CHALMERS

Next generation urban e-bike

A design project in collaboration with Crescent, targeting user experience, product functionality and branding.

Master of Science Thesis in the Master Degree Program, Industrial Design Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2017

Department of Product- and Production Development
Division of Design & Human Factors

Master of Science Thesis

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Preface & Acknowledgements

This report is the result of a master thesis project conducted in collaboration between Cycleurope and two students from the Industrial Design Engineering program at Chalmers University of Technology. The extent of the project covered 30 credits per student and was carried out during the spring semester of 2017.

We would like to thank Cycleurope and their employees, specifically Ulrik Bengtsson and Christer Almqvist for giving us this opportunity to work with such an interesting and inspiring project for our master thesis. Your knowledge, insights and full support throughout this project has been a key component for the final outcome.

We would also like to thank Pontus Wallgren, our supervisor and examiner at the division of Design and Human Factors within the department of Product and Production Development. Thank you for your guidance and positive enthusiasm throughout the project, as well as for sharing all your valuable knowledge within the area of e-bikes.

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Gothenburg June 12th 2017

Filip Svalander & Niklas Ödlund

Abstract

This project was conducted in collaboration with the bicycle manufacturing company Crescent to further explore the potential of electric bicycles, e-bikes, in a growing market. Urbanisation and climate change are two major factors motivating the expansion of the market, where the e-bike can provide an environmentally friendly, healthy and convenient way of transportation. The purpose for this project was to develop the next generation urban e-bike for Crescent, strengthening the brand as a frontier on the market. The project started with a pre-study phase to develop a knowledge base regarding relevant aspects concerning e-bikes and potential users. Based on the findings in the pre-study problems were defined and a goal for the future project was set in the form of a vision. Through a creative and iterative process, with continuous evaluation, the final concept was developed based on this vision.

E-bikes were found to have a rather bad reputation, based on preconceptions in society, where e-bike users were often called lazy or being accused of cheating. The public view of the Crescent brand was found inaccurate, illustrating an inability for Crescent to communicate all of their core values to the public. The final concept utilised a gap in the market being a fitness-urban e-bike, where the electric assist was emphasised as a performance enhancing electric boost, rather than an aid for people not capable of riding a normal bicycle. The final concept enlightens the users and the society, mediating all e-bike related benefits. It has a lifestyle inspired self-expression attractive to a younger user group of early adopters within the urban commuter group and provides improved functionality for the user when interacting with the bike.

The project concludes how the ultimate next generation urban electric bike for Crescent would be an ambassador e-bike, embodying the vision through strategic design considerations. However the vision itself was probably the most important result for the project outcome. The bike challenges old preconceptions regarding male and female, adapted for each individual’s own desires. Without compromising with social, ethical and environmental aspects, the ambassador e-bike could not only contribute to the company profit but also result in positive societal aspects correlating with Crescent’s goals.

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1. INTRODUCTION

This initial chapter provides a brief background to the project. It also describes purpose and limitations, as well as the specific research questions investigated during the project.

1.1 Background

Cycleurope AB is a Swedish company developing and selling a variety of bikes under different brands all across Europe (Crescent, 2017). Crescent is a Swedish brand within Cycleurope with a strong brand heritage of having qualitative and reliable bicycles made for Swedish conditions, pushing the technology of bikes forward. Over the last few years Crescent have also started to develop and sell electric bicycles, referred to as e-bikes.

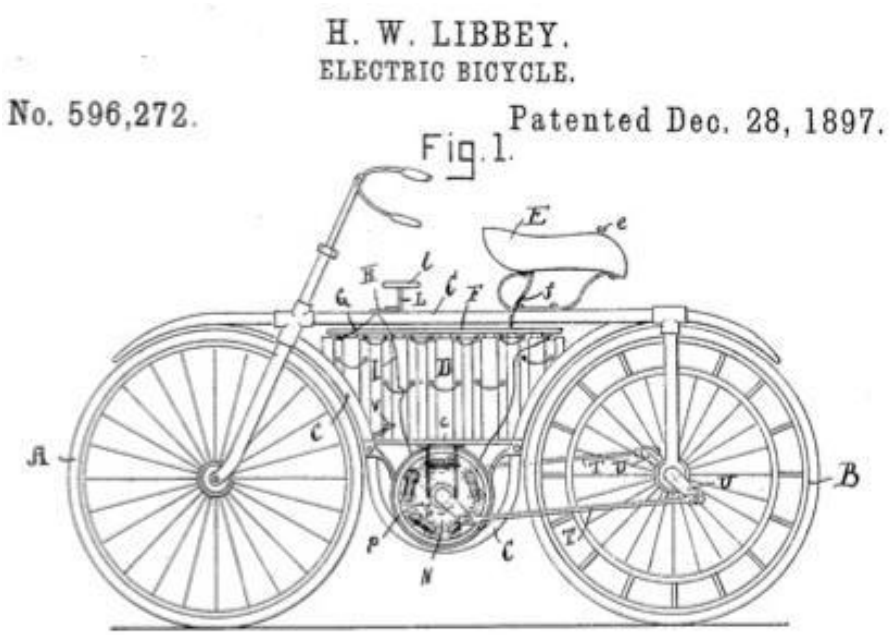


Figure 1: Early patent for an electric bicycle (Libbet, 1897).

The history of the e-bikes starts with the history of bicycles. The first forerunners originates in the late 18th century, and they have looked more or less the same since the safety bike was introduced in 1855 (Heijmans, 2011, p.15). The thought of powering the bicycle with an electric motor was patented a few years later (Figure 1). However, the idea of combining the pedalling power with the electric assist evolved around the 1980's, and has started to sell to a continuously growing market (Key moments in electric bicycle history, 2010). In a world where the human driven climate change is a fact, and where people strive to live healthy but still comfortably, the e-bike seems to be a solution potentially striking the sweet-spot as an environmentally friendly, healthy and convenient means of transportation.

Although e-bikes are slowly rising in sales, it is still a young market. The variations of e-bikes are many and most of them are rather simple add-on solutions derived from the classic bicycles. Crescent is following this add-on trend in a similar manner and their sales are increasing. According to Crescent representative C. Almqvist (personal communication, 31 January 2017), most of their e-bike buyers are either older than 55 years, or new family parents. However, other potential users like the urban commuters

seem to be holding onto their bus-cards, second car or standard bicycles. As of today, it is hard to say what e-bikes will become, but Crescent want to take a few steps ahead in the evolution and explore what it could become. This would not only create a solution providing a greater value that appeals to a larger user group, but also strengthen their brand values as an innovative and sustainable frontier of the e-bike movement. There is a lot of research regarding the benefits and downsides of e-bike usage, however few projects has aimed at embodying these aspects into the e-bike itself.

1.2 Purpose

The purpose of this project is to design the next generation urban e-bike for Crescent, through a structured Industrial Design Engineering-process, finished early June 2017. The goal is to design a premium unisex e-bike concept providing improved value for a larger group of potential users and possibly society as a whole. These values should go beyond the functionality and also target branding related lifestyle values and how this product can strengthen the Crescent brand towards a desired position. The new solution should stand out on the market and position Crescent as one of the leading actors, specifically within the e-bike segment.

1.3 Limitations

- Bike main geometry based on existing Crescent bike
- Electric drivetrain based on existing solutions from Crescent
- Use feasible construction techniques
- Complete technical documentation not required
- Product launch planned 2019
- Deadline 1st of June 2017
- Full time 2 students

1.4 Research question

“How should the ultimate urban electric bike be designed for Crescent, to attract new users in a growing market and position Crescent as a leading actor?”

- What general needs are fulfilled through different means of transportation?
- What needs are possible and feasible to fulfil with an e-bike?
- In terms of ergonomics and handling, what spatial properties are desired from an urban e-bike?
- What drivers and barriers exist for e-bike usage?
- How could Crescent e-bikes attract new customers within the urban commuter user group?
- What is Crescent today and what do they aspire to become in the future, in terms of lifestyles and personas?
- How to attract the user group by pushing softer values connected to branding and lifestyles and make people associate Crescent with those values through the product?

1.5 Project Stakeholders

Company:	Crescent (Cycleurope AB)
Product Manager, Crescent:	Ulrik Bengtsson
R&D, Crescent:	Christer Almqvist
Graphic Designer, Crescent:	Lisa-Stina Pettersson
Supervisor & Examiner, Chalmers:	Pontus Wallgren
Project group:	Filip Svalander & Niklas Ödlund

2. METHOD

This chapter describes all the methods, phases and steps taken in the process of this project. The chapter is mainly divided into three major phases starting off with a Pre-Study creating a knowledge platform for the project. The second phase, Product Specification, summarises the main problem areas from the pre-study and defines a vision for a future e-bike concept. Using the Product Specification as a reference, the third phase, Concept development starts off with an ideation phase, embodying the visions into concepts. The concepts are then evaluated towards the product specification and a final concept is consciously chosen to be taken further into the final Concept refinement where it is finalised.

2.1 Pre-study

The pre-study phase was conducted to explore and gain knowledge about interesting aspects for the project. The proceedings and methods used during the pre-study are presented in the following chapter.

2.1.1 Literature and theory

A major question in the world today is how to solve transportation for the ever growing population moving into the cities. Bicycles are efficient, healthy, environmentally friendly, non traffic congesting tools for transportation, however they do have limitations regarding distance, performance and cargo capabilities. With the introduction of e-bikes researchers have investigated the question whether these could contribute to better transportation with lesser environmental impact, traffic congesting and a greater public health. This study aims to explore the academic material presented regarding the subject to allow for this project to implement key conclusions into the final design.

The material for the literature study was obtained from a literature-collection created by Docent Pontus Wallgren, researcher within the subject, addressing environmental impact, safety concerns and user behaviour regarding e-bikes. Within this collection the limitation was set to especially examine recent studies addressing European or western countries due to similarities in regulations, contextual aspects and public social norms.

2.1.2 Market and Regulations

This study was performed to find out what the market of e-bikes looks like today and to identify what kind of brands and e-bikes Crescent is competing with, in terms of different types of models, features and technologies used. The products offered through the Crescent model program was also analysed. Due to the size of the international market and since Crescent is focused on the Swedish market, the study was focused on the competitors in Sweden. The maturity of the different market segments and bike categories were analysed and based on the findings of the study future market possibilities were identified. In the study eighth major Swedish retailers as well as 3 independent brands were analysed through their websites on internet. The retailers were:

Sportson	Cykelkraft.se	Biltema
Cykelhuset	Smartcyklar.se	EvoBike
XXL	Elcykelbutiken	EcoRide
Team Sportia	El-cykelvaruhuset	

To narrow down the number of competitors and enable a better analysis, the most common brands represented in 2 or more retailers, were focused on. The different e-bikes from the most common brands were grouped into categories and subcategories based on

bike characteristics and visual expression using a KJ-analysis method. A KJ-analysis, also referred to as an affinity diagram, is a method used to organize and group data into categories based on how the different data relate to each other (Project-Management.com, 2017). This was done to enable an analysis of where the brands position their products and to detect future market possibilities for the next generation urban e-bike.

Regulations, restrictions as well as existing patents were needed to be taken into account when designing the final product. To find relevant restrictions and regulations that concern bicycles and e-bikes the website of the Swedish Transport Agency (Transportstyrelsen) was investigated. Relevant patents in regards to e-bike designs were identified by searching on forums and websites for patents, as well as by talking to people familiar with patents on Crescent.

2.1.3 Technical research

In order to fully understand the technologies and physical aspects behind an e-bike the studies described in this technical research chapter were conducted. It includes a study of the bike anatomy, the drivetrain technology, manufacturing and materials as well as a study of the interplay between human and bike.

Bicycle components

To present all important parts of the e-bike and allow for effective communication two visual dictionaries were created. One general for all types of bikes, and one for the specific parts required on an e-bike.

Drivetrain technology

To allow for a deeper understanding regarding e-bike drivetrain technology a brief internet study was conducted. The focus was to investigate what types of motors and batteries there are in the present e-bike market, including factors such as component properties and placement. A more thorough study was conducted regarding the drivetrain motor and battery type this project was limited to.

Manufacturing and materials

As stated in the limitations, this project did not address specific details regarding manufacturing and materials. However, to facilitate a feasible final design, the major properties and aspects of the different material alternatives was investigated. An internet study as well as a small interview with a Crescent employee was conducted to gain knowledge within the area.

Bike-human symbiosis

An exploration of how frame properties impact the bicycle dynamics was carried out through a small internet study and multiple tests of different bicycle frames. To investigate how different e-bikes with different frames and motor alternatives behave and are experienced several test rides were performed. The test rides consisted of various

activities relating to city transportation. Bicycling in different terrains and on different ground conditions, manoeuvring a slalom course and other obstacles to evaluate the responsiveness of the drivetrain and the interaction between the user and the drivetrain.

2.1.4 User studies

The user studies were conducted to gain more knowledge about user attitudes and behaviour in regards to bikes in general and specifically e-bikes. The studies consisted of interviews with users and retailers as well as observations and the establishment of a user scenario.

User interviews

To ensure a deep personal understanding regarding the usage and attitude towards e-bikes six interviews were performed with both potential and active e-bike users. The complete interview form with questions can be found in appendix I. Both male and female interviewees were chosen for participation, all living in or close to the city centre within commuting distance to work. To get a broader perspective as well as to detect potential differences in terms of preconceptions and opinions, the interviewees were both e-bike users as well as non e-bike users.

To allow for a deeper exploration into the different usage scenarios, while still making sure to get answers on a few important key questions the interviews were conducted in a semi-structured manner (Wikberg Nilsson, 2015). The first part of the interview was based around a map where the interviewee marked their different locations during their daily life. The interviewer asked specific questions regarding how the interviewee travelled between the places and why they choose to use the specific kind of transportation. If the interviewee turned out to use a bike or e-bike for traveling to a destination, further questions were asked regarding specific subjects related to the place, like how they park their bike, how that feels, what they bring, how they transport their stuff etc. The goal here was to find obvious and hidden needs, problem areas and potential compensating behaviours.

The second part of the interview concerned specific e-bike related questions, such as if the interviewee owns an e-bike, if they would like to buy one, what their opinion was about e-bikes and what they would look for if buying a new e-bike. The interviewees were also asked about what functionalities they consider important for an e-bike as well as if they had any specific ideas that could be of interest for the project.

Retailer interviews

As of today, the bicycle retailers are major influential actors on the market. They guide the customers to what they should buy, and restock the types of bikes that they asses the buyers want. Because of this, brands like Crescent have a tight communication with their retailers, and they base their new bike designs partly on input from the retailers. An interview study with six different bicycle and e-bike retailers in Gothenburg was carried

out to get to know their view on the e-bike development and market today. The interviews were of a semi-structured qualitative manner, loosely based on a few questions, and a lot of space was offered for follow up questions and deep dives into specific details. After each interview, the different answers for each question was summed up by the interviewers and the questions were as following:

- Who buys an e-bike?
- Who shows interest for e-bikes?
- What do customers ask for and find important?
- What do you think is important and talk about?
- What characterize a good e-bike?

Observations

To really understand how it is experienced to use an e-bike regularly for everyday purposes the project group was equipped with personal e-bikes throughout the project (Figure 2). The bikes tested were of the model Crescent Elda, which is a unisex bike model featuring the same electric drivetrain system as limited for this project. All observations surrounding the e-bike usage was continuously noted into a document in a diary format to allow for key insights to be implemented into the project. The noted observations were both own observations from the experience of the project group, but also interesting aspects when observing other bicycle users in general and specifically other e-bike users.

Figure 2: Using the e-bike for every day purposes.

User scenario

To ensure that the project would cover all aspects of the e-bike experience a customer-journey was defined based on findings from the interviews as well as the literature study.

2.1.5 Brand Strategy Research

When designing a great product both the users and the product has to be considered, but also the brand. The final design must land in an intersecting area correlating with the expectations of the functionality, the user needs and the expression and values of the brand. With a well established brand like Crescent, the conveying of a brand story is an important way of both marketing the product as well as creating a family of identities within the user groups associating themselves with the brand (Klein, 1999). Branding is a complex and sensitive subject with a lot of potential impact if used correctly. One important aspect of branding is to keep it consistent, if changes are to be done they need to be done from the core values of the brand (Hatch, 2001). To allow for this project to not only cohere with the Crescent brand, but also accentuate and amplify the brand image a study of the Crescent brand was conducted. The study consisted out of material provided by Crescent, various interviews with Crescent employees as well as a survey where potential customers would assess their view of the Crescent brand and their products. This survey was performed by asking 16 potential Crescent customers to first look at the Crescent logo and fill in a semantic differential scale. After this they were asked to look at a picture showing the crescent logo along with a set of their products and fill in a new identical semantic differential scale (Figure 3). The expressive words used in the semantic differential scale were based on a previous study in which Crescent was positioned in relation to those words.

Figure 3: Semantic evaluation of the Crescent brand.

Part from the Crescent brand analysis, a design format analysis was conducted. A design format analysis, or design format model, is a method to evaluate products and identify common characteristics, often referred to as design cues (Warell, 2001). These design cues can strategically be used within a brand to create coherence and maintain a relationship between different models. It is therefore important to be aware of these aspects when designing new products to implement those design elements into future designs that will carry the brand forward.

2.2 Product specification

The product specification serves as a gateway between the pre-study and the concept development phase to facilitate a structured approach for this extensive product development process. By summarising the Pre-study into key problem areas and defining visions and goals based on these, it was used to ideate around and evaluate against.

2.2.1 Problem definition

While the Pre-study chapter accounts for results in relation to each separate study, a problem definitions aims to summarise the results from all studies into general problem areas allowing for a more holistic perspective. By summarising all data through a KJ-analysis (Project-Management.com, 2017), the scattered results from the different studies within the Pre-study was grouped into natural groups defining the key problem areas.

2.2.2 Societal Aspects

To allow for this project to reach its goals to provide an added value for a larger group of users as well as the society as a whole a specific user group was defined, and the societal aspects of increased e-bike usage was summarised. The user group was defined through material presented in the Pre-study as well as conversations with Crescent representatives. The societal aspects were summarised through analysing results regarding health, ethics and the environment presented in the Pre-study.

2.2.3 Desired Concept Goals

Based on findings and problems identified during the prestudy, backcasting was used to define a desired future position for the next generation urban electric bike. The backcasting method is a strategic approach where a desired future scenario is imagined and the work is then focused on how to reach the new future (Robinson, 1990). For this project it meant to define the purpose of the new product, which users the product should be aimed at, what the product should express and what functions it must possess. Even though the problem definition can be grouped into a few specific problem areas, the future scenario has to be approached with a holistic perspective. To enable this the future scenario was compiled in three different but still coherent ways. First a general vision was established through a set of themes to describe an optimal vision of how this project concept should contribute to a better future. Second an expression board was created to unite the view of what the concept should express. Some words were added to emphasize the meaning of the expression board. These were selected to highlight the most positive experiences of different means of transportation through a process analysing positive and negative words expressed regarding the subject in the user interviews. Finally, a Functional analysis was compiled specifying all functions required of the concept in order to fulfil all demands in a new future. These visionary ideas were presented for representatives at Crescent for feedback and were later used as a foundation for the ideation on how to reach the future vision through a new strategic product concept.

2.3 Concept development

This chapter describe the methods used and the specific process for the concept development. The process was divided into three different phases presented separately below. These phases were Ideation, Concept Evaluation and Concept Refinement. Even though presented as separate phases continuous iterations were made between the different phases throughout the process.

2.3.1 Ideation

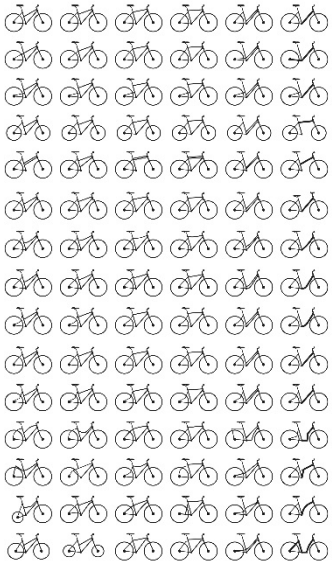
The ideation phase was focused around the product specification, considering the identified problems but mostly focusing on the desired future vision defined in the previous chapter. Efforts were aimed at developing a vast range of innovative and conceptual ideas where the e-bike vision and desired expression could be merged into concepts based on the part functions in the functional areas of the bike. This way the concept could consequently provide a possible sweet spot between user, brand and product.

Figure 4: Sketching and building mockups to share and test ideas as part of the creative ideation phase.

The functional areas from the function analysis provided a structure for the ideation, were each area was considered separately. For each area there was held an ideation session, where brainstorming was the main tool and a lot of inspiration was found in the expression board and vision. Brainstorming is a form of ideation, where the participants ideate around a defined problem and design requirements, to come up with a quantity of ideas (van Boeijen, Daalhuizen, Zijlstra, van der Schoor, 2014). The ideas are not allowed to be criticised during the session to allow for free thinking, but they may be refined and combined to create new interesting solutions to the problem. Brainstorming is suitable throughout a design process, but is however most useful in the early phases to create many ideas. The ideas were visualised with sketches but also built with simple models and mockups (Figure 4). The ideas were continuously evaluated based on how well they fulfilled the vision, to enable simultaneous concept refinements. For the frame design functional area a quite different method was implemented. First there was a free

explorative phase to develop an understanding of how the expression of a bike was affected by the frame design. Small thumbnail sketches were made and discussed regarding expression and function. Another part of this explorative phase was to create generic randomly generated frame designs (Figure 5), based on very small differences to evaluate how these subtle changes in the frame could contribute to how the bike was experienced. A positioning graph was used to position each frame based on the semantic expressions speed-stillness and static-changing, also used in the brand study. This way potential differences in frame expression could be identified, and the cause for a certain outcome could be discussed. The next step of the frame ideation was to establish a reference bike. Several different bikes were tested at Crescent within their current assortment of bikes. Handling, overall riding experience and frame expression were tested and evaluated by riding around in the city of Varberg on different road conditions and in various traffic situations. These tests were conducted in order to find a bike frame with the right characteristics that would be most suitable for the future vision. This bike was used as a reference in terms of dimensions and crucial angles, to avoid adjusting the anatomy of the bike. This made it possible to use the bike as underlay when sketching, ensuring the right dimensions between interdependent parts of the bike, such as wheels, handlebar, chainset and seat. Four conceptual frame groups were compiled from the underlay sketches, for further exploration in Photoshop until all groups reached a satisfactory and promising level.

Figure 5: Randomly generated bicycle frame designs for evaluation of product expression.



When a large number of ideas had been developed within each functional area, the next step of the concept development took place. The most promising part solutions to each functional area were combined into four concept groups, where frame, battery, handlebar, cargo, lock and lights could be turned into four complete and more concrete concepts. These four concepts were iterated once more in Photoshop before prepared for evaluation.

2.3.2 Concept evaluation

All concepts were evaluated in numerous ways, mostly focusing on the overall frame design. To start off, the concepts were presented to the R&D department at Crescent to allow for feedback. They were then presented to 12 employees at the Crescent office, discussed and ranked. The concepts were then processed through an evaluation with a user focus group consisting out of 15 persons fitting the description of the target user group (figure 6). To determine whether the concepts reached their target expression the evaluation started off with a semantic evaluation. The evaluation was similar to the one done in the Crescent Brand Analysis to allow for comparisons. The users were asked to complete a form describing the semantic expression of each concept. The concepts were then ranked towards each other based on which concept the user preferred (Appendix II). Specific spontaneous reactions and opinions mentioned throughout the evaluations were noted. The evaluation ended with the question “Throughout this evaluation, have you thought of these bikes as male, female or unisex?” to allow for opinions regarding the subject. To evaluate the functionality of the concept bikes, a few tests were carried out

Figure 6: Concept evaluation with target users

targeting different concerns presented in the feedback. To further aid the selection of a final concept the results from each bike on all evaluations were compiled into a matrix. Each concept was graded after how well they fulfilled each evaluation criteria, and every type of evaluation criteria was weighed to determine their impact on the outcome.

2.3.3 Concept refinement

The final concept development phase consisted of a finalisation step aimed at refining the chosen concept in a final iteration or refinement loop. Focus was put on how different part solutions developed within the different concepts could be combined with the chosen frame concept to further improve the final product. If well motivated, these part solutions could consequently contribute to a better end result enhancing the connection between product and vision.

Another part of the concept refinement process was to define details not presented on a conceptual level in the product concepts. These details concerned a thorough form definition in Photoshop where the frame was explicitly described in terms of surfaces and surface meetings (Figure 7). Other details refined in this phase was the battery solution where a model and detailed sketches were constructed to describe the form and all functional aspects of the battery. Another aspect considered in this stage was the final design of the handlebar which was also modelled and defined in Photoshop. Based on these refinement steps the final composition of the final concept evolved and the product could be presented.

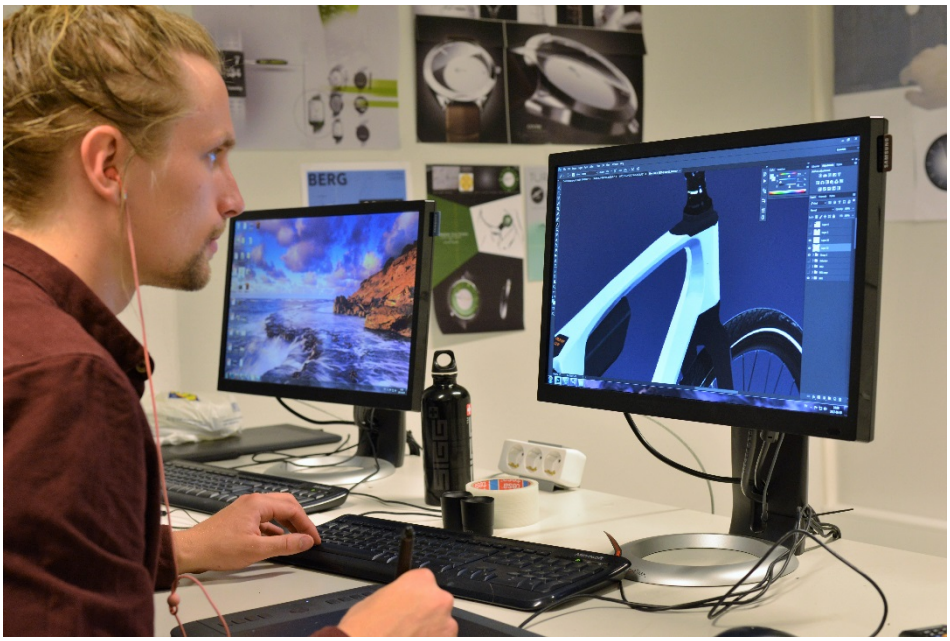


Figure 7: Form definition of the bike frame in Photoshop.

3. RESULTS

The following results chapter presents all findings and results from the entire project. The results chapter is divided into 3 main phases where each phase is presented in respective subchapters. The first present the findings from the pre-study, the second subchapter describe the product specification based on the pre-study and the third and final subchapter disclose the results from the concept development.

3.1 Pre-study

The following pre-study chapter presents findings from the areas investigated in the early phases of the project. The different areas Literature Theory, Market and Regulations, Technical Research, User Studies and Brand Strategy Research, are presented as separate sections.

3.1.1 Literature Theory

The results in the following chapter will be presented within different themes regarding e-bike usage. The themes and most of their content will be based on the literature review "E-bikes in the Mainstream: Reviewing a decade of research" by Elliot Fishman and Christoffer Cherry (2016). When no source is mentioned the claim comes from this publication, however other claims from other studies will be noted with separate sources.

Demographics of users

According to studies in Australia and North America e-bike users often report a higher income and educational level than the general public. Older adults seem to use their e-bikes for leisure and shopping, while younger adults seem to use it more for commuting (Harms, 2016).

Sales

Back in 2010, it was estimated that 31 million e-bikes were sold, 90% of them being sold in China. However, in Europe the sales are growing faster than the ordinary bicycles, and now account for up to one of every six sold bikes. According to a study in Belgium, e-bikes with a price of 2000 euros are preferred above the cheaper ones. Even the new potential users that are a bit more sensitive to the price would like to avoid the cheapest ones. The same study also says that many retailers claims that the design, colour and type of model are the most important factors for users when buying an e-bike (Zijlstra, 2016).

User motivations and benefits

The most central motivator for e-bike usage is the ability to maintain speed, especially in hot or hilly conditions. There is also still a trend that experienced older people prefer e-bikes since they find bicycles to be too physically demanding. Various studies in China and North America also show that e-bike users often have longer travel distances. E-bike users tends to ride with a faster speed than ordinary bicycles and thus have shorter travel times (Dozza, 2013). E-bike users also seem to have lower longitudinal accelerations when riding which gives the conclusion that e-bike usage is more comfortable than bicycles (Ibid). For users with e-bikes there is a lower mental resistance to riding their bikes compared to traditional bicycles, both heading out on the bike in the morning or taking an unexpected detour are considered less resisting (Strömberg, 2016). This is also confirmed in a study from North America that also adds how users that buy an e-bike starts taking the bike more often and to a wider variety of places (Cherry, 2016). For old bicycle users the main drivers for e-bike usage is the ability to save time, be outside, keep

in shape without arriving sweaty to the job and the pure enjoyment of riding the bike. The ones choosing the e-bike instead of a car enjoys the capability of transporting things with it. Most users see it as a step towards a sustainable future, some as a technological frontier and some likes the sustainable and healthy image the e-bike gives them (Nordh, 2015).

Impacts on transportation behaviour

According to studies e-bike users seem to travel more frequently and further than user with ordinary bicycles, they also seem to spend more time on their bikes. There are also studies that have shown that e-bikes have better capacity to replace usage of cars than ordinary bicycles. This in turn could be a benefit since they reduce the traffic congestion, emissions and improves the health from the physical activity and lowered air pollution. E-bike users tend to change their traveling patterns, altering their routes prioritising wider roads and smoother road-conditions and not caring too much about height differences (Dozza, 2014).

Physical activity impact

Studies have shown that the effort while e-bike riding is enough to provide exercise for the users reducing sedentary lifestyle diseases. In tests where e-bike riding is compared to bicycle riding, e-biking requires between 10-25% less effort than the normal bicycles (depending on the assist settings) and also travels faster than the bicycle. This is still rather close to the bicycling effort. According to a study on new e-bike users, the introduction of e-bikes increased the cycling activity for the users, both for exercise and transportation. The increased cycling accumulated more physical effort than a control group without e-bikes. Even users priorly having moderate cycling activity increased their total physical activity since they now biked more often, as well as for longer distances and periods of time (Sundför, 2016).

Environmental impact

Given that the e-bike substitutes other motorised vehicles like a bus or a car, the e-bike greatly reduces the environmental impact. It emits only a fraction of the carbon dioxide compared to a car per km, and fewer emissions than a bus per person and km. The transfer from lead-acid batteries to lithium ion batteries has made sure to lower the rather high environmental impact from the battery source pollution as well.

Road safety

Most studies from China and North America seem to conclude that e-bikes have a higher perceived safety than ordinary bicycles, this is sometimes explained by the ability to keep up with other traffic, the assist to accelerate through intersections and perceived added stability in higher speeds. However, some studies concludes that e-bikes are more likely to be involved in crashes and some claim that whilst e-bikes/bicycles are equally as represented in crashes, e-bike crashes usually lead to more severe injuries(Clark, 2014). According to Dozza, e-bikes are more likely to be involved with dangerous situations with motorized vehicles. This is explained by both the greater speed of the e-bikes and the miscommunication with the motorized vehicle drivers, believing that the e-bikes are

ordinary bikes thus underestimating their speed. The lowered handling on e-bikes due to their weight and often laid back riding positions are also considered a factor to why e-bikes are overrepresented in accidents (Dozza, 2015).

Barriers

A big concern for e-bike users is the fear of theft. This requires the users to find more specific parking spots, and lock their bikes more thoroughly. Users also often detaches and brings the battery with them when parking their e-bikes to lower the risk of theft, this is described as cumbersome, and the battery as heavy and bulky. When arriving at their destination, they get a deterrent social reception, being accused of cheating and being lazy. This annoys the users, especially since car drivers usually don't get the same reception (Strömberg, 2016).

Improvement potential

While most other product areas are moving towards unified products with both physical and software solutions integrated into a complete product, the e-bicycles are not keeping up. Customers are locked into different systems, and are used to being able to customize and repair their bicycles themselves. Embedded software solutions decreases the understanding of the product, and shifts more of the maintenance and control towards the company or repair shops. However, just as in all other product areas, these embedded systems could allow for a better complete experience with the e-bike, with functionalities as for example electronic locks, gps, tracking and electronic gears (Hermanns, 2016).

To eliminate misunderstandings leading to accidents with other trafficants, the design should increase the e-bikes conspicuousness and distinctiveness (Dozza, 2015). A road block for e-bikes is bad road conditions (Nordh, 2015), but if thought the other way around, an e-bike needs to handle bad road conditions in a better way. In a study, it was shown that people who actually love to bicycle really appreciates the e-bikes, they like how it enables them to ride their bikes faster and all year round. These users are suggested to be used to increase the general popularity of e-bikes (Ibid). The same study also concluded a list of technical development areas for increased e-bike experience:

- Better carrier capacity
- Better throttle/brake-functions for smoother acceleration and braking
- Lighter bike
- More heavy gears
- Longer battery time
- Recycle-systems for batteries
- More sporty e-bikes in the demo-campaigns to attract new customers
- Faster charging
- Illumination
- Better usage information
- Better information regarding e-bikes and its impact on health and the environment

Transition to e-bikes

The e-bikes are not yet fully adopted in today's society, a lot of customers still consider it a rather new and innovative product. The Diffusion of innovations theory presented by Everett Rogers (1995) explains how, why and at what rate new technology spreads. The theory divides users into five groups presented chronologically based on when they purchase the bike, innovators, early adopters, early majority, late majority and laggards. The four most important elements in this process is explained as the innovation itself, communication channels, time and social systems. To allow for the e-bikes to fully spread into the market, the type of user should be determined and designed for. The aspects innovation, communication and social systems could all be targeted in different ways to allow for the e-bikes to spread faster. Important aspects within the innovation is the relative advantage towards a current solution, compatibility with existing values and needs, complexity of the usage of the innovation, observability of the innovation in use and the possibility to try it out. As for the communication, it is important to allow for the users to get all necessary information to how the innovation would impact their life. With e-bikes sometimes being considered as a lazy alternative to a bicycle, the social systems could be targeted to alter the perception of e-bikes towards something positive.

For a new potential e-bike customer the purchase doesn’t just mean the acquirement of a new product, but also a behavioural change, a transition from one way of living and transporting themselves to another. This means that the decision-process before buying an e-bike is not just about the artefact itself, but more how the new change will influence the customer's life in the future. An adapted version of Rogers theory The Innovation-Decision Process presented by Strömberg(2015) attempts to explain how this transition plays out. It is described through the five different stages highlighted in italics below. The process starts out with the *Knowledge stage* where the user learns about the product and its functionalities. This can be triggered by a current need or a new need emerging after noticing the product. In the *Persuasion stage* an opinion is formed about the product, it is in this stage that the aspects presented above, innovation, communication channels, time and social systems serve important roles in enlightening the user. In the *Decision stage* the user engages in activities like trials or reading reviews to decide whether they should acquire the product or not. When purchased, the *Implementation stage* begins. In this stage the behavioural change is started, and users try to seek knowledge about how to use the product. The stage ends when the product is a consistent part of the user's daily routines and the final *confirmation stage* begins. In this stage the users might try to evaluate their new behaviour with the product by seeking reinforcing or conflicting arguments to either continue using the product, or change again.

3.1.2 Market and Regulations

The following chapter presents the results and findings from the market and regulations study. This is done in three parts where the first part includes the results from the market analysis, the second part describes important laws and regulations regarding the e-bike design and the third part presents patent considerations that need to be taken into account.

Market analysis

The picture below illustrates the eight different categories of bicycles that Crescent offer today (Crescent, 2017). E-bikes is one of the categories, even though it could be considered an own category of vehicles. All E-bikes sold by Crescent in the year of 2017 are compiled and presented in appendix III. The other seven categories offered by Crescent are Hybrid (Fitness-Urban & Cross-Urban), Classic, Racer, Mountain bike, Cyclocross, City & Kids.

Figure 8: E-bike models offered by the most common brands.

When the Swedish market was analysed 38 different brands were found competing with Crescent in the e-bike segment. All the brands found among the eleven retailers in Sweden are listed in appendix IV. According to the study Crescent was sold in six out of the eleven stores, which demonstrate their influence on the market as one of the biggest brands in the e-bike segment. The second most common brand together with Batavus was Monark, which just as Crescent is a part of Cycleurope.

Twelve brands appeared in two or more retailers and figure 9 below illustrate some of the models offered by the most common brands. All of the e-bikes from the brands were not represented in the figure, however it provided a decent picture of how the market looks in Sweden. The variety of bikes on the market is very big and there are e-bikes in many different categories from city bikes to hybrids and mountain bikes.

Figure 9: Extract from the current Crescent product portfolio

When performing the KJ-analysis regarding bike characteristics and visual expression the groups and subgroups illustrated in figure 10 below were defined, “Nostalgic/Classic”, “City Standard”, “Cross-Urban Hybrid” and “Mountain bike”.

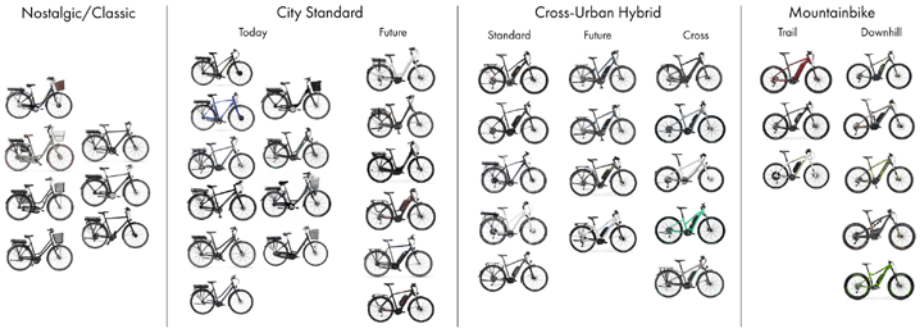


Figure 10: E-bike subgroups identified in the KJ-analysis.

Within all identified groups the market was found to be rather mature with several different models within each category. However, when the results were compared with the bike categories sold by crescent, there were categories that were not present in the analysis. The categories Racer, Fitness-Urban Hybrid and Cyclocross were not represented by any e-bikes, which might indicate a future possibility for the next generation urban e-bike. There might also be a potential to explore new e-bike categories inspired from other types of industries. For example many bicycle categories are today somehow reflected in the car industry and this industry might provide inspiration for a new e-bike category. One example is the SUVs that would correspond to some sort of advanced mountainbike built with a clean city-like look. Other examples could be lifestyle city cars with personality where the corresponding city bike today would rather be a normal bland bicycle. Another area that could inspire a new type of expression for the e-bike is lifestyle brands, where products convey stories about their users, such as environmental awareness, modern city or outdoor-sustainable.

Laws and Regulations

For all bicycles in sweden the following general requirements must be fulfilled, in order for the vehicle to be legal to use (Transportstyrelsen, 2017a). Every bike needs to have brakes and a bell to call attention. For users under 15 it is mandatory to wear a helmet. When it is dark the following additional rules/features must be considered and fulfilled:

- Rear light, red, visible in 300m
- Head light, white or yellow, visible in 300m or enough light to ride safe
- Rear Reflex, red
- Front Reflex, white
- Side reflexes, white or orange/yellow

For electrically assisted 2 wheel vehicles, e-bikes, there are additional regulations regarding motor performance and speed, for it to be classified as a bicycle. According to the Swedish Transport Agency a bicycle with pedaling function and electric assist is

classified as a bicycle if its design meets the following principles (Transportstyrelsen, 2017b):

- The electric motor kicks in when the pressure on the pedals increase.
- The motor is only allowed to enforce the torque from the pedals and is not allowed to provide any power for speeds above 25 km/h.
- The maximum power for the motor is 250 W.

If the vehicle is not following these rules, a bicycle with electric assist will most likely be classified as a moped, which means that other requirements have to be fulfilled for it to be used in traffic.

Patent Consideration

According to Crescent representative Ulrik Bengtsson (personal communication, 31 January 2017) there was at the time for this project only one patent that had to be taken into account regarding electric bicycle design. The patent was published in 2011 by the danish bicycle company Protanium (Munksoe, 2011), which concerns the integration of the battery in the down tube of the frame as illustrated in the picture below. The patent, US 7934576 B2, covers a bicycle frame with fully integrated and detachable battery and a summary of the patent is extracted below .

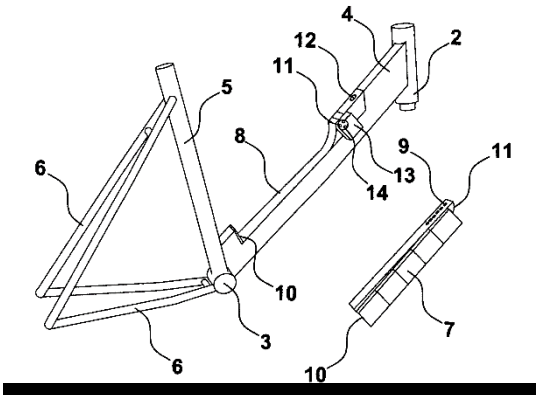


Figure 11: Illustration from the patent: (Munksoe, 2011)

"The present invention concerns a bicycle frame, including a number of frame elements, preferably tubes, where the frame elements are interconnected and constitute a construction with so great rigidity that the cycle frame does not change its geometrical shape under usual load, where an electric battery system is at least partly embedded in the frame, including at least one battery pack for storing electric energy for use in connection with equipment, such as comfort equipment and/or safety equipment on a bicycle, including an electric ***auxiliary*** *motor, where the part of the frame adapted to mounting a battery pack is constituted by a hollow section, the hollow section being a multiple chamber section, where a battery pack is predominantly arranged in a cutout in the multiple chamber section so that at least one chamber in the multiple chamber section is substantially intact. Thus is obtained a cycle frame with a cutout for a battery pack, where the frame has great rigidity."*

(Munksoe, 2011)

3.1.3 Technical Research

This chapter presents the findings from the technical research conducted in the areas of bike anatomy, drivetrain technology, manufacturing and materials as well as the results from the study of the bike-human symbiosis.

Bicycle components

Even though there are thousands of different bike models, all of them share a lot of components and similarities. The fundamental parts of any bicycle are the wheels, the handlebar, the pedals and some sort of frame that ties it all together. However, their properties can vary greatly between different models and there is a whole world of other parts that can be included. Although some of the most obvious parts have been excluded, this picture presents most of the essential components.

Figure 12: An illustration presenting the most essential bicycle components.

For the e-bike there are some specific components, these could also vary between different models, but most of them are always present in some way. In this specific picture the motor is a center motor, and there is a dedicated LCD display. These components will be further explained in Drivetrain technology.

Figure 13: An illustration presenting the most essential e-bike components.

Drivetrain technology

What characterize an e bike and differentiate it from an ordinary bicycle is basically the drivetrain components. These components consists first of all of a motor that provides power to the bike and that way helps the user to propel the bike forward. Another important component is the battery pack that provides electricity for the system and lastly there is a display and control unit where the user can interact with the system. There are different suppliers of e-bike components, and also different configurations of how the components are arranged. The different configurations have pros and cons and provide different characteristics in terms of for example performance and handling.

There are basically three ways in which the motor can be mounted on an e-bike, as seen in the illustration below (figure 15). The first and least complex way is to mount an motor

in the hub of the front wheel. The second way is to place the motor in the hub of the rear wheel, which is a bit more complex. The third option is to mount the motor in the center together with the bottom bracket/crank shaft. This project was limited to the use of a center motor(Figure 14), but it is however important to understand the basics of the different versions. Crescent provide an own drivetrain system on many of their e-bikes, which goes under the name EGOING (Crescent, 2017). The power provided by the motors used by Crescent is equal to the legal max level 250 W, however they provide different torque. 38 Nm from the front motor, 45 Nm from the rear motor and 80 Nm from the center motor. On all three motor types there are five different power modes, plus walking assistance, that can be used to adjust the amount of assistance the user gets from the motor. The front motor has a weight of 2.4 kg, the rear motor 3.4 kg and the center motor 3.9 kg.

Figure 14: Crescent EGOING motor.

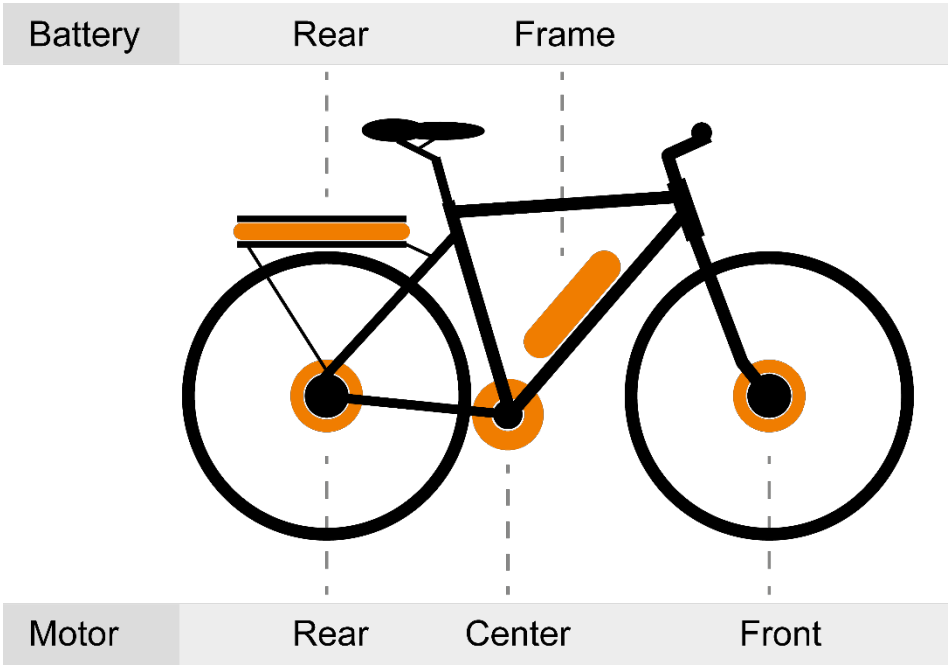


Figure 15: Illustration of different drivetrain configurations.

The batteries can much like the motors be mounted in different positions on the bike frame. Different brands and models provide different solutions on where to put the battery pack, however Crescent have two main options for battery placement. As seen in the picture above, one option is to put the battery on the rear carrier and the other option is to place the battery on the down tube of the frame. The different batteries have different shape but provide the same performance with a range of 50-80 km, but the range could be extended up to 14 km if using the center motor on the lowest power mode. According to specifications from Crescent the batteries are Lithium Ion with a voltage of 36 V, electric charge of 11 Ah and the charging time is approximately 6 hrs (Crescent, 2017). The battery pack is built up by 50 different 3.6V and 2.2Ah single cells (C. Almqvist, personal communication, 23 February 2017). The 50 cells are stacked in 10 units with 5 cells in each unit connected in parallel, making 3.6V and 11Ah. The 10 units are put in series to provide a total voltage of 36V and a total electric charge of 11Ah. There is also a less powerful battery pack available which is built up by 40 different 3.6V and 2.2Ah

single cells. The cells are stacked with four cells in parallel as a unit, making 3.6V 8.8Ah. In both battery types the 10 cells can be ordered differently to alter the shape and design of the battery pack.

Figure 16: Crescent EGOING display.

The display and control unit is typically mounted on the handlebar (Figure 16), where the design and complexity varies a lot between models available. What differs is the way the user interacts with the system and how the system communicates with the user. Some basic models consists of a few buttons to adjust the level of assistance and some led lights indicating power level as well as battery status. More advanced models have larger LCD-screens that, part from battery level and level of assistance, display speed, average speed, max speed, distance travelled and the amount of assistance the motor provides at the moment. The most complex display and control unit is offered by Bosch and has many interesting features presented in an intuitive way on a colour LCD-screen where the user can adapt the display in accordance to own preferences (Bosch, 2017). Part from showing the basic functions such as speed, riding mode, motor power and battery level, the Bosch model also offers Smartphone connectivity, GPS navigation, micro-USB port, as well as information presenting how much power the user puts in. It also provides a real time fitness mode to motivate the user by measuring cadence and pedalling force to calculate the level of exercise.

Manufacturing and Materials

When building a bicycle the material and manufacturing techniques greatly influences the performance and visual expression of the bike. The traditional bicycle frame and front fork were initially built using steel tubes, but have gone through several different materials through the years, aluminium alloy, carbon fibre, magnesium and titanium and more(Exploratorium, 2017). In this chapter the most commonly used materials and manufacturing methods for building bike frames and forks will be explained. Emphasis will also be put on how these materials and manufacturing techniques results on the performance and visual expression of the bikes.

Aluminium alloys

Aluminium is a lightweight but rather soft material. When alloyed with small amounts of copper, manganese, silicon, magnesium and zinc the hardness and durability increases. Compared to steel, the same strength can be achieved with roughly half the weight. When in contact with oxygen it forms a hard, maintenance free protective layer. (Thompson, 2007)

Figure 17: Example of aluminum frame.

To create aluminium alloy bicycle frames, the material is first extruded into tubes. The tubes are then processed into their intended forms using different techniques. Section bending and tube hydroforming are two common processes. Tube hydroforming is a process where the tube is enclosed in both ends, and then internally pressurised using a fluid to form the tube against two tools. The technique allows for seamless, complex uniform shapes along the tube. To create smaller and more sharp geometries, more pressure is required, thus very small radiuses can be hard to achieve with the process, especially if concave (American Hydroformers, 2016). The shaped tubes are then post processed and TIG-welded together into the final frame. The welds can be post processed to allow for different visual expressions, however homogenous shapes between tubes are costly and rarely used (Figure 17).

Carbon fibre

Carbon fibre epoxy composites are very strong, light and stiff. Compared to aluminium the carbon fibre has twice as high stiffness and resistance to damage modulus (Dexcraft, 2016).When forming a frame out of carbon fibre, cut out patches are placed overlapping each other in a mould. There are usually a number of different moulds for the final frame, and each mould produces one part. By varying the amount of layers of carbon fibre on different places of the frame, the specific strength can be altered to allow for extra strength where it is needed, while less strenuous parts can be held as light as possible. Resin is then added to the mould, the mold is shut and a rubber bladder is pressurised inside of the

mould to push the carbon fibre into the shape of the mould. Finally the carbon fibre cures within the form and takes the shape of the mould. The final parts are then glued together and after some post-processing including sanding and painting, the frame is complete (Fitwerx, 2008). Carbon fibre frames allow for a lot of different bike frame designs, separating themselves from the classic aluminium frames by allowing for continuous flow of complex surfaces throughout the whole frame (Figure 18).

Figure 18: Example of carbon fibre frame.

Effect of material type on bike

The carbon fibre bikes are usually a bit lighter than the aluminium ones, however this is not always true, and in the context of an e-bike the percentual weight difference between having a carbon fibre frame and an aluminium frame is minimal. Impact strength, stiffness and resistance against sharp object impacts to the frame are all better on a carbon fibre bike according to tests (Pinkbike, 2012). Some users claim that carbon fibre bikes provides some extra vibration and impact reduction and thus rides better. When comparing prices for producing the bike frames, some really rough numbers given by a Crescent employee was that the production price of a carbon fibre frame is somewhere between five to ten times as expensive as a normal aluminium frame. In terms of environmental impact, aluminium is beneficial compared to carbon fibre, both regarding production and recycling. Another difference between the two frames is the visual expression they allow for. Aluminium frames usually have quite visible welds, and it may therefore be hard to create homogenous shapes between different parts. Carbon fibre frames can on the other hand look more unified, and allows for sweeping forms between different parts. However a more unified expression may also be achieved with aluminium, but it demands extensive post processing which increases the cost.

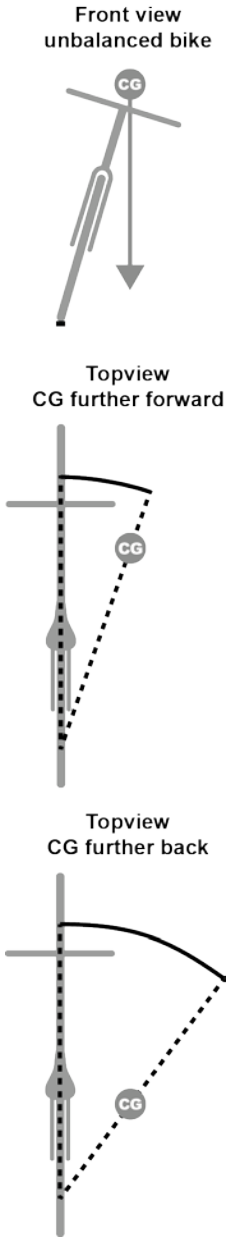
Bike-human symbiosis

In this chapter the relation between the bikes properties and the bicycles dynamics as experienced by a user will be explained.

Bicycle dynamics

The stability and controllability of a bicycle is a result of a lot of different factors. To start of, the balance of the bike is based on keeping the center of gravity aligned vertically with an imaginary line between the contact point of the wheels. If the bike starts leaning one way or another, the front wheel must be steered in a direction so that the wheels regain their position below the center of gravity to keep balance. Thus, the position of the center of gravity is a major factor for the stability and controllability of the bike. Since it is the front wheel that moves side to side when trying to regain balance, while the back wheel slowly follows, the front wheel will have to compensate less if the center of gravity is further forward. However, if the center of gravity is far back, the front wheel will have to move a longer lateral distance for the resulting line between the back wheel and the front wheel to move under the center of gravity, figure 19. Thus, the general rule is that the further forward the center of gravity is, the easier it is to control and balance the bike. Another aspect is the height of the center of mass. The lower the center of mass is, the lower the resulting lateral offset of the center of gravity in a lean will result in, requiring a smaller compensation by the wheels to regain balance. However, if the center of gravity is very low, like on a fully loaded touring bike, the bike itself will be heavy to move into a balanced position. A high center of gravity will require greater compensation by the wheels, and will feel unstable standing still or riding slow. However, the leaning angle will increase slower with a high center of gravity, and the bike will be easier to manoeuvre, making it rather easy to balance, similar to how a broomstick with the center of mass at the top is easy to balance. As the speed increases these compensations will be very easy to do, making the bike feel very stable. (Heine, 2009)

Figure 19: Illustration of how much the bike must turn to regain its balance with the wheels below the center of gravity (CG).



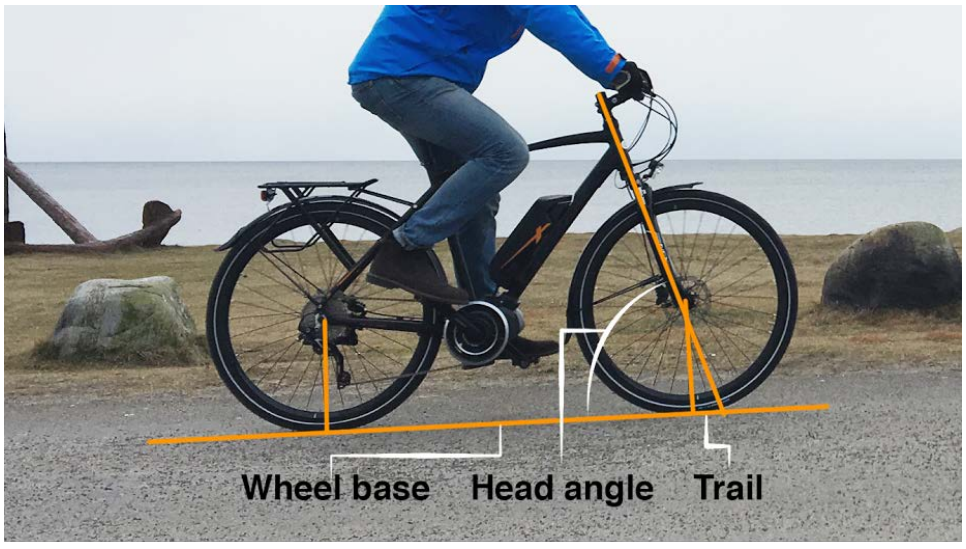


Figure 20: Illustration of bicycle dynamics terminology.

These compensating front wheel motions could be controlled by the user but most bikes also have other properties making it self balancing at speeds. One major self balancing property is the trail (Figure 20). The trail is the distance between the contact point of the front wheel and the point where the steering axle line intersects ground. Wheel size, head angle and fork offset all contribute to the final trail. As the bike starts leaning to one side,

the vertical reaction force in the contact point will push the wheel sideways in relation to the now leaning steering axle, rotating the wheel along the axis making the wheel steer in the same direction as the lean, placing the wheels under the center of gravity again. The bigger the trail, the more stable the bike will feel. However, a too large trail will make the bike feel hard to control, especially if the bike is heavy.
(Zinn, 2006)

Figure 21: Different riding positions.

Riding position

Since the user riding the bicycle usually is quite a lot heavier than the bike, the rider's position will greatly influence the centre of gravity giving the consequential effects as mentioned above. A more upright position will both move the centre of gravity upwards and backwards, giving a lower controllability and stability. Another aspect is the wind resistance, a position where the rider has the body in an aerodynamic position, such as a racer biker leaning forward, will allow for a smaller wind resistance thus achieving more speed for the same effort. The riding position, and specifically the seat position will influence the power production greatly(Neill's Bike Fitting, 2017). Different positions of the pelvis in relation with the crank arms will allow for different muscle groups to work. To achieve the highest efficiency, the saddle should be in a height so that the user can use all major muscle groups in their legs to pedal.

Test manoeuvrability

During the test rides two different bikes were tested in a slalom course. Both were e-bikes with similar centre motor drivetrains, one was a traditional women's bike and the other a cross-urban hybrid. In this test the cross-urban hybrid e-bike was perceived as a lot easier to manoeuvre through the course. The stability-factors presented above regarding centre of gravity was confirmed as the cross-urban hybrid with the center of gravity placed rather low and a bit forward required smaller adjustments to keep the balance, and it also felt like the bike turned around the body position. The women's bike on the other hand, with a centre of mass rather high and far back, required larger adjustment movements. The women's bike felt like it was turning more around the back-wheel, requiring a larger turning radius through the slalom course. Another factor to the manoeuvrability was how the drivetrains acted, the women's bike had a small lag between when the crank arms started turning and when the assist kicked in, and the cross-urban hybrid had a smaller lag. This made the women's bike feel more unpredictable when manoeuvring slowly since you continuously stops and starts pedalling.

Figure 22: Maneuverability test.

Drivetrain behaviour

After a few hours of testing different e-bikes, a goal for how a drivetrain should behave and feel was formed: To achieve symbiosis between the user and the drivetrain to create augmented strength. The closer to this the bike behaves, the more control the user will have over the bike in situations like the slalom course mentioned above. The user will not feel how they suddenly get some assist from the electric motor, but rather the illusion that they have enhanced strength, decreasing the feeling of being helped or cheating. The lag between when the user starts pedalling and when the assist kicks in is a major factor in this goal, the lower lag, the closer it feels to augmented strength. Another important factor is the ratio between input from the user and the electric motor. If the motor gives too much power, the assist will be very noticeable. The goal would be not to allow the motor to kick in with too much power instantaneously, and when a lot of power is required, it could possibly increase gradually instead. The back and front wheel motors did not give the feeling of strength enhancement at all, but rather like you were fake-pedalling on a moped.

3.1.4 User studies

In this chapter the relation between e-bike users, non e-bike users and e-bikes will be explored and explained through the results of a series of studies.

User Interviews

The means of transportations used by the interviewees were car, public transportation (bus, tram and subway), bicycle and e-bike. However the choice of transportation differed a lot between the subjects as well as between what different purpose the travel was intended for. On regular basis the purpose for traveling was often commuting to work, but also for grocery shopping, visiting family and friends, going to the gym and transporting kids. The interviewees chose different means of transportation for the same purpose based on what they consider the best option. Some used almost only public transport, whilst others almost solely took the car. One interviewee had a desire to take the bike, but basically took the bus all year because of the convenience, cold temperatures and that the bike had a flat tire that needed to be fixed. Another interviewee took the car almost everywhere because of the time that was saved in comparison to public transportation and the convenience of not having to squeeze in with a lot of people on the bus every morning. This interviewee also considered the car to be a more economically beneficial alternative since he required the car for other needs anyway, rendering the public transportation more expensive. If the weather allowed for it, not being extremely bad, one interviewee rode a normal bicycle to work almost every day. The same interviewee expressed scepticism about him using electric assists since it would mean less workout. One of the e-bike users took the car during winter and when it was raining, since the person did not appreciate slippery and wet road conditions. However, as soon as the weather allowed for it the e-bike was used as transportation for various purposes.

Even though the people had different opinions about what way of transportation was the best for the same purpose, some motivational words were identified that spur and encourage the usage of any way of transportation. The motivational words were: Smooth, Flexible, Easy, Convenient, Comfortable, Warm, Feel the wind, Fresh air, Free, Exercise, and Time saving. These words could be important to stress in a concept to convince people to choose a specific way of transportation. On the contrary some words were also identified as barriers for using a way of transport. These barrier words were: Cold, Rainy, Smelly, Distant, Theft, Flat tire, Limited space, No time, Laziness. These words are equally important to address in the project, but efforts should then be put on making these words less apparent and minimize its effect on the total experience.

When the users were asked about their opinion about e-bikes they highlighted both positive and negative aspects. Positive aspects were that e-bikes are considered fast, convenient, smooth and flexible. They also highlighted how e-bikes would let users go further and how there is no need for multiple showers during a day, since the users will not have to get sweaty. They are also considered to make people think differently and substitute traveling with car or bus for environmental reasons. Negative opinions about e-bikes mentioned by the interviewees were that they are noisy, clumsy and ungainly to handle. Another thing mentioned as a negative aspect was the battery handling and possible charging complications. Due to the high price tag on electric bikes many people expressed the risk of theft and were worried about the bike or components being stolen since they are so expensive. A usual thought among non e-bike users was that e-bike users are lazier and are somehow cheating since they do not work as hard and get as much exercise as people riding normal bicycles. These thoughts lead to frustration among non users when being passed by an e-bike. They also made the e-bike users feel defensive expressing that they sometimes feel that they need to explain and defend why they use an e-bike.

According to the interviewees there are some important properties they would evaluate if considering to buy an e-bike. First it must be “good looking” which is a very subjective interpretation of the overall bike design. One interviewee said “if if looks bad I will not even consider it, since it is such an investment and then everything must feel good”. Some of the interviewees specifically desired a clean and not flashy aesthetic expression. Part from having an attractive look it must provide high quality due to the relatively high purchase price. It should be light and easy to handle, but does not necessarily have to resemble a normal bicycle by appearance. Another important aspect was that it needs to be easy to perform quick stops, in terms of standing still on the bike as well as getting on/off the bike. The e-bike should also simplify the parking process by enable a safe but simple locking procedure as well as a simple battery handling. An interesting aspect that emerged among several of the interviewees was that their preferred bike model would differ if they would buy a normal bike or an e-bike. If buying a normal bike they would like a bike that allows for high speed and good handling. On the other hand, if buying an e-bike they would rather prefer a traditional women's bike. The explanation was that the e-bike was not considered to be a tool for exercise, but only for transportation.

In terms of new ideas that could be applicable for the project the subjects talked about some interesting features that could be integrated to a future e-bike design. The ideas were grouped into three groups; Digital software, Electrical functions and Physical functions. Concerning digital software people mentioned cruise control, GPS, Altitude meter, Environmental info and the possibility to set up individual goals. A desired possibility was also to be able to mirror a smartphone to a screen on the bike and then use apps on the phone through the bike display. Ideas categorized as electrical functions were for example, stronger headlight, phone charging, turning indicators, auto adjusting air pressure, integrated heat in handlebar and saddle, one-step locking procedure and that the bike would charge as well as illustrate the charging when going downhill. Physical functions mentioned had a lot to do with cargo capabilities, where some interviewees wanted to avoid having a backpack and desired a rigid well functioning cargo solution. Another desired physical function was to have rear mirrors on the handlebar.

Retailer interviews

In the following chapter, a summary of the different opinions and answers from the retailer interview study will be accounted for under each question. Five of the six retailers actively sold e-bikes, however one of them did not provide answers on more than a few questions, and the last retailer did not sell any e-bikes. Although this retailer was a bit sceptical of the concept of e-bikes they said they might start selling them if they found any that would fit into their product assortment.

Figure 23: E-bike section at a local e-bike store.

Who buys an e-bike?

Most of the retailers selling e-bikes mentioned that there had been more specific user groups 5-10 years ago, with women above 55 and people with disabilities or specific needs. However they all stated that the user group had been a lot more homogenous nowadays, with four different retailers claiming that e-bikes currently are sold to everyone. Two of the retailers claimed the customer group started at around 25 years of age and above while two said above 30-35. Mentioned as specific user groups where the

ones buying an e-bike instead of a car, or a second car. Many couples buy one to share within the family. Most customers were described as well educated. Parents with young kids were mentioned as common, and also commuters with a commuting distance of about 15 km. The store not selling e-bikes described e-bike customers as lazy, or with specific needs.

Who shows interest for e-bikes?

Since most of the retailers described the buying group as everyone, most of them had the same answer for this question as the one above. However, some differences were noted. One retailer talked about people coming to the store accompanying a potential customer, and although they initially were sceptical and uninterested, a simple test-ride often changed their minds completely. Another retailer mentioned the buyers that were going to want to use their bike for commuting occasionally, but also for transportation on their spare time, like when visiting their summer house. Companies looking up the possibilities for bike-sharing-pools were also mentioned.

What do customers ask for and find important?

Two of the retailers started of saying that most customers just want the e-bike to be as cheap as possible, quality or design was secondary if present at all in the purchase situation. However, many of them returned dissatisfied after a few weeks even though they had been warned about the quality. Some users come a bit prepared, according to one retailer almost every customer has learnt about a specific bike through the internet, or through friends, and has their mind set to it when they arrive. The most frequent requirements from the customers was the battery capacity, and the ones that wanted a slightly better bike mentioned that they wanted a center-motor. The functional design of the bike was most often based on personal preference based on what they were used to. Quite a lot of the customers want a bike with a low entry frame. A customer question that almost every retailer mentioned was: “How should i lock the bike?”. This seem to be a major concern for every potential e-bike user.

What do you think is important and talk about?

Two of the retailers approached this question with more universal answers, they claimed that the bike should have a center motor, high quality components throughout the bike and a bit stronger frame. The last two who had anything to say around the subject took a more user-need based approach. To start of, they said that there were no optimal frame-design but the customer should rather buy one that suits their riding style and preferred body position. They claimed that there are differences in rigidness between low and high entry frames which influences the ride-characteristics of the bike, however even though some performance is lost with a low entry frame, both are good enough nowadays to be safe and rideable. The battery capacity should be based on what the user requires. The type of drivetrain should be based on two parameters: The preference in how the assist should work decides if they need a center or wheel motor, and the amount of usage determines how qualitative motor and other components they should buy. The retailer not selling e-bikes mentioned the question, “Do you really need an e-bike?”, expressing a

discontent because of the fact that humans are capable of propelling their bikes themselves.

What characterize a good e-bike?

Most retailers answered similarly to the question above, two of them highlighting the center motor, good components and a strong frame, and two of them simply claimed, “If it suits your needs, it’s a good e-bike”. The retailer not selling e-bikes mentioned that a good e-bike should create added value that an ordinary bike cannot provide, like for example cargo capabilities.

Additional comments

Some variations in how different retailers define their bikes were described, some defined bikes as women's and men's bikes, while others talked about them as low entry or high entry frames. One retailer mentioned how suspension on the bike not only ads to the comfort of the bike, but also to its traction in the same manner as car-suspension systems work. He also mentioned how they are a lot more feasible on an e-bike since the loss in efficiency by the weight and pumping when pedalling the bike is less of a concern when there is an electric assist. An important factor with e-bikes is that their components, especially brakes, wear a lot faster than on ordinary bikes. The e-bikes also requires to be handed in for service continuously with intervals of around 1000 km. This service is done in a service shop, and it is considered likely that the users will let service shops do more of the service of the e-bikes than ordinary bikes considering the price of the bike, similarly to how cars today are serviced. Throughout the study, no retailer ever mentioned weight as something negative. Related to the fear of the bikes being stolen, one of the retailers started talking about digital locks. According to him, there are a lot of digital locks being sold separately by third parties. This kind of digital locks could definitely be integrated into the original bike, and a similar digital lock could be integrated into different parts of the drivetrain disabling the drivetrain if it gets stolen making it much harder to both steal and then sell. When asked why no-one does this today, the retailer started talking about how neither retailers nor manufacturers prioritises this since they do not consider themselves losing anything on bicycles being stolen. In fact, he said “Everyone wins on bikes being stolen”, the manufacturer and retailer gets to sell another bike and the customer gets a completely new bike for a rather low cost given that they have a proper insurance. However, considering this is such an important subject, the retailer thought that if a company started providing digital integrated locks on both the bike and the drivetrain, everyone would like to have it and then every company would have to follow. The retailer not selling e-bikes mentioned how there are no good enough e-bikes within a price-range that customers are willing to pay. He also said that the bikes was boring and did not fit into their product assortment.

User scenario

It all starts off with the user getting interested of the bike somehow, this could come from a specific need, hearing about the product or seeing it somewhere. The user then starts to learn about the product somehow, by talking with people, checking company websites, reviews, retailer websites or stores. The next step would be to test-ride the bicycle. This is done by finding a retailer selling the bike and visit the store. From here, a bike from the store is bought, or ordered from the manufacturer. The retailer then installs additional accessories to the bike, and the bike is finally delivered to the customer.

After this, the usage phase begins. Most of the e-bike usage scenarios in the daily life of an e-bike commuter could be summed up by the illustration shown in figure 24. The illustration was based on work presented by Strömberg (2016) and adapted to the findings from the interviews.

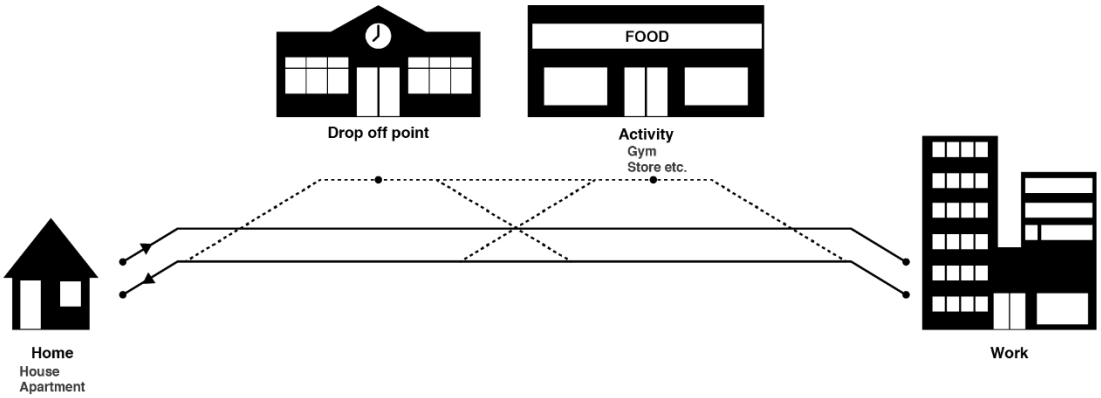


Figure 24: Illustration of possible e-bike usage scenarios.

As explained by the illustration, the user leaves home, and could either go straight to work, or make one or a few stops running errands along the way. Examples here could be dropping of kids to school, buying something from a store or going to the gym. When going back home from work the trip has the same possibilities, the user either goes directly home, or makes a few errands along the way. To exemplify, this is a common trip for an interviewee (I3) from our interview study (Figure 25).

I3 starts off with taking of the rain-protection from his cargo e-bike standing outside in his garden. He then mounts the battery and places his stuff and children in the cargo box. On his way to work, he stops at the kindergarten, locks his back wheel with a small mounted lock and walks his kids into the building. Later, with only his bag and a chain lock in the cargo box he rides to work. It is a sunny day, so he locks his bike to a post

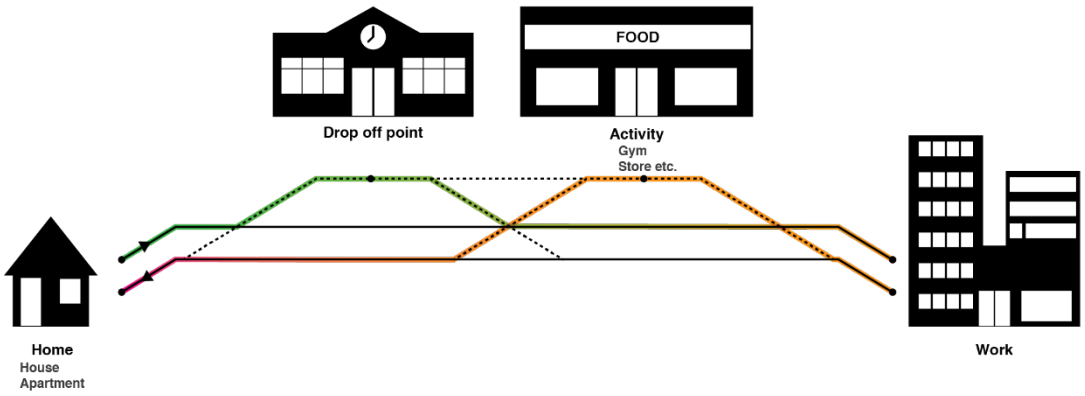


Figure 25: Example of e-bike usage scenario based on interviewee 3.

with the chain lock, detaches the battery and brings it with him to work. After work, he stops by a store and buys some ingredients for the dinner, it is only going to be a quick stop, so he only locks his back wheel. From the store, he heads straight home since his wife picks up the kids after work with the car. At home, he locks the bike and takes out the battery. When walking from the bike to the door, he has his bag on his shoulder, the grocery bag in one hand and the battery in the other. To unlock the door with his hands full, he has to put down both the battery and the grocery bags to take out the key and open the door. After kicking of his shoes, he takes the groceries to the kitchen, takes of his jacket and start preparing for dinner. The battery remains on a chair in the hallway, in the stress he forgot to plug it into the charger that they keep in the basement.

Observations

During the project the test e-bikes were tested in a variety of different situations and for different purposes in the everyday life of the members in the project group. Commuting was the most common activity the bikes were used for, but also for different leisure activities and grocery shopping. The relevant observations made were found to fit in one of two categories. Either it was a functionality aspect concerning the actual usage of the product or it was a social aspect concerning the societal reception an e-bike user encounters.

The most evident functional aspect that was observed by the project group was the handling of the battery, since it often had to be taken along when leaving the bike. A typical situation was to have one hand occupied with groceries or another bag and the other hand was used to carry the battery. This was found annoying since there was no proper handle on the battery and due to its size and weight it was impossible to use the hand for any other purpose while carrying it. For example unlocking and opening doors between the bike storage room and the apartment. Once in the apartment, the battery had to be charged, which was first of all easy to forget and the charger was also found bulky and uninspiring. The charger was therefore hidden away where it was easy to forget the battery when going to the bike the next time. It was also considered hard to know when the battery needed to be charged due to the inconsistent level indicator on the battery and

display unit on the handlebar. A major concern raised by nonusers was the battery performance and especially the battery lifetime which also indicate the importance of addressing the battery in the concept development phase.

Another functional aspect was the locking procedure that was found complicated, time consuming and requiring too many steps for the user, which for example led to avoidance of stops on the way home or insufficient locking at shorter stops. A typical behaviour noted among other e-bike users was to carry items hanging on the handlebar, which can be considered quite sketchy especially with small handlebars. On the contrary the project group found it rather comfortable to ride with heavy packed backpacks since the sweat problem was not found to be as present with e-bikes as with normal bicycles. However it was annoying if it was necessary to carry more than one bag on the back such as a gym bag in addition to the backpack.

The last functional aspect observed by the project group was the importance of ensuring the performance of the bike and to make sure that the bike keeps functioning. One example where one of the test riders encountered a problem related to this was when the chain snapped after only two weeks of usage and approximately 100 km riding. The first reaction was a lot of frustration and many questions arose, eventually leading to lacking motivation to fix or use the bike. Another example is squealing brakes or malfunctioning gears that contribute to a very negative product experience, especially due to the significantly high price a customer needs to pay for an e-bike.

In terms of social aspects there was one significant aspect of being an e-bike user that was hard to ignore. This aspect was the surprisingly negative response received from people when talking about using an e-bike. “Cheater”, “No exercise”, “That’s an old man's bike” were commonly occurring accusations commented by people. Another comment was that people would like to pedal themselves, but when asked if they use their bike often the answer was usually no. From a user's perspective it was found rather difficult to deal with those negative comments and a defence position had to be taken to justify the e-bike. For example when riding longer distances, which provide quite good exercise even on an e-bike, it was hard to claim the own achievement as an e-bike rider compared to if a normal bicycle would have been used, even for a shorter distance. The user always has to add that it was actually not a normal bike but an e-bike that was used and then the achievement was suddenly not worth anything.

Another social aspect noted when using an e-bike was the social mediator it was for conversations, where the bike itself drew attention from people. The battery was found to be the most profound conversation starter where people often asked what it was and wanted an explanation to why the user rode an e-bike. This natural conversation point could possibly be exploited as a positive conversation conveyer since people show a lot of interest for the product. However the user must possess the tools needed to make it a positive conversation regarding e-bikes. The bikes defined as unisex by Crescent that were used throughout the project were often referred to as “women’s bikes” by both male

and female potential users. This raises the question if these bikes really are unisex and how a unisex bike should be designed to attract both genders. The last relevant social aspect identified was that it was found to be hard to ride along with friends not having an e-bike. The electric assist could always be turned off but it was found a bit annoying.

3.1.5 Brand Strategy Research

In this chapter, the internal view of Crescent is accounted for, and the common view of the brand is explored and analysed.

Crescent today

The main goal for Crescent is to create a value for the customers through branding driven design and communication (Crescent, 2015). Value is being described as increasing life quality and experiences for the customers: Increased health, better environment, better economy and more time. The Crescent goals are built from a rich history consisting out of racing competition successes, being part of solving health problems in Sweden and the perceptiveness towards user needs such as time-management, economy and environmental concerns.

To allow for a desired and united brand image Crescent has developed the following branding guidelines:

Crescent

Core values:

Activity - For movement in exercise or performance
Exuberance - Create wealth and positive experience
Attraction - Adds value/status through functionality, design and quality
Pride - Satisfied bike-ambassadors carries the brand

Vision: "The first choice for the cyclist"
Mission: "For a healthy and environmentally friendly lifestyle"
Brand philosophy and promise: "Life in motion"
Visual identity: Based on the orange brand color, the logotypes as well as the "världsmästarranden" and the checker-pattern.
(Crescent, 2015)

By using these brand values as a communicative platform, Crescent reaches out broadly to the consumer groups as well as more specifically towards retailers and bicycle-specialists in the sport-business. With their communicative platform, they strive to deliver an attitude with emotional and positive dimensions.

Crescent has through a mosaic study compiled their customers into the following four personas: The sporty exerciser, The sporty commuter, The regular commuter and The parents of young children.

Analysis of Crescent brand

When talking to Crescent employees, trying to percept the internal common view of the brand, the employees paints the picture of a brand that is tech-driven, advanced, a bit experimental, ambitious, changing and modern. This correlates with the brand positioning made in a study by Crescent, visualised in figure 26.

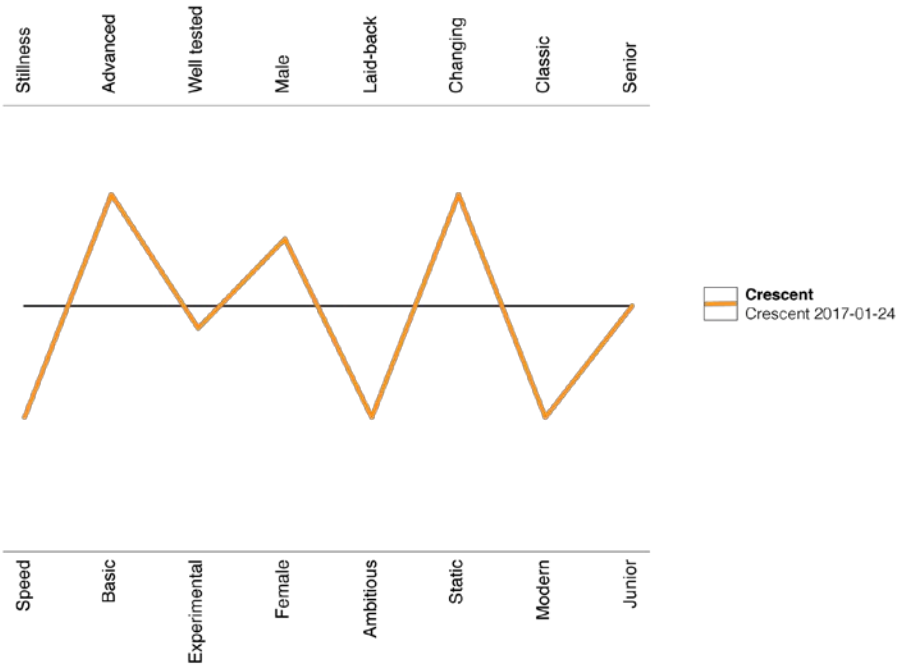


Figure 26: Internal view of brand positioning at Crescent.

It seems like the employees mostly sees the pro-scene side of the brand, with products for the professional brand ambassadors. The perception is that the common bikes benefit from the knowledge presented in the pro-products. The feeling is that the employees do not think as much of the healthy and environmentally friendly parts of their brand mission, but more of the specific goals Activity, Attraction and Pride.

When investigating the common view of the Crescent brand and its products separately to younger potential customers, the results are rather scattered. The following graphs present the mean values in a bold line, and all results as the thin lines within the coloured area.

The Crescent brand image proves to have the least scattered results (Figure 27). In contrast to the image Crescent has of themselves, the brand seem to be perceived as classic, well tested, senior and static, it is also described as a bit basic and laid back. It seems clear that people find the Crescent brand stuck in the old nostalgic heritage, thinking of well-built bikes from the 20th century that still roll around the streets.

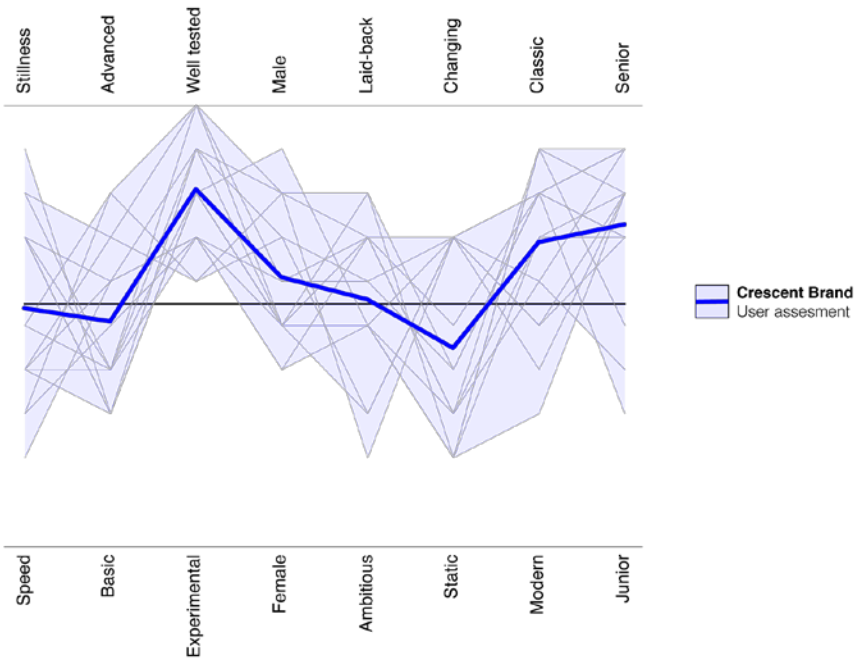


Figure 27: Common view of Crescent brand.

The brand image presented by the Crescent products seems to be even more scattered. One way of explaining this is that Crescent has a lot of different types of bikes, and the perceived brand image will be greatly influenced depending on which type of bike the user find the most descriptive of the brand.

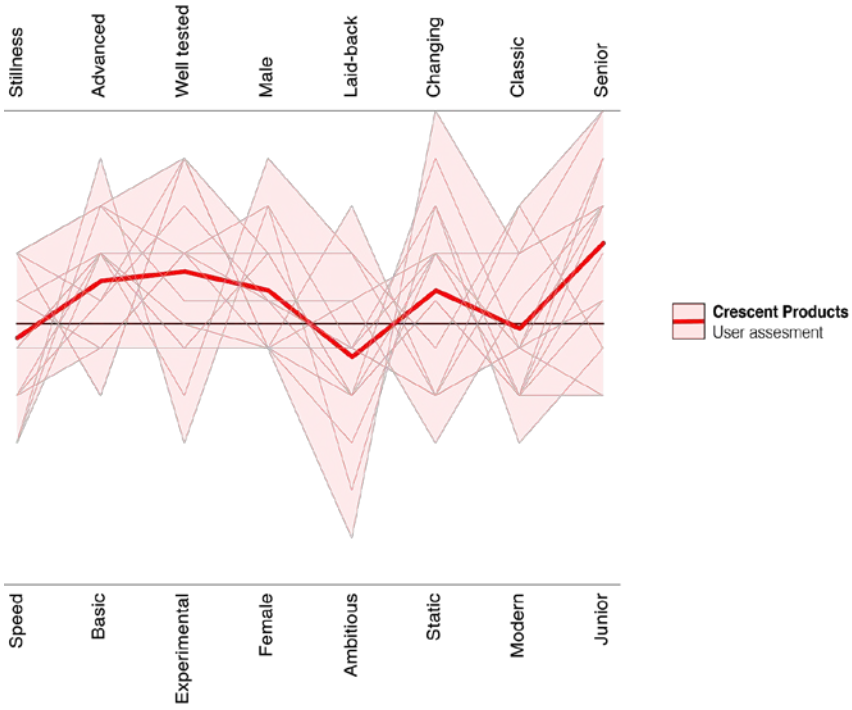


Figure 28: Common view of Crescent products.

When comparing the mean values of all results, a rather interesting correlation occurs. The perceived Crescent brand image almost always directly conflicts the internal image of Crescent. However, the Crescent products are always perceived a bit closer to the internal image, always placed somewhere in between the Internal image and the perceived brand image.

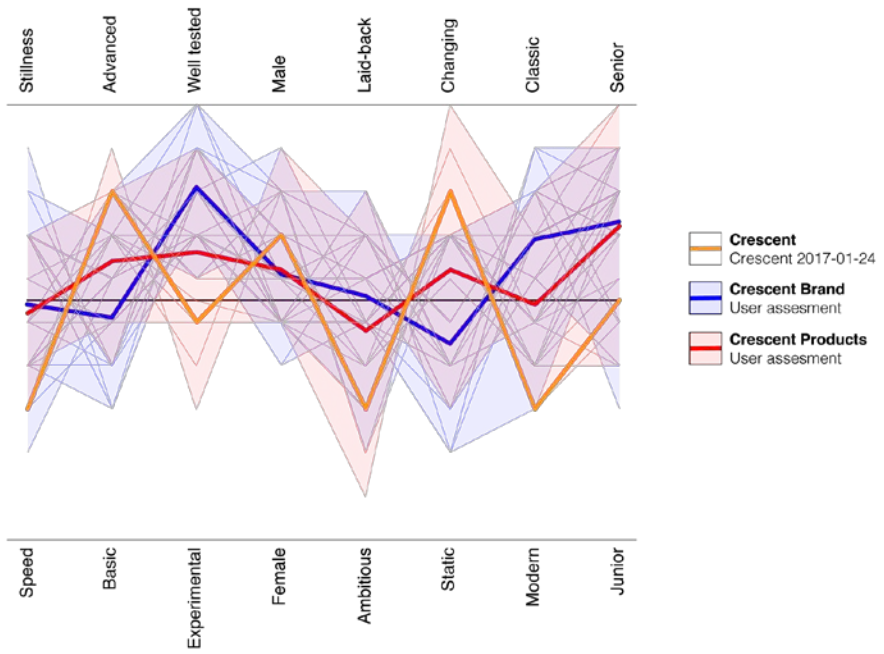


Figure 29: An overlay with the internal Crescent brand image compared to the general view of the Crescent brand and their products.

Crescent is just one of many brands within the Cycleurope family, and although most brands are used in different countries because of their regional strength Crescent still has to adapt and differentiate to the Cycleurope brands present in Sweden. Monark is one of the most important brands to take into consideration within this aspect, and it would make sense to differentiate Crescent and Monark to allow them to complement each other. This would allow for a stronger and more unified picture of the brands. Monark is also a brand with a strong heritage, mostly doing classical city-bikes. As of lately, the Monark brand has also started doing modern city bikes with a higher sensitivity towards trends and city lifestyles.

Design Format Analysis

When analysing the design format of Crescents product portfolio of bicycles, some common characteristics could be identified. Crescent have established a visual guide regarding graphical elements on the bikes, including colours, accent colours as well as logo placement (Crescent, 2015). This guide was only used as a complement to the own analysis, since it was found to be insufficient regarding form design cues, only covering graphical aspects. The most profound graphical element is the logotype, placed on the side of the down tube of all models. It is also placed in front of the head tube together with the logo emblem. Another major visual element used is the orange colour, and the

use of accent colours on specific surfaces of the bike. In terms of graphical elements Crescent also often use a checkered pattern as well as the world champion colour stripes.

Figure 30: Design format analysis of Crescent products.

When examining shapes and forms, the most profound Crescent design cue is the bend or arc on the top tube. Another form element is the almost triangular cross section of the down tube transitioning into a more square cross section by the crank shaft. Another visual form cue is the surface meeting between top tube and down tube where the forms connect through the head tube creating a flowing form. Graphical elements are sometimes used to accentuate the form elements such as the bend of the top tube or the head tube surface meetings.

3.2 Product specification

In this chapter the results from the Pre-study is summarised into the problem definition covering three areas: User, Product and Brand. Societal aspects regarding the project are also brought up. Finally a vision for how a future e-bike experience should be as well as correlate with the Crescent brand is presented along with other tools supporting the following Concept generation chapter.

3.2.1 Problem definition

The problem definition summarise and clarify the different problem areas found during the prestudy in regards to the project scope. Three focus areas were identified where actions may be taken to provide a better solution and product in the end. The first area, User, addresses the perception of e-bikes, the needs of the user and motivations for e-bike usage. The second focus area, Brand, address softer lifestyle values to attract the user

group of younger individuals where there is a big potential of customers, but also aspects regarding purchasing of Crescent products. The third and final area Product cover the more specific aspects regarding the usage phase and functionality of the product.

User

The acceptance level for e-bikes is rising, the most common users are still the people above 40 or the new family parents. Although most people could see themselves riding an e-bike today, there is still a negative perception of e-bikes that inhibits the segment. E-bikes are considered as ordinary bikes plus electric assist helping the user so they do not have to work as hard or at all, even retailers occasionally present them this way. E-bikes are not considered as a separate means of transportation. Current e-bike users seem to use their e-bikes a lot more than users riding their ordinary bicycles, and they use it for a lot more different tasks. Non-users fail to see how e-bikes often provide a better door to door transportation experience than other means of transportation. Users explain e-bike usage as effective, cheap, healthy, fun, environmentally friendly, comfortable in most weathers and as a nice experience of the city or nature. Non-users on the other hand sees it as somewhat effective and environmentally friendly, but also lazy, expensive and as something you only do if the weather allows for it. This incomprehension of the nature of e-bikes might be the explanation to why non-users are reluctant to embrace the new product category and thus more sensitive to the pricing of the e-bikes. This difference in perspectives also results in a rather bad social reception for e-bike users where they frequently are confronted and accused of cheating or being lazy with no supporting measurable arguments to defend themselves with.

Non e-bike users seem to want different things from an e-bike compared to an ordinary bike. When asked what they want in an ordinary bike, many users say they want an effective, fast and manoeuvrable bike that is good looking, enjoyable to ride, capable of riding fast with and maybe also exercise with. However, when asked what they want in an e-bike, they often say something in the style of: “Well, then I’d just like a comfortable and practical traditional women’s bike”. They don’t see it as how the assist could just amplify the experience they wanted from an ordinary bike. According to literature, the switch to e-bike usage both enhances the biking experience and the amount of exercise for the user since the assist is not taking away as much effort as new users imagine, and most users increases their total bike usage. However, most potential users perceive e-bike usage as effortless and as completely useless for exercising purposes. Another interesting factor here is that when e-bikes are ridden on a flat surface, the legal speed limit for electric assist is reached quite fast and it is very likely that users would like to ride even faster on their own effort, but few users seem to take this into consideration when thinking of e-bikes. Although most retailers and users claim that e-bikes are for everyone, most of the e-bikes visible in the streets and the stores are traditional women’s bikes. This inhibits the perception of e-bikes as something fun and healthy for everyone. Even though some e-bike segments are in a rather established phase where even late adopters are buying the bikes, e-bikes for the younger segment targeted in this project are in an earlier phase. In

this phase it is important to attract the innovators and early adopters, but as mentioned by a popular bike retailer: “As of today, there are no interesting e-bikes”.

All drivetrains today allow the users to control how much power the motor should provide, and some visualise the current motor power for the user. However, the user is not provided with any information regarding how much power they provide themselves. This leads to e-bike users not knowing that they actually put in quite a lot of effort themselves, and cannot claim the satisfying feeling of doing something healthy or exhausting. This increases the negative feeling of being assisted.

Brand

There is a scattered public opinion about Crescent and what the brand stands for. When comparing average impressions about the brand, they are rather far away from what Crescent think of themselves, often dwelling in old experiences of classic bicycles. When examining the crescent product portfolio, the opinion moves a little bit towards what Crescent think of themselves. Crescent does not communicate their core values through their products enough, and don’t have any clear inspiring purpose. Another factor coming into play here is the third party products. Crescent bikes are often showcased without the basic features like reflexes, lamps, mudguards or carriers. These are added to the bike later on either in the retailer shop or at home. These products are often rather important for the product expression and functionality of the bike and could be bought from any company, and of any quality. This results in Crescent not having control of the overall expression and experience of the bikes out in the streets, potentially hurting the brand image with bad biking experiences, low quality accessories and overall bad looking expression. A lot of potential users often explore different products online before going to a specific store to see or test them. Crescent do not provide enough inspiration on their website regarding their products for these customers. The presentations are inconsistent and most bikes are only presented by one single side view and they are not presented in context. Bicycles are often experienced from a lot of different angles, and almost the least from the side view, which makes the way Crescent present their products inefficient. It is difficult to connect to the pictures and feel presence in the pictures where the users can connect to the usage of the product in a realistic scenario.

The e-bike retailers do not give any information about the positive health and exercise effects from the e-bikes, which could have been used to help motivate the customer. Some even say things like “Do you even need an e-bike?”.

On the mature and competitive market of bicycles and e-bikes it is very important to differentiate from other brands with a clear brand story where a product can tell something about a user. However, as of today Crescent do not represent any strong specific target groups, user ambassadors nor design language. The general perception of Crescent and their products is very spread, often conflicting with the internal view held by the Crescent

employees. Selling almost every type of bicycles, their design language is rather spread and the appliance-area of a Crescent is rather unspecified.

Product

There are almost no e-bikes within the racer or fitness-urban hybrid segments. There are almost no complete integrated e-bikes with integrated drivetrain technology and components like reflexes, mud-guards, lamps and carriers. The area of new technologies are almost never integrated into the e-bikes.

The parking sequence of the e-bikes are greatly affected by the common fear of theft. Almost no e-bikes have integrated locking or digital locks, everything is handed to third-party components. This makes the parking sequence a multi step process. The user has to find a proper anchor point, lock the bike with different locks on different places using both hands and different keys. And when they ride their bikes they have to store the bulky locks somewhere.

Figure 31: Current carrying and charging solutions.

From the moment the user disconnects the battery, it is a completely useless product. It doesn't look good in itself, it is heavy, bulky and hard to carry (Figure 31). The user usually carries a lot of other things back and forth to the bike, and the battery without any decent handle requires the user to occupy one hand for the battery, and there is still a fear of dropping and breaking the battery. When walking with the battery in hand it becomes a talking point where users often have to defend their usage of e-bikes. Crescent is missing out on a opportunity to use this natural talking point to something positive. The charging solution looks and feels cheap and old fashioned, making users charge their batteries in more hidden places where they easily forget the battery. The battery also behaves unpredictable when riding the e-bike in terms of remaining capacity. Going out with a half full battery will not guarantee full electric assist in the steepest hills since it then temporarily depletes and completely turns of the assist. This can lead to users never going below 50 percent battery charge. The user have to make a choice when unmounting their bicycles if they are going to bring along their battery to charge it. This results in a sporadic behaviour, where the user has no clear routine to where they store their battery, allowing for mistakes such as forgetting the battery in the apartment and having to go back to get it.

When buying an e-bike, the user do not get the feeling of buying a complete solution that is finished, but rather a more complex combination of products. The purchasing situation is rather complex, and if only purchasing the bike it is even illegal for some cases with no bell, lights nor reflexes. Compare this to when buying a car where everything is included and integrated. The e-bikes are harder to understand than ordinary bicycles, and thus harder for the user to maintain. Bike-customers are used to modular systems that they can manage themselves, and now when e-bikes has to be handed in for maintenance, this is often thought of as cumbersome and is therefore postponed. However maintenance of

normal bicycles is often also postponed by many users. The ability for a user to maintain his or her own bicycle is sometimes a positive experience that in a way is lost when the e-bike has to be handed in for maintenance and repairs.

When riding in a city environment the e-bike user is in a rather exposed situation having to deal with cars, pedestrians, other bike users and bad road conditions simultaneously. Bikes with lower riding positions provides worse overview of the situation. Handling and maneuvering are important factors to navigate the tight spaces and bad road conditions, but also to evade potentially dangerous situations. On a traditional women's e-bike this can be rather tricky. There are a lot of quick stops when riding in the city that can be hard to handle if having a too high top tube on the bike. It can be hard to get on and of the bike in these situations. The increased speed on an e-bike requires the users to pass other bike users frequently, and the speed is not anticipated from car drivers, potentially creating dangerous situations. It is also hard to communicate to other trafficants. There is no way to alert cars without making eye-contact, the bell is not loud enough to reach into the car cabins, but still loud enough to be experienced as unpleasant and almost rude for the pedestrians. The bell is also placed in a spot where the user has to adjust their grips to reach it, making it harder to steer and brake while ringing the bell. When turning or switching lanes, the e-bike rider has to let go of the handlebar with one hand to communicate their intentions. This could be dangerous, and is therefore sometimes skipped since these turns often requires the use of both hands to turn safely. Cities often have rather inefficient bicycle routes, making it rather hard for a e-bike user to navigate. There are solutions to place a GPS on the bike, but many users use their phone instead which in many cases is rather difficult.

3.2.2 Societal aspects

This chapter present relevant societal aspects regarding the project. First the user group is defined and then the impact the project may have on society is described.

User group definition

The current customer groups for Crescent presented through their personas are men and women that are educated, financially strong and usually owners of their own houses or apartments. They often have some sort of healthy interest like sports, exercise or healthy food. Their personas are of 30-50 years of age. For this project the user group intersects with these customer groups but focuses on the younger part that also lives within 4-20 km from a major city center. These persons are aware about their surroundings and follow the societal trends and movements. Further focus will therefore be kept at health aspects but also environmental awareness for the final parts of this project

Project impact

Given that the e-bike evolution will continue, where e-bikes in greater numbers challenge other means of transportation, it might have significant impact on society in regards to ethical, environmental and health related aspects. Specifically e-bikes has a lower

environmental footprint than other comparable vehicles except normal bicycles. It emits less carbon dioxide, has negligible air and noise pollution. It is cheaper than commuting with a car and is economically comparable to public transportation. The exercise performed while riding an e-bike produces better health aspects than any other means of transportation except bicycles. However, since e-bike users tend to increase their bike usage they will often compensate for the slightly lower effort even compared to bikes.

There are a lot of e-bike variations on the market today suiting the needs of most customers. The goal in this project was to increase the general acceptance of e-bikes, increasing attraction and sales of all types of e-bikes. As the e-bike grows as a tool for transportation, everyone will benefit from it. The transportation sector will lower the total carbon footprint, the city environment will be less congested, polluted and noisy and the general health will increase, in turn lowering costs for health care. Even though e-bikes are cheaper than for example cars or motorbikes they are still rather expensive. However, as the e-bike sales rises cheaper e-bikes will also be produced, making the e-bike an accessible alternative for everyone. This will enable everyone to move around in the city, lowering the geographically based societal gaps in the city.

3.2.3 Desired concept goals

The problem definition was focused on the specific problems that needed to be addressed whilst this chapter focuses on how to address the problems. This is done by presenting a desired vision for a future product concept, as well as a coherent expression board closely connected to the vision. Finally more tangible functional aspects are presented in terms of how the bike should function in order to solve the problems explained in the problem definition.

Concept vision

The future strategic vision for Crescent e-bikes consist of and rely on four major areas, Enlighten, Self Expression, Design for Early Adopters and Functionality & Usage. The four areas are explained more thoroughly below.

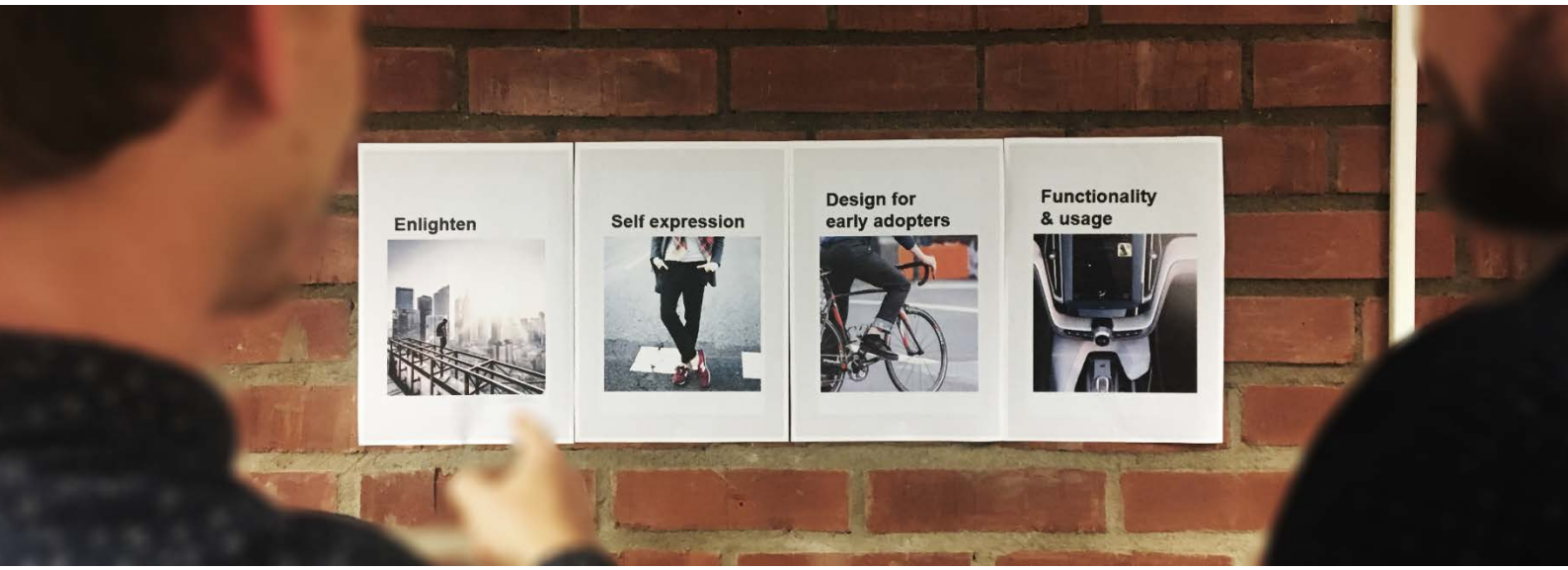


Figure 32: Concept vision areas.

Enlighten

The future concept should mediate all identified e-bike benefits, such as positive health effects, nature and city presence, environmental benefits, time efficiency, increased motivation and thus usage, more applications as well as fun aspects of riding an e-bike. It is also important to provide the tools needed for the user to feel pride in his or her achievement. This could be achieved if the bike confirms and evaluates the user's effort, empowering the users to turn the social reception of e-bike usage around to something positive. To manage to attract the desired user group it is key to consider electric assist as improved performance rather than an aid for those who cannot ride a normal bike. Imagine a fast performance bike with extra boost, instead of a traditional women's bike minus effort. This is an important aspects for the whole outcome of the project. Benefits with good performance of the bike should therefore be emphasised to encourage users think beyond the motor speed limit of 25 km/h. The goal with all of these aspects: bike expression, social reception and changed perspective to electric boost is for the acceptance level of e-bike to increase and spread. To allow for this effect to influence the view of e-bikes, it is important to ensure that the bike is identified as an e-bike and not an ordinary bicycle.

Self-Expression

On the mature e-bike market of 2017 where only minor differences separate the products offered by different brands, self-expression is important for a product to succeed. This means that the product must convey a story about the user and what kind of person it is using such a product. A story about an active and efficient urban lifestyle expressing the user's awareness about health, environment and trends. The concept should also inspire the user through expressive design and functionality, matching the user’s own lifestyle aspirations. Considering these aspects of self-expression it is possible and important to provide a clear product identity that through its design is recognisable on the streets. By using strategic design elements it should also match and strengthen the desired Crescents design profile, clarifying the connection to the brand. Customisability is a great tool to allow users to personalise their e-bikes. By offering customisability in the purchase phase Crescent will still have the control over how their bikes are experienced. The result of the personalisation should enable the bike to feel like it matches the user with the functional properties as well as their personality through the expression. This is also the way unisex is approached, where the bike should serve as a foundation from where customisability will make it a perfect fit, regardless of any gender.

Design for Early Adopters

As a product representing the next generation of urban e-bikes the result from this project is supposed to function as an ambassador for e-bikes and should therefore be designed for a specific user group with specific and high requirements in an early phase of the adoption curve. This type of users are the ones that are willing to pay a slightly higher price for their specific requirements and needs. The target user is a subgroup of the user group defined in this project, 25-35 years old, has a high education, lives in an urban environment and is of any gender. The target user should already be rather interested in

bikes and really appreciate riding faster bikes as a means of transportation. They could be the type of customer owning or considering to buy a fitness hybrid or racer to commute and exercise with, or a person relating to those individuals. This user group should strategically be targeted, making the target users into e-bike ambassadors improving the reputation of not only this e-bike, but also all types of e-bikes. When seeing this bike on the street or an ambassador riding it really fast through a city, it should evoke a feeling of how it would be to try and ride this bike. This initiates the first step in any purchase or acceptance process, planting the idea of electric boost into the mind of every potential customer. Electric boost is an example of the terminology desired to be used when talking about e-bikes, to achieve a shift in the public attitude towards the product, rather than referring to electric assist. To attract the target user and make the product beneficial for the Crescent brand the concept should also have a radical Crescent profile that alludes to the following design guidelines set by Crescent:
Attraction through Design, Function and Quality
Designed for exercise and performance
Pride through satisfied bike ambassadors

Functionality & Usage

For an ambassador product for future e-bikes it is important to provide good functionality and usability. This means to provide a complete product where the most vital functions, such as light, lock, mudguards and cargo solutions are well integrated to the bike. Part from all basic functions the concept may also include new physical or digital features allowing for a better product experience. Integration has been considered from the first project scope presented by crescent, but the word can mean many different things. In the project integration has been defined as not necessarily hidden but rather claiming its space and contributing to form by complementing the overall shapes.

A key usability aspect is the handling of the battery, which includes charging, mounting and transportation. This handling should be a positive experience and provide some extra value for the user. Other aspects the concept must address is security and safety. The concept should address the fear of theft through a more sophisticated and simple lock. To increase the safety while riding, the bike should have really good riding characteristics, a more distinguished e-bike look as well as better communicative tools. The product must attract a unisex group of people, but not necessarily through traditional frame designs but rather through provided modularity. The modularity and customizability should help the user connect stronger to their bicycle, replacing the positive aspects sometimes experienced when repairing their own bike since this is now more often handed away. The final aspect concerning functionality and usage is to simply keep the bike rolling through high quality components and proper maintenance.

Expression board

The expression board is illustrated below with both pictures and text to complement the meaning of the pictures. The pictures were to function as inspiration, both in terms of a feeling or a message they convey through more specific materials or forms.

Figure 33: The expression board i use during the ideation phase.

"Shortcuts and detours" represent exploration of the unexpected and unknown adventures in your environment. "Responsible" represent the user as a responsible and aware person, both for his/her own health as well as for the environment. "Unrestrained Presence" stands for living in the present and the total presence experienced when being outdoors enjoying physical activity. "City Pulse, Flexibility" represent how the e-bike allows the user to be fully involved in the urban pulse, but at the same time being very flexible. "Efficient" stands for quick door to door transportation with an efficient user interface and outstanding usability, beating many other means of transportation. "Performance" means a high performance quality product contributing to satisfied ambassador users. Lastly it is important to consider the Crescent heritage and maintain a Crescent profile, and that is why the expression board is complemented with the world champion colour stripes.

Function analysis

Part functions for the product were categorized into six main areas: Frame, Battery, Handlebar, Utilities, Lock and Lights. These areas are further described under each paragraph below.

Frame

First of all the new e-bike frame should have a unique expression, with design cues inherited from the Crescent brand directed to attract the user group aspirations. It should have a specific performance design, with a sporty riding position, providing superior

handling, dynamics and expression for the user. In terms of high performance the bike should be equipped with high performing components to avoid unnecessary failures. The frame should also consider good functionality in terms of usage. Lastly the frame should also provide possibilities for integrating the essential e-bike components. Given the importance of the expression of the concept, more costly materials and manufacturing techniques should be allowed if required.

Battery

The battery should provide optimized capacity and range suitable for the users needs, possibly through modularity. A modular smaller battery would be lighter, more reasonable to carry around, keep accessible in plain sight and to use as charging hub. It would also provide a more routinely charging sequence habit. When mounted on the bike, the battery should be well integrated in the bike design, but still claim the space it needs and rather contribute to the rest of the bike design harmonising with the form while simultaneously avoiding all integration-related patents. When not mounted on the bike, the battery should provide added functionality for the user, encouraging the user to bring the battery for other purposes. The carrying of the battery must also be improved as well as the design that could provide visual value for the user. Lastly the whole charging procedure should be improved and simplified, both from a functional and visual design related point of view.

Handlebar

The handlebar needs to include all vital functions for a bicycle such as gears but also an informative interface for the user displaying necessary information regarding all relevant e-bike related usage aspects while riding. It should also be possible to personalize the handlebar with digital and physical means. The handlebar should be designed in a way providing good ergonomics.

Utilities

To provide superior usability the bike concept need to target some utility aspects to facilitate the daily use of the product. The bike must provide cargo possibilities adapted for what the user needs, where at least some cargo capacity always should be available on the bike. It should also provide a modular solution that the user can easily mount to the bike if needed. The carrier solution should have the capacity to allow for the essential needs required for a day at work with an additional stop at the store or gym. It is important that these cargo solutions harmonise with the rest of the bike through specifically designed products. The bike should also always protect the user from weather related problems such as splattering water from the spinning tyres.

Lock

Due to the widespread fear of theft among users it is important to enhance the perceived security to relief the user from unnecessary stress. To achieve this the bike must provide a simple and safe solution for locking the bike when it is parked. The locking solution should be quick to simplify quick stops in the city and it must enable anchoring to a certain

position to prevent theft. The lock should break new ground in the area of bike locks which as of today is rather underdeveloped, placing Crescent in the frontier of the industry segment. Like the battery, the solution for locking the bike should be integrated with the rest of the bike design in a way where it doesn't interfere with the overall design expression.

Lights

The bike concept should have expressive and recognisable head and rear lights with integrated reflexes, always mounted and well integrated to the rest of the bike. The user should be able to control the light intensity to adapt for different light conditions. The light on the bike should also enable better communication to other trafficants.

3.3 Concept development

This chapter starts of explaining the process from the initial ideation phase to four different e-bike concepts. The evaluation of these concepts are then presented, and finally a single concept is selected and refined into a final concept.

3.3.1 Ideation

The ideation resulted in a variety of ideas concerning each functional area. The ideas were illustrated in hundreds of sketches with different levels of refinement, some of the early sketches can be seen to the left in figure 34. The explorative thumbnail frame sketches (Figure 34) clearly showed that it was possible to achieve many different expressions of a bike and also to influence the functionality of the bike. By employing different frames it is thus possible to attract different users. The randomly generated bike frames confirmed what was found out in the thumbnail sketches, and further emphasised that very small changes in the frame design can make a big difference in how the bike is perceived. This demonstrates how delicate bike design is, since the slightest change can influence the design greatly either in a positive or negative way.

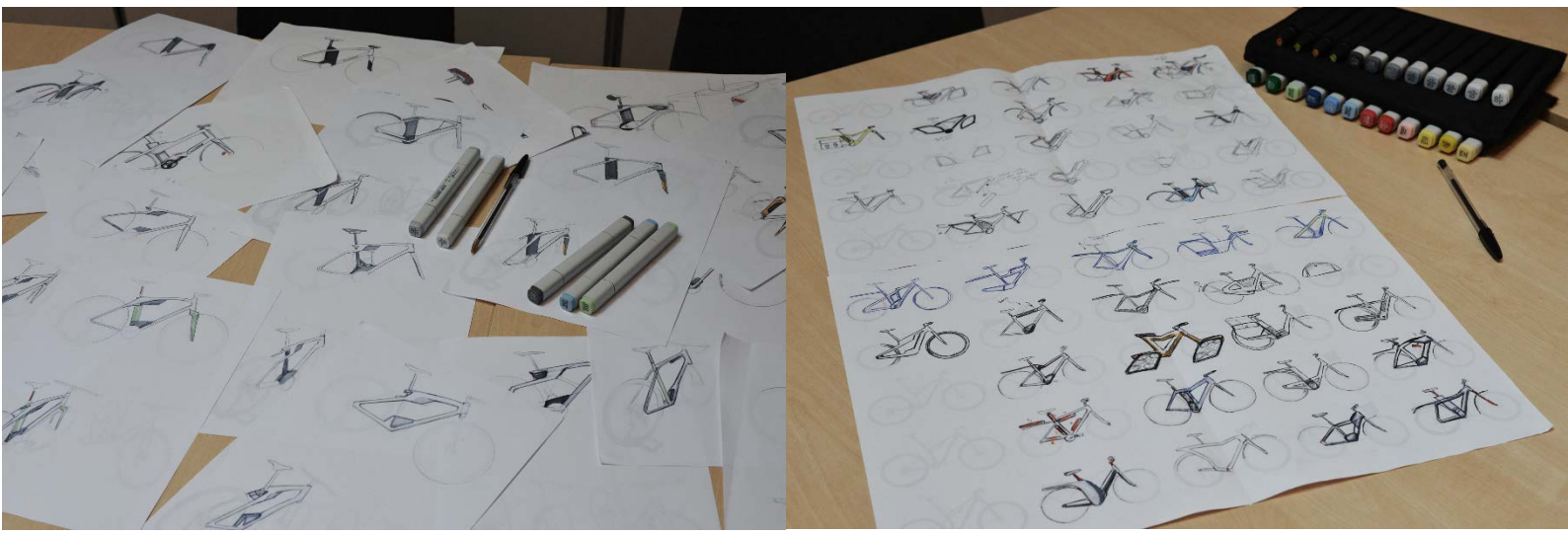


Figure 34: Early sketches to the left and thumbnail sketches to the right.

Based on the bike test in Varberg, Crescent Pico was chosen as reference bike for the future e-bike concept, figure 35.

Figure 35: Photo session of reference bike to allow for correct bike geometry in the ideation phase.

Crescent Pico is defined by Crescent as a hybrid fitness bike, with a sporty frame and a rigid front fork. It was considered to have an appropriate performance riding position matching the future vision and also good manoeuvrability in many urban riding situations. However, the riding position is not as aggressive as a full racer, it still allows for the user to have a good overview of the surrounding environment which is essential in a hectic city environment. It was also considered to have a design composition that could attract the right user group through the right expression. In the earlier phases the advantages with a front suspension on the reference bike for improved riding comfort was mentioned. However, tests proved that it did not contribute enough to the riding comfort to motivate the resulting lowered pedalling efficiency and less desired look. Adding a suspended front fork to the Pico led to a more mountainbike like expression with a more upright position. Since the new product concept should be an ambassador bike, it needs to be pushed towards performance and racing rather than comfort, in order to match the vision. Therefore the reference bike was decided to have a rigid front fork.

The four concepts that were developed based on the desired concept goals and the reference bike will be presented in E-bike Concepts below. However some solutions to the functional areas were considered to be global. Which meant that they were to be somehow implemented in all of the design, regardless of which concept that would be chosen as final. These global concepts are presented in the following chapter.

3.3.2 Global concept ideas

The global concept ideas were considered to work as design guidelines for any future e-bike concept. The ideas are therefore not fully developed and refined since they have to be adapted for the concept they will be implemented in, to contribute in the best possible way to the overall design.

Digital interface

In an increasingly digitalised environment, more and more products that were formerly considered analogue are stepping into the digital world. One example is the electrified bicycles, but the electric motor could just be the start of a new era of smart bikes. To become a frontier on the e-bike market it could be crucial to keep up with the rapid advances in technology and implement new features into the bike. This can already be seen in many e-bikes on the market, including Crescent's with digital displays showing some basic information such as speed and battery level, but it is important to explore what lies ahead and what users will expect from the product tomorrow.

The global concept idea of digital interfaces concerns two major aspects. The first aspect is basically to do what is done today, but better. This means to provide information in a clear way where the user has easy access to what is important at the time. This concerns for example to display speed, battery level, distance travelled and time. But it also concerns to make the information more accessible for the user at any time, through a Crescent e-bike smartphone app. In this app, the user can find everything relevant connected to the bike such as, current stats, historic stats, the bike's GPS position, lock status and bike status to get information about when it needs maintenance, as well as provide help to book a mechanic appointment. The app can also enable easy bike sharing with multiple users if the bike is equipped with a digital lock that can be unlocked through the phone.

The second aspect concerning digital interfaces is to provide appropriate feedback to the user. The purpose of feedback is to enlighten the user about important aspects concerning the use of the bike. The digital interface should mediate the positive benefits of riding an e-bike, such as health and environmental effects. However the most significant matter is to provide the user with the tools needed to be proud of riding an e-bike. During the prestudy a lack of knowledge regarding how much effort the user puts in was identified as a big problem, since it was a big contributor to unpleasant social reception. The new digital interface should therefore explicitly mediate how much power the user puts in, in relation to the electric motor as seen in the orange and purple bars in figure 36. The interface showcase both the present power ratio through the bars and digits, but also the history in the coloured graph to the left of the bars. This enables the user to know how they actually contribute to the total performance of the bike. An honest and positive social reception can then be achieved where no one needs to be accused of cheating. The user can feel confident in his or her performance and be proud of the effort put into the pedals.

Figure 36: Example of digital interface on a smartphone.

Battery usage

The second global concept idea concerns the battery and specifically the handling of the battery. Since the frame design were not set at this stage the design of the battery had to remain generic to enable a unified total product expression in the end. However there were some aspect concerning the battery that could be implemented regardless of how the battery would turn out form wise in the end.

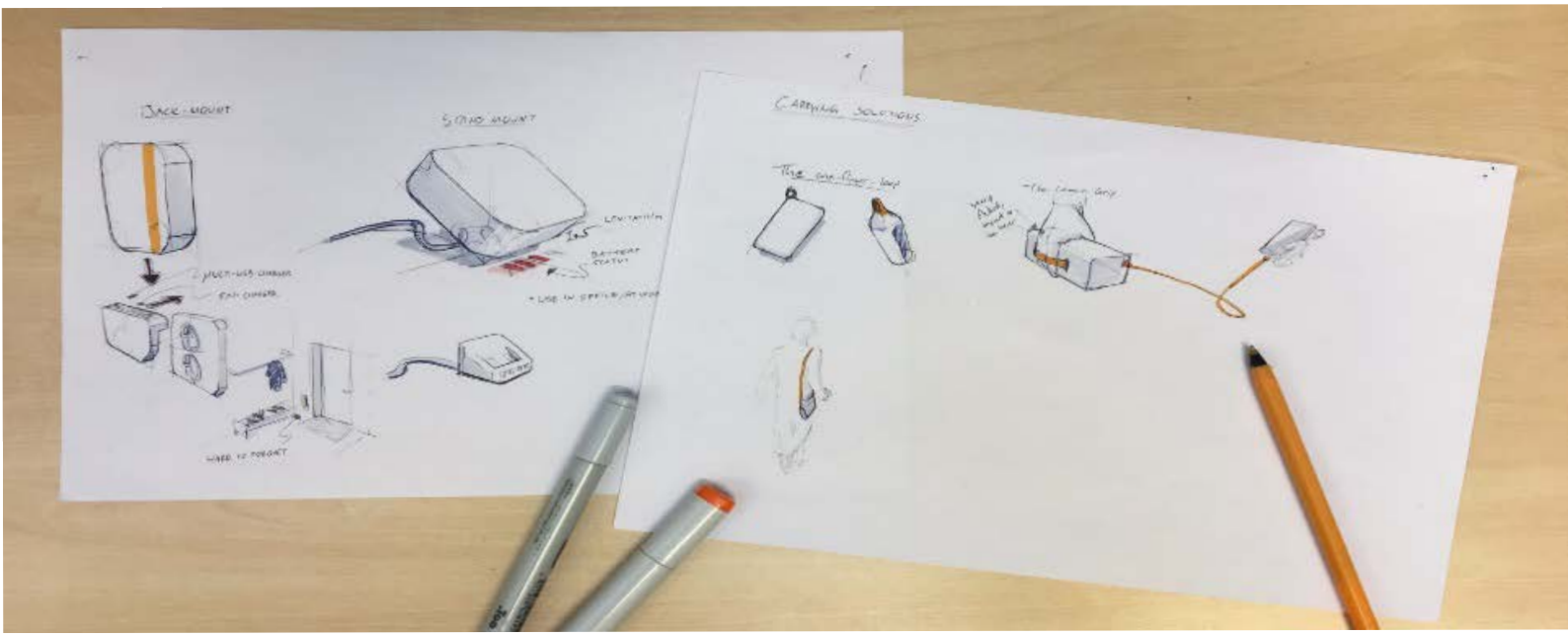


Figure 37: Illustrations of global battery concept ideas.

First of all the charging procedure is improved by offering a user friendly attractive home charging station, thus providing not only charging but also good storage for the battery when it is not on the bike. The charging station should be designed with the same guidelines following the form and expression of the chosen concept. The good design makes it suitable to be on display at all times, in contrast to the less attractive charging adapter offered by Crescent today. This way the user will always know where the battery or charger is and it contributes to a more regular charging behaviour for the user. Another aspect concerning the battery usage that has to be taken into consideration is that the user must be able to bring it. Therefore the battery solution should be equipped with a proper handle or gripping area for easy carrying, due to its significant weight.

The third global concept idea regarding battery usage concerns the functionality of the battery when it is not on the bike. Today the battery is a rather useless product to carry around, however it could be quite useful in many applications, such as a power bank for other devices such as computers, smartphones and portable speakers. This would also demand a more attractive visual product design that the user would want to bring and that could contribute to a positive social reception, even when the battery is taken of the bike.

Finally the battery solution does not have to consist of just one battery. It could also be a modular solution, allowing for a smaller battery for most trips and an add on if needed. This modular battery system could open up opportunities for Crescent to provide a take

back or alternatively a subscription service that would be not only convenient for the user, but also environmentally beneficial and thus brand strengthening. It would also become a lighter bike where these lighter and smaller modules would help facilitate a nicer, easier to bring with you solution. Even though this battery would need to be charged more often, this could actually improve the battery charging behaviour. Creating a habit of bringing the battery inside every night for charging, minimising routine based mistakes such as forgetting to charge it or forgetting it in the apartment.

Lights

The third global concept idea concerns legally required traffic lights as well as other lighting. Crescent develop bikes for Swedish conditions and lights would then be considered a necessity since it is required by law to have lights when it is dark, especially since it is dark most parts of the day during the winter. The e-bike concept will utilize this and both head and rear lights will be integrated in the design. This allows for creating a unique expression for the bike in darkness, making the bike recognisable, a lot like cars are today. A set of proper lights will also help distinguishing the bicycle as an e-bike for other trafficants, increasing road safety.

Figure 38: Example of integrated distinguishable lighting.

Customisation and personal touch

The fourth and last global concept idea considers self expression and personal touch, where the user will be in charge of the final look and performance of the bike, creating a stronger bond between user and product. The e-bike is sold complete with all essential components and features included to ensure a controlled overall expression. However the bike can be modified and adapted for individual preferences thanks to modularity, which concerns handles, seat, visual accent colours, customisable interface and additional cargo

solutions. A range of seats and handles can be chosen based on user preferences regarding comfort and performance as well as to facilitate an ergonomic adaptation. This will be done in the store together with a well-educated sales person to ensure the right choice. These visual elements as well as functional components will make sure that the bike is personalised to the user. It does not matter if the user is male or female, the bike will express the personality desired from the user, and be physically adapted to the needs and properties of the user. After deciding on handles and seat the user can add cargo solutions for the bike that are specifically design for the e-bike design to ensure a unified total product expression. These cargo applications may also be bought and supplemented afterwards.

Drivetrain behaviour

The ultimate goal for how the drivetrain should behave in usage is to achieve symbiosis between the user and the drivetrain to create a feeling of augmented strength. This will increase the control for the user over the bike, helping in tighter manoeuvring situations and also increase the riding experience of riding the bike. This will minimise the unnecessary and rather unmotivated feeling that the user is being pulled around by an electrical motor since this mostly is not the case. By using an interface displaying comprehensive honest data about user and motor input, the goal is to create an even more honest experience of riding an e-bike. This drivetrain should be designed with a minimal input-lag between the user and motor input, and never put in its maximum power momentaneously, but rather ramp it up.

3.3.3 E-bike concepts

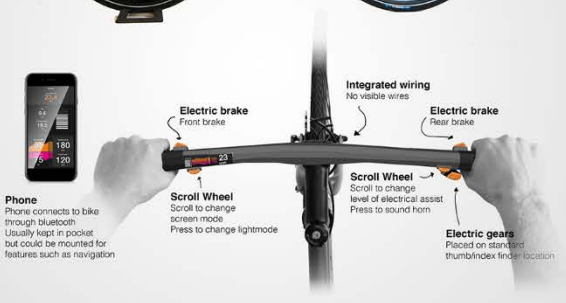
The four different product concepts that were developed based on combinations of the part functions are illustrated in the figure to the right. The concepts were named Crescent Flow, Toro, Air and Pro and are further explained in detail in the following chapter. Each concept consist of different part solutions that were combined together based on how well they would contribute to a unified product. However these part solutions can be replaced with a solution from another concept. For example there were three different handlebar concepts presented with the concepts applied for the design considered most suitable, however they are all applicable to all frame designs in the Concept refinement phase.

CRESCENT TORO

CRESCENT PRO

CRESCENT FLOW

CRESCENT AIR



CRESCENT FLOW

Crescent Flow

The first of the four e-bike concepts was named “Crescent Flow”, referred to in the text as just Flow. The frame design of Flow has a clean and dynamic form and the relatively horizontal and high top tube gives it a sporty performance look. The most distinguishing design element of the Flow is the shape of the seatstays that were designed to resemble the hind legs of a quick and fast animal. It also provides a natural and innovative battery position that is easy to reach and the shape of the battery and seat stays create a unique expression. The battery pack is 40% smaller than what Crescent use today and is packed with 30 battery cells instead of 50. The smaller and thus lighter battery will be easier to handle and it can contribute to a more regular charging pattern where the user charge the battery every day. The high position of the battery makes it easy to reach and is inserted backwards between the seat stays underneath the top tube. In addition to the 30 cell standard battery the user may also buy an extra 20 cell battery pack that is mounted in front of the other battery under the top tube for extra battery capacity. The motor is mounted in the center and the motor housing matches the design of the bike.

The handlebar of the Flow provide a simplistic interface where two LED light bars indicate battery status and motor assist level. This sleek look is suitable for most situations, but if the user wants more information available there is also a smartphone quick mount on the stem. This enables the user to utilize all the functionalities in the smartphone interface explained under global concept ideas. The Flow is equipped with a hydraulic brake system for adequate performance and hydraulic brake levers are therefore mounted on the handlebar. The gears are electric and controlled on the right hand brake lever, similar to how gears are controlled on most race bikes. The performance level of the motor is controlled the same way but on the left hand brake lever. Thumb buttons on the handlebar control flashers mounted on the bar ends of the handlebar. Additionally the thumbs are used for controlling light and bell, by pushing two other buttons on the handlebar.

In terms of cargo solutions, the Flow is equipped with an always on waterproof expandable saddle pack. The pack can either be used for small storage when folded in under the saddle or for more cargo if folded out. The user can also add a detachable cargo box mounted on the right seat stay. The design of the cargo box follows the design of the rest of the bike making it blend in.

Flow offers a fully integrated digital lock solution, on both wheels as well as the motor. The locking mechanism consists of two mechanic locks in the front and rear wheel. The rear lock is positioned behind the motor and the front wheel lock is positioned by the front fork. The motor is also locked either mechanically or digitally. Utilising gps and accelerometers, the bike will alarm and alert nearby people as well as signal the user if the bike is moved or tinkered with. Similar to how some locks encapsulates a smelly gas that leak if the lock is breached, the bike will trigger a smell alarm if the bike is moved enough. This will intimidate the thief and make the theft attempt very uncomfortable. With the possibilities granted by electronic locks, the bike will use near bike sensors to auto-unlock the bike when the remote key is nearby, similarly to how cars work today. The bike will light up and welcome the user when they approach. The bike may also be unlocked using the app, which in turn enables sharing of the e-bike with multiple users.

CRESCENT TORO

Bell
Integrated on brake

Ambient lighting
Customiseable

Performace switch
Changes behaviour of electric assist

Light Switch
Manages lighting and blinkes

Electric gears
Placed on standard thumb/index finder location

Display
Shows all relevant information
Bluetooth connectivity to phones allows for exteded functionality such as navigation.
Mirrors the phone display.

Crescent Toro

The second e-bike concept was named “Crescent Toro” and is referred to as Toro. The Toro has a high top tube with a sharp Crescent bend towards the front, contributing to a force forward and a strong, sporty and almost aggressive expression. Toro has unique lowered seat stays that creates a volume together with the battery and motor. The battery is mounted on top of the motor completing the lower form. It is a 40 cell battery pack which makes it slightly smaller, lighter and easier to handle compared to today's solutions. The low position of the battery lowers the total center of gravity of the bike but it is still easy to reach.

The handlebar for the Toro provide a screen based interface illustrating all interesting and relevant aspects for the user. A smartphone can also be mirrored to the display through bluetooth to enable for example Google maps for navigation. The handlebar has hydraulic brake levers and electric gears controlled with right hand index finger and thumb, which is the standard position today for most gears. The performance level of the motor is controlled the same way but on the left hand side. Light and flashers are controlled with left thumb using a standard “moped switch”. The bell is integrated on the left brake lever mount to be easy to reach without changing the grip.
Concept Toro has two different cargo solutions. The first one is a rack mounted on the seat tube hovering above the rear wheel. The second cargo solution for the Toro is an expandable 3-stage roll up bag. When not used it is rolled up underneath the handlebar and when the user wants to carry something on the bike the bag can be rolled out to either fit smaller objects such as a laptop. A zipper can also be unlocked to enable carrying of larger objects such as a gym bag.

Toro has a rear electric digital ring lock, GPS and accelerometer anchoring as well as alarm. To lock the front wheel there is a cable lock that can be pulled out underneath the top tube, which may also be used to lock the bike physically. All locks are unlocked either through the app or by using a remote digital key. The bike can also unlock itself if the user approaches within a certain distance of the bike.

CRESCENT AIR

Phone
Phone connects to bike
through bluetooth
Usually kept in pocket
but could be mounted for
features such as navigation

Electric brake
Front brake

Integrated wiring
No visible wires

Electric brake
Rear brake

Scroll Wheel
Scroll to change
screen mode
Press to change lightmode

Scroll Wheel
Scroll to change
level of electrical assist
Press to sound horn

Electric gears
Placed on standard
thumb/index finder location

Crescent Air

Crescent Air is the name of the third product concept and is referred to as Air. The frame of Air has a profound design element with a lengthwise elongated aerodynamic seat tube between seat and motor. This provides a natural, easy to reach battery position within the seat tube volume, where a relatively thin battery can be inserted from the front. The battery is a 50 cell battery pack providing the same properties as Crescent E-going does today. The centered position contributes to a natural center of gravity of the entire bike. The frame has a high top tube stretching with a slight curvature through the seat stays connecting the form. This gives a fast and sporty expression. The top tube is also equipped with the characteristic Crescent bend towards the front, to connect with the brand.

The Air handlebar has a moderate design providing a sleek and clean expression with almost everything integrated and no visible wires. A screen based interface is flush mounted on the left side of the handlebar, showcasing different information based on user preferences, such as speed, own effort and time. The left thumb is used to navigate the display by scrolling a wheel and thus changing screen mode. The scroll wheel can also be pressed to change light mode. A smartphone can be connected to the bike through bluetooth and provide simultaneous feedback as well as statistics, however the phone is mostly kept in the pocket of the user. The handlebar has electric brakes controlled by the left and right index finger, which eliminates the need for any brake levers. Electric gears are controlled by right thumb and index finger, using standard positioned gear levers as most gears today. To adjust the level of electric assist from the motor, a wheel is scrolled on the right hand side of the handlebar using the right thumb. To sound the horn, the right scroll wheel is pressed.

In terms of cargo solutions, Air has a modular system with a standard mount integrated in the rear mudguard. This allows for different modules to be easily mounted on the bike based on what the user needs for each time. The users can then buy the accessories they consider most suitable for their situation, such as a basket, different waterproof bags or just a carrier platform.

When parked, the Air concept is locked using a simple folding lock that can be used to anchor the bike to a rigid object. The lock is stored in an integrated storage compartment in the rear top of the seat tube, simplifying the handling and does not interfere with the visual expression of the bike.

CRESCENT PRO

Bell
Integrated on brake

Ambient lighting
Customiseable

Performace switch
Changes behaviour of electric assist

Light Switch
Manages lighting and blinkes

Electric gears
Placed on standard thumb/index finder location

Display
Shows all relevant information
Bluetooth connectivity to phones allows for exteded functionality such as navigation.
Mirrors the phone display.

Crescent Pro

The fourth concept, named Crescent Pro and referred to as Pro is a futuristic bike concept. Visually consisting out of two split up shifted pentagons with sharp lines and shapes, the frame creates a new and high tech expression. The high, straight, top tube creates a rather fast and aggressive look. Designed with a seat tube shifted forward it allows for a space with enough volume to fit the battery, motor and also additional storage. Positioned in the front of the storage volume, the 50 cell battery pack provides the same properties as the Crescent E-going bikes today with potential for even more. Its position both enables a low and centered center of gravity as well as a comfortable mounting position. Shaped with the same expression as the rest of the bike, the motor is mounted in the bottom and partly below the storage area.

The Pro uses the same handlebar described in the Toro concept with a large phone compatible centered screen, hydraulic brakes, electronic gears and performance switched on standard lever positions.

For cargo solutions the Pro offers a rear rack with shapes contributing to the overall shape of the bike, mounted on the seat stays. It also provides a smaller cargo box in the center body of the bike. As for locks, this bike comes with the same fully integrated digital lock solution as concept Flow, that is unlocked through the app or by using a digital key. The bike is anchored digitally with a GPS position as well as an accelerometer that can sense movement. If the e-bike is moved it will trigger a sound and smell alarm as well as send a notification to the user that the bike might have been moved.

3.3.4 Concept evaluation

In the following section the results from the complete evaluation process will be summarised for each concept. Main focus has been kept on the overall frame design, however other functional areas have been commented but not rated. The percentage presented under rating is based on how each evaluation participant ranked the concepts towards each other. At the end of each concept a verdict will determine the final score of each concept that will be used in the final evaluation matrix.

CRESCENT FLOW EVALUATION

Rating Crescent	Rating user group
1st: **50 %**	1st: **67%**
2nd: **30%**	2nd: **27%**
3rd: **20 %**	3rd: **0%**
4th: **0 %**	4th: **6%**

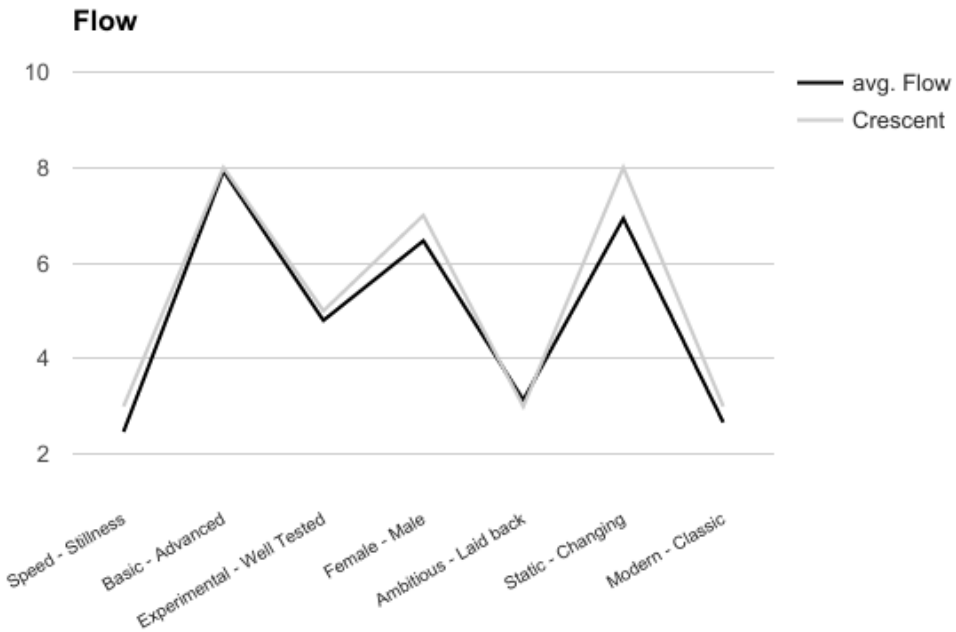


Figure 39: Semantic evaluation of Crescent Flow compared to internal view of the Crescent brand.

Feedback Crescent

The only concerns regarding this bike was represented in the R&D department, where concerns were brought up about the unrealistically small motor and battery, and the hanging battery was considered as an unnecessary challenge requiring the battery mount to deal with gravity. Another argument was that the battery and the seatstays created an unnecessary width in a critical spot where the legs might touch, bump into or grind against the frame. However, after testing the dimensions with a mockup with correct measurements on a bike this argument was ruled invalid (Appendix V). Beyond this all

comments were positive. The integration of the battery was described as good looking, being partly covered and nicely integrated to the shapes of the frame. The overall impression of the bike was described as light, fast, nimble, clean, simple, cool and good looking.

Feedback User group

"Spontaneously, I like Flow the most!" and "The Flow directly caught the attention of my eyes" was two spontaneous reactions from the evaluation. The concept was generally liked by most users. It was described as light, stripped down, unified and really good looking from a lot of people. The lines in the frame was liked and described as having a nice flow, being balanced, fast, nice, symmetric, interesting, directional, premium and a few user compared its expression to cars. It was described as forward thinking, but still similar to how bikes look today. Some saw the bike as a racing bike for competitions and exercise. The integration of the battery was described as really good looking, not only complementing the bike but also creating a really good looking overall expression. The battery placement also felt like it would be convenient in mounting/unmounting situations. The separation of the battery and the motor made the bike feel more advanced and also balanced. The accent colours on the battery, the motor and the front fork created an interesting expression while simultaneously creating a balanced feel of the bike. The high center of gravity created by the battery position was experienced as something giving more speed and balance, and it also made the bike look a lot lighter and faster. However, one user wondered whether the high center of gravity actually might impair the riding characteristics of the bike. The complementing bag on the seatpost was mentioned as something giving the bike an even cooler and faster expression. When analysing the results from the semantic evaluation, this concept truly hits the desired expression of a next generation Crescent bike. Compared to their current products, and the other concepts, the Flow show an unrepresented accuracy in its semantic expression. For some users, this concept was experienced as rather female or unisex, however, some considered the sporty frame as a male attribute.

CRESCENT FLOW VERDICT

Semantic evaluation:	**5 – On point**
Rating:	**5 – Best at Crescent, Superior at user group**
Manufacturing:	**3 – Rather easy, a bit more expensive than current solution**
Functionality:	**4 – Good handling and battery management, unintuitive design**
Unisex:	**3 – Considered rather unisex**

CRESCENT TORO EVALUATION

Rating Crescent	Rating user group
1st: **45 %**	1st: **27%**
2nd: **27%**	2nd: **33%**
3rd: **0 %**	3rd: **13%**
4th: **28 %**	4th: **27%**

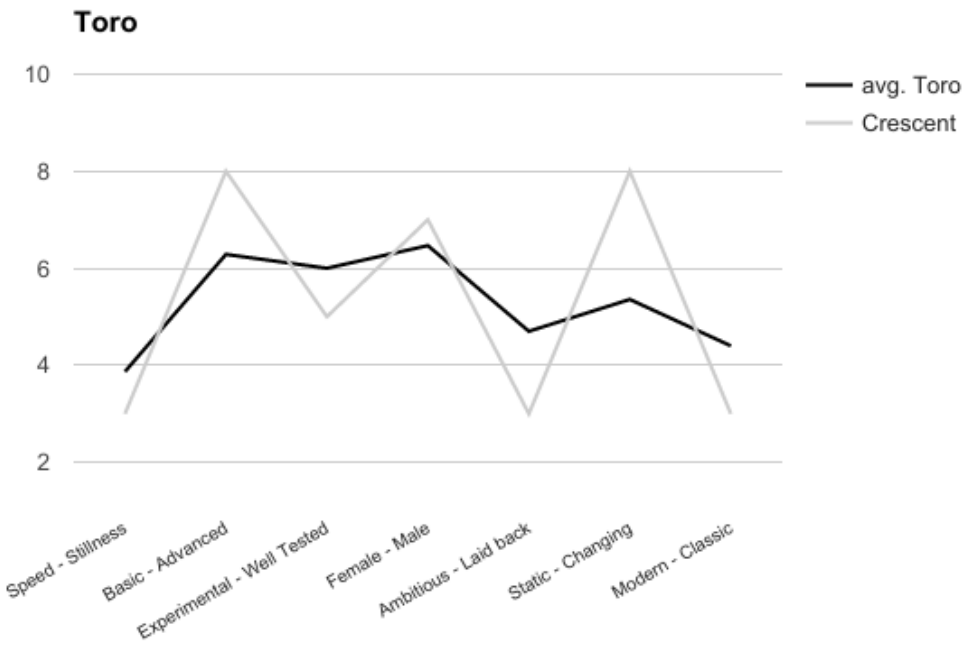


Figure 40: Semantic evaluation of Crescent Toro compared to internal view of the Crescent brand.

Feedback Crescent

For some the frame felt weird, mentioning how the angles were weird and how it felt like something was missing. However, for most users it was experienced as fast and cool, with nice arcs and bends giving it a sporty and aggressive look. It was also described as light and clean. For some the lower part of the bike reminded of a standard double diamond bike frame which was good. For the R&D department at Crescent, this was their favourite. They saw it as good looking and interesting and being rather easy to manufacture, their only concern was whether the battery and motor would fit in the small lower package.

Feedback User Group

One user mentioned how the low seat-stays makes it harder to use rear rack bags. The lower part of the frame was experienced as rather heavy, the low dark area placed rather far back gave the expression of heaviness. Some claimed that the dark colour amplified the heavy impression. For some users the heavy lower part only made the bike look full of energy, giving the bike a solid boost and thus high speed. The placement of the battery and the motor was popular, the battery was described as not as apparent and rather conveniently placed. The integration of the battery and motor towards the lower frame

was liked. The material meeting between the back end and the front end frame of the bike was compared to car interior design as something nice. The bike felt feasible and easy to manufacture. The lowered seat stay elicited a city vibe for some, and mountain bike for others, and the whole bike did get some comments on feeling like a bike for the city. The bend on the top tube gave the bike frame a lot more flow, giving the impression of a bike that was strong and wanted to move forward. With the top tube bending, the users also felt that it provided the feel of a high top tube while still allowing for a slightly lowered top tube that the user could reach above while standing still. The bike gave a strong and robust impression while still implying that it could be ridden fast. The carrier add on was commented as something cool complementing the overall shape of the bike. The sporty frame was sometimes referred to as rather male and sometimes as hard to define.

CRESCENT TORO VERDICT

Semantic evaluation:	**3 – Slightly better than present Crescent products**
Rating:	**3 – Almost best at Crescent, 2nd for user group**
Manufacturing:	**4 – Not optimal weight/strength ratio, easy to manufacture**
Functionality:	**4 – Good handling and battery management, unintuitive design**
Unisex:	**3 – Considered rather unisex**

CRESCENT AIR EVALUATION

Rating Crescent	Rating user group
1st: **11 %**	1st: **7%**
2nd: **34%**	2nd: **33%**
3rd: **22 %**	3rd: **40%**
4th: **33 %**	4th: **20%**

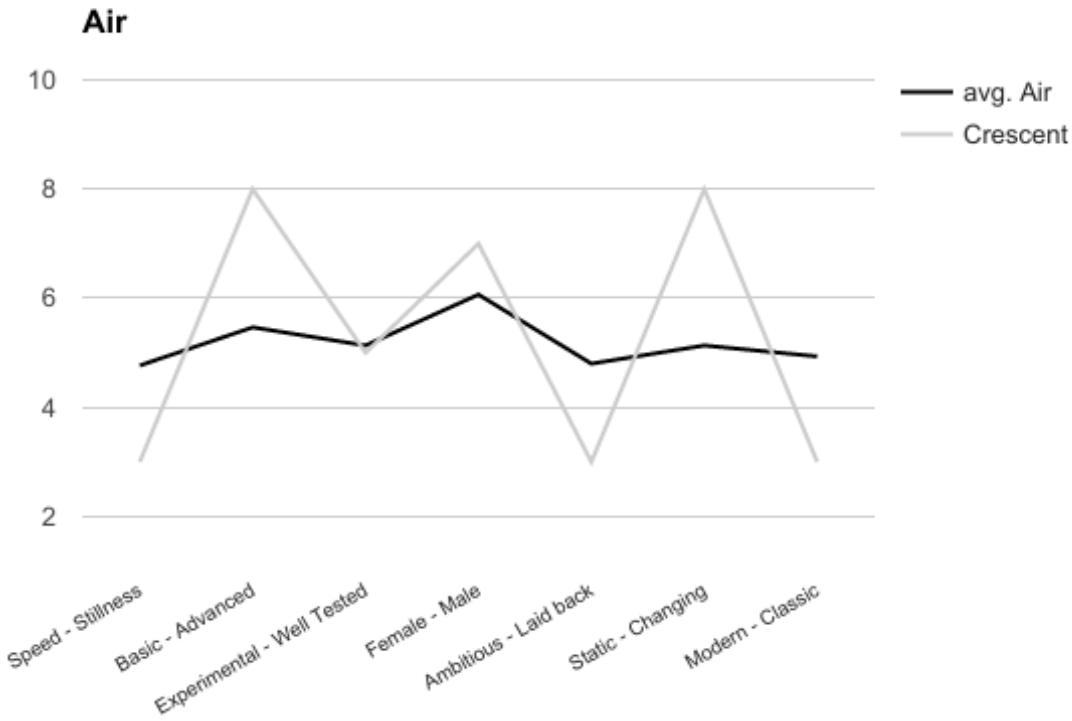


Figure 41: Semantic evaluation of Crescent Air compared to internal view of the Crescent brand.

Feedback Crescent

The larger alternative to a seat tube was early mentioned as bulky, and for the R&D at Crescent the meeting between the seat post and the seat tube was considered repulsive. The concept was also described as standard and boring, reminding of currently used solutions. The frame itself was considered to look fast with specific comments regarding the speed expressed by the distinct Crescent bend on the top tube.

Feedback User Group

This bike was considered rather standard and classic. There were no interesting things to look at, and a lot of associations were drawn to present e-bikes on the market. For some, this was positive but for the most users it was considered dull. The flatter battery pack unit expanding in the vertical and longitudinal directions was considered rather big and bulky, and some described it as looking like something that already exists on the market.

The frame was also described as good looking, sporty and fast. The lines in the frame was experienced as well balanced with a clear direction and a fast flow. The bulkier front fork hinted about how this bike was built to be ridden at great speeds. This bike was considered rather unisex or female, referring to the sleek lines, but also the slower boxy shapes.

CRESCENT AIR VERDICT

Semantic evaluation:	**2 – Similar to old Crescent products, better and worse**
Rating:	**2 – Ok at both Crescent and user group**
Manufacturing:	**3 – Rather conventional, additional costs for polymer tools**
Functionality:	**4 – Similar to ordinary bike, slim bike, slim battery for storage**
Unisex:	**4 – Considered the most unisex of all concepts**

CRESCENT PRO EVALUATION

Rating Crescent	Rating user group
1st: **11 %**	1st: **0%**
2nd: **0 %**	2nd: **7%**
3rd: **11 %**	3rd: **47%**
4th: **78 %**	4th: **46%**

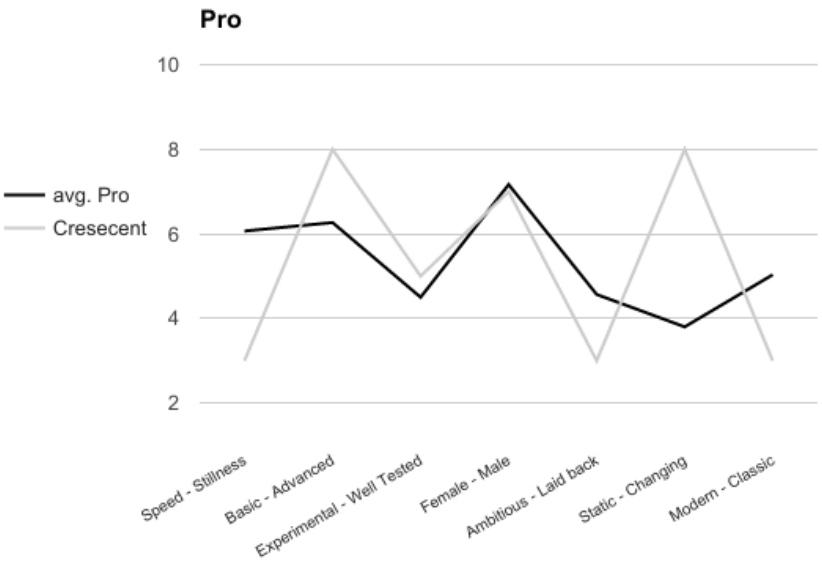


Figure 42: Semantic evaluation of Crescent Pro compared to internal view of the Crescent brand.

Feedback Crescent

The pro model was considered to be large and bulky. The volume for the battery and cargo box was experienced as really large and heavy. Most participants described the frame as complex, resulting in both negative and positive experiences. For some there was too much weird stuff going on, and it was considered to be way to complex and expensive to manufacture. The frame evoked incongruent feelings with people both liking and disliking it at the same time. However, the frame was also described as interesting, special, cool and novel.

Feedback User group

"I don't like that at all" was the answer from the first participant. The frame was described as messy with too many abrupted angles. The potential user group for Pro was described as the old man with bluetooth headset and utility pants. It was experienced as boxy and uncomfortable, really heavy, and slow in spite of the electric assist. Futuristic was a common adjective used both in a positive and a discouraging way. However, a few users also experienced the bike as aggressive, city and really good looking. Most users considered this bike as male, however for some, the boxy slower shape made it look rather female.

CRESCENT PRO VERDICT

Semantic evaluation:	**2 – Part good, part worse**
Rating:	**1 – Low at both Crescent and user group**
Manufacturing:	**1 – Complex and expensive**
Functionality:	**4 – Large design space for components and storage**
Unisex:	**1 – Considered as rather male by most interviewees**

Concept choice

To guide in the decision process the concepts were evaluated in an evaluation matrix (Figure 43) where the verdicts from each concept was combined with a weight representing the importance of each evaluation criteria, based on the project scope. Considering the branding related goals of the project and the goal of achieving an admirable ambassador bike, both the *Semantic Evaluation* and *Rating* was distributed full impact on the weight scale. *Functionality* and *Unisex* were both given 80 percent weight given their relevant but yet subordinate importance. Given that the goal of this project was to create an optimal e-bike concept to strive towards and achieve maximum potential for an urban e-bike, the *Manufacturability* was given the lowest impact of 60 percent.

The evaluation matrix indicated the most promise from the Flow concept, with excelling results in the Semantic Evaluation and Rating and rather high scores in all other areas. The concepts and the results from the evaluation was presented and discussed with the project stakeholders from both Chalmers and Crescent. Since the Flow both won the evaluation matrix and excelled at the most important branding related aspects in this project, Semantic Expression and Rating, it was chosen as the concept to develop further. However, other functional areas such as the handlebar had to be further examined and developed based on the input from the evaluations.

	Weight	Pro		Toro		Flow		Air		OPTIMAL SOLUTION
Semantic Evaluation	**1**	Part good, part worse	**2**	Better than original, low amplitude	**3**	Very good	**5**	Similar to old, sometimes better sometimes worse, dull	**2**	5
Rating	**1**	Low both Crescent and User group	**1**	Almost best at Crescent, 2nd at User group	**3**	Best at Crescent and Superior at User group	**5**	Ok at both places	**2**	5
Manufacturing	**0.6**	Complex and expensive	**1**	Not optimal weight/strength, but easy to manufacture	**4**	Rather easy to manufacture, a bit more expensive than original	**3**	Rather easy, requires extra plastic tools	**3**	5
Functionality	**0.8**	Good extra storage	**4**	Good stability, easy battery management, hard to add carrier	**4**	Good handling, really good battery management, unnecessary risk of grinding against seatstays	**4**	Similar to ordinary bike, slim, slim battery for storage	**4**	5
Unisex	**0.8**		**1**		**3**		**3**		**4**	5
Crescent feedback	**0**		**1**		**4**		**3**		**2**	5
		Sum Pro	**7.6**	Sum Toro	**14**	Sum Flow	**17.4**	Sum Air	**12.2**	**21**

Figure 43: Evaluation matrix.

Additional feedback

This chapter describes aspects and feedback brought up during the evaluation that were not directly influencing the results but rather considered as extra input.

Unisex

There was a lot of different conceptions of whether the bikes were male, female or unisex. To start of, the results from the female part of the evaluators will be presented. A few women saw all of the concepts as male bikes, and claimed that it would be hard to mount and unmount the bike in dresses or tight jeans. However, they also mentioned how this perspective was an old way of seeing it, based on old and mostly outdated requirements. Most of the evaluators did not base their perspective from the height of the top tube but

more from the general expression of the bikes. A few female evaluators saw the bikes as a little bit more male, referring to the boxiness or sporty look as male properties. Most users saw the Air and Flow as a bit more female or unisex, referring to the light, streamlined shapes and the lighter colours. The heavier and boxier concepts like the Pro, and sometimes the Toro, were considered a bit more male. The women evaluators often mentioned how women often like to pack more stuff on the bike while men would often keep their stuff in their pockets or in a backpack. A few of the evaluators would already ride a bike with a high top tube today, for them all of the concepts felt rather unisex. The female evaluators from Crescent mentioned how the height of the top tube would not define the bike as male or female. When asked if they thought that a lowered top tube would make the concepts more attractive for females, a lot of the evaluators said that it would not make it more unisex, but rather destroy the overall expression of the bikes. The quote from the evaluation regarding the view of male and female in the bike industry kind of says it all: “It is time to become a bit more modern”.

When asking the male evaluators the lightness, both in shapes and colours, were mentioned as female. However, the expressed male properties such as dark, boxy and bulky were all mentioned as rather negative properties, for them the sleeker bikes like the Flow and the Toro were both considered more unisex but also more beautiful. A few of the males saw all concepts as male because of the sharp lines and foremost the high top tube, however they thought that a younger generation of women might not care about the old way of dividing male and female bikes. At Crescent, most of the male employees believed that a lower top tube would be required to attract women. For them, the most important factor of the low instep would not be the functional properties, but rather the expression of being unisex or female. However as mentioned, this perception was not shared with any women at Crescent, and only a few of the target user evaluators.

Handlebars

Although this evaluation mainly targeted the general expression of the bikes, some opinions regarding the handlebars were mentioned. Some thought that they would not use their phone except for when out exercising, they would rather have it in their pockets. The perspective of having a clean handlebar with a screen showing the essentials, with the capability to use a phone to gain access to more information was generally liked. The large screen felt a bit too much, and people used to regular bikes were a bit confused to what kind of information a user would need from a bike. According to Crescent, the integrated screens could be a problem when considering the strength and durability of the handlebar. It would be easier to have an external screen mounted to the handlebar. Regarding phone integration, concerns were mentioned about how it is hard to allow for phone compatibility with new types of phones being released every month. Crescent also mentioned how these solutions would be compatible with racing or bullhorn handlebars, and suggested that the bike maybe should have a bullhorn or racing handlebar to amplify the speedy expression.

3.3.5 Concept refinement

This chapter explains the process where the chosen concept from the evaluation as well as the global concepts was refined into a unified final concept. The battery was modeled in full scale using styrofoam and clay to investigate the visual expression of the battery as well as the spatial requirements of the handle (Figure 44).

Figure 44: Mockup model and 3D print of handlebar ends.

The battery was also modelled in CAD to allow for proper measurements in the final CAD model. With a well defined shape of the final battery, a charging solution was designed to match the properties and expression of the battery through sketches and renderings. The frame was then rendered in a higher level of detailing using Photoshop. This was done to decide the flow of the surfaces over the shape, as well as increase the level of detail of additional design features. It was concluded that the Crescent Flow would require complex surfaces flowing over multiple parts of the bike. This design would require the frame to be built out of either carbon fibre or sufficiently post processed aluminum. Since the bike is to serve as an ambassador bike with a performance expression, these rather expensive manufacturing techniques were motivated to ensure an effective result. Based on lower manufacturing and material costs, as well as a lower environmental impact, aluminum was chosen as the material to be used for the frame. The bike was then modeled in a 3D CAD program to define the final shape. With both users and Crescent suggesting alternative handlebars on the concept, a few test rides with as well as visualisations of racer and bullhorn handlebars were performed. Since the bullhorn allowed for a really high performance functionality and expression further amplifying the goals of Crescent Flow, and since the drop down bars differentiating the racer from the bullhorn were observed as rarely used, it was decided that the final concept should have a bullhorn handlebar. A clay model of the proposed bullhorn handlebar was modeled in clay to allow for tests regarding ergonomy as well as button placements.

4. FINAL PRODUCT CONCEPT

Crescent Flow

This chapter presents and describe the final concept, and relate the final result to the desired concept goals set in the product specification.

4.1 Concept description

In this chapter the concept is established and defined in subchapters corresponding to the functional areas presented in Desired concept goals.

4.1.1 Frame

The aluminium frame of the Crescent Flow is the most important part of the bicycle, merging all key components together in a smooth way while simultaneously providing a functional performance as well as a striking visual expression (Figure 48). The riding position allows for a balanced ride targeting a sweet spot combining a good overview of the surroundings for the user with high performance. The frame positions the center of gravity of the rider in a centered and rather low position allowing for great handling as well as low wind resistance. The stiffness of the bike enabled by the high top tube and the stiff front fork ensures that all of the power generated by the user and the motor transfers directly into the ground with minimal loss to generate as much speed as possible.

Figure 48: The Crescent Flow e-bike.

Figure 49: Renderings describing form details and of

The bike is designed with key design formats from the Crescent brand as well as shapes harmonising with the e-bike drivetrain. Formwise implemented design cues inspired by Crescent were first of all the arc of the top tube, but also transitioning cross sections and the surface meeting between top and down tube creating a nice flow through the head tube. The expression and general theme of the shapes is clean and similar to the vehicle design shown in the expression board, based on complex but well defined surfaces with a well defined flow and crisp lines. The bicycle has a two coloured theme with darker seat tube, battery and motor framed in by a brightly coloured frame. The frame and the drivetrain components reflect each other's shapes to create a bicycle where all components consociate to a unified expression. The chainstays are designed in a shape referencing the hind legs of a sprinting animal, partly covering the battery and harmonising with its shape. The lighter colour highlights the revolving shape of the frame, creating a circular flow through the bike metaphorically mimicking the nature of cycling. The graphics of the bike are kept clean consisting out of a few complementing dark areas enhancing the forms. A theme with hexagonal shapes can also be found throughout the bike, both in terms of graphics and form (Figure 49). In addition to the lighter and darker colored areas the frame has an accent colour for the user to specify to suit their preferred expression. A Crescent logotype is placed on the down tube and the Crescent logo emblem is placed on the head tube according to the design format analysis (Figure 49). The frame is equipped with overall high quality components such as hydraulic brakes, electronic gears and racer tyres and rims. In terms of seat the user can choose from a range of seats, selected by Crescent, to find the most suitable for their body and desired riding position.

4.1.2 Battery

Figure 50: Exploded view of battery, showcasing battery cells, detachable handle and charging dock.

The battery is a 30 cell (36V, 6.6Ah) power pack optimized to provide capacity and range adapted for the user's needs (Figure 50). The smaller battery capacity contributes to a more regular routinely charging habit where the user charge the battery after each use, comparable to a smartphone. The battery was also designed to facilitate handling where the smaller cell stack, smaller size and proper handle simplifies the battery management for the user. The battery is equipped with a USB port in the bottom of one side making the battery possible to be used as a powerful power bank for other products. This function together with a clean and simplistic design were consciously implemented in order to create added value for the user and encourage the user to bring the battery along (Figure 51). The hexagon cross section of the battery alludes to other design elements on the bike with the same hexagonal shape. The battery is mounted on the bike backwards between the seat stays in an ergonomically favourable position that is easy to reach without having to bend down (Figure 52).

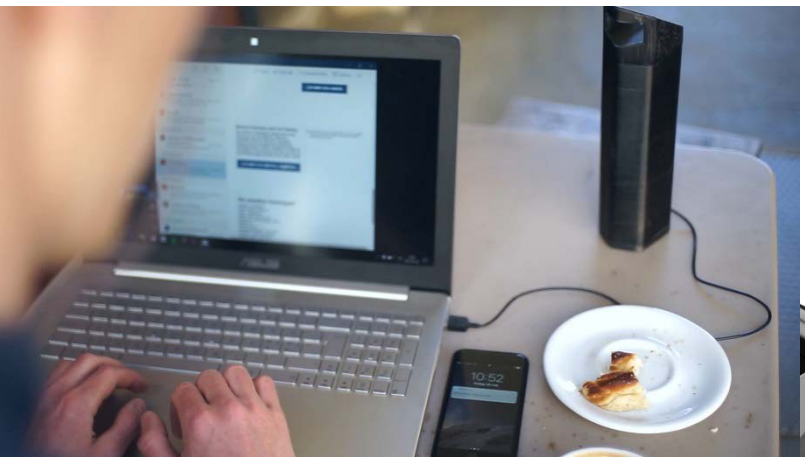


Figure 51: Charging a computer at a café using the battery as power bank.

Figure 52: Position of battery between chain stays and mounting direction.

In addition to the standard 30 cell battery pack the user can buy another extra 30 cell battery pack to extend the range of the bike when needed (Figure 53). The total battery capacity will then be 36V 13.2Ah increasing the range significantly. This modularity makes the user in charge of the final performance of the bike to further optimise the product for the user needs. The modular battery system builds on a standardised interface used in both ends of the battery and by having a detachable handle utilising the same interface it is possible to connect two batteries leaving the cell stacks intact and using the same handle. This enables the extra 30 cell pack to be inserted either behind the original battery or between the original battery and the handle.

Figure 53: Modular battery solution.

This modular system also enables the user to exchange batteries over time and use the old battery as extra while phasing it out and the same handle may also be used for several batteries over time. The battery is a major contributor to the environmental impact of the e-bike, and its lifespan is a major concern for any potential customer given its price. By offering a take-back system with reduced price on new batteries when handing in old ones, Crescent could make sure that the old batteries are properly recycled. This would not only strengthen their brand through following through and expressing their environmental goals. It would also make it more convenient and lower the barrier for customers being concerned about the battery handling.

Part from the battery the bike comes with a charging dock, illustrated in figure 54. It is a table top product with a minimalistic design making it suitable to be kept on display even without the battery. The user may also flip the charging dock upside down making its appearance even more subtle. To charge the battery the charging dock is plugged into a normal wall socket and the battery is put standing on top of the dock. This way the the battery has a natural position in the battery stand and it provides good storage when the user is not using the bike which simplifies the charging procedure. The home charging dock is also small and easy to bring if the user would like to charge the battery out of the home.

Figure 54: Battery charging dock enabling the battery to be on display.

4.1.3 Handlebar

Figure 55: Different riding positions possible with a bullhorn handlebar.

The handlebar is a type of bullhorn handlebar (Figure 56). Bullhorn handlebars could be considered as the upper part of a racer handlebar, without the drop section. These allow for multiple riding positions such as a lower racer type of positioning with a really low wind resistance or a more upright relaxed riding position (Figure 55). For users spending a lot of time on the bike, the variation of grips and riding positions will contribute to a better ergonomics. The aggressive riding position as well as the handlebar itself contributes to a fast expression.

The handlebar is a complete package, combining all essential functions into a unified design with integrated wiring (Figure 56). The hydraulic brake lever housings come with integrated lights and electronic gear switches on the right brake lever (Figure 56). They also provide accessible functional areas for the buttons required to control the performance switches, horn, lights and blinkers. The performance switches are located on the left hand side in an accessible area to allow for a dynamic changing of performance levels. The horn button is placed on the right hand thumb position closest to the grip held when riding so that the user can access it easy and intuitively when needed. The light switch is positioned right above the horn. To ensure a natural placement of the blinkers each indicator switch is placed on respective side of the handlebar. In the middle of the handlebar there is an additional head light as well as an 43 by 90 mm integrated screen for displaying the interface.

4.1.4 Lights

Front and rear lights are integrated in the bike to improve the usability and relieve the user from considering or bringing external lights. By integrating the lights, it is possible to ensure a recognisable expression for the bike regardless of external products (Figure 57). The headlight is provided by two light sources positioned in front of the brake hubs on the ends of the bullhorn handlebar. These lights are always on and also function as flashers to communicate to other trafficants. If the user wants to have more light a centered lightbar can be lit in two intensities using the light switch on the handlebar. The rear lights consist of a main light bar integrated in the bike frame behind the seat tube as well as two smaller LEDs on the lower seat stays. Part from functioning as positioning lights these lights increase in intensity when the user is braking and they also function as flashers. Both head and rear lights provide safety for the user by enabling communication in traffic and also to by providing proper light for the rider.

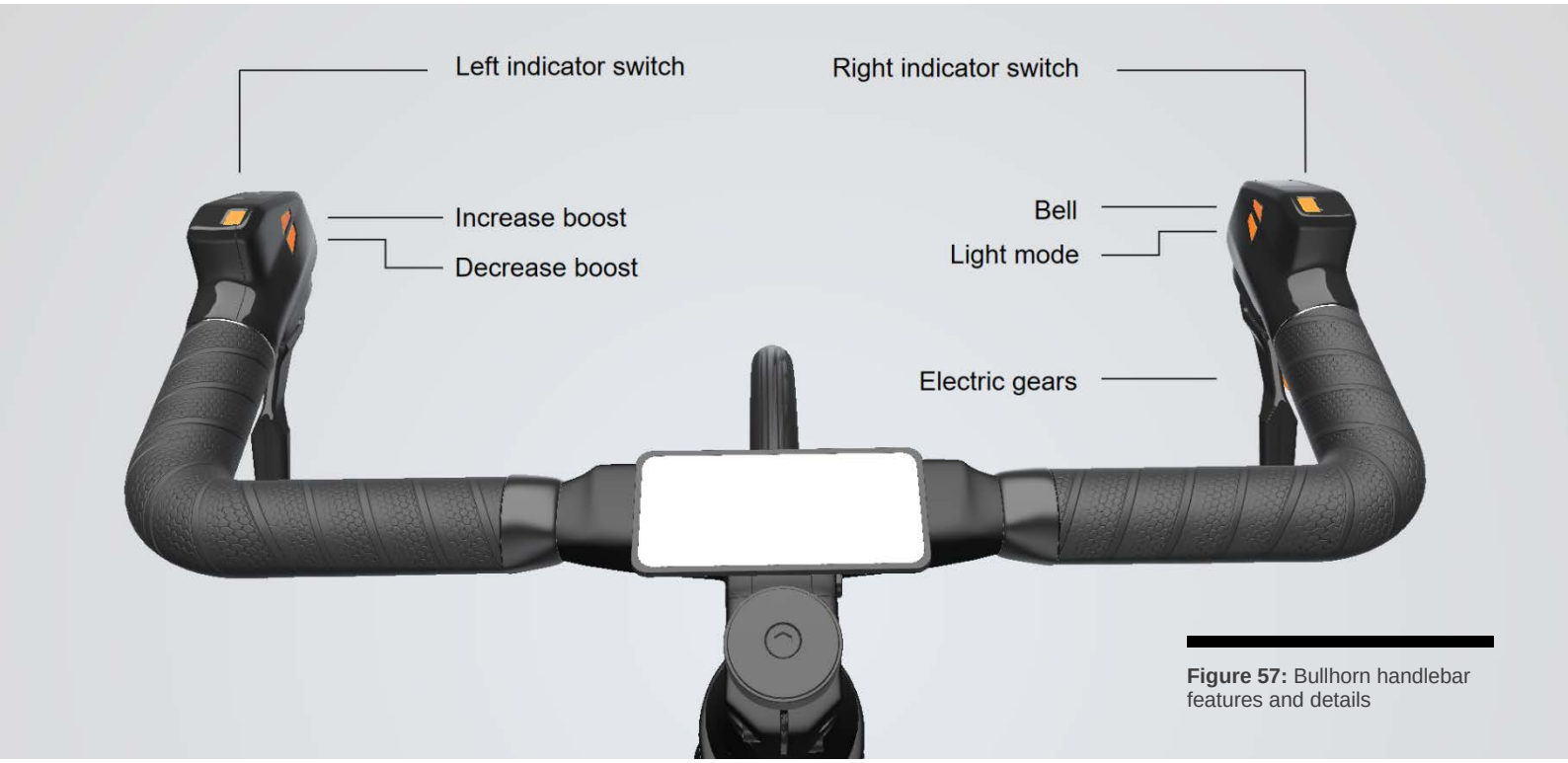


Figure 57: Bullhorn handlebar features and details

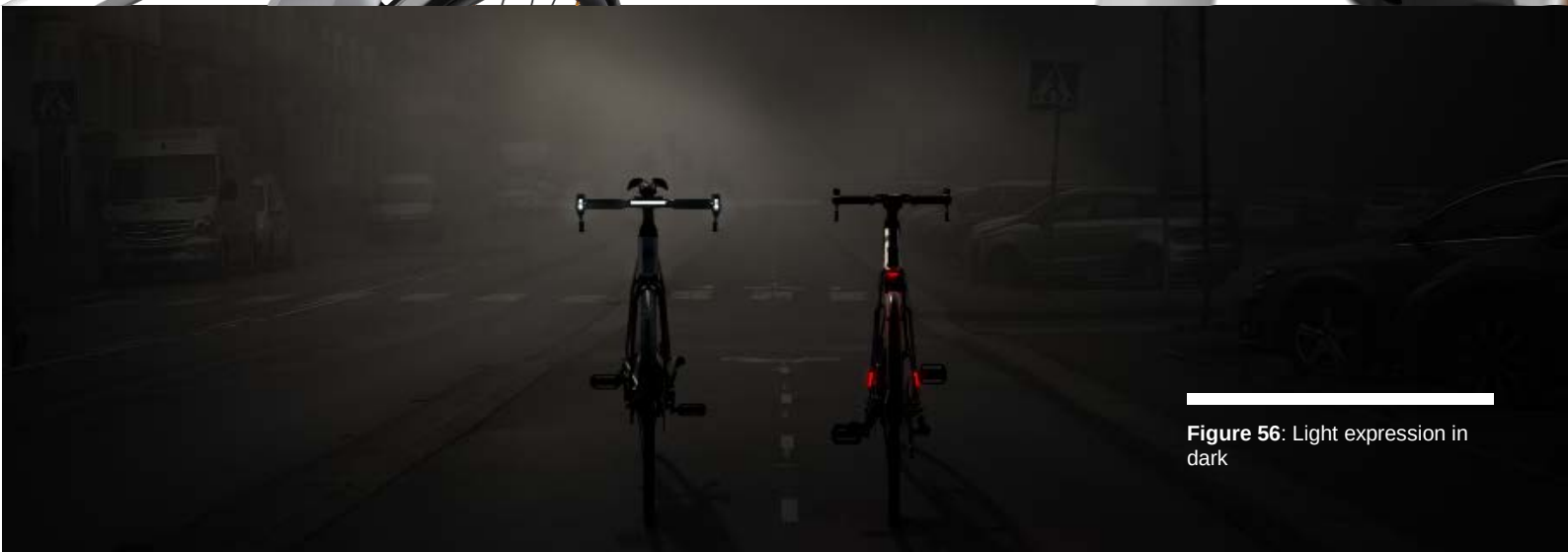


Figure 56: Light expression in dark

4.1.5 Interface

The interface of the bike is a combined solution with both a smartphone app and an independent screen on the bike visualising relevant data for the user while riding (Figure 58).

Figure 58: On bike and smartphone interface.

The interface on the handlebar is showing the optimal information needed for the user while riding. Here, the user can see their current speed, battery status, performance mode, current time and a trip meter. In addition to this, there is a section displaying how the user and the motor works together to propel the bike, shown in the coloured part of the interface. This section starts of on the right hand side, displaying the current power input from both the pedalling with the orange bars, and the motor power with the pink bars. To the left of this, there is a graph illustrating a five minute history of how the user and the motor has worked together to propel the bike. In the lower left corner there is a percentage number showing exactly how much of the power the user has contributed with during the current trip. The interface is customisable with different color themes for the user to pick and choose from.

The app connects to the e-bike through bluetooth to allow for synchronisation of information, and consists out of three major parts. First of all there is the Bike status, which is enabled through an independent 4G connection established by the bike. From here the user can see the current position of the bike based on a GPS signal, monitor whether the bike is locked or unlocked and also unlock or unlock the bike. The interface also displays the status of key components on the bike, and can make suggestions for when to service the bike. The second part is the statistics section where the user can access their trip history with distances, pedalling percentage and more. This statistics can also be used to evaluate environmental impact from using the e-bike compared to other

vehicles, and could also be used by Crescent for marketing campaigns and research, if accepted by the user. The third part of the interface is the Community section. Here the user can choose to follow other e-bike users, share data regarding times on different distances, recommended roads, effort curves or get help from experts or other user by sending in possible error notifications.

4.1.6 Utilities

To facilitate the usability during daily usage the e-bike provide a set of bars suitable for mounting rear rack bags, where the bars also provide support for the bag when hanging (Figure 59). Cooperation with other brands with strong lifestyle connections associated to the target group is used to provide carrier alternatives in the purchase phase. These should be coherent with the Crescent brand and also allow for the user to express themselves with their bag, both on the e-bike but also when carrying the bag without the e-bike.

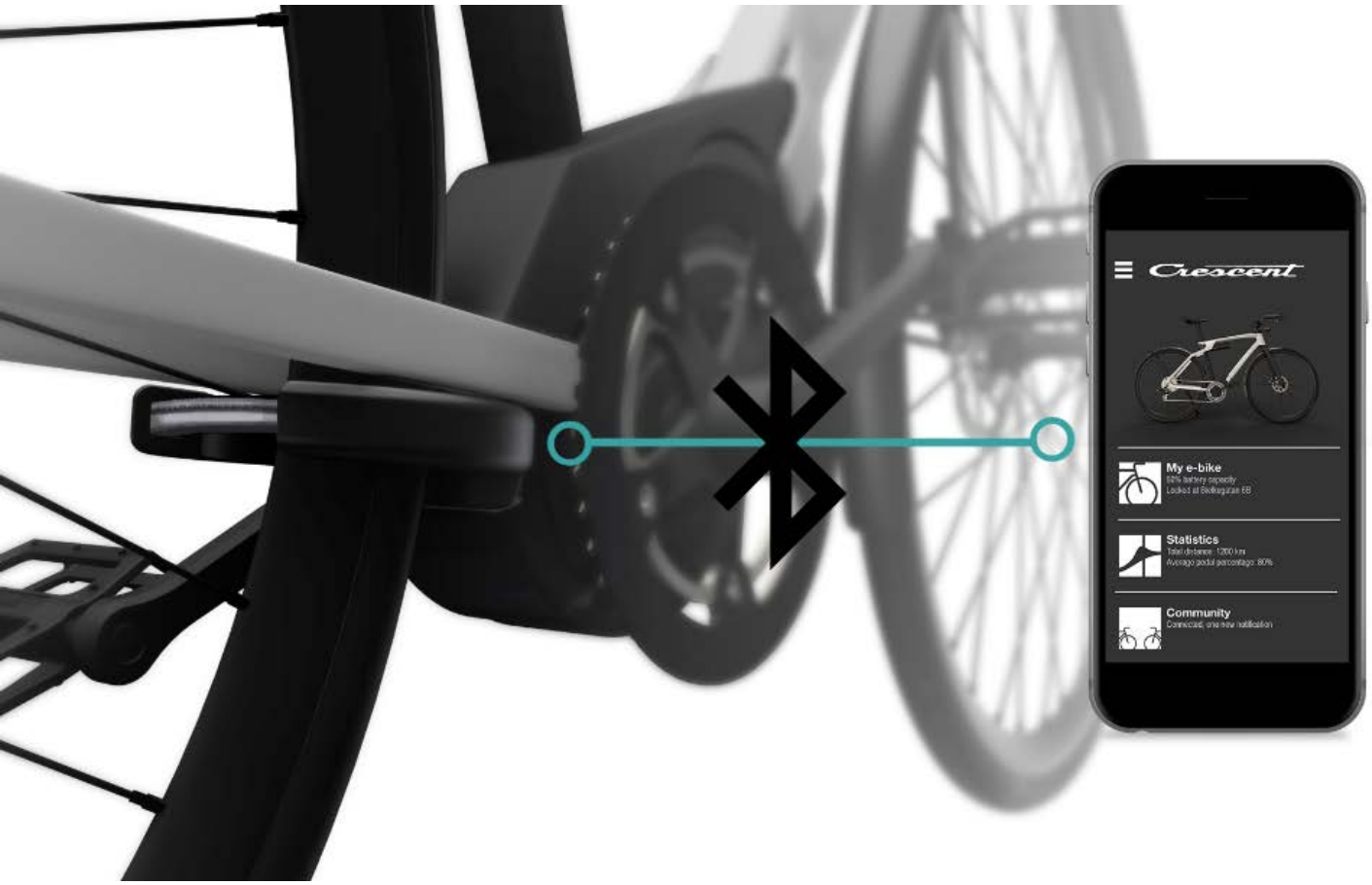
Figure 59: Mudguards and an example of a set of mounted bike bags.

The bike is equipped with black mudguards mounted closely to the tyres, creating a unified and almost seamless expression with the rest of the bike. The front mudguard uses a standard mount connected to the front fork, and the rear mudguard utilise the rear cargo bars to avoid additional disturbing form elements. This will keep the user safe from splashing water from the tyres in wet riding conditions.

4.1.7 Lock

The locking procedure of the e-bike has been simplified from a multistep process to a stop and go solution. Similarly to how a car works, the bike is simply locked by the press of a button on a remote key or in the smartphone app(Figure 60). This is achieved through having fully integrated digital locks as well as alarm systems. The rear wheel is locked with a certified keyless lock and the motor is locked with a digital immobiliser preventing the bike from starting and blocking the motor without the key. For the alarm to work the bike combines both accelerometers and the gps for triggering the alarm and tracking the bike. If the sensors senses that the bike is moved or tinkered with, it will notify the user through the app instantaneously and sound an alarm. This will call for the attention of nearby people and discourage the thief. However, if the bike is moved, the hidden gps will enable the user to track it down. By using this sort of alarm, the bike do not have to be physically anchored when parked, but is instead digitally anchored by the alarm system. For all of these functions to work, the bike uses a smaller integrated battery that recharges every time the drivetrain battery is mounted.

Figure 60: Integrated digital lock and smartphone connectivity



4.2 Concept goal fulfilment

This chapter present how the concept fulfils the Vision as well as correlates to the Expression board set up earlier in the project, thus motivating the design of the final concept.

4.2.1 Vision

The ultimate goal of the Crescent Flow is to achieve the vision presented in the Vision chapter. This chapter will explain how all parts of the Crescent Flow concept cooperates to achieve this (Figure 61).

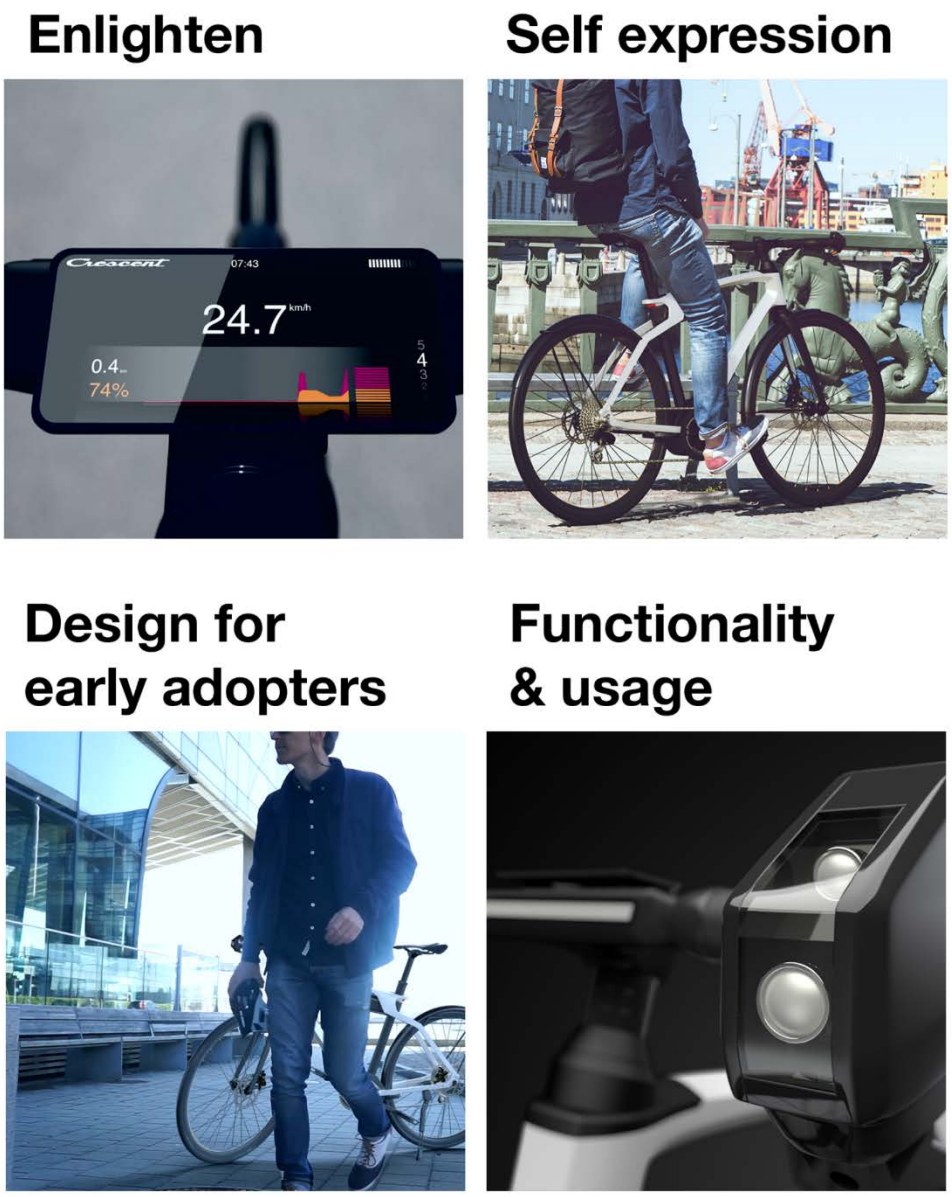


Figure 61: Pictures of Crescent Flow inserted into the vision.

Enlighten

The Crescent Flow combines multiple functions to communicate the positive health aspects of riding an e-bike. With an interface teaching every user about the effort they put into riding their e-bike, misconceptions regarding lazy e-bikers will quickly be eliminated among users. With this empowering information the users will spread their knowledge regarding the positive health aspects of riding e-bikes into the minds of the general public through everyday conversation. The potential data provided from loyal e-bike users could also be used by Crescent to spread the knowledge in a commercial purpose. With its sporty performance look, the Crescent Flow plants the idea of e-bikes being something possible to exercise with for every observer, almost provoking them to ask the question and research the area. The positive environmental aspects of e-bikes will be further clarified and quantified for the users through the interface. Results regarding increased bike usage for e-bike users could be gathered by Crescent and communicated to their current and potential customers. Through the battery take back system Crescent positions themselves as environmentally aware and responsible while simultaneously giving the customers more knowledge and a better experience. The feeling of presence felt when being on a bike riding through the urban nature will increase for the users since they now will use their bikes more often during a longer period of the year. With the e-boost enabling users to dress for the cold or rainy weather, the users will discover new possibilities and experiences. By offering convenient carrier solutions, extra battery potential and a smooth stop and lock procedure the Crescent Flow empowers users to take an extra detour on their way back home from work: stopping in the city for some shopping, taking a fast gym session or just a coffee on a hilltop. The performance look of the bike, the ambassadors manoeuvring them through the city at great speeds and the smooth lock procedure will consociate to spread the picture of e-bikes as something time efficient and fun to ride. By creating a distinct e-bike look, proudly displaying the e-bike drivetrain in harmony with the frame together with great components for higher speeds the bike will communicate how the electric assist doesn't have to be an assistive aid, but rather an electric boost. The information provided through the interface regarding pedal/motor-power is the foundation from where the users can get the proof needed to take pride in riding an e-bike. The way the on-bike display shows the power meter for the pedals and the motor will also spur the users to push themselves into using more of their pedal power when biking, both increasing health aspects range and battery lifespan. With a bike actually communicating its value, visually claiming that it is a performance e-bike, the users will take pride in being e-bike owners. All of these enlightenment effects will not only apply for the Crescent Flow, but for all types of e-bikes while simultaneously increasing the brand image of Crescent as an industry leader.

Self expression

With an expression inspired of car design and form elements from Crescent, the clean design with complex surfaces and clear lines creates a recognisable and likeable bike. The shape is unique enough to distinguish it from ordinary bike, while still keeping it within an acceptance levels for the users. It is clearly related to bikes, but takes the design one

step towards more complex vehicles like cars. Upon this base the user can create a unique bike with the Crescent customisability allowing for a personal bike suiting the needs, and expressing the personality for every user: woman, man, careerist or free spirit. The customisability, still controlled by the Crescent brand, creates a connection between the user and the bike, making them feel more proud of their bikes. The type of bike, being a sort of performance and fitness bike suggests that the user has an active lifestyle, taking care of their health.

Design for early adopters

With a solid foundation built by the Self-expression and Enlightenment aspects presented above, the early adopters have a unified, clear and strong message to deliver for the general public. Crescent Flow functions as an ambassador bike for early adopters, being a high quality build with many sought after properties. The expression of the bike has been proven to be appreciated within the target user group, pinpointing the values of the Crescent brand through its semantics. It has a clear and fast expression, with a focus on the Crescent design guidelines presented below.

- Attraction through Design, Function and Quality
- Designed for exercise and performance
- Pride through satisfied bike ambassadors

The great riding characteristics provided by the Crescent Flow will ensure keeping the ambassadors satisfied. With the battery now being a slightly smaller and nicer product with added functionality being a portable power bank as well as having a proper handle it is more likely to be carried around by the users. This will enable the users to be e-bike ambassadors not only while riding their bikes, but also when at home, at work or on an excursion.

Functionality and usage

With the Crescent Flow packing all the essential functions into a single package, allowing for even more functionality through the customisation, the customer will be delivered a complete package without the need of having to buy additional products from other companies to complete the bike. This will increase the user experience significantly, and also guarantee a better functionality and brand image of the Crescent brand. With fast riding characteristics and a really smooth locking and battery handling procedure, the bike will be really efficient to use almost guaranteeing the fastest door to door experience within the city. With the battery having a lowered capacity, it will more likely be brought into the apartment or office every time for charging. This will ensure that bringing and charging the battery will become a steady routine, minimising the risk of forgetting the battery or forgetting to charge it. Since the bike is now more distinguishable as an e-bike with a unique expression and integrated lights and blinkers, the safety issues caused by miscommunication between e-bikes and other trafficants will decrease.

4.2.2 Expression Board

Figure 62: Crescent flow presented together with the expression board.

When placed together with the expression board created for determining the desired expression and feeling of the e-bike, the Crescent Flow blends in naturally, complementing the feel of the expression board (Figure 62). Both in terms of visual appearance as well as in terms of functionality and how the product usage is experienced.

4.3 Environmental impact

For every car or bus journey replaced by an e-bike, there is an positive environmental impact in terms of reduced emissions. The same goes for when an e-bike is produced and purchased instead of a car. The positive health aspects of using an e-bike mentioned throughout the report could also have a positive environmental impact in the long run, increasing the age for when users can commute on the e-bike and minimising environmental impacts associated with health care. Considering that a major goal of this project is to increase the general e-bike acceptance and usage for a larger group of users, this project has environmental beneficial intentions from the core. The modular battery system with the possibility for Crescent to have a take back system would allow for a more responsible handling of the environmentally impactful batteries. This specific e-bike has an aluminium frame instead of the possible carbon fibre frame to lower the environmental footprint. However, it will require some additional post processing to allow for its specific design expression. These processes will cause some additional environmental impacts that a simpler bike could avoid, however they are required to fulfil its purpose as an ambassador e-bike increasing the general acceptance for all types of e-bikes. If the flow succeeds with its goal to increase the general e-bike usage, this additional footprint will be more than compensated for.

5. DISCUSSION

When analysing the outcome and results of this project there are some aspects interesting to enlighten and discuss further. From a holistic perspective the Vision defined in the Product specification might have been the most important result rather than the actual design of the final product concept. The insights leading to the Vision, based on the Problem definition, was probably the most novel scientific contribution made in this report. This does not diminish the Crescent Flow since it successfully fulfils the goals described in the Product specification chapter. However, the same visionary standpoint could possibly lead to a variation of concepts. More than anything else, this emphasises the importance of the vision for the project outcome and how all or parts of it could be used as a base for all sorts of future e-bike designs for Crescent. Throughout the report the bike was referred to as an ambassador product for e-bikes, however it also serves as an ambassador for the vision of a better tomorrow, beneficial for both brand and users.

Advanced manufacturing techniques and high performance components would result in a rather high retail price for the Crescent Flow if implemented today, but the concept should be realistic to implement in a few years with continuous technology advances within the bicycle industry. The concept was aimed for the market in 2019 and as a future ambassador bike it will open up the minds of Crescent and their partners to inspire a direction for future product development. However, if the Crescent Flow concept would be implemented today as a stripped down version there are some crucial design aspects the concept rely on that are essential to consider to ensure a fulfilment of the vision. First of all the bike needs to provide performance functionality and quality throughout all parts and components. Second the bike must have a performance expression attracting the user group and planting the perception of electric boost instead of electric assist. It should also clearly communicate its identity as an e-bike where the drivetrain components harmonise with the rest of the frame. Lastly the bike must enlighten the user about their own effort through the interface. Part from these essential aspects mentioned, additional facilitating functionalities such as lighting and lock could also be implemented, addressing the idea of a complete solution. Where these components are well integrated to the rest of the bike, enforcing the feeling of a complete product and ensuring the desired product experience.

From an objective point of view the final end result match both purpose and research question quite well. However, an interesting aspect to discuss is if the result of this project would have differed without Crescent. Supposing a project scope without the company, where the main target for the project was not to contribute to the profit of a business but rather to the good for society. First of all the bike was not targeted for everyone which seems contradicting to being beneficial for society as a whole. However as identified in the study, one of the biggest barriers hindering the increase of e-bike usage was the low acceptance towards the product category. According to our study the most beneficial thing to do was to increase the e-bike acceptance level through the design of an ambassador e-bike, pushing the product segment towards being attractive for a larger group of society. So even if the goal of the project would have been purely societal, the outcome would probably have been rather similar. The bike also challenges old preconceptions regarding male and female, where it is rather adapted for each individual’s own desires. Without

compromising with the social, ethical and environmental aspects, this bike could possibly provide a product not only contributing to the company but also to the greater good.

The methods used were based on a typical Industrial Design Engineering methodology providing good structure, however the extensive overall scope for the project made it impossible to within the limitations for the project investigate every aspect in detail. This led to a selective approach regarding where extra focus for details had to be implemented. An example is the concept evaluation where the bikes were only presented in 2D, which could be inadequate for a 3D object, and especially for a bike where the interplay between volumes is of great importance. However, the results from the evaluation were found rather unambiguous, proving the method convincing. Another lacking evaluation aspect due to the resource limitations were that some functional aspects of the bike were not tested thoroughly by external individuals. This led to somehow lacking scientifically proven backgrounds to some decisions taken for the final design. These were instead based on expertise and insights from the Crescent employees as well as the project members.

6. CONCLUSION

Different types of tasks requires different means of transportation. However, for most of the transportation situations in a city environment the e-bike is a really good choice. Since e-bikes often move faster than ordinary bicycles and more often uses the car lanes they need to be rigid and maneuverable to manage high speed maneuvers, as well as have means required for communication with other trafficants. The drivers for e-bike users are many, increased health, environmental benefits, enjoyment, convenience and presence. The barriers are on the other hand often based on misconceptions regarding the results of e-bike usage. E-bikes are often considered to be too expensive, often since the non users fail to see the full value an e-bike can provide. Another barrier is the conception of how e-bikes are considered as cheating, and how e-bike users are considered lazy even though they generally spend a larger amount of overall physical activity on their bikes than non e-bike users. Crescent are currently successfully targeting the convenience of e-bikes compared to ordinary bicycles. However, they could also target the other drivers presented above to enlighten and thus increase their potential user group. The general view of the Crescent brand is stuck in old conceptions of Crescent as being an old brand with classic bicycles. Crescent themselves on the other hand do have a rather strong internal view of their brand, however this philosophy is not successfully communicated. By pushing these values through embodying it into their product designs, they could alter the general perception of the Crescent brand towards their visions. The ultimate urban e-bike for Crescent should attract new users, enhance the perception of the brand and also position Crescent as a leading actor within the area. This should be done by launching the ambassador e-bike Crescent Flow, communicating the positive aspects of e-bike usage through its design and functionality. This would raise the general acceptance of e-bikes and open up for an overall increase of e-bike sales as well as push the Crescent brand towards a position as a leading actor in the market. Since the e-bike benefits correlates with the Crescent brand philosophy, the Crescent Flow e-bike would also increase the perception of the Crescent brand. The resulting increase of e-bike usage would in turn also generate even more positive societal aspects in regards to increased health and environmental benefits.

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Appendix I - Interview questionnaire

Basics:

Age?

Gender?

Occupation?

General needs of transportation - (Related to map):

How do you move around in your daily life?

Where do you live?

What type of accommodation, apartment/house?

Where do you work?

On every location, ask the questions:

How do you get there? (Consider all seasons of the year)

Why do you use that type of transportation?

If bike/e-bike: How do you use it?

When do you go there?

Other routinely places, like groceries, friends or exercise?

What do you do during your spare time, where you need transportation?

E-bike related questions, (connect to previous answers):

Do you own a bicycle?

Do you own an electric bicycle?

What is your opinion about e-bikes?

What is positive?

What is negative?
Would you like to buy an e-bike?
Why? Why not?
What do you look for when buying a bike? (Ask first without giving examples, then discuss the different examples)
Model
Design
Price
Colour
Brand
Other...
What do/would you look for when/if buying an e-bike? Emphasise differences. (Ask first without giving examples, then discuss the different examples)
Model
Design
Similarity to ordinary bike
Price
Colour
Brand
Battery
Engine

Additional functionalities:
What functionalities of the electric bike are important?
Do you have any specific ideas around the subject?

Appendix II - Semantic evaluation form

The following form was filled out by each participant during the semantic evaluation of the four e-bike concepts.

Evaluation of concepts

Semantic evaluation

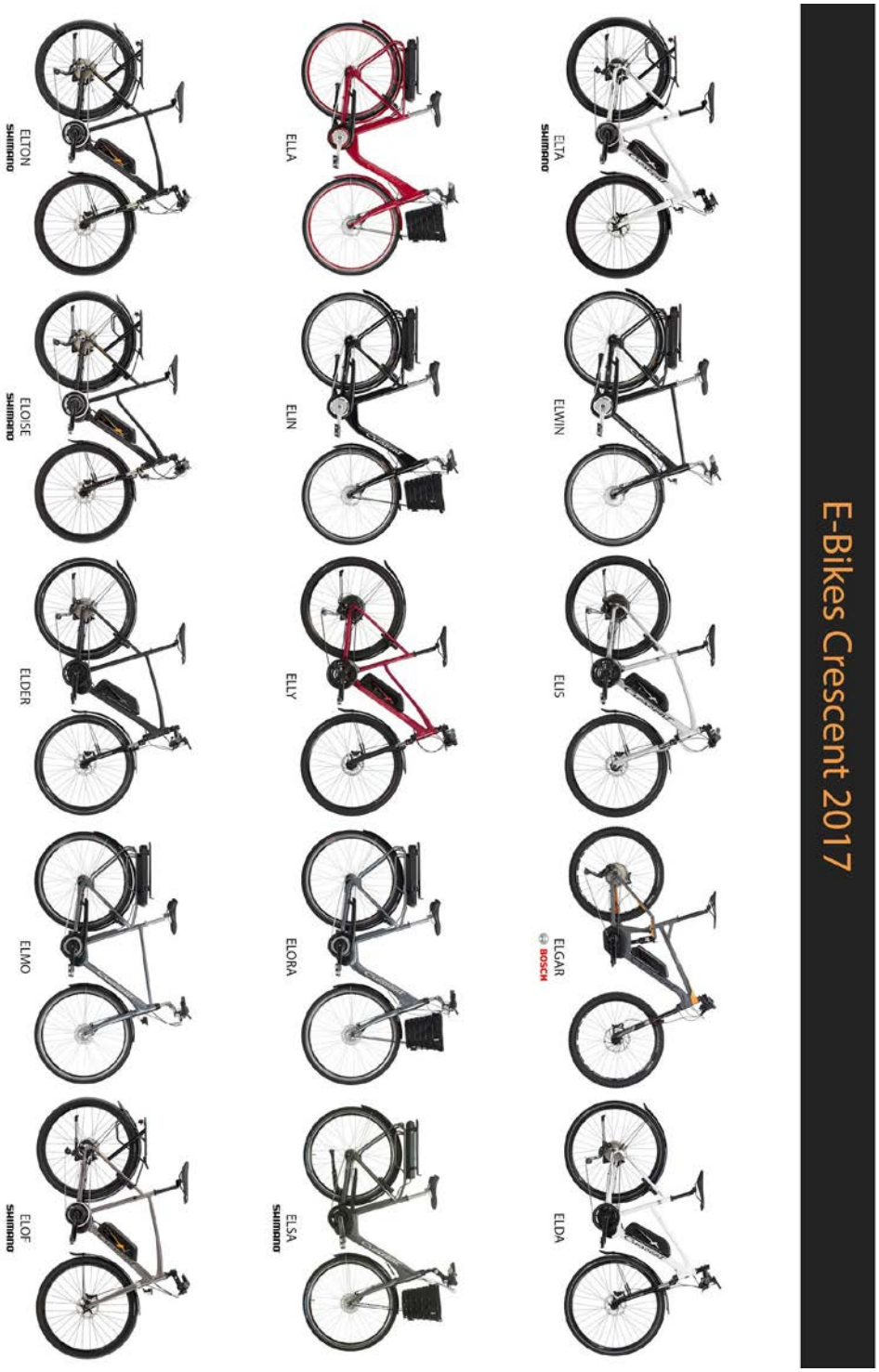
Speed	1	2	3	4	5	6	7	8	9	10	Stillness
Basic	1	2	3	4	5	6	7	8	9	10	Advanced
Experimental	1	2	3	4	5	6	7	8	9	10	Well Tested
Female	1	2	3	4	5	6	7	8	9	10	Male
Ambitious	1	2	3	4	5	6	7	8	9	10	Laid-back
Static	1	2	3	4	5	6	7	8	9	10	Changing
Modern	1	2	3	4	5	6	7	8	9	10	Classic

Rating

	1st	2nd	3d	4th
Toro				
Air				
Flow				
Pro				

Appendix III - Crescent e-bikes 2017

The picture below illustrate the e-bikes sold by Crescent in the year of 2017.



Appendix IV - Swedish market competitor brands

The list below present the 38 different brands that were found competing with Crescent in the e-bike segment on the Swedish market.

Batavus (5)
BH Bikes (1)
Bianchi (1)
Bluelabel (1)
Brinckers (1)
Cortina (1)
Crescent (6)
Cube (1)
EcoRide (1)
E-Green (2)
E-motion (1)
EvoBike (1)
Gepida (1)
Giant (3)
Gocycle (1)
Haibike (1)
Hercules (1)
LaPierre (2)
Lifebike (1)
Marvil (2)
MBK (1)
Merida (3)
Monark (5)
Nishiki (3)
Scott (4)
Sjösala (1)
Skeppshult (2)
Specialized (1)
Stromer (1)
Trek (2)
trioBike* (1)
Velocity by White (1)
Victesse (1)
Walleräng (1)
White (1)
Winora (1)
Winther (1)
Yosemite (1)

* Only cargobikes.
(X) Number of stores, among the 11 checked, where they sell e-bikes from the specific brand.

Appendix V - Flow battery feasibility test

Tests were conducted to enable an evaluation of the battery position for the Flow concept. A mock-up battery was built and mounted on one of the test bikes. Several test rides were performed with different people. The bike was also used by the project group for three days to test all possible aspects and scenarios. Based on these tests the battery position was found to be an insignificant problem, making a further development of the Flow concept possible.

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