concept ideas" (Garner & McDonagh, 2001, p.62). The sizes most used on the sheets are A3, A2 or A1. The fundamental purpose of a mood board is to present emotions, feelings or certain "moods" based on the original design brief, or the brief as it develops. Since it is only expressed visually, it is hard to express them linguistically. Therefore, they are important to express the creators thinking. It is almost like the icons of big brands where they express the brands imagery, like for instance Nike, Adidas, or BMW who each have an icon that familiarizes and are connected to certain thoughts or feelings. The quality of a mood board lies in the flexibility and application, which is why the guidelines are non-prescriptive. They have a function to both problem finding and problem solving. Mood boards does not have to be expensive or time consuming (Garner & McDonagh, 2001).

3.7 Design Format Analysis

The importance of visual appearance in enhancing brand experience has grown and is important to distinguish a brand's products on the market. Businesses must create products that are visually appealing, easy to use, and reflect the brand's distinct expressions. By carefully managing the visual appearance of products, it is possible to significantly influence the brand's recognition and experience. The Design Format Analysis (DFA) is considered an effective method for evaluating aesthetic consistency in the brand experience. This approach focuses on the visual recognition of the brand by examining selected design features. First step is to identify key features from the initial analysis and then it is checked how consistently they are occurring among the products from the brand (Gonzalez et al., 2019).

In DFA several features are first selected. The selection can be based on numerous criteria. Features that are considered most important or relevant due to their visual recognition are selected from the analysis of a brand's products, either through subjective, or more objective approaches. A good starting point can be features that the company themselves has defined as their recognition. Once the features are established, the next step is to assess whether the chosen products contain them. The evaluation may start by individually reviewing each product to identify the various features it includes and gradually building the matrix. The DFA approach can be used to analyse different characteristics such as form, materials, and colours (Karjalainen, 2007).

Karjalainen (2007) gives an example of how DFA can be used in a systematic way. If there is a strong occurrence of a specific feature in a certain product, it can be marked with a black dot. Instead, if there is a weak occurrence, it can be marked with a white dot. Afterwards it is possible to sum up all the occurrences of black and white dots, where black dots scores two points and white dots one point. Through that way, design features and products can be ranked in terms of their occurrence and importance for visual brand recognition. It is also possible to identify the most typical product and feature, which can be marked by a black square and a double lined square respectively (Karjalainen, 2007).

3.8 User journey

One of the common first steps applied in user research for design is to use a product or service similar to the one that is going to be developed but with a critical mind. This is called making a user trip, or user journey, where the product or service is used with the purpose to make notes about reactions. The idea of user journeys is simple. The developers make a trip through the

whole process similar to what the users are supposed to do with the particular product or system and acting as a critical, self-aware, and observant user. Through this critical attitude it helps designers to make improvement to already existing products. The key is to transform negative feelings into constructive and creative form of criticism, and to adopt a mindset of productive dissatisfaction. It is ideal to write down thoughts and impressions during the trip or immediately afterwards to ensure an accurate observation is made. Experienced users of a product or system may have adopted ways of difficulties and therefore may not be aware of challenges faced by inexperienced users. To imitate the usability of the product or system, one should attempt to revisit the mindset of a novice user and be attentive to even the smallest difficulties or impressions (Cross, 2021).

3.9 Survey

The survey will contain both interviews and questionnaires, where the interviews will represent the explanatory and qualitative data, while the questionnaire will contain quantitative data. The difference between qualitative and quantitative methods are that qualitative focuses more on reaching a deeper understanding, while quantitative gathers numerical or measurable data. If the survey contains personal or sensitive information, it will be important to consider the protection and handling of that kind of information and enable the opportunity of anonymity and confidentiality.

3.9.1 Interviews

Interviews are described as a method that interacts with a person to understand their experiences, attitudes, thoughts, motivations, and behaviour, as the purpose to gather information. The method is not strictly bounded to certain occasion as it can be used in different occasions depending on the purpose of it. For instance, at an early-stage interviews can provide information on already existing products on the market, the usage of them and potential frustrations from the user. Though, further into the process they can provide valuable perspectives and feedback on concepts that have been developed (Wikberg-Nilsson et al., 2015).

The interviews conducted will be of a qualitative type and they will be semi-structured. This allows for the person being interviewed to answer in a freer manner, which can develop the conversation into new insights within the subject. The questions will be formulated beforehand, but they do not have to be answered in a structured manner. The occasion will be recorded via audio, given that the participant agrees to do so. This will contribute to an increased reliability of the interviews (Patel & Davidson, 2011).

The sampling technique for choosing the individuals that will be included in the sample, will be done through convenience sampling. The interviews will be held in Swedish to facilitate for the one being interviewed to avoid language barriers. After the interviews are done, the interviews will be translated to English, transcribed, and the data gathered will be analysed by thematic analysis. With regards to privacy reasons there will only be a summarize of the most important conclusions from the interviews.

Three persons will be interviewed which will be picked with care to spread out over the target group to cover different users. Persons with varied age will be interviewed and they all have different experiences regarding camping and off-road bicycling. By doing this, a deeper understanding of different types of users can be gained to obtain a broader view of what is excepted from the product while in use in the intended environment, thus opening insights which the development of the trailer could gain on. Some of the questions will be the same as in the questionnaires to gain a complete picture of the person being interviewed. In addition to that, other questions for deeper knowledge will be asked that was not appropriate to include in the questionnaire.

3.9.2 Questionnaires

Questionnaires has the purpose to gather information about the user's perspective on the product. It both includes quantitative and qualitative methods. The method can be quantitative where the aim is to gather numerical data, but it can also be qualitative with the aim to gather opinions and subjective answers. The questionnaires design and the questions included will determine if it is quantitative or qualitative. Most questionnaires require answers that are predetermined, for instance a scale where the participant can choose from 1-5. The advantages with that are the relative speed and ease it requires to answer the questionnaire as a participant. It is also suitable for processing the data collected and the numerical data. On the other hand, there is also questionnaires with open answers. These types can give useful insights, where the participant can give their own answer by typing instead of choosing between predetermined answers. This needs to be carefully designed though, since a questionnaire should not be too long or too hard for the participants to answer, which can lower the number of completions. Also, it requires more processing of the answers since they can be harder to measure since they consist of thoughts and subjective opinions (Cross, 2021).

The questionnaire will be sent out on different platforms to gain as much answers as possible. The questionnaire itself has an introduction that describes who the intended target group is and how the answers will be handled. Therefore, the people answering it are people who identify themselves with the intended target group. Another way to ensure that the right people will answer it is to spread the questionnaire in places where these kinds of people find themselves. The company responsible for this project are well known for their active products in many shapes and forms, so their research and development department were handed the questionnaire since many people that works there are into bicycling, camping, and other similar activities. In addition to that, the questionnaire was sent to similar kinds of people via other forums and direct messaging applications to reach even more people and be spread.

3.10 Function analysis

The intention with a function analysis is to investigate an already existing product's functions or a product that is still in the development phase. The aim is to get an understanding of what the product should achieve. Österlin (2007) explains that knowing why the product even exists, the main purpose and how it was achieved is a necessary starting point to understand its functions. The method provides a focused perspective of the product or service from the customers perspective, where the result is displayed in a systematic framework (Baxter, 1996).

3.11 Product specification

The pre-study will generate a lot of data about the needs the solution has to possess to cope with the customer standard. To ensure that it does so, the needs have to be translated into measurable requirements to be able to control over the solution so that it can fulfil the performance and requirements. This compilation of requirements can have different names, but is often referred to as a product specification, which will also be the case in this report (Wikberg-Nilsson et al., 2015).

The product specification can include a demand, which is often an interpretation and translation of different wants that a user has. These demands are things that the product must embody to fulfil different rules and regulations. Wishes are desirables by the user but are not required to fulfil. The specification also provides a uniformed image of what the solution should perform, but also provides a common understanding of what is needed to achieve that. This can later be used to evaluate concepts where the specification can act as a foundation and compare the concepts against it to see if they meet the demanded performance of the product specification. Wishes and demands can be added or excluded to the product specification as the

work progresses and as more insight is gained on what the solution needs to obtain (Wikberg-Nilsson et al., 2015).

3.12 Idea generation

The idea generation contains of methods and tools to help generate creative ideas, concepts, and proposals. Methods included are brainstorming and thumbnails, while mock-ups are considered a tool to evaluate and present concepts.

3.12.1 Brainstorming

Brainstorming is a method that aims to generate many ideas. It sets out to include intriguing and stimulating the involved persons and their creativity, potential and ability by seeing and hearing other people's ideas. Thus, it is important to not be critical when exercising this method and instead try to welcome all ideas and encourage ideas outside the box. The aim is to generate quantity over quality, since the philosophy is that ideas of quality will emerge due to the more there is to choose of (Wikberg-Nilsson et al., 2015).

3.12.2 Thumbnails

This method is about producing small and fast sketches. The essences are to think creatively and express the ideas by documenting them on paper. It also allows for exploring problem, challenges, solutions, and limitations. Often callouts are used in combination with thumbnails, which are short notes or annotations to the sketches. They enable mediating what is known about the problem but also provides understanding of thoughts and functions that the sketches have (Cross, 2021).

3.12.3 Mock-ups

This is a tool to embody the sketches on paper into physical models. Usually, it is done to test a certain part of a solution. It acts as an object to learn lessons upon for further development. The purpose is to get a further understanding of the part being evaluated that simply cannot be understood by a sketch. Interactions and perceptions between the human and the physical object can also be explored, but also getting a feeling for dimensions (Wikberg-Nilsson et al., 2015).

3.13 Idea evaluation

This method can be used in many ways, but the overall principles is that in relative short time evaluate plenty of concepts. By using democratically voting, a fair assessment is given and prevents participants from making individual decisions (Wikberg-Nilsson et al., 2015).

3.14 Concept weighting matrix

When multiple ideas and concepts have been generated, a concept weighting matrix can be used to select the most suitable one to move forward with in the product development process. This decision is crucial, as it greatly impacts the final outcome in terms of both aesthetics and functionality. To ensure that the chosen concept is the most optimal one and meets all necessary requirements, it is important to evaluate each concept in an impartial manner. Therefore, the requirements and desires of the products are weighted against one another depending on how important they are to be fulfilled. The concepts are then scored based on how well they meet the criterium, and by summing up the scores, it becomes clear which concept is the most appropriate to continue working on (Wikberg-Nilsson et al., 2015).

3.15 Prototyping

The object of a prototype is to test the conceptual design and features the final product is intended to obtain, in a more cost-effective way. The purpose of the prototype can vary, depending on what it will be used for, and the medium it is created in, such as being a virtual or physical model. Prototypes can range from being functional working models of the final product, or simplified versions that only showcase the visual design (Jones & Richey, 2000).

3.16 Cost calculation

In modern society advanced technologies such as cloud computing, artificial intelligence algorithms, and sensor technology have enabled the development of modeling and calculation methods that can create digital replicas of objects, systems, and processes. These digital twins can represent the entire chain of processes involved in raw material mining and processing. These modeling and calculation methods can then be used to calculate the costs of different materials and processes (Czajka et al., 2022). Peters (2007) also mentions that the cost of raw materials and their prices are in most cases crucial factors, as they constitute the majority of the overall costs.

4 Findings and analysis

This chapter is the generative phase of the project where methods and their respective results will be included. Methods such as market research, user journey, survey, product specification, brainstorming, concept weighting matrix, and prototyping will be conducted. Figures and texts belonging to the methods will be added to get a full understanding of the reasoning and procedure. The result of all the methods will come together in the prototype, which will be the final deliverable of this chapter together with a cost calculation.

4.1 Market research

Regarding the market research for the bicycle trailers, it could be separated into two categories that are either two-wheelers or one-wheelers. The size differs, but also other functionalities and features. In the market research conducted for this project, which can be seen in figure 3, the trailers are ranked based on their price on the Y-axis and their weight on the X-axis. The reason price and weight were compared was to see what a more expensive trailer looks like. Weight is also important since it is a physical activity and it is important for the trailer to be as light as possible, since that limits how much cargo it is possible to bring before it gets too heavy. Other aspects could have been compared, but the reason these were chosen was that they were considered most important when buying a trailer. To read further on the various trailers and view the sources of the photos in the market research, see the List of figures for references.

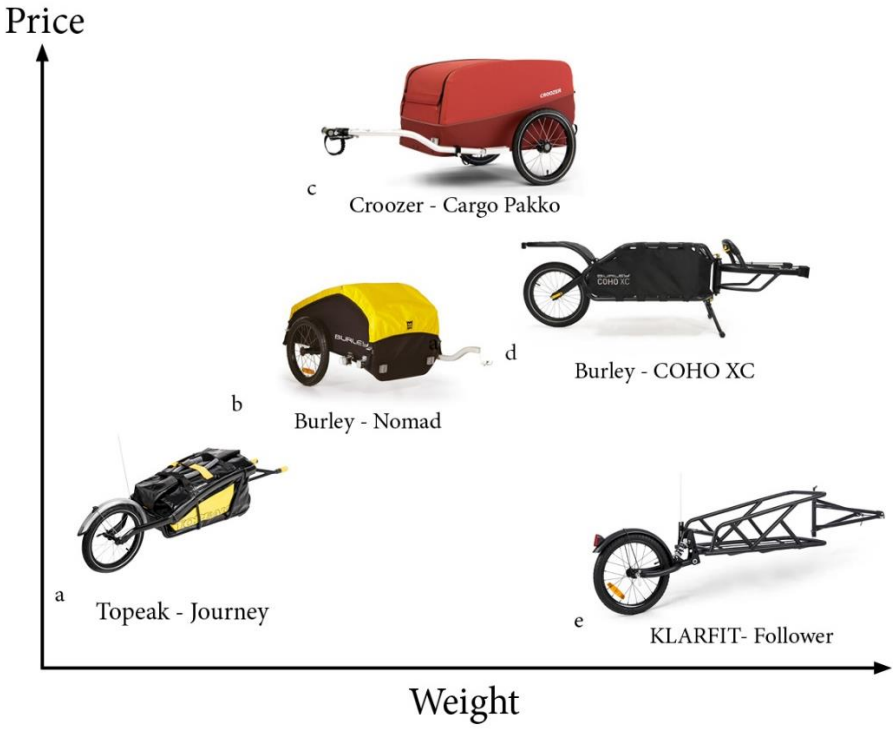


Figure 3a-e. *Market research of bicycle trailers structured based on price and weight.*

The common aspects of one-wheelers are that they consist of a structures frame of aluminium which is formed to have a cargo space in the centre of the trailer. Some brands and models keep the cargo space just as an open space out of the frames, like the KLARFIT Follower. Some enables dry bags to store in the frame like the Topeak Journey, and others have fabrics integrated with the frame to form the cargo space like the Burley COHO XC. All of them mostly offers a big open space for the cargo without predetermined pockets or dividers. One-wheelers tend to have a worse turning circle than the two-wheelers, and two-wheelers tend to have a good turning circle in the direction of the side that the arm is connected to. Turning the opposite way

is less good since the rear wheel of the bicycle will bump into the trailer arm. The common size of wheels are 16-inch wheels, regardless of what trailer type it is and they all vary in their capacity of maximum load, cargo space volume, and physical measurements such as length, width, and height. To see the full specification of the trailers included in the market research, see table 1.

Table 1. *The price and weight of the trailers included in the market research.*

Brand - Name	Price [kr]	Weight [kg]
Burley - Nomad	4477	7,6
Burley - COHO XC	6199	9,74
Croozer - Cargo Pakko	6431	9
KLARFIT - Follower	1925	11
Topeak - Journey	4100	6,95

For the two-wheelers they often look like a big box or such, where the internal storge usually is one big open space. Depending on product and model there can be some pockets and dividers. For instance, the Burley Nomad has six mesh pockets and a divider to move back and forth in the storage space, whereas the Croozer Cargo Pakko is just one big open space with some additional pockets. The Croozer has a hard base surface though, which seems to set it apart from some the other competitors. The common thing they have is that the structure is usually made of aluminium where textile is attached to enclose the shape. The access to the storage space can sometimes differ, but it usually opens from the top. They often come with a rain cover of some sort or water repellent materials. The trailer arm which attaches to the bicycle generally works better if the bicycle is equipped with a quick release function.

Regarding the Burley Nomad, if the bicycles are assembled with a bult, it should come loose and it should be able to attach the mount that goes onto the trailer arm. Although, on some bicycles it requires an extender since the bult would not be long enough. If it has a through axle a specific axle is needed in order to mount the trailer. It comes with a little steel hitch mount to attach to the rear axle of the bicycle, and then the trailer arm would mount onto the hitch. The arm can be assembled on both sides of the trailer depending on the choice. The arm is aligned in the hitch, and are held together by a pin, which is secure with a lock underneath once the pin is through.

The Croozer Cargo Pakko however has worked around this problem, as it is easy to attach to the bicycle with the Croozer Click and Crooz securing system. This system attaches the trailer arm to the axle coupling in the bicycle. Additionally, the head of the trailer arm features a lock to prevent theft. The mount sits on the axle of the trailer, and then the trailer arm clicks on to that mount. The key slot allows for locking the system in place. There is also an extra strap with a pin that goes around the bicycle frame in case the system should fail, like the setup we are used to for car trailers. A common feature for the two-wheelers is the ability to fold down the trailer and take off the wheels for storage or fitting it in the trunk of a car.

Regarding the one-wheeler trailers the most common characteristics they have is that they pull straight. Since a one-wheeler requires attachment on both sides of the rear wheel on the bicycle, unlike the two-wheelers, which is often only attached on one side, they tend to follow the bicycle better and can be described as a more rigid follower. Another common thing is that since they attach on both sides of the rear wheel it can be problematic to fit on certain bicycles, since it attaches to an axle that usually comes with the trailer. That axles needs to replace the original one that sits in the bicycle. The problem is that the axle which comes with the trailer does not

fit on all bicycles because the geometry of the rear assembly on the bicycles, which mainly contains of chain, gears, brake disc, and frames. That region of the bicycle looks different depending on what bicycle and model it is. Therefore, the axle may not fit on certain bicycles which can be problematic. Although if the axle does fit on the bicycle, certain bicycle trailers are easy to attach, sometimes even easier than a two-wheeler that only has one side to attach to.

The Topeak Journey is an example of that, where the two yellow plastic bits on each side of the trailer arm slides backwards whilst slid onto the axle on both sides. Ones the alignment is done the yellow plastic bits are released and they slide back onto the axle and keeps it linked in that position. The tricky bit is that both sides need to be aligned and it can be problematic if the bicycle does not have a kickstand to stand up on its own. This is where to Burley COHO XC excels. It is also a one-wheeler with the same attachment principles, but instead of operating each side separately, it is operated by the yellow handle right in front of the cargo space. Pulling the handle will open the attachment points on each side at the same time through wires and therefore the other hand of the user can be used to align both sides at the same time. Other features and functions regarding the Burley COHO XC are that it has a kickstand which is strong enough to hold the trailer and the bicycle up on its own. It features a mudflap on the back that is flat on the top, which enables longer object to be tied on top of the cargo space, for instance fishing rods. It also features a suspension.

Another market segment that has caught attention is camping trailers for cars, which can be seen in figure 4. This is relevant to investigate as these trailers are used in a similar way but on a bigger scale aimed for cars and it might be possible to implement some of the functions in a trailer aimed for bicycles. The conclusion of this was that a lot of them has a boxy shape, and the sleeping area and storage are organized and structured differently. Many of them seemed to have kitchen section that can be pulled out from the trailer as a unit and pushed back in when not in use. They often have big robust off-road wheels and some even allow to attach solar panels at the top. Having hatches on the sides to gain access to the storage area also seems like a common feature within the market. These are functions and features that are worth considering when developing an off-road cargo trailer for bicycles. To read further on the various trailers and view the sources of the photos in the market research, see the List of figures for references.

Figure 4a-h. *Market research of car trailers.*

4.2 Scenarios

The target group is based in the scenarios to try and describe what kind of users the trailer should focus on. When developing the scenarios, which was done in Adobe Illustrator, it was discovered that there were not many different scenarios. In fact, it was concluded that there are mainly two different scenarios that affects the usage of the trailer. One scenario, which is called the Adventure and can be seen in figure 5, is describing a more adventurous scenario where the trailer is used all the way from starting at home until reaching the camp. The other scenario, which is called Day Trip and can be seen in figure 6, is where the trailer is brought by the users to a chosen starting point by a vehicle, to then emerge from there to set up a camp and perform their activities, where the camp can act as a base for the user to come back to. In this case it was downhill which acted as the activities for the users.

There were not more scenarios that can contribute and affect the trailer. Surely, more scenarios could be generated where the activity downhill is substituted for something else, like fishing for instance. That would only affect the trailer in the sense that it needs to be able to carry other types of equipment that suits fishing better than downhill, but the user scenario starting from loading it in the vehicle from home all the way to setting up the camp does not change. The only changes are that the user sets of to perform other activities, but that does not affect the trailer as much. Though, there is an important difference from the Day Trip scenario from the Adventure scenario, since the Adventure is more extreme where the trailer needs to cope with more longevity, trickier and extreme usage to reach the desired camp spot and that affects the trailer significantly. The purpose of the trailer is always to allow for camping, either if it is simpler like in Day Trip or more extreme like in Adventure and that is why these two scenarios cover the most usage.

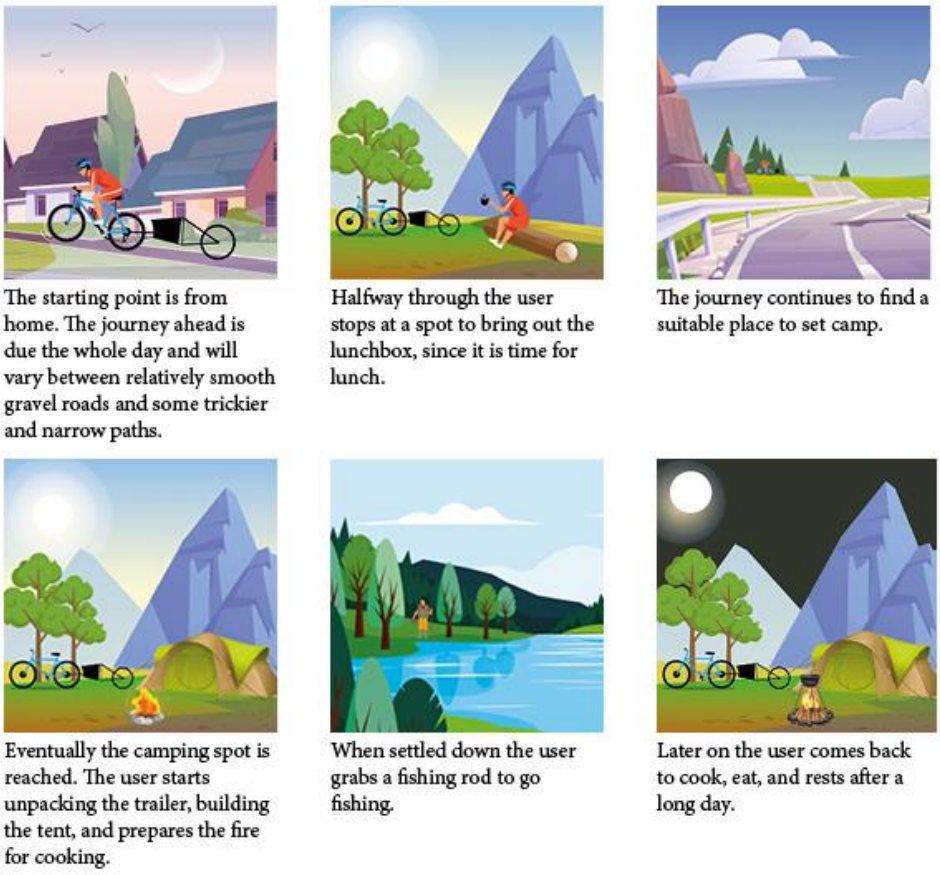


Figure 5. *Scenario called "Adventure".*

Figure 6. *Scenario called "Day Trip".*

4.3 Target group

This leads on to the target group. Which ones are the users? Based on the scenarios, the target group should be active people who like to spend time outside in nature by camping. They are either interested in more extreme camping, or less extreme camping where the focus is to implement camping to allow for their activity which they want to excel. Therefore, they are interested in various activities like biking, fishing, running, hiking, climbing, or other examples of activities or sports that are performed outdoors in nature. Since the environments could be dangerous where people can hurt themselves or need help in any shape of form, the age span is limited from 18 – 65 years old. People younger than 18 should travel with an older responsible person and people older than 65 should travel with a younger responsible person. This is for safety precautions in case something happens, as it could be reasoned that a person can think rationally and is physically capable between 18 and 65.

4.4 Load testing

The load testing was performed in forest like environment that contained walking and bicycle tracks. A suitable uphill was found that represents a typical piece of trail when out cycling to find a camping spot or going for an adventure. The conditions were wet, and the ground consisted of sand, mud, leaves, and roots. High end full suspension mountain bikes were used for the test. Two trailers were used for the test, a sportier single seat trailer that weighs 15.9 kg and a double seated trailer more aimed for urban areas that weighs 16 kg, that can be seen in figures 7-8. Several bags of weights were used to test how heavy it can be for different users to carry a certain amount of weight up the slope. Two participants were included with similar weight and height, but one more used to mountain biking than the other.

The single seated trailer in figure 7 had a suspension in the form of a double leaf spring, with the option to either have one or both leaves activated depending on the desired dampening, while the double seated trailer in figure 8 did not have a suspension. The double seated trailer

was only used to compare the feeling of pulling a damped trailer against an undamped trailer to see if there were any noticeable difference. The conclusions were that the single seated trailer, which were damped, felt much more civilized and manageable on rougher terrain than the double seated and did not bump around as much.

Figure 7. *Sportier single seated trailer*.

Figure 8. *Double seated trailer more aimed for urban areas*.

The slope was measured to be around 70-80 m long, and the incline varied from the lowest point of 9 degrees up to the highest point of 18 degrees. The slope was divided into four different sections, marked with S1-S4 in figure 9. S1 had an incline of 9 degrees, S2 of 9 degrees, S3 of 11 degrees, and S4 had an incline of 18 degrees.

Several attempts were performed to clear the slope with varying weights packed in the trailer, in addition to the trailer's kerb weight. All tests were performed with the same trailer, which were the sportier single seated trailer. Each participant had two attempts. If one of the attempts were successful, it was considered a pass on that weight level. If the participant had to stop or put down a foot, it was considered a failure.

Figure 9. *The slope divided into four segments.*

The test started at 10 kg, additional weight beyond the net weight of the trailer, which were 15.9 kg. This means that the total weight that was pulled in the first run was summed up to 25.9 kg. After that 10 kg were added for each run beyond the net weight of the trailer. The participants are named participant 1 and participant 2, where participant 1 is considered a beginner and participant 2 an intermediate, based on their previous experience with mountain biking. Each attempt (ATT) was documented, and the results of both participants are compiled in table 2.

Table 2. *Results of attempts with different loads.*

	10 kg load		20 load		30 kg load		40 kg load		50 kg load	
	ATT 1	ATT 2	ATT 1	ATT 2	ATT 1	ATT 2	ATT 1	ATT 2	ATT 1	ATT 2
Participant 1	fail 18°	pass	fail 18°	fail 18°	fail 18°	fail 18°	fail 18°	fail 18°	fail 18°	fail 18°
Participant 2	pass	-	pass	-	pass	-	fail 18°	fail 18°	fail 18°	fail 18°

Participant 1 had problems at ATT 1 but managed to successfully clear the whole slope on ATT 2. At 20 kg participant 1 struggled and felt it was heavy and failed at 18 degrees. Participant 2 managed three runs up to 30 kg on the first attempt, but at the third run the person got tired and it felt heavy. To pull more than 30 kg seems difficult, although it was at its worst in the fourth part of 18 degrees. Both participants managed to pull all weights each round to at least the point of 18 degrees. However, to cope with longevity and varying degrees in incline, 30 kg additional weight seems to be the benchmark of what a normal person can handle even during shorter slopes.

4.5 Turn testing

The turn tests that were carried out during this project has been simplified because of the limited resources and what was wanted to be achieved. The wanted outcome from the turn tests was to get an approximately number of how narrow turns that is possible to take with the trailer. Therefore, as can be seen in figure 10, the maximum allowed turning angle was measured to be 115 degrees, before the trailer itself limits further turning.

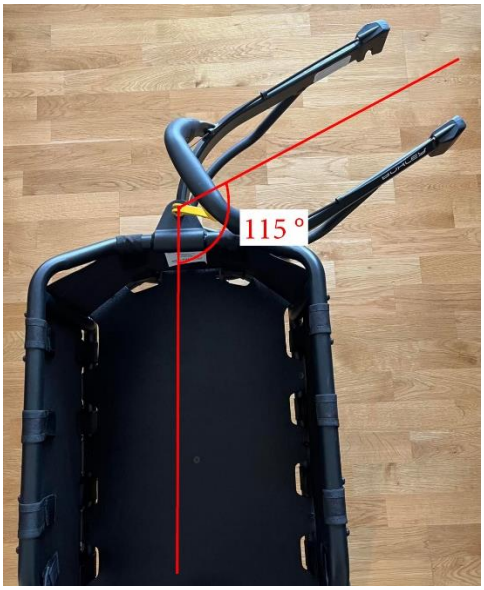


Figure 10. *Measured turning angle of a one-wheeled trailer.*

The same thing was done with the two-wheeled trailer, which can be seen in figure 7. Since it only has one arm, the turning angle will vary depending on which side the arm is connected to the bicycle. Therefore, just one side of the turning angle could be measured and turned out to be 115 degrees, just as for the one-wheeled trailer.

In order to get an understanding of how much a person is able to turn without being limited by the trailer or the bicycle, a test track was setup, which can be seen in figure 11. Varying angles was tested ranging from 160-130 degrees with 10 degrees span from each attempt to try to find the most challenging angle possible to complete the track. The width of the trailer used was measured to be 50 cm. The width of the track had an additional 50 cm adding up to 100 cm from side to side. Each participant had two attempts to clear the track and an attempt was considered a pass if neither the bicycle nor the trailer got outside of the lines or got in contact with any of the cones. The two participants that carried out the test was the same that performed the load testing, where one is considered a beginner and the other intermediate at mountain biking.

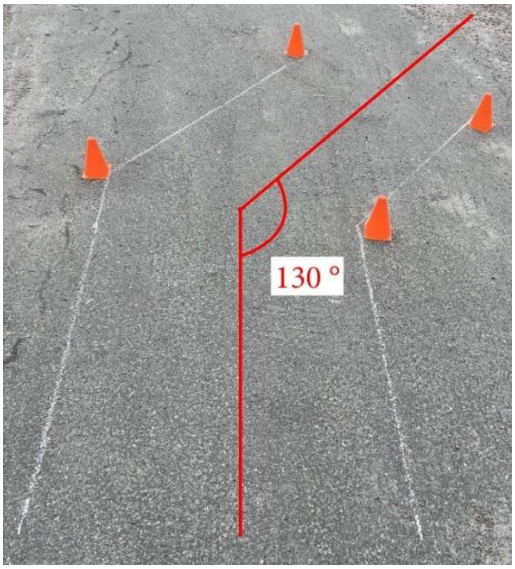


Figure 11. *Turn testing track to measure the turning angle of the trailer.*

The tests were performed without any additional weight in the trailer, so it was just the kerb weight. Both participants passed all the runs at the first attempt ranging from 160-130 degrees. Clearing any of the tracks narrower than 130 degrees was not possible for neither of the participants. Therefore, the conclusion from the turn tests were that even if the trailer allows the user to take turns narrower than 130 degrees it will be difficult for the user to successfully do it. What also should be kept in mind is that the turn tests performed were on good conditions with even ground and without slopes, trees, or stones in the way which might occur in an off-road environment. This means that even thought it might be possible to take turns of 130 degrees in these conditions, it will not be possible in the intended off-road terrain.

Another conclusion that can be drawn is that if the trailer allows the user to take turns of at least 130 degrees, it will not be the trailer or bicycle that limits the user from taking turns, but instead the capability of the rider or the terrain. Factors that also plays a significant role if someone is able to take a turn, is how well the trailer follows the bicycle, but also the space available to take the turn. If there is plenty of space to take a 90 degrees turn it might be possible, since it will not be necessary to take it as tight, but can instead take out the turn. On more narrow paths, if the trailer does not follow the trailer well and cut corners, it might be more difficult to take tighter turns. Also, the length of the trailer will affect how tight of a corner it can manage. The longer it is in relation to the steering point the more it will tend to cut corners.

4.6 Mood board

Two mood boards were created for this project to understand the environment which the product will be used in, to a greater extent than just linguistic expression. The first mood board, displayed in figure 12, aims to express the usage of the trailer itself, the intended scene it will be exploited in, important accessories, and actions. It conveys the feeling of being remote out in the woods, where the users are relying on the trailer itself and the things it carries. It also expresses different types of remote places, such as being in the middle of the forest or by a lake with bedrock. It also shows what type of objects it can be expected to carry, for instance like the tent, sleeping bags, food, and storm kitchen.

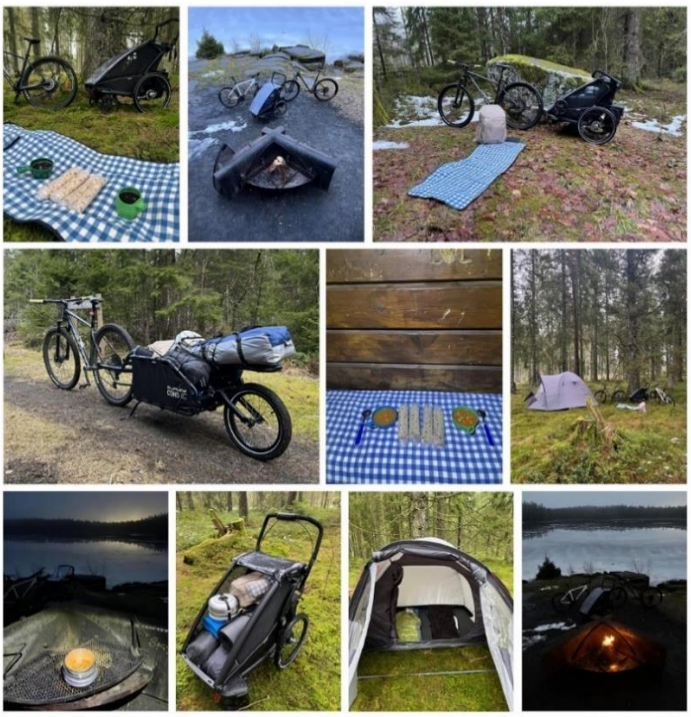


Figure 12. *Mood board inspired by camping*.

The second mood board, shown in figure 13, is focusing on the ground conditions it is expected to be used and cope with to get to the desired campsite. Depending on the user and their meaning of camping, that camp site might be on different kind of places that requires different types of paths to get there. Some users might be more hardcore and want to reach places with harsh terrain, whereas intermediate and beginners might choose easier places to reach. The mood board expresses this by containing both narrow and wide paths. Some contain roots, stumps, and stones, whereas other are more of an even surface.

Figure 13. *Mood board inspired by different terrains.*

4.7 Design Format Analysis

The products that were chosen for the Design Format Analysis (DFA) is a sample of the products the brand offers. The sample represents products with similar areas of use as the intended product to be developed. The reason was that these products might be used in association with the product in this project and therefore needs to go well together with regards to aesthetics and design language. All features that were chosen are strong characteristics of the brand that might be important to consider in the product to be developed. As can be seen in figure 14, the most typical products based on these features were a stroller and a bicycle trailer, which both scored 17 points. Even though the brand is most known for their roof boxes worldwide, the features was chosen with development of a trailer in mind, which explains it not scoring as high as the stroller and bicycle trailer.

The most occurring features were visible white logo, functional design, and expresses quality, which all scored 9 points. What also should be noted is that even though ‘product name visible’ scored lowest of the features, it occurred on both the stroller and bicycle trailer that are most similar to the new trailer to be developed and therefore might be considered important to implement. Other features such as chamfers, rounded corners, visible structure, and uncoloured plastic is also features that could be applied.

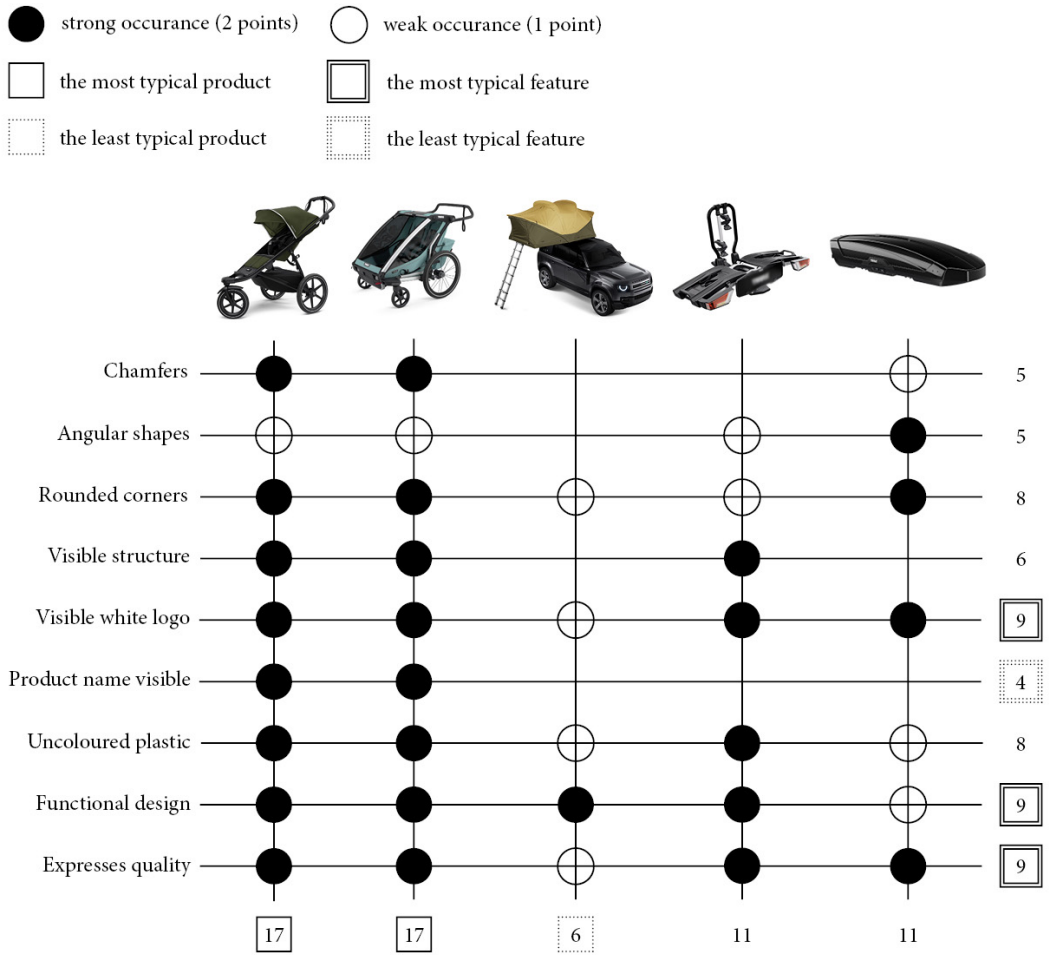


Figure 14. *Design Format Analysis on products from the company.*

Together with the DFA, a colour palette was established to represent the choice of colours of different products the brand uses, which can be seen in figure 15. When a colour that is not black is used, it is often used together with black, which is one of the core colours that represents the brand. This is due to the fact that their plastic parts often are uncoloured and therefore there is a lot of black details within the products. The features in the DFA and the colour palette will be important to consider regarding the aesthetics and construction of the trailer in order for it to fit in with the brands product portfolio.

Figure 15. *Colour palette on products from the company.*

4.8 User journey

One-wheel trailer

The trailer used for performing the user journey was a one-wheel trailer, aimed to be used in an off-road environment. Activities that were carried out was unloading the trailer and the bicycles

from the car, travel to find a destination to set up camp, stopping on the way to have something to eat, setting up camp, going to another spot to have dinner, go back to camp to spend the night. The terrain consisted of roots, mud, and stones with varying widths of the paths with trees surrounding.

Weight of the packing was 15 kg and water and food approximately another 5 kg. The trailer itself weighs 9,74 kg. Thereby, estimated total weight adds up to 29,74 kg. Figure 16 shows all items brought in the trailer for performing the user journey. To see the complete list of items brought, see appendix 1. How the cargo was packed and the trailer that was used during this user journey can be seen in figure 17.

Figure 16. *All items packed in the trailer.*

Since the trailer only have one wheel, it followed the bicycle well on smaller paths and the rider did not have to worry about the trailer tilting or fall over when going over obstacles. Even though the trailer had a conventional suspension it was perceived that the trailer bounced around a bit behind the trailer when going over roots. This was not considered a problem since the trailer followed the bicycle well but using a 20-inch wheel might make the ride smoother. During the user journey the ground conditions were wet, which made the trailer and the cargo dirty. There is an option to use a dry bag for this trailer but even if one does, it is exhausting to have to clean it afterwards. Therefore, it would be beneficial to have an extra cover that protects the cargo, that is removable and easily washable after a trip. The quick release of the trailer from the bicycle was convenient when removing the trailer from the bicycle. When attaching the trailer to the bicycle, it was problematic doing it alone. Since the trailer needs to be lifted to be placed on the axis and the bicycle needs support to not fall over, two persons was needed if the bicycle cannot stand on its own. To see the trailer and how the cargo was packed, see figure 17.

During sharper turns a perceived rotation from the cargo was noticeable, causing a pulling feeling downwards, towards the side turning. The reason this perceived rotation occurs is because while turning, the centre of gravity of the trailer moves away from equilibrium due to the movement of the bicycle, causing a force with a lever along the side turning. This momentum is perceived from the rider as a force wanting to pull one down and therefore needs to be counteracted by the driver, which is visualized in figure 17. The feeling becomes greater depending on how heavy the cargo that is packed in the trailer is and was more noticeable in

lower speeds, making it more difficult to maintain balance. When this becomes a problem is especially when turning around on smaller paths, since the trailer wants to “fold” itself.

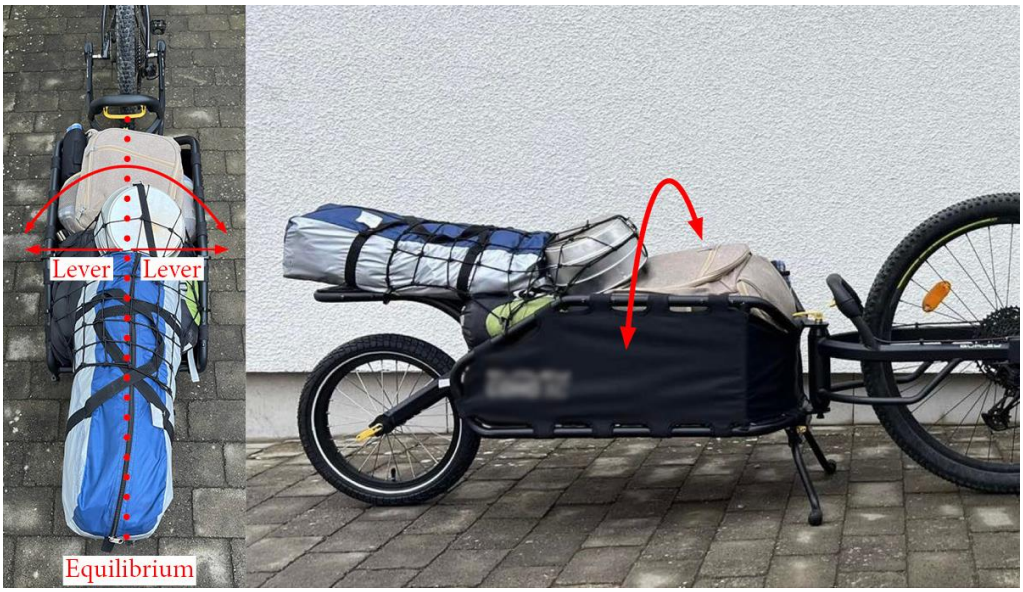


Figure 17. *Packed cargo and perceived rotation of the trailer.*

Two-wheel trailer

In addition to the user journey with the one-wheel trailer, a similar journey was performed with a two-wheel trailer to compare the experience. The trailer used for performing the user journey was a sportier single seated trailer with two wheels, the same that was used in the load testing, which can be seen in figure 7. A similar route as for the one-wheeler was carried out, with resembling terrain, environment, and activities. The cargo that was brought during the journey was also approximate to the one brought with the one-wheeler, with similar weight and volume. The difference between the weight among the trailers is the kerb weight, where the two-wheel trailer weighs 15.9 kg in difference to the one-wheel trailers 9.74 kg, adding another 6,16 kg to the total weight. Thereby, estimated total weight for the two-wheel trailer adds up to 35.9 kg.

It was hard to ride on small and narrow paths, especially when there were stumps and stones nearby the path. The trailer would tip over easily if one wheel drove over an obstacle. The high centre of gravity did not help against that either because of the way the trailer allowed the packing. It would be beneficial if the trailer could follow the bicycle better and not be as wide as it was. When riding on narrow paths containing roots, stumps, and stones it requires control and stability from the trailer. That way it is easier to feel and anticipate where the trailer is. On surfaces covered with snow and ice the trailer and bicycle would fold itself around the joint of attachment when braking with the bicycle. This becomes worse if they both start to glide. This is caused by the trailer pushing on from behind, and it could also be a problem on hills where the surface might be wet or loosely packed.

Having packed 20 kg in the trailer was not a problem to pull even in steeper hills. The two-wheeler copes well on slightly wider paths with an even surface. When riding over roots it becomes very bumpy and it creates a rocking feeling that pushes and pulls back and forth, which makes it hard to maintain the course. It is annoying to attach and detach the trailer arm which connects the trailer to the bicycle, especially the way it was constructed. The smaller front tires were also problematic to attach or detach the other way around when not using them since the trailer rests on the bicycle instead. It uses the same function as attaching or detaching the trailer arm, so they share a common problem. Dirt and mud did not make things easier either. The folding mechanism to fold the trailer in half was also problematic to use since it tended to jam

the first few inches, and sometimes it was hard to even push the buttons in. It would be beneficial to have additional pockets in the storage area and something to tighten down the packaging to hold it in place.

It was also annoying having to open the trailer every time access was needed to something simple, like a bottle of water for instance. This is because it has two layers, first a net with a zip and lastly a transparent mud cover which attaches on each side through loops. The loops were quite difficult to get on and off, especially when wearing gloves. Garbage disposal was also a problem when being on such a remote spot. It was also problematic that the bicycle could not stand up on its own, since that one was not equipped with a kickstand. A tree or something else was needed to lean the bicycle against. It would be easier if the trailer could allow for keeping itself but also the bicycle standing up on its own. It would be beneficial if the trailer could be locked and not have to be brought when leaving the campsite for a longer period, for example heading off for fishing.

These insights gained by doing the user journeys are of value since both flaws and advantages regarding the whole use of the trailer can be used and implemented as inspiration in the development for the new off-road cargo trailer.

4.9 Survey

Under this subheading the most important results and findings regarding the trailer from the survey will be presented, including both the interviews and the questionnaire. The take aways from the interview will be presented in a bullet list, while the results from the questionnaire will be shown with different kinds of charts.

4.9.1 Interviews

In this section the results from the interviews will be presented. The results from the interviews have been transcribed, translated from Swedish into English, analysed with thematic analysis, and summarized here. The most important take aways will be presented in a bullet list below. To see all the questions that was asked and discussed in the interviews, see appendix 2.

Take aways from the interviews:

- Afraid of other people that may be nearby when alone and remotely or that animals do not see the tent at night and walks over it or comes up to the tent to steal food.
- To increase safety when camping, one could be more visible considering the animals at night or something else that keeps the animals away from the tent.
- Afraid that valuables and the bicycle getting stolen. To prevent this, one inserted a tent peg through the bike at night-time, so they had to ruin the tent to steel the bike.
- When raining and unpacking the trailer, prevent the cargo within the trailer from getting wet.
- Many does not have a kickstand on the bike, so they put the bike down on the ground, leans it against a tree, or similar.
- Prefers to pack the trailer in a semi-structured way with some possibilities to divide the cargo. Fully structured occupies to much space.
- One used to pack the side bags with regards to one room in the house, so each bag represented a room for example the bedroom, the garage, and kitchen etc.

Desirable features on the trailer:

- A kickstand that keeps both the bike and trailer in an upstand position.
- Mudguard since most bikes do not obtain one themselves.
- Be able to adjust the cargo space depending on how many there are in the company.
- Some kind of organisation system that is possible to adapt according to their needs by removing or adding walls etc.
- A storage space for tools separated from the other cargo.
- Some extra openings where it is possible to store water, snacks, camera, the phone, charger etc for easy accessibility in addition to a large one in the storage space.
- Carries valuables, such as car key or wallet in the jacket if carrying one, otherwise in a specific safe compartment in the trailer, since it would be disastrous to lose those items in the forest.

4.9.2 Questionnaires

The questionnaire was available to answer for one week. After one week it was ended, and the results was that 71 people participated and answered the questionnaire. Most of the people who participated where 25–35-year-old (30% out of the 71 participants), and the most of them where men (69%). Most of them considered themselves to be experienced with biking in off-road environments (46%) and most of them also considered themselves experienced with camping in the nature (47%). Thus, it can be concluded so far based on the questionnaire that most of the potential users are men between 25-35 years old who are experienced with biking and camping in off-road environments. However, this also comes down to who the questionnaire reached. In the report the most important results from the questionnaire regarding the trailer are included. To see the remaining results, see appendix 3.

In figure 18 a horizontal bar chart can be seen where different activities are presented which the users tend to do while out camping. The three most popular activities where hiking (61 people), biking (35 people), and fishing (24 people). Therefore, these activities and their respective gear need to be considered when the development of the trailer starts.

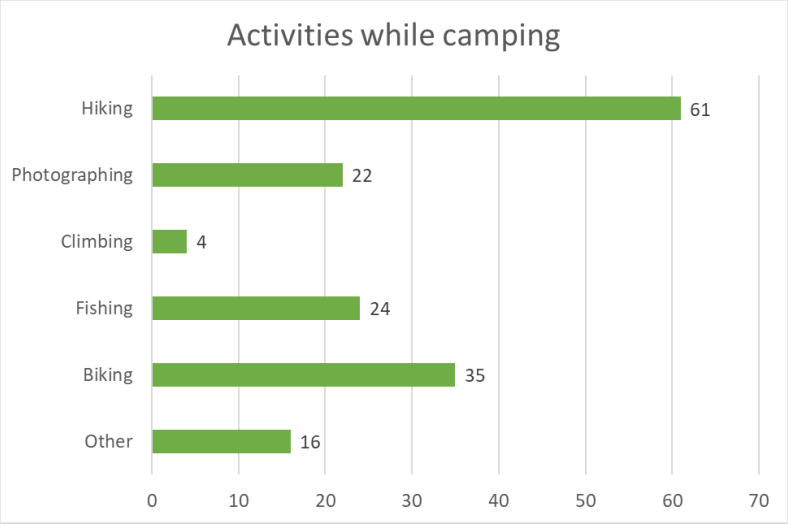


Figure 18. *Horizontal bar chart of activities while camping*.

Most people camp in pairs (43%). Regarding the bicycle they use, the most common one was a hardtail (52 %). The bicycles they use tend to have no electric power supply (92%) and they often do not have a kickstand (63%).

What can be concluded based on figure 19 is that the majority are willing to challenge the terrain represented in alternative 3 (45 %). To do that, it is also clear from figure 20 that the majority choose a one-wheeler (64 %). Although, that do not necessarily mean that people who chose a one-wheeler are the same people that chose alternative 3 as terrain. People who chose alternative 1 and 2 could still have chosen a one-wheeler, and there is also a possibility that they chose a two-wheeler instead, despite possibly going onto the terrain of alternative 3. What can be clear though is that the majority chose a one-wheeler (64 %). Therefore, it is likely that it will be used and cover all three terrains presented in figure 19.

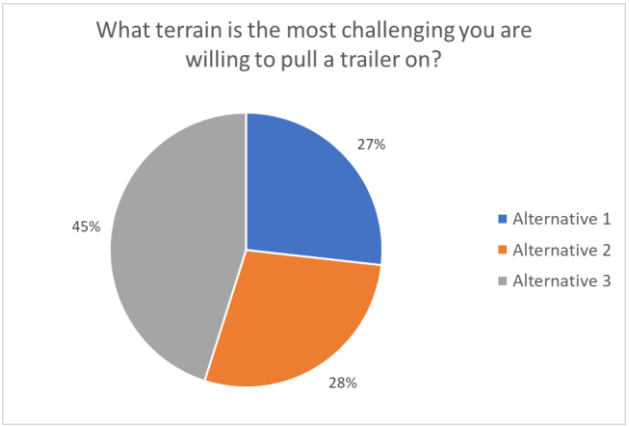


Figure 19. *Pie chart of what terrain is the most challenging the users are willing to pull a trailer on.*

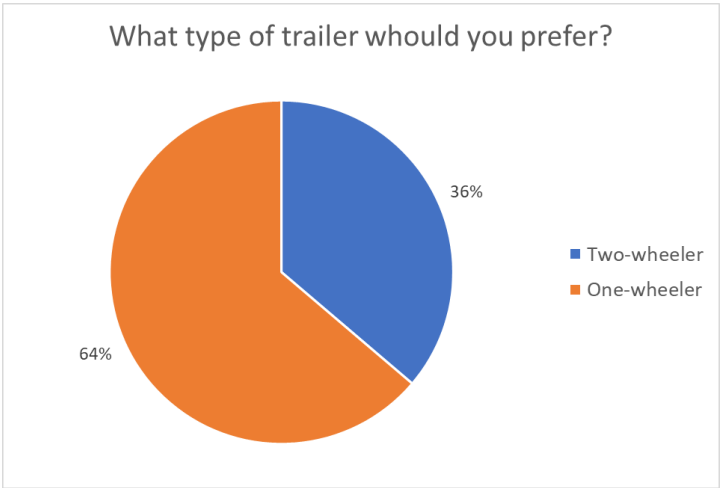


Figure 20. *Pie chart of what type of trailer the users prefer.*

The price bracket that most people were willing to pay for a trailer was 2500-5000 kr (39 %). In appendix 3 a list of items can be seen that the users want to bring in their trailers when going

out camping. The estimated weight of their cargo is 10-20 kg (67 %). That seems reasonable, since the average weight of a bicycle trailer on the market is 7-9 kg, which means that the total weight would be approximately 29 kg at maximum. That corresponds well with the load test performed, where it was concluded that weight above 30 kg is not feasible for everyone considering the terrain because it is hard to pull that amount of weight in those circumstances.

Finally, in figure 21, most people want a semi structured cargo space to load their items in. A semi structured cargo space can be seen as an example of a suitcase in figure 21, where the characteristics are to have some pocket, nets, or dividers to structure the different items from each other to a certain extent but leaving it up to the user how to structure the packing itself.

Figure 21. *Pie chart of which way the user prefers to pack.*

4.10 Function analysis

The function analysis in table 3 is constructed as a table where each function starts with a verb which alters between “enable” and “provide”. Following up to the verb is the noun of what is going to be enabled or provided and their respective classification. There are three different classifications which are Head function (H), Need (N), and Wish (W). Head functions are functions that are necessary for the product to have to be able to excel and inherent the essence of that type of product. Needed functions are functions that are not required at the level as head functions but are needed for the product to perform at a pleasant and descent way. A wish function is function that will add value for the user when using the product but is not a must to have. Lastly, a remark to each function adds a description to clarify what the function will do. An example is the first function which says that the product should enable for connection when attaching it to the bicycle, and that is a head function.

In this case there are four different head functions which by noun are Connection, Cargo, Protection, and Accessibility. It needs to be able to connect to the bicycle by attachment of some sort, otherwise it does not perform the most primary thing which is to be towed by the bicycle. It also needs to be able to bring cargo, otherwise it is being towed for no reason. That cargo space also needs to be protected against external factors like dust, rain, or sunlight since it will be used out in the open nature. Lastly, it needs accessibility, which means that it needs to cope

with different terrains since it is an off-road product, otherwise it will limit the users and their intentions in the natural habitat it is developed for, which is not desired.

This function analysis can be of good use when developing the product since these functions can be integrated in the design in many different shapes and forms depending on the generated concepts. They are not solution orientated since that should be left to the creativity of the development to sort out. When developing the product there is a chance that new functions will be discovered which can be added to the function analysis along the way. On the other hand, some functions that is already in the analysis might have to be refined or removed along the way when the development shines perspective on them.

Table 3. *Function analysis of an off-road bicycle trailer.*

Functional analysis - Off-road bicycle trailer			
Verb	**Noun**	**Classification**	**Remark**
Enable	Connection	H	Attaching to the bicycle
Enable	Cargo	H	Bringing cargo within the trailer
Provide	Protection	H	Protect against external factors
Enable	Accessibility	H	Enable emergence in different terrains
Provide	Stability	N	Increase the maneuverability
Enable	Adaptability	N	Fit to different types of bikes
Provide	Robustness	N	Construction of product and material choice
Enable	Disassembly	N	Change of spare parts
Provide	Dampening	W	Absorb shocks from irregularities
Enable	Flexibility	W	Adjust packing volume
Reduce	Weight	W	Make the trailer lightweight
Enable	Change	W	Adjust the ride height
Enable	Standing	W	Enable up right standing
Provide	Strucutre	W	Seperate things

4.11 Product specification

Table 4 shows the product specification that was made based on gathered information during the theoretical framework and methods used. This information has been analysed and translated into measurable wishes and demands.

Table 4. *Product specification.*

Product specification							
Category	Specification	Requirement	Wish	Unit	Test method	Source	Comment
Dimensions	Total height	< 700		mm	Measure	Own confirmation	Total height of the trailer
	Total lengt	< 2100		mm			Total length of the trailer
	Protruding length	< 1650		mm			Protruding lengt of the trailer behind the wheel of the bike
	Total width	< 500		mm			Total width of the trailer
	Kerb weight	< 10	7	kg	Weigh		The weight of the trailer construction
	Max load capacity	40	50	kg			Maxed allowed weight of additional cargo packed in the trailer
	Wheel size	18	20	in.	Measure		The size of the wheels
	Cargo volume	80	90	L	Calculation		The volume that the trailer is able to carry
	Attachment to bikes	X		Yes/No	Inspection		Being able to attach to different types of bikes
Tests	Turn testing	130	115	degree	Turn testing	Results	The angle of turns that the trailer allows for
	Load testing	30	40	kg	Load testing		Weight of the cargo packed in the trailer
	Drum test	Pass		Pass/Fail	Drum tet		The trailer must pass the drum test to be allowed to be selled on the market
	Hitch arm test	Pass			Hitch arm test		The trailer must pass the hitch arm test to be allowed to be selled on the market
	Ramp test	Pass			Ramp test		The trailer must pass the ramp test to be allowed to be selled on the market
Material	Water resistant	X		Yes/No	Inspection	Own confirmation	The trailer should be able to sustain water
	Waterproof	5000	10 000	mm	Water pillar test	Results	The trailer should be able to resist water
	Corrosion resistant	1	< 1	mm/year	Accelerated corrosion test		The trailer should be able to withstand corrosion
	UV resistant	290 - 400		nm	Accelerated UV test		It should cope with UV lights with the measures of 290-400 nm
	Temperature	– 30 < X < 50		Celsius	Inspection		It should be able to use it in temperatures between - 30 to 50 degrees Celsius
	Durability	10	> 10	years	Inspection		The trailer should last at least 10 years when considering joinst, no breaking, or collapsing
Enviroment	Recyclable materials	> 50	70	%	Calculation	Own confirmation	At least 50 % of the product's materials should be recycable
	Able to disassembly	X		Yes/No	Assembly test		It should be able to disassemble the trailer to some extent to pieces able to recycle
	No heavy metals	X			Inspection		No metals with toxic substances can be used
	No toxic chemicals	X					No chemicals with toxic substances can be used
	No toxic polymers	X					No polymers with toxic substances can be used
Safety	Bring first aid kit		X	Yes/No	Inspection	Own confirmation	Provide storage or the ability to bring a first aid kit
	No sharp edges	> 2,5		mm			To sharp edges to minimize the risk of injury
	Reflexes	X		Yes/No			Provide reflectors that can be attached to the trailer
	Rear lights		X				Provide rear lights that can be attached to the trailer
Production	Produced products	5000		Number	Calculation	Own confirmation	How many products are going to be produced in a year
	Cost of gods	2000		kr			The total cost per product including manufacturing
	Price of product	10 000		kr			The selling price of the product on the market
Performance	Yield stress	50	40	%	Yield stress test	Own confirmation	Should cope with at least 50 % of the yield stress
	Fatigue	200	300	%	Fatigue test		Should cope with the load cycles without breaking or deforming
	Sealing	< 1		mm	Sand test	Inspection	Acceptable gap between sealing to prevent dirt getting in
	Absorb shocks		X	Yes/No	Inspection	Own confirmation	The ability to absorb shocks from the uneven road surfaces
	Ground clearence	150 < X < 250		mm	Measure		The clearance between the ground and the undertray of the trailer
	Enable up right standing		X	Yes/No	Inspection		The ability to stand upright without holding it by hand

4.12 Idea generation

The idea generation will present results, figures, learnings, and conclusions from the phases brainstorming, thumbnails, and mock-ups.

4.12.1 Brainstorming

During the brainstorming sessions there were several discussions about how an off-road cargo trailer could be constructed and what kind of features that could be implemented. Things that were discussed were whether the trailer should have one, two or more wheels, where they should be placed, how to optimize the cargo space, if the cargo space should be made of fabric with a pipe construction or a hard shell of plastic with a platform, and how the trailer should be connected to the bicycle. These things will be further investigated in the following sub-headings 4.12.2 Thumbnails and 4.12.3 Mock-ups with belonging figures, learnings, and conclusions that could be drawn.

4.12.2 Thumbnails

After the brainstorming it was time to turn the ideas into concrete concepts. In figure 22 it is possible to see a selection of the concepts and features that was generated. To see the whole explored design space of thumbnails, see appendix 4.

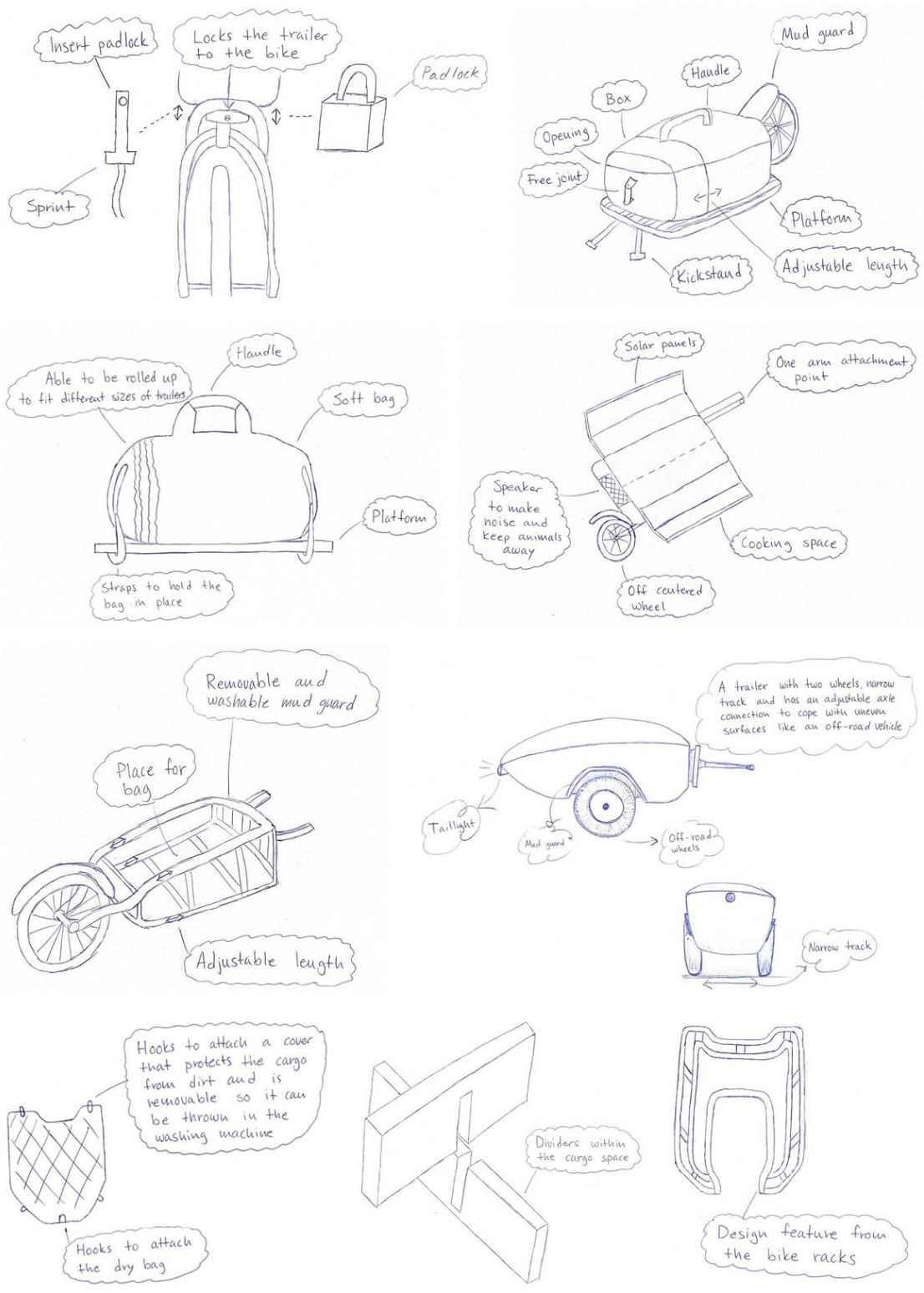


Figure 22. *Thumbnails of trailers, features, and functions.*

4.12.3 Mock-ups

To get a better understanding of the cargo volume suited for a bicycle trailer, a mock-up was made. The measurements of the basis were measured to be 600 x 400 x 300 mm in length, width, and height accordingly, which makes up a volume of 72 litres. The construction of the trailer was made from OSB-boards, the attachments to the wheels were 3D-printed, and the

wheels and arm to connect to the bicycle was reused from another trailer. The mock-up was also used to try out different positions of the wheels. Since the attachments to the wheels were easily moved alongside the joists underneath the trailer, it was possible to move around the wheels and test different wheel positions. In figure 23 it is possible to see the trailer and some of the positioning of the wheels that were tested.

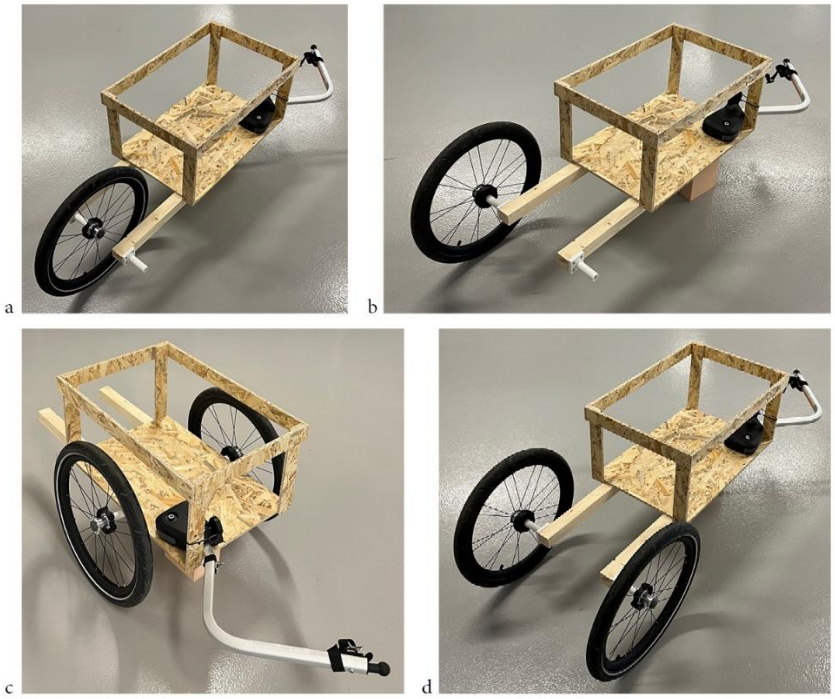


Figure 23a-d. *Mock-up made to test different positions of the wheels and cargo volume.*

Learnings from the mock-up and conclusions that could be drawn were that the cargo volume was a bit too small. To fit all the cargo the user needs to bring when camping it would need to be a bit bigger. Regarding the positioning of the wheels, it was concluded that when travelling on a narrow path it would be easier with just one wheel. The positioning of the wheel as can be seen in figure 23b was tried to see if it is possible to have just one wheel and that the trailer connects to just one side of the bicycle. The conclusion was that it provided somewhat more stability than the positioning in figure 23a, but if the trailer is heavily packed on the right side, it will most likely be tilted towards that direction. Also, when travelling on narrower paths, the wheel will not be in line with the bicycle, but instead aside of the path the bicycle is travelling on. This could be solved by displacing the trailer in one direction, but that would lead to that the trailer most likely will stick out on one side of the handlebar and that the width between the arm and wheel comes closer to one another making it more unstable.

Another learning from the mock-up was that when just having one wheel and an arm connecting to the trailer, it becomes more unstable than with two wheels and one arm. This is since the one wheel, one arm allows for more degrees of freedom, due to that it can rotate around its own axis to some degree. This is prevented by having two wheels, or for one-wheelers having two arms connecting to the bicycle, one on each side of the rear wheel.

Beyond the mock-up and learnings previously described, it was also used to test an idea to prevent the perceived feeling of a force pulling the rider downwards the side turning, which was described in 4.8 User journey under the subheading One-wheel trailer. The idea was to use trucks, like the ones used on a longboard or skateboard, to tilt the rear wheel of the trailer. The thought was that the occurring momentum from the cargo while turning would apply a force on the trucks, causing the wheel to tilt in the desired direction. The phenomenon is comparable to turning with a longboard or skateboard. If it is desired to take a right-hand turn, the foot is

moved to the right side of the longboard or skateboard and the trucks is compressed, causing it to turn to the right. The same thing applies but conversely if it is desired to turn to the left, which is visualised in figure 24.

Figure 24. *The principal usage of trucks from a longboard.*

Akin to turning with a longboard or skateboard happens when turning with the bicycle or leaning it into a turn. Due to the momentum of the cargo, it would apply pressure on the truck that was placed in the rear end of the trailer, connecting to the trailer arm that goes to the rear wheel, causing it to tilt in the same direction the bicycle goes. The idea was that it would counteract the pulling feeling downwards when turning. After the tests with the mock-up, it was concluded that it rather does the opposite, making the feeling worse. Since the use of trucks causes the rear wheel of the trailer to tilt in the same direction as the bicycle, the lever of the force from the cargo would increase, resulting in a greater momentum.

Therefore, to reduce the pulling feeling, the lever that occurs when turning needs to be avoided or counteracted, keeping the cargo in equilibrium. By doing that, it would instead result in a counteracting force against the one that occurs from the bicycle leaning into a turn and might result in a worse turning radius, since the trailer naturally wants to lean into the turn together with the bicycle. Due to that, the conclusion that was drawn was that it might be difficult to avoid the pulling feeling without impair the turning radius and depending on the solution to avoid or counteract the pulling feeling, it might just work against the force from the rider when taking a turn.

4.13 Idea evaluation

After a large volume of concepts were generated, it was time to converge and limit the alternatives. This was done through idea evaluation where both participants had four votes each to place on whatever concepts felt most promising. If a concept got two votes, it was moving on for further development and the concepts that got one vote were afterwards chosen between separately until four concepts were chosen. When four concepts were decided to move on for further development, some features were also chosen in discussion between the participants that were suitable to implement on certain concepts. The concepts and features that was chosen in the idea evaluation can be seen in figure 22. When the alternatives had been limited, more

detailed, and developed sketches were done of the concepts containing the assigned features, which can be seen in figure 25-28.

Concept 1

Concept 1 as can be seen in figure 25 has one wheel and an arm connecting to the bicycle that can be moved from both sides of the trailer to accommodate the user's preference. The foldable sides of the cargo space contain on one side solar panels and on the other a table or cooking area. The solar panels can be used to charge the phone or the speaker that is in the rear end of the trailer that can be used to play music or certain sounds to keep animals away from the tent at night.

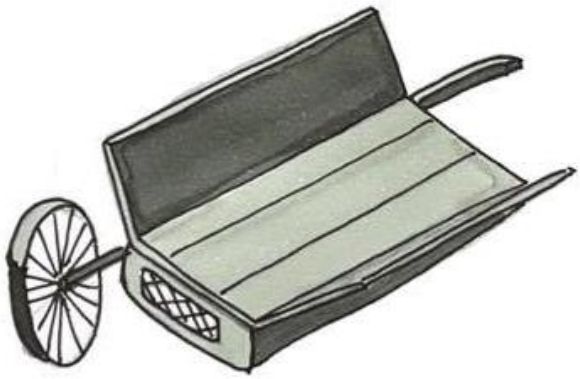


Figure 25. *Concept 1.*

Concept 2

Concept 2 has a pipe structure with changeable lengths and a belonging bag where the cargo will be packed, which can be seen in figure 26. The bag is also flexible to be able to adjust to the length of the trailer. On the pipe structure there are hooks along the sides to place a cover that protects the bag and the cargo from getting dirty. This is easily removed and can be washed in the laundry machine after use. The handle of the pipe structure is a design feature from the bicycle holder that could be implemented, which can be seen in figure 14.

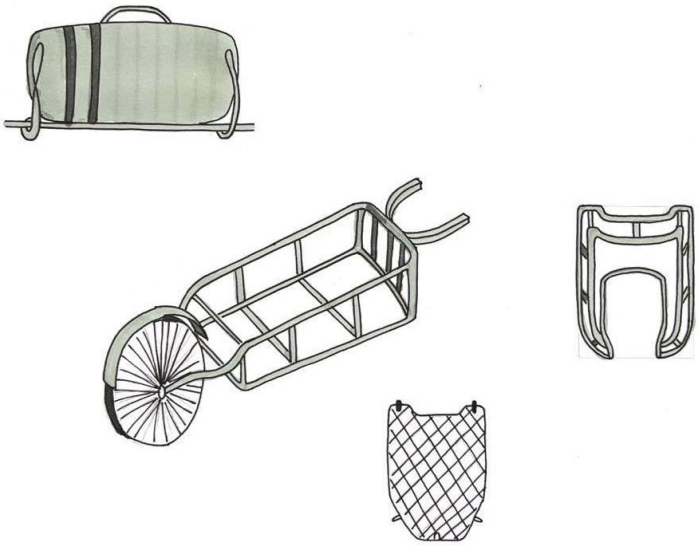


Figure 26. *Concept 2.*

Concept 3

Concept 3 builds instead upon a hard-shell box solution, which can be seen in figure 27. The box is placed on a platform with a kickstand. Inside the box it is possible to place dividers that splits the cargo space into certain packing areas. The trailer and the bicycle are lockable through a sprint that goes through the handle of the quick release of the bike with a padlock, preventing it from being released. In this way, both the bicycle and the trailer are locked at the same place.

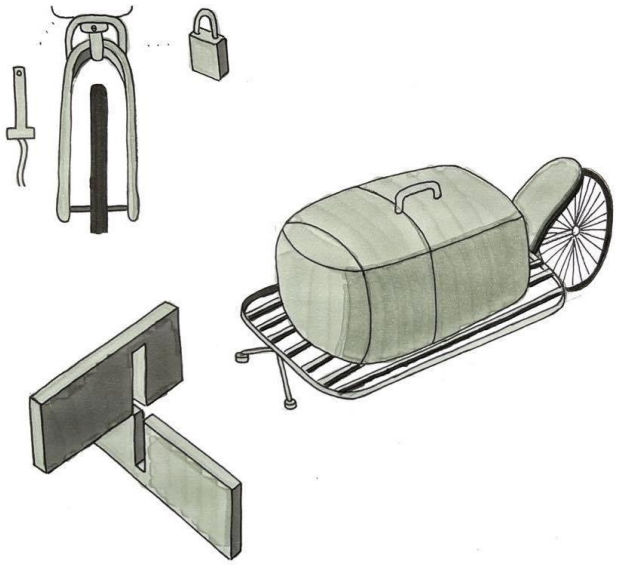


Figure 27. *Concept 3.*

Concept 4

Concept 4 is a two-wheeler with an adjustable axle to be able to handle uneven surfaces, similar to an off-road vehicle. The wheels are placed on each side of the trailer to provide stability, which can be seen in figure 28. The adjustable axle that goes between the wheels prevents the trailer from tilting to a certain side when going over an obstacle with just one of the wheels. This will provide a smoother and more stable ride for the user.

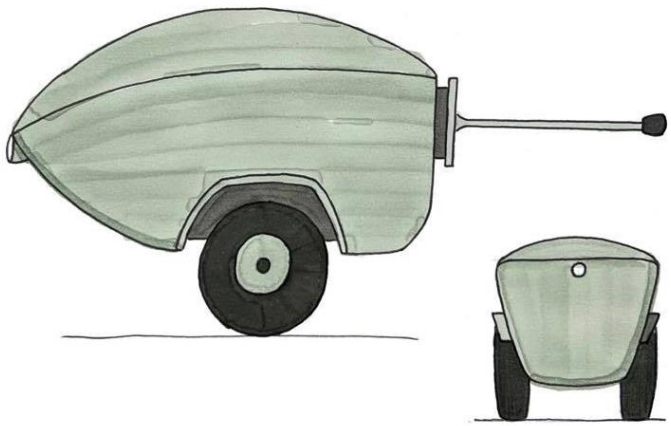


Figure 28. *Concept 4.*

4.14 Concept weighting matrix

The criteriums that were chosen in the concept weighting matrix are mostly requirements from the product specification. Some of the criteriums are also design features that can be found in 4.7 Design Format Analysis. The criteriums were weighted, depending on how important they are concerning the product. The weight of the criteriums is distributed to make up a total of 100%. Each concept is then rated between 1-5, where 1 indicates that the concept does not fulfil the criterium well, and 5 stand for fulfilling the criterium well. Based on that each concept gets a weighted score, that is summed up in the total score. As can be seen in table 5, concept 2 got the highest score and will therefore be further developed.

Table 5. *Concept weighting matrix.*

		Concept 1		Concept 2		Concept 3		Concept 4	
Selection criteria	**Weight**	**Rating**	**Weighted score**	**Rating**	**Weighted score**	**Rating**	**Weighted score**	**Rating**	**Weighted score**
Protruding length	0,1	3	0,3	3	0,3	3	0,3	4	0,4
Kerb weight	0,15	1	0,15	4	0,6	2	0,3	2	0,3
Max load capacity	0,05	2	0,1	3	0,15	4	0,2	4	0,2
Wheel size	0,05	3	0,15	4	0,2	4	0,2	2	0,1
Cargo volume	0,15	2	0,3	5	0,75	4	0,6	3	0,45
Uniform design	0,05	2	0,1	3	0,15	4	0,2	2	0,1
Functional design	0,02	3	0,06	4	0,08	4	0,08	3	0,06
Expresses quality	0,03	2	0,06	3	0,09	4	0,12	4	0,12
Waterproof	0,1	2	0,2	3	0,3	4	0,4	4	0,4
Termperature	0,05	1	0,05	3	0,15	2	0,1	2	0,1
Manufacturability	0,05	2	0,1	4	0,2	3	0,15	3	0,15
Tooling	0,05	2	0,1	5	0,25	3	0,15	3	0,15
Number of parts	0,05	3	0,15	4	0,2	2	0,1	4	0,2
Cost	0,1	2	0,2	4	0,4	3	0,3	3	0,3
Total score	100,00%	2,02		3,82		3,2		3,03	
	Rank	4		1		2		3	
	Further development	**NO**		**YES**		**NO**		**NO**	

4.15 Prototyping

The prototype of the final concept can be seen in figure 29, in relation to a bicycle placed in one of many intended environments for it. The purpose of building this 1:1 prototype is to embody the whole concept into something more tangible than just a CAD-assembly and to see proportions. This embodiment allows for understanding the concept in a whole other perspective, as virtual modelling is not always going to portray potential problems as well as a physical model. Therefore, to investigate all functions, size, materials, proportions, details, and in general the concept as a whole, it had to be made in full scale.

Figure 29. *The prototype in relation to a bicycle in an intended environment.*

The build had to be compromised because of the material available but also the building techniques available. The frame was intended to be of aluminium, where it would be bent and welded together. Aluminium is difficult to weld in and can be dangerous due to its low melting point, so that had to be worked around. Instead, all the splices where the aluminium is supposed to be bent, are replaced with 3D-printed parts that have attachment points on each side to connect the aluminium profiles on the inside. The ribs that run between each side of the frame are connected via 3D-printed connecters that slides onto the frame and have connection points that slides into the aluminium profile of the ribs. The 3D-printed parts are secured in place by drilling a whole through them and the aluminium profiles to then be fastened by a screw and bult, which can be seen in figure 30. The aluminium profiles themselves are not the same as the ones in the CAD-model. They had to be used because there was not any other size or shape available. The trailer arm that connects the trailer wheel follows the same philosophy as the frame, where it uses aluminium profiles and 3D-printed splices to be put together. The rest of the trailer, which is the mudguard, the handle, trailer arms that connects to the bicycle, the kickstand, and the trailer wheel connecter are all 3D-printed parts that are assembled to the rest of the trailer.

Figure 30. *The final prototype of the trailer.*

What can be concluded after building the prototype and testing it was that the cargo space is a leap forward compared to the competitors. The same cargo was packed into it as was packed in each of the trailer used in the user journeys. Even in its shortest configuration it managed to contain all things without any big issues. When having it in its longest position even more cargo can fit, which is reassuring, as that was one of the wishes from the users. Also, the quick release function for the rear wheel was tested and confirmed working well. Although, the way the prototype had to be built due to the circumstances makes it quite fragile and does therefore not allow for any driving with it since it will most likely break. Therefore, no insights can be gained regarding the turning aspects and riding feel. What can be determined with the prototype is the proportions which gives a good understanding of how big it will appear next to a bicycle.

4.16 Cost calculation

Based on the information explained in 3.16 Cost calculation about the complex modelling and calculation methods, the procedure of how the estimated costs will be calculated, will be simplified. The total cost of the trailer will only consider the raw material cost of the components of the trailer since that in most cases constitutes the majority of the overall costs due to Peters (2007). Regarding this trailer, the assembly of the trailer will also be expensive

since it requires welding in aluminium. That will probably contribute to a higher total cost of the trailer but will not be considered in the cost calculation.

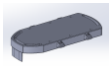
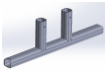
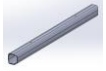
The formula to calculate the estimated cost per part will also be simplified to easier extract the total cost. The way the cost per part will be calculated is through multiplying the weight of the part with the purchasing price of a certain raw material per kilogram and multiplying that with the amount of that certain part used in the trailer. The purchasing price of the materials are an estimation and might not be the real value. The formula used to calculate the cost per part is visualised in eq. (1), with a further explanation of the purchasing price in eq. (2). When all the costs per part are calculated, they are added together to get the total cost of the trailer. The total weight of the trailer is obtained by summing up the weight part, multiplied with the amount of that part, which is expressed in eq. (3). The cost calculation can be seen in table 6. As can be seen in the table, there is a total part amount of 124, while there is only a part amount of unique parts of 37. This is because the frame of the trailer is based on symmetry and therefore several of the parts are the same.

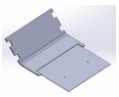
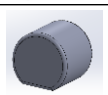
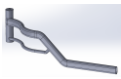
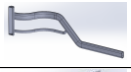
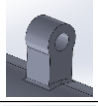
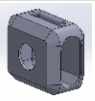
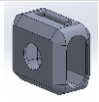
$$Cost\ per\ part = Weight\ part\ \times Purchasing\ price\ \times Amount \quad \text{eq. (1)}$$

$$Purchasing\ price = Cost\ \div kg\ (raw\ material) \quad \text{eq. (2)}$$

$$Total\ weight = \sum Weight\ part\ \times Amount \quad \text{eq. (3)}$$

Table 6. *Cost calculation of the raw material for the trailer.*

Cost calculation							
Part	**Part Name**	**Visual**	**Material**	**Weight part [kg]**	**Purchasing price [kr/kg]**	**Amount**	**Cost per part [kr]**
1	FAT Bike tire 20x4 inch		Natural Rubber 6061-T6 (SS) Aluminium	-	-	1	400
2	MUDGUARD		PA Type 6 30% GF	1,837	15,14	1	27,819
3	MUDGUARD AXIS 272 mm		Steel	0,123	15	2	3,697
4	AXIS END BAR STOP		Steel	0,014	15	4	0,832
5	BOLT M5X18		Steel	0,003	15	10	0,387
6	NUT M5		Steel	0,001	15	5	0,098
7	MUDGUARD HANDLE		6061-T6 (SS) Aluminium	0,723	25	1	18,083
8	SPOKES HOLDER		PA Type 6 30% GF	0,121	15,14	1	1,837
9	SWING ARM		6061-T6 (SS) Aluminium	0,571	25	1	14,265
10	CONNECTOR		Steel	0,037	15	6	3,340
11	NUT M10		Steel	0,013	15	6	1,161
12	BOLT M10X40		Steel	0,037	15	2	1,108
13	SUSPENSION		Steel	0,590	15	1	8,853
14	SUSPENSION AXIS 230 mm		Steel	0,140	15	1	2,093
15	FRAME SYMMETRY		6061-T6 (SS) Aluminium	0,622	25	4	62,234
16	HANDLE HOLDER		6061-T6 (SS) Aluminium	0,308	25	2	15,376
17	RIB		6061-T6 (SS) Aluminium	0,211	25	4	21,098
18	SPRINT		Steel	0,0072	15	4	0,429
19	UPPER FLOOR		PA Type 6 30% GF	0,791	15,14	1	11,974

20	LOWER FLOOR		PA Type 6 30% GF	1,120	15,14	1	16,954
21	SCREW M3X12		Steel	0,0009	15	20	0,258
22	PLUG 3mm		Silicon rubber	0,00006	53,54	18	0,058
23	QUICK RELEASE		Steel	0,031	15	4	1,853
24	KICKSTAND STOP		Steel	0,282	15	1	4,233
25	KICKSTAND AXIS 140 mm		Steel	0,085	15	1	1,270
26	KICKSTAND		Steel	0,807	15	1	12,111
27	KICKSTAND LEG		Steel	0,211	15	2	6,330
28	KICKSTAND FOOTREST		Silicon Rubber	0,029	53,54	2	3,124
29	TRAILER HANDLE		6061-T6 (SS) Aluminium	0,550	25	1	13,744
30	BRACKET TRAILER ARM		Steel	0,502	15	2	15,054
31	QUICK RELEASE AXIS		Steel	0,046	15	1	0,683
32	TRAILER ARM FEMALE		6061-T6 (SS) Aluminium	0,638	25	1	15,940
33	TRAILER ARM MALE		6061-T6 (SS) Aluminium	0,632	25	1	15,803
34	WIRE		Steel Silicon Rubber	-	-	1	10
35	WIRE HOLDER		PA Type 6 30% GF	0,00012	15,14	8	0,015
36	CONNECTOR BIKE		PA Type 6 30% GF	0,021	15,14	1	0,324
37	CONNECTOR BIKE REVERSE		PA Type 6 30% GF	0,021	15,14	1	0,324
Part amount 37			**Total weight** 15,3		**Total part amount** 124		**Total price** 713

5 Results

The result of the off-road bicycle trailer can be seen in figure 31-38 from different angles and configurations. To explain the concept in its detail, it bases itself on the symmetrical frame, which everything builds upon. The frame has a telescopic function with four clamps on each side of the frame which enables the ability to shorten and lengthen the trailer in a stepless motion, which increases or decreases the cargo space depending on the user's desire. The cargo space can be lengthened by 15 cm, which is equal to 26 litres in volume. The idea is that the user unfastens the four clamps before starting packing and then loads the trailer with cargo on one side. After all cargo is placed in the trailer, the trailer can be shortened to the smallest configuration possible depending on the cargo that is brought, which enables not having to pull a longer trailer than necessary. The intention is that the user can either pack the cargo into the cargo space itself or pack it in a dry bag which then sits in the cargo space. The telescopic function and the clamps can be seen in figure 31, while the smallest and longest configuration of the frame can be seen in figure 32 and 34.

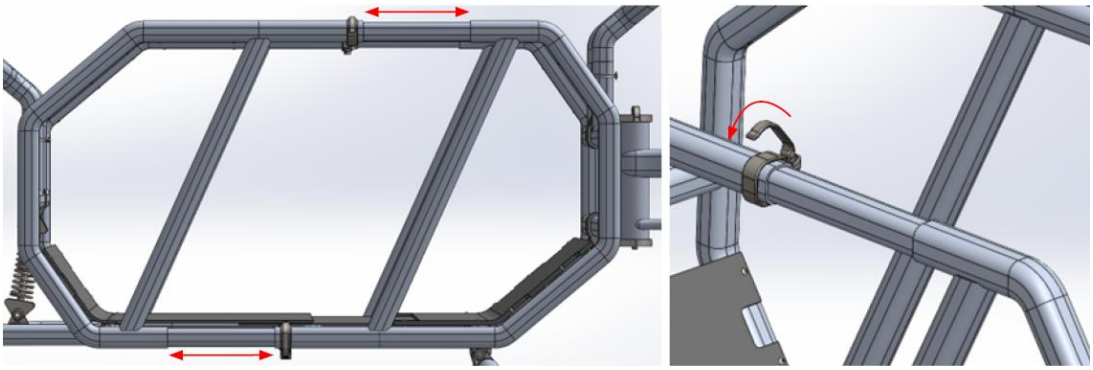


Figure 31. *The telescopic function with the clamps.*

At the front of the trailer there is a kickstand, handle, and the trailer arms that connects to the bicycle. The kickstand, alike the frame, has a telescopic function with three different fixed positions. The lowest position is set to the equivalent height of a 26-inch rear wheel of a bicycle. When extending it out the trailer will raise to be the height of a 27.5-inch wheel in the middle position and a 29-inch wheel in the third position. This is to aid the user for an easier experience when attaching the trailer to the rear wheel of the bicycle. Instead of changing the angle of the kickstand, the length of the kickstand is changed to fit different wheel sizes. When the trailer is in the correct height in relation the real wheel of the bicycle the user only has to focus on attaching the trailer arms and not worrying about holding the trailer in place. The kickstand can be seen in figure 32.

The handle carries the same design and construction as the mudguard. The idea for it being a bit taller than the competitors and bigger is that the trailer should be easily moved by grabbing it there. There is an idea that it can be manoeuvred around by grabbing the handle and pushing it like a wheelbarrow. The handle can be seen in figure 32.

The trailer arms that connect to the bicycle are constructed via a rotation point at the front of the trailer. There is a cylindrical mechanism, which are split into two parts, which allows the arms to rotate away from each other. The reason for that is to widen or close the distance between them, as different bicycles have different widths and therefore so does the axles that are the connection point to the arms. Once the trailer is connected, both arms will rotate in the same directions simultaneously in the path of the bicycle for a pleasant turning radius. The interface for connecting the arms to the axle hitch that sits in the rear wheel of the bicycle are constructed to be a hole on each inside of the arms. Inside these holes there are a conical latch that will be displaced when pushing the arms onto the knobs on the ends of the axle. When the knobs have gone through the latch it will pop back again via a spring, so that it grabs around

the axle. This will secure the trailer onto the axle hitch unless the user pulls the wire to manually open the latches for taking off the trailer from the bicycle. The trailer then clicks on by simply pushing it onto the axle hitch. For it to be released, the wire has to be pulled. The arms and wire can be seen in figure 32.

Figure 32. *Render of the final concept from the side.*

The wheel assembly contains the wheel and the single trailer arm. The trailer arm is fastened in one of the ribs to the frame and runs back with an end-interface that contains the same quick release interface as the company's other trailers have. This means that the trailer wheel can easily be removed by pushing a button on the centre cap of the wheel to release it from the trailer arm. This allows for smooth changing between different wheels sizes and types of wheels depending on the user's choice and terrain. The ride height is set to be 20 cm when using a 20-inch wheel on the trailer. The reason being is that a 20-inch wheel will be standard for the trailer to allow it to smoother go over roots and obstacles, since it is an off-road trailer. Therefore, the ride height will be compromised and a bit lower when choosing a smaller wheel. The trailer arm is also connected to the upper rib via a suspension to ensure a smooth ride over the course. The suspension is a conventional suspension that is placed in the centre of the rib. The mudguard, wheel, single trailer arm, and suspension can be seen in figure 33.

Figure 33. *Render of the final concept from the back.*

The mudguard protects the cargo space from getting dirty and wet, but the cover which sits on the frame has a function itself. When the trailer is in the smaller configuration, the volume of the cargo space is approximately 106 L, while in the extended configuration it is 132 L. If the user then wants to pack more, it is possible to add the side bags. The sides of the mudguard have been given an interface for attaching additional side bags. These side bags are already offered to buy alone or in addition to other products by the company, so the thought of having the same opportunity with this trailer made sense. The interface for fastening the side bags will be implemented on the mudguard to allow the user to additionally buy the side bags as an accessory. The interface and dry bags can be seen in figure 34.

Figure 34. *Render of the final concept extended with side bag attached.*

Whether the customer wants to pack their cargo directly in the trailer or withing a dry bag, both options would benefit from a flooring and textile to enclose the frame and create the cargo space itself. This however entails difficulties to be able to lengthen and shorten the trailer. This was solved by having a two-piece flooring, where they overlap. One of them would go above the other, which then allows the flooring to slide with the trailer. This will result in a slight height difference between the two floor pieces but can be neglected as it is such a small measure in relation to the amount of cargo space. The other difficulty would be the middle textile parts that sits on each side of the trailer between the tilted ribs. This was solved similarly to the flooring, where it would be two pieces of textile that overlaps each other. They are attached with velcro which are long enough to suit the shortest configuration of the trailer, but also the longest. The cargo space can be seen in figure 35.

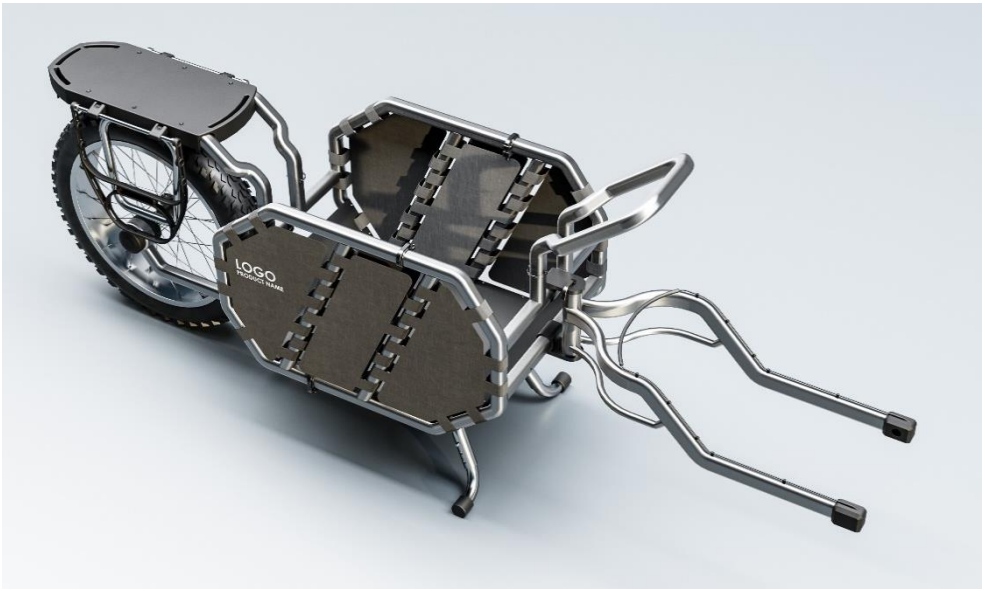


Figure 35. *Render that shows the cargo space.*

On top of the trailer there is a cover which is made of textile. The length of the cover is static, which means that the cover itself is not expandable. However, it is measured from the shortest configurations. Therefore, in the shortest configuration, it will run further back along the trailer and fasten further back. When the trailer is extended, the same cover piece will not cover the same distance as in the shorter configuration, yet enough to keep the cargo dry from mud and rain. The only difference is that the attachment points of the cover will be a bit further towards the front of the trailer and attaches with loops around plugs in pre-drilled holes. The cover on top and on the sides that protects the cargo from getting dirty are all removable and able to be washed in the laundry machine to ease the cleaning of the trailer. The two configurations of the top cover can be seen in figure 36 and 37.

Figure 36. *Render with cover to protect the cargo.*

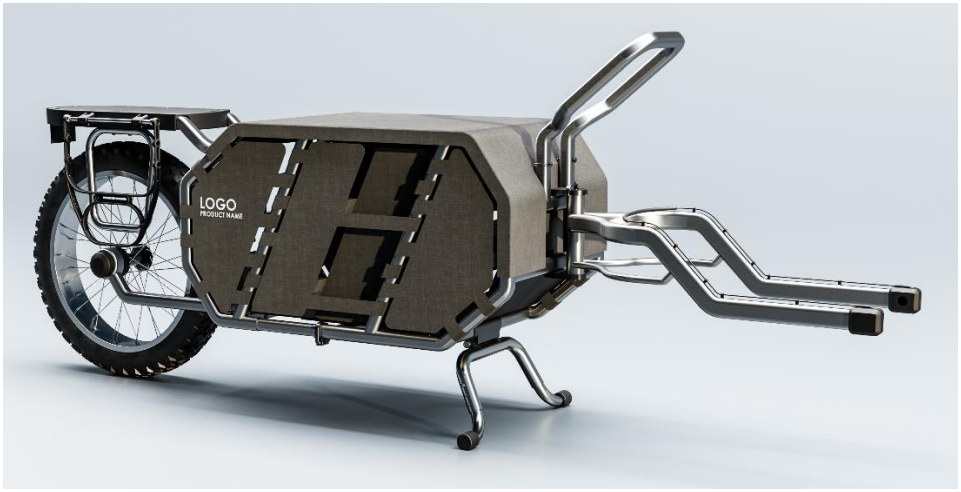


Figure 37. *Render in extended position with cover to protect the cargo.*

The trailer is aimed to be used in an off-road environment and has been developed for that certain purpose. The goal has been to enable accessibility in different terrains and transport cargo during the journey to enable spending some nights in the nature. In figure 38 it is possible to see the trailer placed in the intended environment it is going to be used in.

Figure 38. *Render of the final concept placed in the intended environment.*

The result presented in this chapter is just a suggestion how the trailer could look like regarding the colour combination. In Chapter 4.7 Design Format Analysis, an example of the colour palette from the company was given, which can be seen in figure 15. These colours and possibly others could be combined to create different versions of the trailer and offer the customer the right colour combination in their preference.

6 Discussion and conclusions

The trailer in figure 39 is a trailer from Burley called COHO XC, which is also included in 4.1 Market research and used in 4.8 User journey. After the market research, this was the trailer that was considered the best on the current market and therefore the company decided to buy this for the project. This led to that the Burley COHO XC became a benchmark for the project to compare functions, cargo space, and the experience.

Figure 39. *Benchmarking trailer Burley COHO XC.*

What distinguish the trailer developed in this project against the Burley COHO XC, and other trailers available on the market is the telescopic function, which enables to lengthen and shorten the trailer. This makes the cargo space more flexible since the users can adjust it according to their usage. The cargo space has also been expanded in comparison to the COHO XC's 70 litres to 106 litres in the smallest configuration and 132 litres in the longest. The reason being, was that it was considered too small to fit all the cargo in a convenient manner.

Other differences between the trailer developed and the Burley COHO XC is the kickstand, together with the arms connecting to the bicycle. With the Burley trailer, the angle of the kickstand adjusts the length of the kickstand in an upstand position, which affects the height of trailer. For the kickstand on the trailer developed in this project it has instead three pre-determined holes to be able to adjust the height. The way the trailer arms on the Burley COHO XC is constructed, requires it to be attached from above onto the axle of the bicycle by hooking it into place. This leads to that the user needs to lift the trailer to be able to place it onto the axle. The difference between the trailer arms of the Burley COHO XC which attaches from above, the trailer developed in this project instead attaches from the sides. By adjusting the height of the kickstand depending on the rear wheel size of the bicycle, the trailer arms will be in the right position regarding the axle of the bicycle. After that the trailer arms are rotated inwards towards the axle until they are fastened. This prevents the user from having to lift the trailer when attaching it onto the axle, which can be difficult when the trailer is heavily packed.

Another difference is that the Burley COHO XC has its handle integrated onto the trailer arms, with the wire for the quick release. The way this was constructed gave a feeling of being wobbly and cheap, since it requires a certain clearance for the arms to be able to rotate. Therefore, for the trailer developed in this project, these parts were separated and independent of each other. The handle was placed onto the frame instead of the trailer arms and was made larger to easier be able to operate the trailer when transporting it without a bicycle, while the wire runs around the trailer arms by itself to avoid the wobbly feeling.

What can be considered as another improvement with the trailer developed in comparison to the Burley COHO XC, is that the user either packs their cargo directly in the trailer or within a dry bag when using the Burley trailer. This easily makes the cargo or dry bag dirty when

traveling through off-road terrains. Therefore, a cover that protects the cargo space was developed that is easily attachable and removable. This prevents the cargo space from getting dirty and eases the cleaning since the cover together with the fabric on the sides can be washed in the laundry machine.

Another thing that differentiates the trailer developed to the Burley is the single trailer arm. While the Burley holds the rear wheel of the trailer in place by two trailer arms and a through axis, the trailer developed in this project has a single trailer arm with a quick release on the wheel. By a push on the centre cap of the wheel it can be substituted to another wheel size or type of wheel depending on the terrain.

Regarding how the development and construction of the trailer has taken sustainability into account, there are several aspects that motivates sustainable thinking. First, there are three main pillars that builds up the concept of sustainability, which are social, economic, and environmental and is explained under 2.8 Sustainable development. Sustainable development has been considered during the project by the construction of the trailer, which builds on symmetry, reused parts from previous trailers, and ease of disassembly when the lifetime has come to an end for the trailer. By using the concept of symmetry there are less various parts to produce, as some parts are the same due to the symmetry, which keeps the complexity of the product down. By producing less unique parts there are less different manufacturing steps required, which keeps the manufacturing costs and time down. It also eases the assembly, packaging, and distribution of the product, which contributes to an economic and environmental sustainability. That is also achieved by reusing parts from already available products by the company, where the development and machine costs for these parts can be neglected. Otherwise, these parts would have to be developed from scratch and machines to manufacture them would be required to purchase.

The ability to disassemble the trailer to some extend where various parts of different materials can be separated, allows for a more streamlined recycling process. Here, the choice of material will play a crucial role. If there are parts that can be reused instead of recycled, the opportunity to do so is also available, due to the possibility to disassemble the trailer. This also leads to that the trailers lifetime can be extended if something breaks. Instead of recycling it, spare parts can be bought to repair the trailer. These aspects contribute to an environmental sustainability.

Regarding the context of the trailer's usage, particularly focusing on its telescopic function, the flexibility and adaptability of the trailer allow the user to customize its usage based on the size of the company and cargo requirements. The trailer's wide capabilities reduce the need for users to purchase additional products to address specific occasions, that the trailer otherwise cannot cope with. This versatility extends the trailer's lifetime, as it can cater a larger user base and accommodate a variety of needs. Consequently, this contributes to both social and economic sustainability, as user can embrace a more interactive and social lifestyle by involving more people in their activities. The trailer's extensive capabilities also reduce the overall economic expenditure since users are not required to invest in other products or accessories to meet their requirement unless it is wanted to improve the experience.

In general, the concept generated and specifically presented in chapter 5 resulted in a solution that has the complete package. It may not necessarily have everything, but it has the widened scope to offer everything a user would want, and possibly even more. The key aspect is the telescopic function for shorten and lengthen the trailer, which could be regarded as a bonus point for this concept, as that is yet to be seen in any of the competitors' products on the market. Other than that, the rest of the solution is nothing ground-breaking, but it is the way things are designed and connected to each other, which makes it good. Looking at the mudguard, there is nothing radical about it, but that in combination with the interface for fastening the side bags gives it the extra value a user would want.

Also, looking at how the trailer arms that connect to the bicycle works are nothing ground-breaking either, but they are yet enough different to make life easier when attaching the trailer to the bicycle. Instead of the arms coming above the axle, these comes from the sides and "hugs" it into place. That in combination with the telescopic kickstand that have three positions measures for the three most common wheel sizes of bicycle rear tires, makes life easier as the trailer can stand still in the right height of the axle while attaching it to the bicycle. This prevents the user from having to lift the trailer into place onto the axle and instead the arms are just rotated from the sides onto the axle.

The way the textile, flooring and top cover works to follow the shortening and lengthening of the trailer also adds value. The wheel of the trailer can easily be removed as the quick release function have been kept from the company's other products. The design itself with the chamfers, tilted, and bent frameworks gives it a look that communicates robustness, quality, and endurance.

Regarding methods used in the project, it would been beneficial to conduct more interviews in the survey to get a broader perspective from potential users. It ended up only being three interviews, due to the problems of aligning the schedule with the ones intended to be interviewed. Also finding appropriate people to interview which suits the target group was also problematic. The intended time and focus were given towards the interviews, but at last there was no time left to spend as the project had to move further, hence only the three interviews. This is because time was also needed to compile and analyse the interviews before heading into the idea generation phase and time was eventually running out. With the questionnaire having a lot of respondents and providing valuable insights, together with the user journeys performed, it was considered enough to proceed with the project.

Interviews in a later stage of the project together with the prototype would also have been helpful to carry out with the presented concept to gain insights, perspective, and thoughts on it from the users. This could then be analysed to see what was good and less good in order to potentially improve it for the better. With the circumstances regarding the build of the prototype, it did not end up quite as intended. It has been some delays due to lead time of 3D-printing. The main challenge though is the way it had to be build makes it quite fragile, which makes it hard to physically test it. It can be tested to some extend regarding some of the functions, but it certainly cannot be driven around with. The prototype therefore had to act more as a visual prototype rather than a fully functional.

The basis of answering the first research question "What are the needs that users have, regarding a bicycle trailer when camping?" lies in the content of the function analysis, which can be found in chapter 4.10 Function analysis. The needs are expressed in functions that the product have to cope with in regard to the expectance and performance set by the market and the users. The function analysis itself is based on gathered knowledge about the users and their needs, which are discovered by the survey when preforming interviews and questionnaires, but also gathering information about fundamental functions of a bicycle trailer, which are chapter 4.9 Survey and 2.3 Fundamental functions respectively.

The answer to the second research question "What are the challenges the users have with a trailer in an off-road environment?" is mainly displayed in chapter 4.8 User journey where the experience of using a trailer in such an environment is carried out. All problems regarding packing, manoeuvring, riding, and many other aspects regarding riding with a trailer is brought up and explained. Challenges that the users themselves expressed in the interviews can be seen in chapter 4.9.1 Interviews.

The requirement specification is the representative framework of which needs, requirements and aspects the solution has to cope with to be regarded as successful. By covering as many requirements as possible it will therefore cover as many needs as possible which will be perceived as a pleasant solution by the users. This partly answers the third research question

“How can the design of the trailer be developed to cover all these needs and requirements?”. Though, fulfilling the requirement specification can be done by various solution with different designs and functions. Reading Chapter 5 Results will display how this design and functions covers the requirement specification and how these aspects are embodied into a physical solution. By reading Chapter 5 Results and understanding the design, functions and features they can be compared to the requirement specification in table 7 below to see what has been fulfilled and not. If the requirement or wish has been marked with green, it means it has been fulfilled by the concept. If it is marked yellow, it needs further work or testing to ensure the outcome. If it is red, that means it has not been fulfilled and needs further work and development. As can be seen, not every single requirement has been fulfilled. Some are not fulfilled, and some still needs further testing. This brings it to the last chapter, which is Chapter 7 Further work.

Table 7. *Validation of the requirement specification.*

Category	Specification	Requirement	Wish	Unit	Test method	Source	Comment
							Product specification
Dimensions	Total height	< 700		mm	Measure	Own confirmation	Total height of the trailer
	Total lengt	< 2100		mm			Total length of the trailer
	Protruding length	< 1650		mm			Protruding lengt of the trailer behind the wheel of the bike
	Total width	< 500		mm			Total width of the trailer
	Kerb weight	< 10	7	kg	Weigh		The weight of the trailer construction
	Max load capacity	40	50	kg			Maxed allowed weight of additional cargo packed in the trailer
	Wheel size	18	20	in.	Measure		The size of the wheels
	Cargo volume	80	90	L	Calculation		The volume that the trailer is able to carry
	Attachment to bikes	X		Yes/No	Inspection		Being able to attach to different types of bikes
Tests	Turn testing	130	115	degree	Turn testing	Results	The angle of turns that the trailer allows for
	Load testing	30	40	kg	Load testing		Weight of the cargo packed in the trailer
	Drum test	Pass		Pass/Fail	Drum tet		The trailer must pass the drum test to be allowed to be selled on the market
	Hitch arm test	Pass			Hitch arm test		The trailer must pass the hitch arm test to be allowed to be selled on the market
	Ramp test	Pass			Ramp test		The trailer must pass the ramp test to be allowed to be selled on the market
Material	Water resistant	X		Yes/No	Inspection	Own confirmation	The trailer should be able to sustain water
	Waterproof	5000	10 000	mm	Water pillar test	Results	The trailer should be able to resist water
	Corrosion resistant	1	< 1	mm/year	Accelerated corrosion test		The trailer should be able to withstand corrosion
	UV resistant	290 - 400		nm	Accelerated UV test		It should cope with UV lights with the measures of 290-400 nm
	Temperature	– 30 < X < 50		Celsius	Inspection		It should be able to use it in temperatures between - 30 to 50 degrees Celsius
	Durability	10	> 10	years	Inspection		The trailer should last at least 10 years when considering joinst, no breaking, or collapsing
Enviroment	Recyclable materials	> 50	70	%	Calculation	Own confirmation	At least 50 % of the product's materials should be recyclable
	Able to disassembly	X		Yes/No	Assembly test		It should be able to disassemble the trailer to some extent to pieces able to recycle
	No heavy metals	X			Inspection		No metals with toxic substances can be used
	No toxic chemicals	X					No chemicals with toxic substances can be used
	No toxic polymers	X					No polymers with toxic substances can be used
Safety	Bring first aid kit		X	Yes/No	Inspection	Own confirmation	Provide storage or the ability to bring a first aid kit
	No sharp edges	> 2,5		mm			To sharp edges to minimize the risk of injury
	Reflexes	X		Yes/No			Provide reflectors that can be attached to the trailer
	Rear lights		X				Provide rear lights that can be attached to the trailer
Production	Produced products	5000		Number	Calculation	Own confirmation	How many products are going to be produced in a year
	Cost of gods	2000		kr			The total cost per product including manufacturing
	Price of product	10 000		kr			The selling price of the product on the market
Performance	Yield stress	50	40	%	Yield stress test	Own confirmation	Should cope with at least 50 % of the yield stress
	Fatigue	200	300	%	Fatigue test		Should cope with the load cycles without breaking or deforming
	Sealing	< 1		mm	Sand test	Inspection	Acceptable gap between sealing to prevent dirt getting in
	Absorb shocks		X	Yes/No	Inspection	Own confirmation	The ability to absorb shocks from the uneven road surfaces
	Ground clearence	150 < X < 250		mm	Measure		The clearance between the ground and the undertray of the trailer
	Enable up right standing		X	Yes/No	Inspection		The ability to stand upright without holding it by hand

7 Further work

Even though the concept has come kind of far in the development stage, there is still plenty of things that needs to be worked on before it can be manufactured. As mentioned lastly in the chapter before, some requirements are not fulfilled, and others still needs further testing to validate the outcome. That is why several of the requirements are still yellow and red in table 7.

An example on a requirement that needs further work and testing is the kerb weight of the trailer. The requirement said that the kerb weight should be at maximum 10 kg and in 4.16 Cost calculation it is possible see that the trailer weighs about 15 kg at the moment. Therefore, some weight needs to be cut of the trailer. To do that in the right manner, a FEM analysis has to be carried out at first to see where the trailer is at the moment regarding physical strength towards the stresses that acts on the trailer while in use. These FEM-simulations also needs to be validated against the tests mentioned in the requirement specification to see if they correlate. When they correlate, further FEM-analysis can be carried out and based on the results it can be optimised and possibly cut some weight of the trailer to get it down to the wanted kerb weight. Another possible solution to lower the current kerb weight could be to consider making the frame of another material than aluminium, that is more lightweight but still obtains similar mechanical properties as aluminium.

The concept of the trailer presented can be seen as the core or basis of the trailer, which enables going out in the nature and spending a few nights there on a simple level. If the customer wants to improve the experience, the idea is that they can buy accessories that makes the trailer more useable. This allows the company to set a lower selling price for the trailer and the trailer still fulfils the fundamentals of what a trailer is supposed to do. Whether the customer then wants to customize their trailer and buy accessories and configure it according to their preference is up to them.

As was established during the survey, the majority of answers preferred to pack their cargo in a semi-structured way. This can be achieved in several ways. The most common solution is to sell a dry bag as an accessory to the trailer. Another solution can be to have walls or dividers that separates the cargo space. Regarding this trailer, since it obtains the possibility to be lengthened and shortened, a dry bag would be preferable. Since the dry bag is flexible it would have an easier time to cope with the adjustable length of the trailer in comparison to walls or dividers. The company already offers bags that could be used but will not fit to all configurations. Therefore, it would be beneficial to develop a bag suited for this trailer that also can be extended in a stepless motion.

Other things that were brought up during the survey that might be good to have in mind when developing the dry bag is how essentials, like car keys, wallets, phones etc. would be stored. If the user decides to stop somewhere, they might want to bring just these things and not the whole dry bag with them. Another thing that was pointed out during the survey but also the user journey was to store waste when being remote. This usually becomes a problem when there is no accessibility to trash cans. Other things that are not of value but is required often like water bottle or snacks also needs easy and fast access. Avoiding having to go through the whole dry bag to find certain things both saves time and frustration.

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Appendix

Appendix 1. Packing list.

- Power bank
- Charging cord
- Toiletry bag
- Sleeping mat
- Cool bag
- Sleeping bags
- Tent
- Seat base
- Powdered coffee
- Matches
- Plastic bags
- Mugs
- Bowls
- Toilet paper
- Multitool
- Knife
- Flashlight
- T-red alcohol
- 2 water bottles
- Thermos
- 2 forks
- 2 knives
- 2 spoons
- Portable stove

Appendix 2. Interview questions.

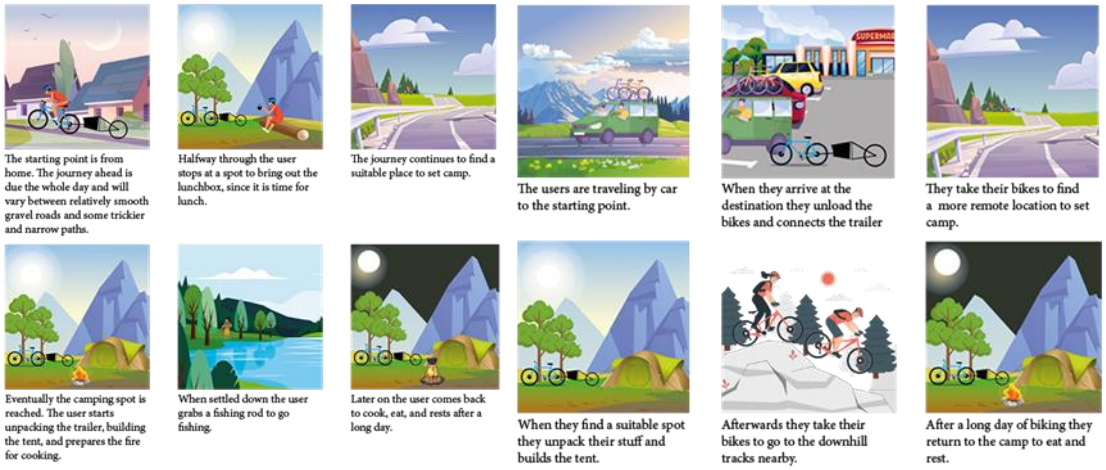
We are William and Viktor and are doing our master thesis at Jönköping University, where we are studying Product Design with focus on Product Lifecycle management (PLM). The thesis is about investigating the development of an offroad cargo trailer for bicycles on a conceptual level and enable camping in the nature and bring cargo for activities such as biking, fishing, climbing, hiking, and photographing. The purpose of this survey is to gain insights of the target group, how they would use such a trailer, in what terrains, and what it should be able to carry.

The participation of the interview is completely anonymous and individual answers is protected enclosed from the public. General statistical conclusions will be made from the results and will be included in the report that will be published publicly but the statistically conclusions cannot be linked to individual responses. Before we begin, do we have your consent to record the sound of the interview? It is only to be able to analyse and conclude the interview.

The user

- How old are you?
- How experienced do you consider yourself in bicycling in offroad environments? Beginner, experienced, very experienced, expert.
- How experienced do you consider yourself in camping in the nature? Beginner, experienced, very experienced, expert.

- What activities do you tend to do whilst camping in the nature? Biking, fishing, climbing, hiking, hunting. Examples are biking, fishing, climbing, hiking, and photography etc.
- Are you camping alone or in the company of others? If you are several, how many are you usually in the total company?



- Which of the two following scenarios are you most likely to perform when you are going out camping with a trailer? Show the scenarios with accompanying explanation.

- What kind of bike resembles best the one you use for bicycling in offroad environments? Do you rent or do you have your own bike?
- Is your bike powered with help of electricity?
- Does the bike you use have a kickstand?
- Do you feel safe when you are out camping? If you do, why do you feel safe? If you do not, why do you not feel safe? Is it the fear of nature itself, animals, or other humans?
- Can you think of anything that might improve the security when you are out camping? Both regarding the use of the trailer but also features to make you feel safer in that environment

The trailer



- What kind of terrain is the most difficult you would consider pulling a trailer on behind your bicycle? See different examples and alternatives on the pictures.

- Based on your experience within biking, camping, possible activities you perform meantime, what bike you use, and the terrain you find yourself in, which type of trailer would you prefer to use? See the two pictures for examples.
- What price would you be prepared to pay for such a trailer? As a reference from the market, entry level trailers costs between 0-2500 kr, average costs among 2500-4000 kr, and high-end costs between 4000-7000 kr.
- Can you think of any desirable functions you would like the trailer to obtain to facilitate the camping experience? If the interviewee has problems with giving any suggestions, give the example of Burley COHO XC kickstand.

Packing

- Can you try to name as many items as possible you can think of that you need to bring to manage staying out for 1-2 nights, considering the activity you usually do? Do not include food and clothing.

- Do you want to pack and structure the trailer by yourself or do you which there were predetermined places/compartments/pockets for the cargo? If the latter is desirable, to what degree? Should everything be predetermined or only part of it and how could such a structure be designed and with help of what? Also see the images to increase the understanding for the interviewee.
- Most trailer have a single large opening into the storage space. Is that something you think is enough, or would you like to have several entrances to the same storage space?
- What items do you use most often when you are out camping, and would you like to have easy access to those? Would it be advantageous if they are not in the same space as the other things but have a special place instead?
- Other things such as valuables, car keys, and wallet for example, do you keep them in the trailer, or would you carry them on you? If they are stored in the trailer, how would you best store them?

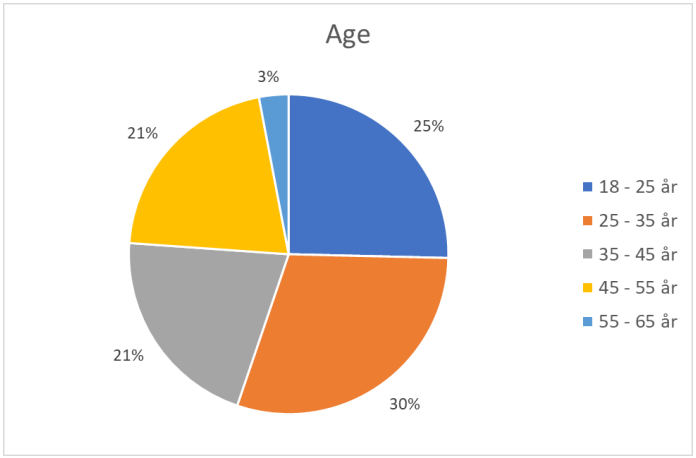
Appendix 3. Questionnaire.

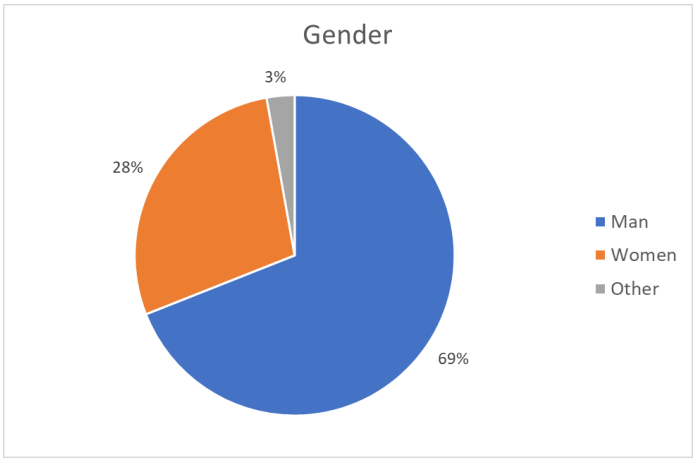
Survey for concept development of a bicycle trailer used in an off-road environment

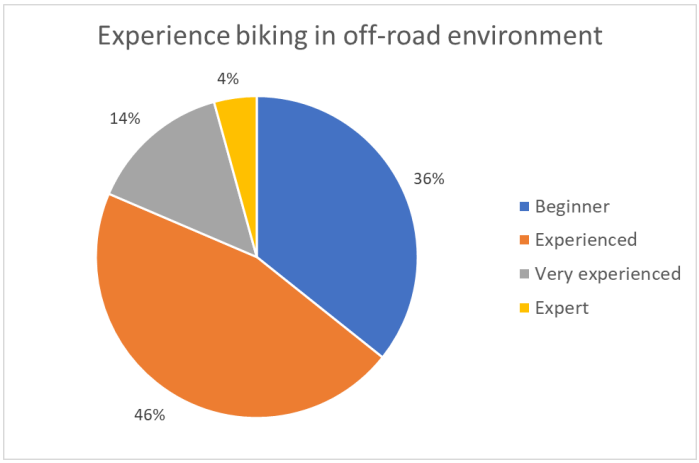
We are William and Viktor and are doing our master thesis at Jönköping University, where we are studying Product Design with focus on Product Lifecycle management (PLM). The thesis is about investigating the development of an offroad cargo trailer for bicycles on a conceptual level and enable camping in the nature and bring cargo for activities such as biking, fishing, climbing, hiking, and photographing. The purpose of this survey is to gain insights of the target group, how they would use such a trailer, in what terrains, and what it should be able to carry. The target audience for this survey are individuals between 18 and 65 years old, who are active and likes spending time outdoors in the nature through cycling and camping. If you think you fit into the target group, your answer to the survey would be appreciated! The survey takes approximately 5 minutes to answer.

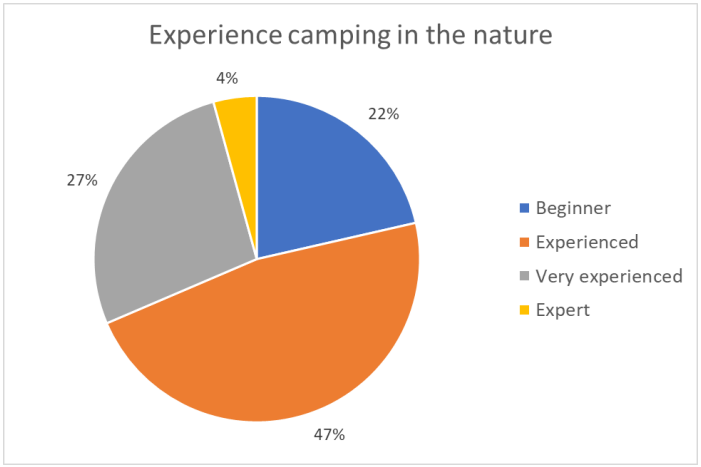
The participation of the interview is completely anonymous and individual answers is protected enclosed from the public. General statistical conclusions will be made from the results and will be included in the report that will be published publicly but the statistically conclusions cannot be linked to individual responses.

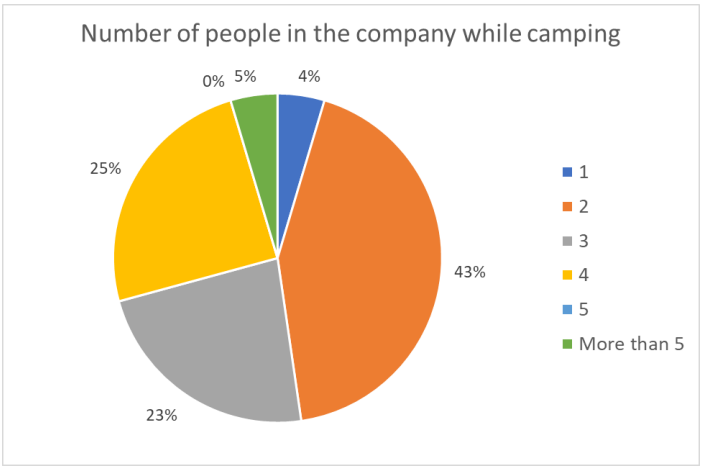
The survey consists of several single-choice questions, symbolized by circular boxes in the answer options. If the question is a multiple-choice question, the alternatives are squared instead.


Age
3%
25%
21%
21%
30%
18 - 25 år
25 - 35 år
35 - 45 år
45 - 55 år
55 - 65 år

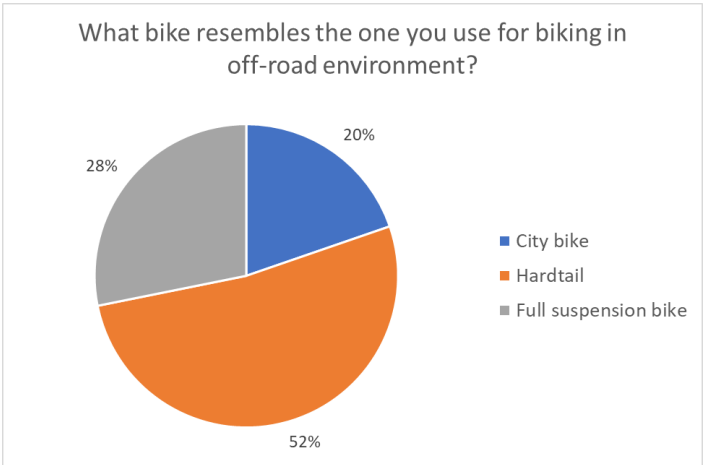

Gender
3%
28%
69%
Man
Women
Other

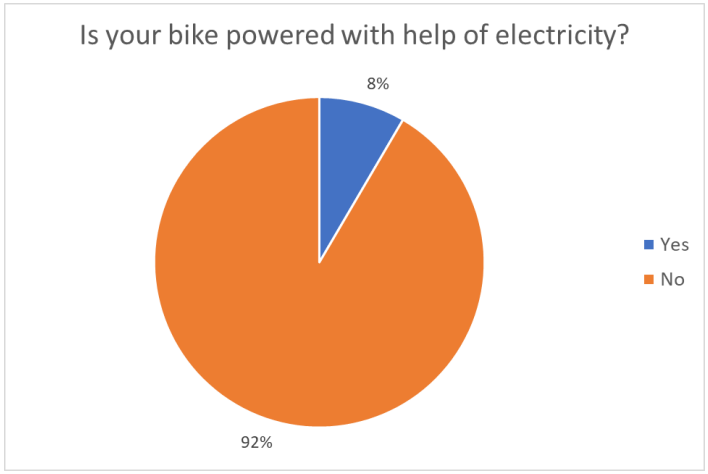

Experience biking in off-road environment
4%
14%
36%
46%
Beginner
Experienced
Very experienced
Expert

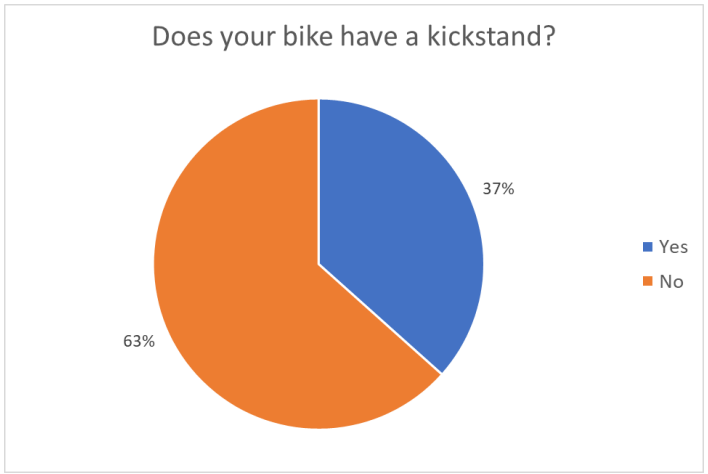


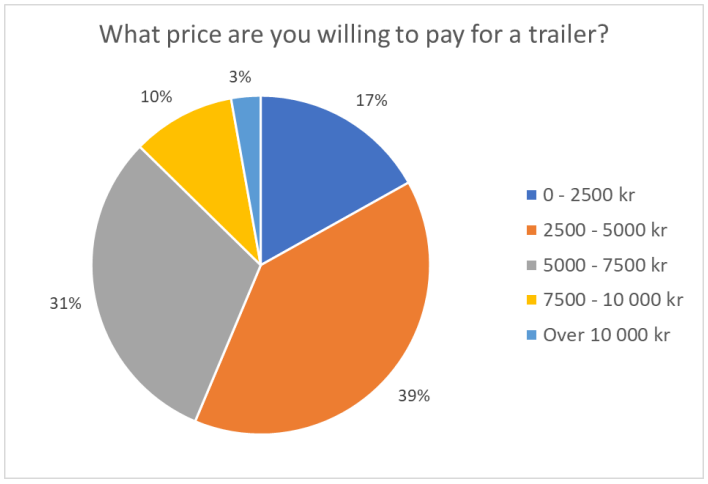


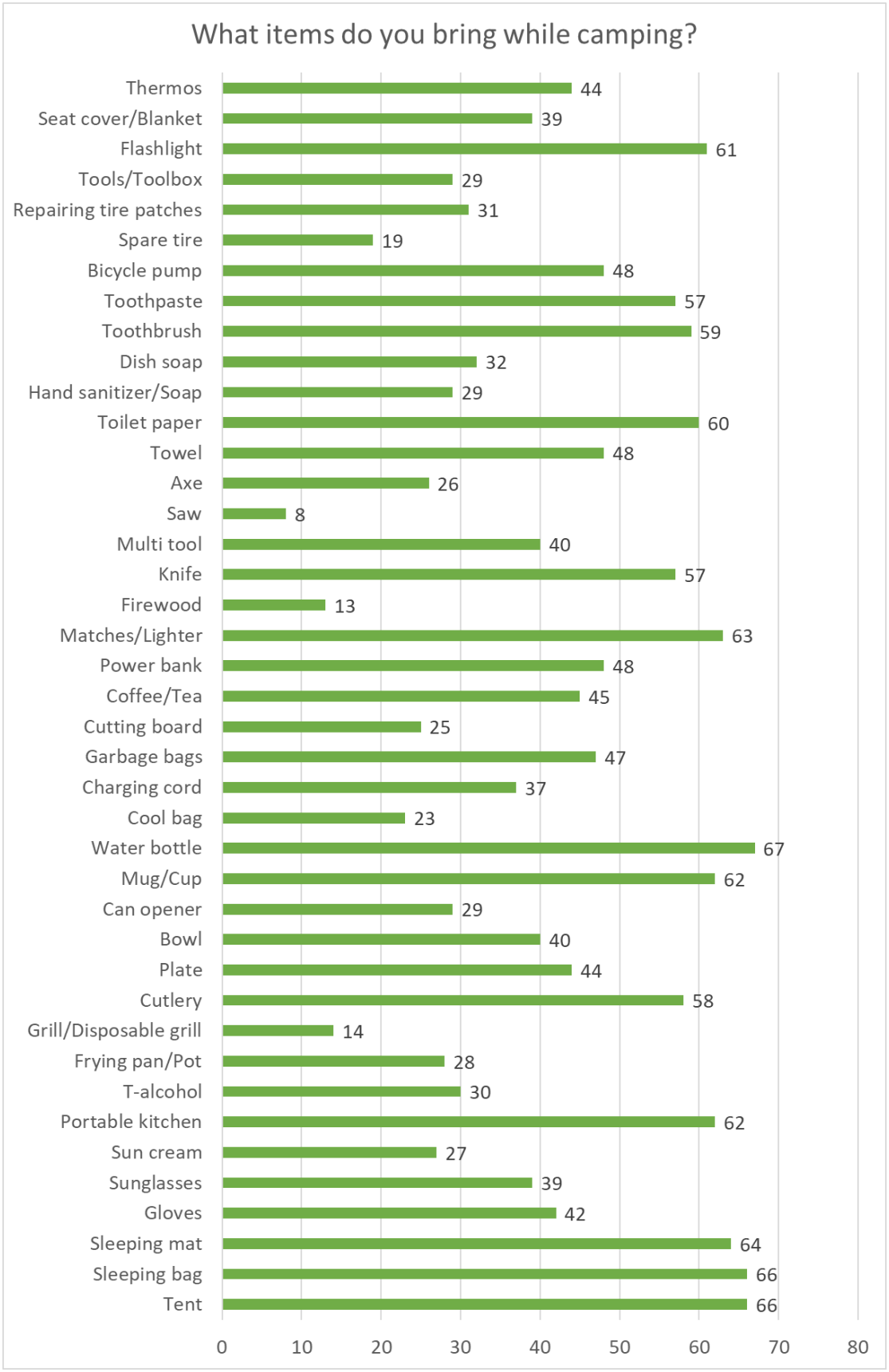
City bike Hardtail Full suspension bike

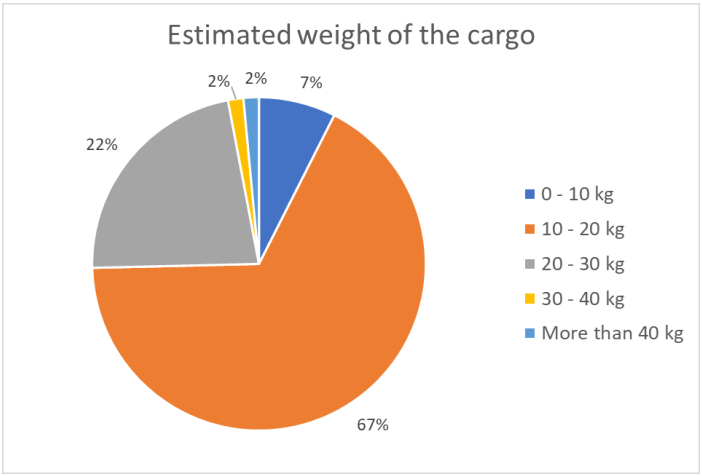



Is your bike powered with help of electricity?
8%
92%
Yes
No

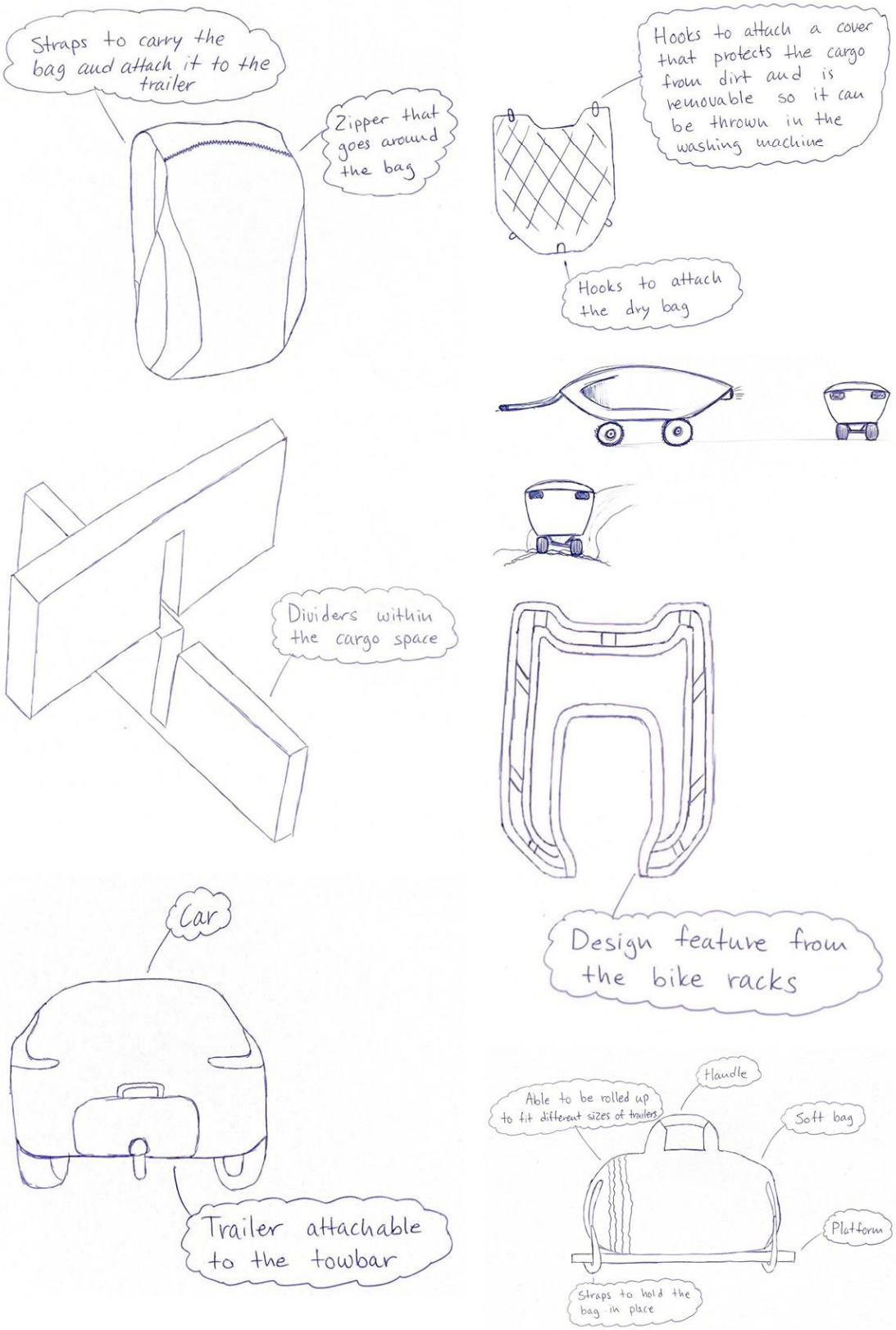

Does your bike have a kickstand?
37%
63%
Yes
No

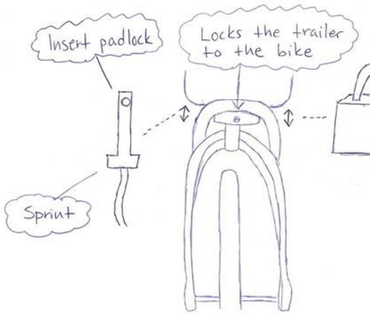

What price are you willing to pay for a trailer?
3%
10%
17%
31%
39%
0 - 2500 kr
2500 - 5000 kr
5000 - 7500 kr
7500 - 10 000 kr
Over 10 000 kr

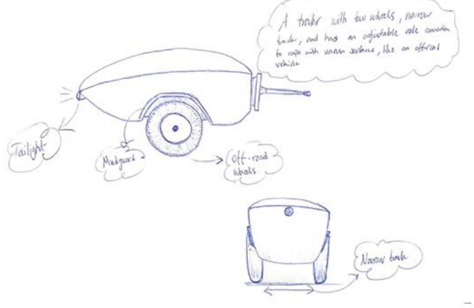

What items do you bring while camping?
Thermos 44
Seat cover/Blanket 39
Flashlight 61
Tools/Toolbox 29
Repairing tire patches 31
Spare tire 19
Bicycle pump 48
Toothpaste 57
Toothbrush 59
Dish soap 32
Hand sanitizer/Soap 29
Toilet paper 60
Towel 48
Axe 26
Saw 8
Multi tool 40
Knife 57
Firewood 13
Matches/Lighter 63
Power bank 48
Coffee/Tea 45
Cutting board 25
Garbage bags 47
Charging cord 37
Cool bag 23
Water bottle 67
Mug/Cup 62
Can opener 29
Bowl 40
Plate 44
Cutlery 58
Grill/Disposable grill 14
Frying pan/Pot 28
T-alcohol 30
Portable kitchen 62
Sun cream 27
Sunglasses 39
Gloves 42
Sleeping mat 64
Sleeping bag 66
Tent 66
0 10 20 30 40 50 60 70 80

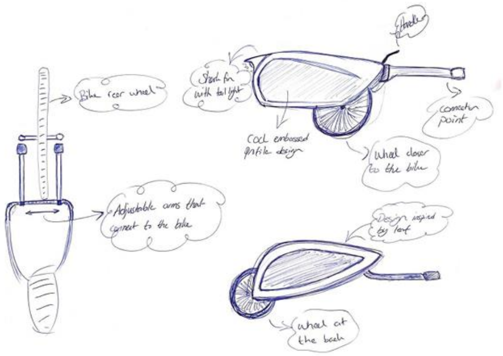

Estimated weight of the cargo
2%
2%
7%
22%
67%
0 - 10 kg
10 - 20 kg
20 - 30 kg
30 - 40 kg
More than 40 kg

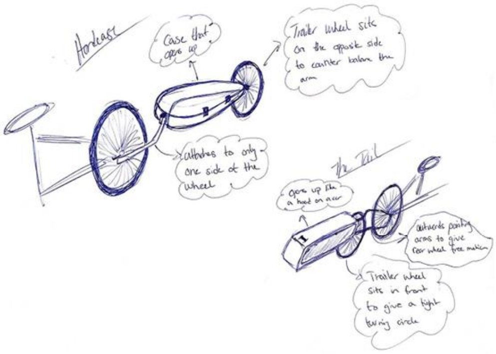
Appendix 4. Thumbnails.

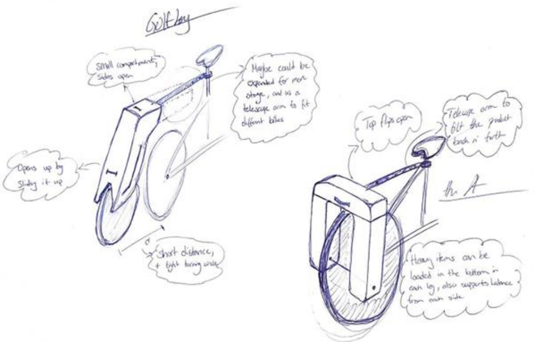


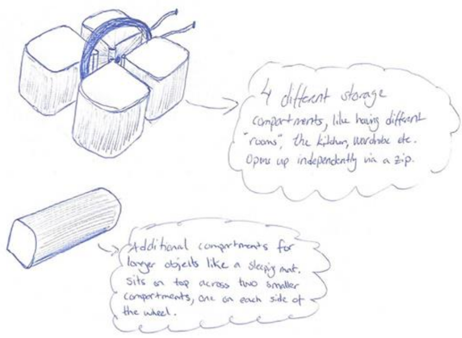

Insert padlock
Locks the trailer to the bike
Padlock
Sprint

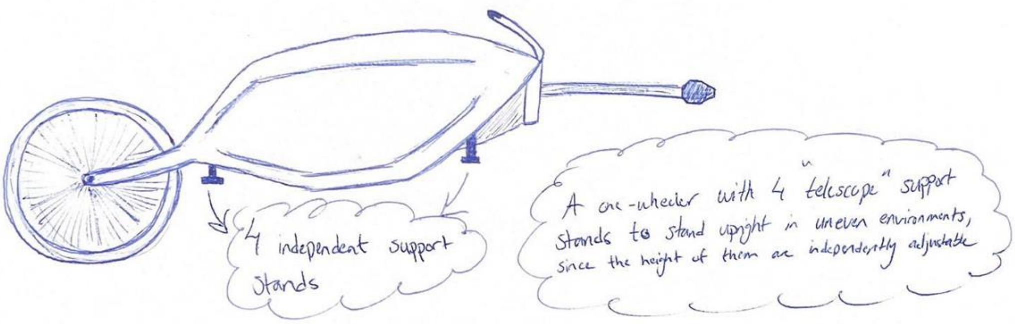

Taillight
Mudguard
Off-road wheels
Narrow track

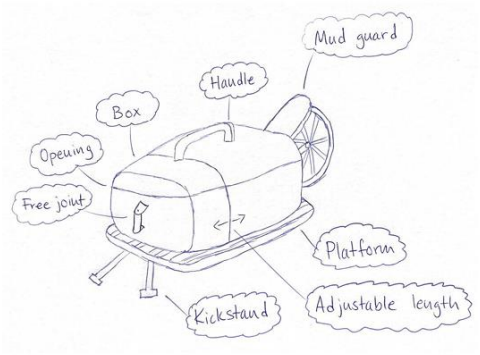

Bike rear wheel
Adjustable arms that connect to the bike
connection point
Cool embossed profile design
Wheel closer to the bike
wheel at the back

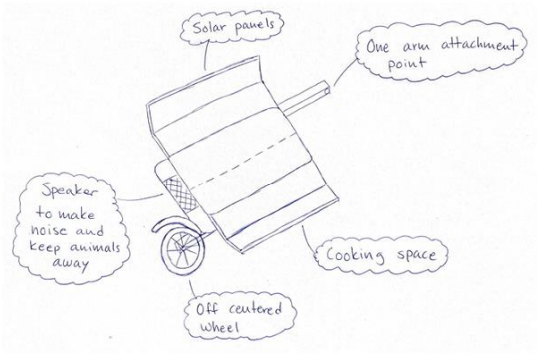

Case that opens up
Trailer wheel sits on the opposite side to counter balance the arm
Attaches to only one side of the wheel
Trailer wheel sits in front to give a tight turning circle

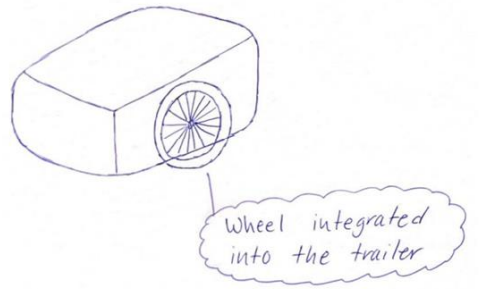

Opens up by sliding it up
Short distance, + tight turning circle
Top flaps open

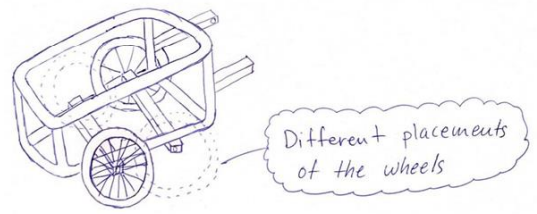

4 different storage compartments, like having different "rooms", the kitchen, wardrobe etc. Opens up independently via a zip.
Additional compartments for longer objects like a sleeping mat. Sits on top across two smaller compartments, one on each side of the wheel.

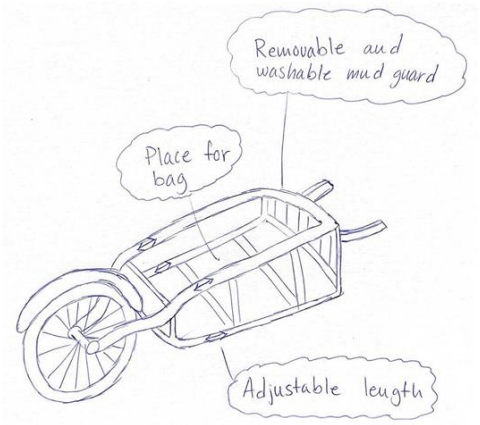

4 independent support stands
A one-wheeler with 4 "telescope" support stands to stand upright in uneven environments, since the height of them are independently adjustable

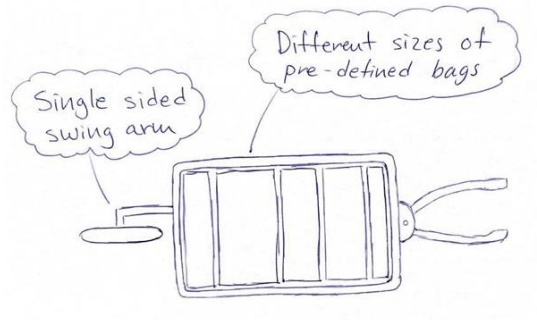

Mud guard
Haudle
Box
Opening
Free joint
Platform
Kickstand
Adjustable length

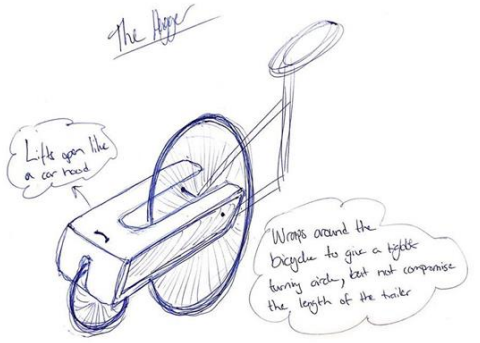

Solar panels
One arm attachment point
Speaker to make noise and keep animals away
Cooking space
Off centered wheel

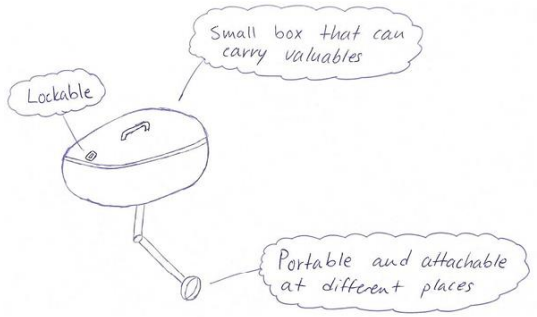

Wheel integrated into the trailer


Different placements of the wheels


Removable and washable mud guard
Place for bag
Adjustable length


Different sizes of pre-defined bags
Single sided swing arm


The Hoop
Lifts upon like a car hood
Wraps around the bicycle to give a tighter turning circle, but not compromise the length of the trailer


Small box that can carry valuables
Lockable
Portable and attachable at different places