CHALMERS

The re-design of an electrical distribution moped

Development of a versatile cost-efficient vehicle

Master of Science thesis

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Cover: Image of the final concept, Bemo.
The concept is described in detail in chapter 9.

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Abstract

The starting point in this project is a three-wheeled electrical distribution moped that was developed and marketed until 2002. The vehicle is still considered to have a potential market and is intended to be re-designed and introduced during the coming years. This master thesis project intends to conduct a redesign of the vehicle with a focus on form and functionality and also taking ergonomics, technical aspects and cost into consideration.

The development process started with a requirement gathering phase, where needs from different users were gathered through interviews and observations, legal and technical aspects were gathered through literature studies and market studies were provided by collaborating parties. With the requirement specification in place, a development framework was created consisting of image boards describing intended expressions and moods, ergonomic guidelines and certain technical aspects on a basic level. Many ideas concerning different vehicle layouts and overall forms as well as detail solutions of specific problems were generated in a creative ideation phase. The ideas were summaraized in three initial concepts.

The concepts were evaluated against each other as well as the original vehicle and the strongest concept was developed further in a refinement phase. The refinement involved specifying and deciding how different solutions should work, look and interact. Forms were defined using CAD software and evaluated towards the development framework. The structural parts of the design were validated through finite element analysis.

The final concept is based on two functional areas, a driver area and a cargo area. The driver area is the focal point of the vehicle and is enclosed by a thick steel frame that is very characteristic. The driver area provides good ergonomics through adjustment possibilities and user oriented functionality through the driver interface and storage possibilities. The cargo area is attached like a sidecar to the driver area and provides a flexible foundation to customize the area to specific user needs.

An evaluation of the results using concept scoring show that compared to the old vehicle, improvements have been made regarding functionality, but mostly within identity and ergonomic aspects. The most important work that should be done when taking the concept further is an evaluation towards users to ensure that their needs are fulfilled and practical tests on a physical prototype to ensure that the vehicle is safe when driving.

The new design utilizes the strengths in the original vehicle and adds additional value to the vehicle and the brand through a thought through design with a characteristic expression and good ergonomics. The vehicle requires further definition, but is realisable witin a near future and customizable in a way that should suit many potential markets.

Keywords: industrial, design, engineering, concept, electrical, vehicle, product, development

Sammanfattning

Detta projekt har sin början i en trehjulig elektrisk distributionsmoped som utvecklades och såldes fram till år 2002. Det anses fortfarande finnas en potentiell marknad för fordonet varför en ny version av fordonet ska utvecklas och lanseras inom de närmsta åren. Detta examensarbete har för avsikt att genomföra en redesign av fordonet med fokus på form och funktionalitet och också ta hänsyn till ergonomiska och tekniska aspekter såväl som kostnad.

Utvecklingsprocessen inleddes med en kravinsamlingsfas, där behov och krav från olika användare samlades in via intervjuer och observationer. En litteraturstudie genererade lagkrav och teknisk kunskap och marknadsstudier genomfördes av samarbetsparter. Med kravspecifikationen färdig togs ett utvecklingsramverk fram, bestående av image boards som beskriver eftersträvade uttryck och känslor, ergonomiska riktlinjer och tekniska aspekter på en grundläggande nivå. I en kreativ idegenereringsfas skapades många idéer kring övergripande konfiguration och helhetsutformning såväl som detaljlösningar på specifika funktioner och problem. Idéerna sammanfattades i tre initialkoncept.

Koncepten utvärderades mot varandra och mot orignialfordonet. Det starkaste konceptet utvecklades vidare i en definitionsfas som innefattade specificering av hur olika lösningar ska fungera, se ut och interagera med varandra. Formerna utvecklades med hjälp av CAD-program och utvärderades mot innehållet i utvecklingsramverket. De huvudsakliga strukturella delarna validerades med hjälp av finita element-metoden.

Det slutliga konceptet utgår från två funktionella områden, förarmiljön och lastutrymmet. Förarmiljön är det centrala i fordonet och omsluts av en tjock stålram som ger fordonet ett karaktäristiskt uttryck. Förarmiljön erbjuder god ergonomi genom många inställningsmöjligheter och användarorienterad funktionalitet i förargränssnittet och förvaringsutrymmen. Lastutrymmet är kopplat likt en sidovagn på förardelen och erbjuder en flexibel grund frö att anpassa utrymmet till specifika applikationer.

En jämförande utvärdering av resultatet visar att det har gjorts förbättringar när det gäller funktionalitet, men framförallt kring identitet och ergonomi. Viktiga saker som bör genomföras när konceptet tas vidare är att utvärdera det gentemot verkliga användare för att säkerställa att deras behov och krav uppfylls och att utföra praktiska tester på en fysisk prototyp för att försäkra sig om att fordonet är säkert när det framförs.

Den nya utformningen utnyttjar styrkorna hos det ursprungliga fordonet och adderar ytterliggare värde till fordonet i form av ett karaktäristiskt uttryck och god ergonomi. Fordonet kräver ytterligare utveckling, men ses som realiserbart inom en snar framtid och medger anpassningsbarhet på ett sätt som borde passa många potentiella marknader.

Acknowledgements

We would like to thank everybody involved for making this project possible, all the interviewees and people taking their time to help us create a new vehicle. We would like to pay special thanks to a few key people during the project.

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Table of Contents

1. Introduction

This chapter describes the project background and the project scope in terms of purpose, aim and delimitations. The project's relation to connected projects and the structure of the report is also presented.

1.1 Background

The initiators of this project are conducting a project at Chalmers School of Entrepreneurship (CSE) that aims to bring industrial electrical vehicles to the market. The CSE project is focused around a three-wheeled electrical distribution moped (Figure 1.1) that was first introduced in 1989 and continuously developed and marketed until 2002. The moped is still used at various companies today, for example within postal delivery and industrial use (Nilsson, 2010).

Figure 1.1 The original Tugger

The initiators intend to introduce a re-designed version of the electrical distribution vehicle on the market during the coming years. The upcoming version aims to differentiate itself on the market by introducing a more characteristic design and a strong brand identity that is well connected to the core values of the company. It is however important to consider and work within the economical and mechanical limitations that are set to be able to realize a new concept. Furthermore, the initiators also emphasize the importance of a vehicle where the needs of the actual end users are fulfilled to a high extent (Nilsson, 2010).

1.2 Purpose

The purpose of the master thesis project is to improve the possibility of a successful product and brand introduction on the market by implementing a methodical re-design process on the Electrical Distribution Vehicle.

1.3 Aim

The development process strives to create a strong brand identity based on the core values defined by the company as well as capturing the different needs of the end users to a high extent. The product development will have a main focus on creating a characteristic form language and fulfilling user requirements through good design. In combination with the mechanical and economical boundaries, the project thereby aims to result in a conceptual product that should be realizable in the coming years. The general goals with the project are stated as follows:

- Environmental friendliness should be considered throughout the development process
- There should be a high correlation between the desired core values of the company and the perceived design attributes of the final product
- The final product design should be perceived as a characteristic vehicle with attributes that attract the users
- The demands and wishes from the end users should be fulfilled to a high extent
- The final product design should follow general ergonomic guidelines and be ergonomically adapted to its users
- The mechanical design of the product should be able to fulfil the requirements regarding cost and safety
- The final product design should be adapted to feasible as well as suitable manufacturing methods that are in line with the predetermined budget

The project aims to deliver the following:

- A CAD-model of the finalized product
- High quality renderings of the product and important product details
- A documented development process including detailed descriptions of the final product and its features
- An analysis of the final product in relation to the requirements and desired functions stated in the beginning of the project
- Recommendations and guidelines of how the concept should be handled during further development

An important learning goal is to consider the mechanical and economical issues throughout the development process and incorporate this as a natural part of the process. The purpose of this is to gain further understanding for these issues and enhance the project team's competence within the development process as well as create a more convincing end product.

1.4 Delimitations

In order to create a convincing final concept of high quality regarding the main focal areas of the project, the following delimitations have been made:

- The result is not aimed to be incorporated in the first production series of the product, but instead serve as a target for the second or third generation
- The mechanical design will not reach a completely production ready state and no detailed mechanical drawings will be produced
- Manufacturing and production methods will be taken into consideration but not evaluated thoroughly to find optimal solutions
- The cost analysis will include estimations and not contain detailed costs of different parts and manufacturing processes
- No final physical model will be produced but mock-ups will be created when deemed necessary

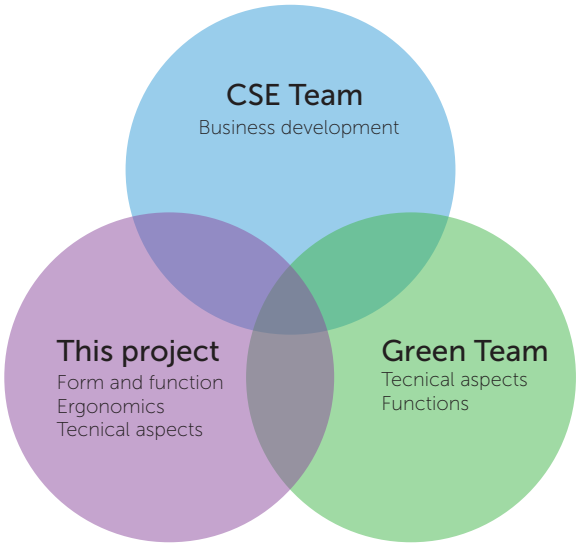

Figure 1.2 The project organization

1.5 Organisation

The project is linked to other projects that have a lot of influence on the direction and results of the master thesis. The people and projects involved are presented below to describe the relationships between and the main focus of the different projects.

1.5.1 CSE Team

Gustav Nilsson, Jonas Mårtensson and Rizwan Ahmad at Chalmers School of Entrepreneurship are the initiators of the project and are responsible for the business development and strategies regarding the product.

1.5.2 Douglas Grundevik

Douglas is the original inventor of the current product and has a lot of knowledge regarding the product and the different markets it was introduced on. He has provided the CSE project and collaborates with the CSE Team.

1.5.3 Green Team

Per Ahlm, Emmie Fryland, Robin Loman Stridholm, Simon Niemelä, Johannes Quist and Laura Vaughan at the Product Development master at Chalmers are conducting a redesign of the vehicle from a mechanical point of view. They develop the structural design and are responsible for the powertrain. The result is a concept that will serve as basis for building a prototype and provide a foundation for the first commercial version of the vehicle.

There has been a high degree of collaboration with Green Team to ensure that the concepts are similar on a basic level. This is done to allow the results of this thesis project serve as a base for a second or third generation of the vehicle without doing any drastic changes on the main structure.

1.6 Report structure

Since the product is complex and there are several different interdisciplinary aspects to consider, the structure of the different chapters is built around four main headlines; Form and functionality, Ergonomics, Technical aspects and Constraining aspects. The purpose of this is to create a red thread and make it easier to follow the development process.

Form and functionality presents information around subjects such as form language, visual brand identity and different functions regarding use.

Ergonomics focus on different aspects of physical and cognitive ergonomics in the working environment as well as user interaction and usability.

Technical aspects focuses on important technical information connected to mechanical issues such as material selection, vehicle structures, manufacturability and powertrain functionality.

Constraining aspects presents additional data that influences the development. This could for example be different legal aspects or frameworks given by the initiators concerning performance and environmental and economical issues.

1.6.1 Chapter overview

Chapters 2 and 3 provide a factual background and knowledge base that presents gathered information about knowledge fields that already existed when the thesis began.

Chapter 4 explains the core foundation of every method that was used throughout the project.

Chapters 5, 6, 7 and 8 describe the development process in different stages. The application and results of the different methods is then explained under each chapter. The purpose of this is to create an understandable connection of where and how the methods have been applied throughout the project.

Chapter 9 presents the final result of the product development done during the project.

Chapters 10 and 11 provide an evaluation of the final concept and recommendations for further work.

Chapters 12, 13 and 14 end the report with a discussion, a conclusion and references for all sources.

2. Product Background

This chapter will present facts that cover the current product, its history and its competitors. The background information provides a basic understanding of the project as well as the product that is to be redesigned. The main competitors are presented briefly with a focus on performance and usage.

2.1 History

The man who introduced the vehicle that this project is based on, Douglas Grundevik, saw a business opportunity in introducing a low-cost distribution vehicle on the Swedish market in 1989. In collaboration with different suppliers he started to produce a vehicle called Tugger that was built on the principles of a motorcycle with a sidecar and powered by an electrical motor. The vehicle was produced in low quantities but was very appreciated by its users (Nilsson, 2010).

Figure 2.1 Tugger

The Tugger was produced until 2002 but Douglas contacted CSE In 2009 since he still believes that the old concept is viable. CSE found the project interesting and started to create a new business plan around the old vehicle. In order to get things going on a small budget, CSE also involved several groups of students at Chalmers to further develop the concept and create a new modern version of the vehicle (Nilsson, 2010).

The big advantages with the old Tugger were stated by Douglas and the CSE Team as (Nilsson, 2010):

- Environmentally friendly
- Small turning radius
- High loading capacity (300 kg)
- Ability to tow a trailer
- Stable
- Robust

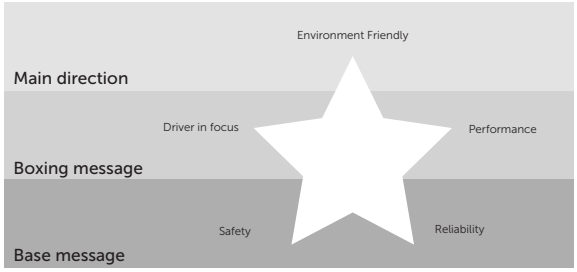

Figure 2.2 Message Star

2.2 CSE Team information

The CSE Team focus on developing the business plan and defining a feasible business model around the product. They are the initiators of this master thesis project and have a large influence on the direction of the project. The team has provided information about technology, markets and general strategies regarding the product, much of which is confidential. The working name of the vehicle is Bemo (Nilsson, 2010). Their internal values and how they want the brand to be perceived has been central in the product development and is presented below.

2.2.1 Core Values

Four core values have been defined to describe the core ideology of the business. All core values are accompanied by phrases that help define the meaning further (Mårtensson, Ahmad, & Nilson, 2009).

Creativity

"Nothing is impossible" , "The sky is not the limit"

Sustainability

"Care for the environment, society and economic value"

Honesty & reliability

"The steady point in stormy weathers"

Personal leverage

"Together everyone achieves miracles"

2.2.2 Message star

Five basic messages that shall shine through in all external and internal communication have been defined. The basic messages are prioritized in three levels and presented as a message star. The main direction is "Environment friendly", this is what they will be known for. The second level is the boxing message where "Driver in focus" and "Performance" will help differentiate them on the market. The third level; the base message "Safety" and "Reliability" must always be in place to avoid credibility and reputation problems (Mårtensson, Ahmad, & Nilson, 2009).

2.3 Product description

A product breakdown identified the following functional areas on the Tugger: supporting structure, driver area, platform and powertrain. Each area is described further below and the full product breakdown can be found in Appendix A.

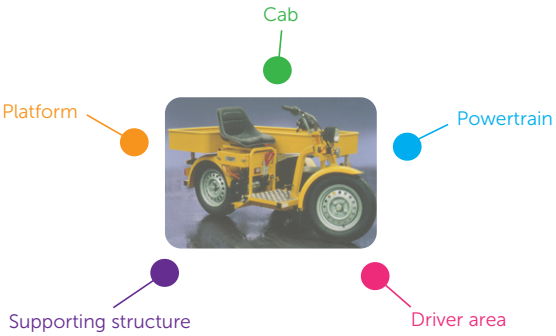

Figure 2.3 Product breakdown overview

2.3.1 *Supporting structure*

The vehicle measures 215 by 130 cm and the structural frame of the vehicle is built by welded steel pipes with a square cross-section. The frame has an open structure and is not covered with any aprons customized for the vehicle. Front and rear lights are of 24 volts type and fastened as standard parts directly to the frame. The fenders are also made of steel and welded together with the frame. The vehicle has suspension in the front fork as an extra option and consists of a single armed leading-link system. The wheels are positioned asymmetrically to provide a good balance between the driver area, platform, battery and load. The frame and wheel configuration also makes it possible to have a turning radius of 1.5 meters (TWR Sweden AB).

2.3.2 *Driver area*

The driving interface is equipped with a handlebar as standard but this could be substituted for a geared steering wheel for easier manoeuvrability. A pedal controls the throttle and the gear (forward/backwards) is electrically controlled by a lever next to the steering wheel. A separate handle to the right of the steering wheel manoeuvres the braking system. The small lever for the blinkers and the ignition is also placed to the side of the steering wheel, integrated in the black control box. Furthermore, there is a display positioned in front of the steering wheel on the control box, which informs the driver of the capacity of the battery (TWR Sweden AB).

Figure 2.4 Different views of the Tugger

The standard seat is a plastic seat that could be adjusted horizontally but could, as an extra option, be substituted to a seat with suspension that is adjustable both horizontally and vertically. Additionally it also has adjustment possibilities for the backrest (TWR Sweden AB).

Cab

The vehicle could furthermore be adjusted to fit the mail distribution sector. It is possible to add a windshield and a cab over the vehicle so that the driver and the cargo are protected from the weather. The weather protection is made of a strong fabric and is held up by a framework that is mounted around the vehicle (Svenska Trade Wind AB).

Figure 2.5 Tugger customized for Posten

2.3.3 Platform

The platform is L-shaped and could be configured either to the right or to the left of the driver. The sides on the platform could be exchanged into folding flaps as an extra option and the whole platform could then also be tilted backwards or to the side. Tilting the platform is done manually by lifting in the handle that is positioned on the side of the platform. Maximum loading capacity is 300 kg on the platform but it is also possible to connect a trailer to the vehicle for additional loading capacity (TWR Sweden AB).

Figure 2.6 Tiltable platform

2.3.4 Powertrain

The powertrain consists of a 24 or 48 volt electrical motor with a power of 2, 3 or 4 kW that drives the back wheel via a chain. The motor is placed underneath the seat and is powered by a battery pack placed underneath the platform. The batteries are lead-acid batteries with a capacity of 100-180 Ah. The recharge interface is positioned underneath the seat and the user needs to connect the recharge input to a separate recharger by removing the red handle (TWR Sweden AB).

2.4 Context and user

The Tugger was used within a variety of user segments and acted in several different contexts. Mail delivery, park services, industrial logistics and amusement parks were some of the most popular segments. The users were consequently of a broad spectrum, varying in age, gender, size and knowledge/experience (Nilsson, 2010).

2.5 Competitors

The main competitors as presented by the CSE Team are focused on the Swedish market with one exception, which is a three-wheeled moped from Switzerland. The reason for including this vehicle was based on its popularity by its users and its wheel configuration. The competitors are as follows:

2.5.1 Dobbin

Dobbin is very similar to the old Tugger, with a wheel configuration as a motorcycle with a sidecar. It is sold by the Swedish company E-Tron that classifies Dobbin as an electrically driven working tool with high quality and strength as focal points. Dobbin is manufactured by standard components that allow for low service and small operating cost. The users of this vehicle put demands on a robust design and good strength in order to pull trailers (E-tron). The price to customer is around 60-70 000 SEK (Nilsson, 2010).

The Dobbin is powered by an electrical motor connected concentrically directly to the rear wheel through a cyclo gear. The motor can be delivered as either 24 Volts with a power of 2 kW or 48 Volts and 3 kW. The batteries are lead-acid and are placed underneath the platform and the capacity range from 180 Ah to 240 Ah. The maximum driving distance is specified to 120 km. Recharging is done by connecting the charger to a 230 volt power socket. The charger is called C-PACK and identifies the condition of the battery and adjusts the recharging procedure accordingly in order to maximize the life time of the batteries (E-tron). The recharging time is around 8 hours (Nilsson, 2010). The vehicle measurements are; length 2150 mm, width 1200 mm and height 1100 mm and the turning radius is around 2 meters (E-tron).

Figure 2.7 Dobbin

The vehicle has an L-shaped platform that is tiltable in two directions and has a maximum capacity of 300 kg. The driver area is provided with an adjustable seat that can be adjusted horizontally. The steering is geared in order to be able to use less force when turning and the steering wheel is vertically adjustable. The controllers and the battery display are placed in front of the steering wheel on a plastic box. The vehicle is furthermore equipped with an automatic parking brake and two pedals that control the disc brakes and the throttle (E-tron).

2.5.2 Norsjö Carrier Electronic

Norsjö Carrier Electronic is a three-wheeled delivery moped that is sold and manufactured by the company Norsjö. The moped that has been included in the competitor analysis is a model specialized in mail delivery and has been used by Swedish Posten for several years and costs around 70 000 SEK (Nilsson, 2010).

The moped is powered by an electrical motor of 3 kW from Sepex and driven by a chain. Battery packs can be delivered in three configurations; 96/128/160 Ah. The batteries are of the type lead-acid and placed underneath the platform in the front (Norsjö). The recharging time is around 8 hours (Nilsson, 2010).

The platform is covered with a metal apron that could be opened from the front and has some small cargo boxes placed on the top facing the driver. These boxes are covered with a transparent plastic hatch to protect the cargo from bad weather. The measurements of the platform are 95 cm wide and 120 cm long (Norsjö). The loading capacity is around 170 kg and the vehicle has a turning radius of 2 metres (Nilsson, 2010).

The driver area has a seat that is adjustable vertically and horizontally and a handlebar that can be adjusted vertically. Some controls are placed on a module in the centre of the handlebar and some on the left and the right handle. The gear lever is placed underneath the seat and the speed is managed by pushing a pedal. Additional handles control the braking (Norsjö).

2.5.3 Transportel delivery moped

Transportel delivery moped is very similar to Norsjö Carrier Electronic. The moped has the same structure that is based on three wheels; one in the back and two in the front. The moped is manufactured and sold by the Swedish company Tranpsortel and costs around 60-70 000 SEK (Nilsson, 2010). Transportel also delivers specialized models to Posten and the configuration is almost identical as Norsjö Carrier Electronic. The difference is that it is possible to open the cargo box from the side instead for in the front (Transportel).

Total measurements of the vehicle are; length 2580 mm, width 1000mm and height 1060 mm and the platform is 1000 mm wide and 1200 mm long. The loading capacity is around 270 kg (Transportel).

The moped is powered by an electrical motor of either 1,5 kW or 3,5 kW and the battery packs comes as either 175 Ah or 110 Ah and consist of lead-acid batteries. The batteries are recharged by plugging the built in charger into a 230 volts power socket (Transportel). Time for full recharge is around 8 hours (Nilsson, 2010).

The driver area is also very similar to Norsjö Carrier Electronic with an adjustable seat and a handlebar where different controls are placed (Transportel).

Figure 2.8 Norsjö Carrier Electronic

Figure 2.9 Transportel delivery moped

2.5.4 PGO Scooter

Bring Citymail uses a standard two-wheeled scooter from PGO that has been customized with an additional frame structure in order to carry mail in the back and in the front of the driver (Andersson, 2010). The Scooter is driven by a traditional air-cooled 2-stroke 50cc combustion engine with a power of 2 kW at 6250 rpm. The fuel tank holds a capacity of 6.7 litres of petrol and the vehicle measurements are; length 1870 mm, width 850 mm and height 1284 mm (PGO-Scooter).

The seat is a traditional scooter seat that has a fixed position with storage space underneath. The vehicle is manoeuvred with a handlebar and all controls are placed in near position to the handles on the handlebar. Driving forward is done by twisting the right handle and braking by using the hand brakes positioned on each steering handle (PGO-Scooter).

Figure 2.10 PGO Scooter

2.5.5 *ClubCar Carryall 2*

The ClubCar Carryall 2 is a four-wheeled vehicle that is sold by Epton Trading and developed by the company ClubCar. ClubCar provides a series of different working vehicles adjusted to different user needs. The Carryall 2 is one of their most popular vehicles and is, among others customizable for the Swedish Posten (ClubCar). The price varies depending on configuration but is estimated to somewhere between 70 – 130 000 SEK (Nilsson, 2010).

The vehicle is powered by a 48 Volt electrical motor with a power of 2,24 kW and a battery pack providing 225Ah. The batteries are of lead-acid type and placed underneath the seat. They can be recharged in around 8 hours with the integrated charger by plugging it into a 230 volt power source. The vehicle is furthermore equipped with an IQ system that allows the vehicle to be configured regarding max speed and acceleration. It additionally provides the motor with the possibility to have an adjustable regenerative motor brake that recharges the batteries and a magnetic brake that prevents the vehicle for accidentally moving when it is parked (ClubCar).

The platform is placed behind the driver and measures 1240 mm in width and 1260 mm in length. The loading capacity is around 550 kg. This loading area can be covered with an apron or substituted to a cage as an extra option. The driver seat is either a non-adjustable sofa for two persons or an adjustable seat with a seating belt. The seat can be combined with a cargo area next to the driver for easy access to small cargo. The seating area is an open area with a roof and windshield but can be customized so the driver area becomes a cab with sliding doors on the sides. This is how the mail-version is configured. The vehicle is manoeuvred similar to a car with a steering wheel and pedals for throttle and brake. The control panel consist of some indicators and buttons and a display showing the volt capacity. This interface is placed on a ramp underneath the steering wheel towards the windshield (ClubCar).

Figure 2.11 ClubCar Carryall 2

2.5.6 *Kyburz DXP*

Kyburz DXP is developed by the company Ing. Büro M. Kyburz AG in Switzerland. The vehicle is a three-wheeled trike with two wheels in the back and one in the front and its target customer is elderly people (Kyburz). The company has also further developed and customized a new version for mail delivery that has gotten good feedback from its customers. The cost is around 130 – 150 000 SEK (Nilsson, 2010).

The vehicle is powered by an electrical 24 volts AC motor of 2.4 kW and a battery pack consisting of lithium-iron-phosphate batteries with a capacity of 160 Ah. The batteries can be recharged by connecting the built in charger module to an ordinary 230 volt power socket (Kyburz) and the recharging time is estimated to around 4 hours (Nilsson, 2010). The vehicle measures 1850 mm in length, 800 mm in width and 1240 mm in height and has a turning radius of 1.8 meters (Kyburz).

Cargo can be placed in front of the handlebar and behind the driver to a combined payload of 125 kg. The vehicle can furthermore connect to a trailer for an additional cargo capacity of 150 kg. The driver is positioned on a seat with suspension that can be adjusted vertically and steers the vehicle with a handlebar. The throttle is controlled by twisting the right handlebar or can, as an option, been done by pushing a pedal. Braking is done by pushing the right or left handle similar to a scooter but can also, as an extra option, be done by pushing a pedal (Kyburz).

Figure 2.12 Kyburz Classic

3. Knowledge Base

This chapter will present a knowledge foundation of facts and principles that is important to possess in order to fully understand the development process and the decisions made throughout the process. The information gathered here is used during the development process and works as an important framework in order to understand different configurations of vehicles and get ideas on how to enhance the performance and design of a new vehicle.

3.1 Form and functionality

3.1.1 Gestalt

Gestalt can be seen as a set of parts that appear and function as a whole that is more prominent than the parts themselves. It means that different aspects of a whole will influence each other and are experienced together, not as individual parts. The following factors help discern gestalts; proximity (objects closer together), similarity (figures with the same properties), area (the smaller the area the clearer the gestalt), symmetry (objects places symmetrically creates gestalt), enclosedness (an enclosed area is more easily seen as a whole), the good curve (separate lines with small changes in direction are seen as continuous), common movement (objects moving in the same direction creates gestalt) and experience (sometimes a gestalt is only discernable if recognized by someone with the correct experience) (Monö, 2004).

3.1.2 Ordering features

The different parts of a product can be ordered in three levels; topological ordering, typological ordering and morphological ordering. Topological ordering describes how different elements are placed in relation to each other, e.g. linear, radial, central and orthogonal. Typological ordering relates to the form of an element. Forms can be created by using the primitive shapes and modifying them through scale, additive or subtractive transformations. Morphological ordering describes how matter is shaped to create the forms in the elements. Three morphological classes can be identified; linear (e.g. frames of wire or tubes), flat (e.g. flat, single or double curved sheets or hulls), solid (e.g. 3D volumes) (Muller, 2001).

3.1.3 Semantic aspects

Semantic functions cover how a product communicates to the user and include describing the purpose and mode of operation, expressing the properties, exhorting a reaction in the user and identifying the product and its origin (Monö, 2004).

To describe

Describing the purpose can be made by not covering the mechanical functionality of a product, thereby making it clear how it works. Sometimes casings are needed to avoid injury or to cover sensitive parts, this can make it more difficult to describe the purpose and the way it works. If it is not important to know how something works, efforts can instead be made to make it clear how a product is operated (Monö, 2004).

To express

A product can express things through its appearance and functions. It is important to define which aspects of the business, the product purpose or the expectations of the target group should be expressed in the design of a product. It is also important that the expression is in sync with other technical and semantic aspects a product has, otherwise the design can be perceived as cosmetic or dishonest (Monö, 2004).

To exhort

Exhorting always intends to result in a reaction from the person receiving the signal. It is not always an easily identifiable function within a product and can sometimes be disguised as a really clear description or a strong expression. The function can also be very explicit through for instance signs or blinking lights. It is important that the exhortation is clear and used in the right context and situation, otherwise the effect can be lost (Monö, 2004).

To identify

Identifying is about establishing a likeness to something, e.g. a product's origin, its purpose, its affiliations. The origin can be apparent if the company has developed a design strategy that defines how products should look, logotypes, trademarks and colours can also be used to emphasize this. The purpose can be understood if the product is close to the archetype of that product type or if the product describes the purpose semantically. Identifying affiliations can include recognizing it as part of a range or family of products (Monö, 2004).

3.1.4 Symmetry

Symmetry has been associated with beauty for a long time and can be found in many variants in nature; in humans, animals as well as plants. From a design perspective, symmetric forms are more commonly seen as figure and not as ground which leads to more attention. Symmetry can be used to convey balance, harmony and stability. There are three basic types of symmetry; reflection, rotation and translation (Lidwell, Holden, & Butler, 2010).

3.1.5 *Visual brand identity*

Everything a company does affect the perception of its brand. As illustrated by the Innovaform Brand Flower (Innovaform, 2010) in Figure 3.1 not only the graphic design of business cards and the look of products influence a brand, but everything from the location of the office and the people employed to trademark strategies and the retailers used all play a part in defining the brand identity. This project is however focused on the visual aspects of the brand identity which will be described further in the following sections.

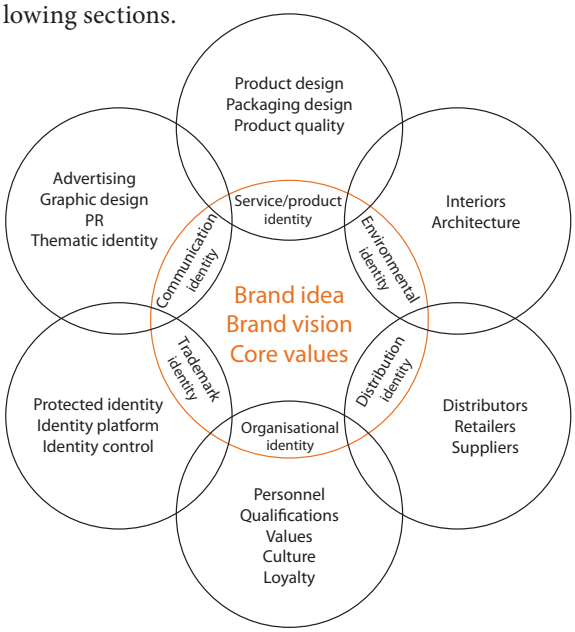

Figure 3.1 The Innovaform brand flower

In many different categories of products, it is easy to recognize certain brands only through the visual design of their products. Brands like this use certain design features consistently on a whole range of products to build coherent and recognizable products that stand out from their competitors. Visual aspects of a design draw attention to the product in shops, in advertisements and when used. In this way, design helps create expectations and beliefs about a product even before it is used first hand. Managing these aspects in a conscious way can help create a strong brand identity and generate added value to the brand (Karjalainen, 2007).

Value based design

Different design features such as shapes, lines, colours and materials can be used to create recognition. These features can be chosen arbitrarily only by the attractiveness of the forms themselves or they can be value based, connected to the core values of the company. The latter is preferred since the design philosophy of a brand should take the strategic intent into account as well. This creates a credible connection between the actions of a company and the functionality and design of its products. Arbitrary design cues not connected to brand values can be perceived as artificial, but if they are used consistently over time they can still become strong sources of recognition. More than one product is needed to develop recognition, since only then is it apparent which features are deemed important. Companies do however have a variety of strategies to create recognition, ranging from developing very similar products that strictly adhere to certain design decisions, to making inconsistency conveyed through revolutionary design the consistent strategy. (Karjalainen, 2007).

Explicit and implicit cues

The associations and meanings generated by design features are central within the semantic aspects descried earlier. The challenge is to construct value based design features from brand values formulated as words. To achieve this, design features can be connected to the brand explicitly or implicitly. Explicit design cues are meant to be instantly recognizable and apparent in the design, e.g. the grille of a car is often an explicit design cue. Implicit design cues are things that cannot be distinguished but make sense when they are present, this can be shapes that help convey overall impressions such as dynamic or safe. These shapes can be implemented in different ways across a product range but they emphasise the same values. Explicit design cues can be value based or arbitrary, but implicit design cues are always value based in order to help create recognition (Karjalainen, 2007).

3.2 Ergonomics

Ergonomics is the study of how the interaction between people and a product or system is performed. The purpose with ergonomics is to enhance the human machine interaction and make the user environment around a product more favourable. By considering ergonomics as a part of the engineering development process it is possible to create benefits on several different social planes; for the individual, for the company or organisation and for the society in general (Bohgard, et al., 2008).

These different segments all benefit from good ergonomics but on different levels. On an individual level it could mean better safety, decreasing work related injuries, decreasing risk for injury, satisfied users, less mental work load, increased confident etcetera (Bohgard, et al., 2008).

On company and organisational level it could lead to higher productivity and quality, higher competitiveness, increased customer market and sales, possibilities to find other market segments etcetera (Bohgard, et al., 2008).

For the society it is favourable in that way that it increases the competitiveness on the market, it increases safety and decreases working related injuries, it creates a better economical situation, less absence due to illness and it can increase exports etcetera (Bohgard, et al., 2008).

The following section will present important parts of physical as well as cognitive ergonomic aspects that are vital to understand when designing a vehicle.

3.2.1 Physical ergonomics

Physical ergonomics concerns aspects that are connected to the physical structure of the human. This is often connected to mechanical interaction between the user and a product or system, how forces and moment affects the body. It is also about the body measurements, anthropometry, and how measurements proportions differs from different populations (Bohgard, et al., 2008).

Anthropometry

The anthropometry data presents normal distributed measurements of the body in tables sorted on specific populations. These measurements are often presented as X percentile. This means that by using measurements for example a 95-percentile man would statically mean that 95 percent of the men in that population are smaller. Anthropometry connected to ergonomics is consequently one important tool in order to adjust a working environment to its users. This could be seen in applied anthropometry when "designing for all". This means that the user population is somewhat diffuse and consist of both men and women. This increases the need of customisation and adjustability of the product or system and it is often suitable to look at the population varying from 5-percentile female to 95-percentile male (Bohgard, et al., 2008). However, when using this kind of data it is very important to consider that anthropometric dimensions are poorly correlated. This means that people with the same stature according to the data tables actually can have very individual proportions when it comes to leg lengths, arm lengths, back length etcetera (Happian-Smith, 2001).

Presented in Figure 3.1 is a comparison of 5-percentile woman and a 95-percentile man in both sitting and standing posture. The difference in dimensions is then presented in Table 3.1 in order to simplify the actual variance of the dimensions. The dimensions are gathered from Bodyspace: Anthropometry, Ergonomics and the Design of Work, Table 10.7 Anthropometric estimates for Swedish adults (Pheasant, 2003).

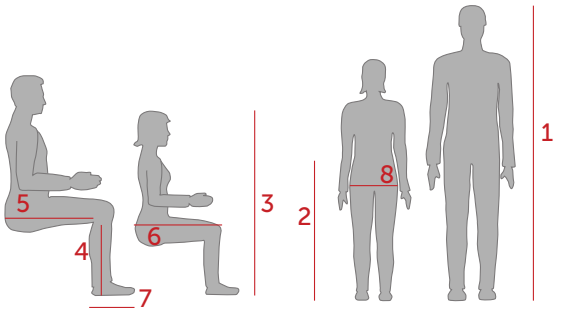

Figure 3.2 Comparison 5-percentile woman and 95-percentile man. The numbers are connected to the table below.

As an additional tool to anthropometrical tables there are also computer-based manikins within CAD-programs that can be customized according to data based on anthropometrical findings (see Figure 3.2). These manikins could be used as guidance when designing a working environment but it is still important to test the design in full-scale mock-ups to identify other issues (Happian-Smith, 2001).

Dimensions (mm)	5th %-ile female	95th %-ile male	Difference
1. Stature	1540	1850	310
2. Standing elbow height	905	1180	275
3. Sitting height	805	970	165
4. Popliteal height	350	475	125
5. Buttock-popliteal length	430	530	100
6. Buttock-knee length	525	645	120
7. Foot length	225	290	65
8. Hip breadth	315	410	95

Table 3.1 Important anthropometric data for the project

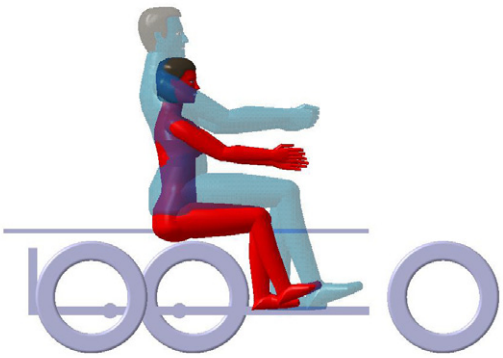

Figure 3.3 3D CAD Manikin from Catia V5

Driving and seat ergonomics

The driver environment is highly dependent on where the most important operating devices are placed in relation to the driver seat. A good design of a driver seat should urge the driver to choose a good ergonomic posture. The seat should lean backwards between 10-15 degrees and the backrest should be angled backwards so it creates an angle of 105-110 degrees towards to the seat. The seat should also have an adjustable support for the S-shaped curve of the back. The thigh should have an angle against the horizontal plane at around 10-15 degrees and the knee should be bent 60-70 degrees (Bohgard, et al., 2008).

The steering wheel is the most important control and it should be between 400-450 mm in diameter and the steering column should create an angle towards the floor of approximately 50-60 degrees. The most important and most frequently used controls should be placed in a comfortable distance from the seating position in such way that they easily could be manoeuvred during driving (Bohgard, et al., 2008).

The optimal seat height is in many cases close to the popliteal height. If this cannot be achieved it is better to adapt the height so it is lower compared to the popliteal height rather than too high. It can consequently be more suitable to adapt the seat height to the 5-percentile female if a compromise needs to be done. The seat depth should not be greater than the buttock-popliteal length since it results in a non-effectively engagement of the backrest and leads to unacceptable pressure on the back of the knees. The minimum ergonomic requirement for the seat width should not be less than 25 mm less on either side of the maximum breadth of the hips. These measurements are valid if the seat does not have any armrests (Pheasant, 2003).

The backrest of the seat is generally more effective in supporting the weight of the trunk the higher it is. Even if this always is desirable it could sometimes be more important to consider other requirements, such as the mobility of the shoulder area. The backrest types are therefore divided into three areas: the low-level backrest; the medium-level backrest and the high-level backrest. The low-level backrest provides support for the lumbar and lower thoracic region and ends below the shoulder blades. This allows for movement freedom of the shoulders and arms and requires a backrest of 400 mm. The medium-level backrest also supports the upper back and shoulder regions but also gives support on mid-thoracic level. The height of the backrest then needs to be around 500 to 650 mm. The high-level backrest gives support for the whole back but also the neck and the head. In this case an overall backrest height of 900 mm is required (Pheasant, 2003).

Regardless the backrest height it is preferable for the shape of the backrest to be adapted to the S-shaped contour of the spine in order to give good support to the lumbar region. To take full advantage of the lumbar support it is necessary to provide clearance for the buttocks. It could therefore be appropriate to leave a gap between the seat surface and the bottom edge of the backrest. It is however important to consider that the S-shaped curve of the lumbar does not become too excessive, since this is worse compared to no curve at all. A lumbar pad that at its maximum protrudes around 40 mm is suitable to support the back in a favourable position close to the normal standing (Pheasant, 2003).

In addition to these guidelines the Department of Human Sciences at Loughborough University has published guidelines of how the driving ergonomics within a car should be optimized. The following aspects are important to consider for seat adjustability (Gyi, Sang, Haslam, & Williams);

- The driver should be able to see as much as possible of the road. The driver should consequently be able to adjust the height of the seat to have good visibility but not touch the roof.
- The driver should be able to fully depress the pedals. It should be possible to adjust the height and the horizontal position of the seat.
- The driver should be able to support his/her thighs along the length of the seat cushion to avoid pressure behind the knees. The seat cushion should therefore be possible to angle.

- The driver should be able to provide continuous support along the length of the back and up to shoulder height. The backrest should be adjustable vertically.
- The driver should be able support the lumbar in order to give even pressure along the backrest. The seat should have a built in possibility to adjust lumbar support in the backrest.
- The driver should be able to adjust the steering wheel to get clearance for thighs and good visibility for the display panel. The steering wheel needs to be adjustable vertical as well as horizontal.
- The driver should be able to adjust head restraint to ensure the risk of injury is reduced in the event of a car accident. The head restraint consequently needs to be adjustable both vertical and horizontal. (Gyi, Sang, Haslam, & Williams)

Body postures

The relation between the working environment and the human body dimensions decides what kind of postures that need to be taken in order to perform a task. In order to avoid body postures that provide unhealthy loads one should consider the following recommendations in the design (Bohgard, et al., 2008):

- Facilitate the possibility to vary body posture as much as possible
- Avoid front tilted posture for head and body
- The upper arms should be as close to the body as possible, working with hands above head is only allowed for very short periods of time
- Avoid twisting and asymmetrical postures
- Avoid postures where joints need to be positioned in stretched out position for longer periods of time
- When there is a need of heavy muscle power, the body part that carries the load should then be positioned in such way that maximum power is retrieved.
- Avoid high pressure on sensitive tissue when designing support structures

If a task requires lifting it is important to consider the possibility to lift the object with bent knees in somewhat front tilted posture without twisting or bending the back. It is also important to be able to stand with quite broad distance between the feet on a stabile surface. The recommendation for heavy work is to have the work surface between 150-400 mm below elbow height (Bohgard, et al., 2008).

Vibration exposure

Vibration exposure means that energy is transferred from a product to the user with the possible result of different types of injuries. Whole body vibrations are mainly discovered within different types of vehicles and could contribute to back and muscle discomfort and nausea. Vibrations could furthermore injure the hands, which can cause gaucherie, decreased precision and lowered working ability. European Parliament has set up directives regarding minimum requirements for daily vibration exposure. These are categorized into two categories; Effort values and Threshold values (Bohgard, et al., 2008).

Infringed effort values sets demand on the employer to take action and fix the issue as well as offer a medical examination. These values are for hand and arm vibration 2,5 m/s2 and for whole body vibration 0,5 m/s2.

Threshold values are not allowed to be infringed. For hand and arm vibrations the value is set to 5,0 m/s2 and for whole body vibrations 1,1 m/s2.

Climate

The climate environment in which a user operates is very important to consider when designing and constructing a new product. There are several known ergonomic issues connected to different types of climate but the technology development of new materials has provided new solutions. An example of this is better quality clothing adapted for different environments (Bohgard, et al., 2008).

The heat balance of the human body is established by the interaction between the energy production of the body and the heat exchange that constantly occurs with the surrounding environment. This energy exchange is influenced by several different climate parameters and what kind of clothes a person is wearing. The climate parameters that need to be considered are; air temperature, average radiation temperature, air humidity and air velocity (Bohgard, et al., 2008).

Exposure to cold climate, less than 10 degrees Celsius, does mainly result in discomfort but if the exposure time is long enough it could give rise to permanent injury. Local injuries on feet and hands are common but the cold climate could also affect the physical and mental working ability. An important aspect to consider in cold climate is that the air velocity affects the perceived coldness. For example; an air temperature of minus 5 degrees Celsius and an air velocity of around 40 km/h give a perceived temperature of minus 14 degrees Celsius (Bohgard, et al., 2008).

Discomfort and injury could also rise due to the difference in energy that different body parts emit. The discomfort often increases due to local draughts, temperature variances from different surfaces or temperature variance between body parts (Bohgard, et al., 2008).

3.2.2 Cognitive ergonomics

Cognitive ergonomics focus on how the human perceives information from the surrounding environment and process information for interpretation. The cognitive process of how humans deal with information could be simplified by Wicken's model (see Figure 3.3). The information process model includes; sensory input, the sensory buffer, attention, perception, short-term memory, long-term memory, decision-making and problem-solving, response and a feedback loop. All are parts of the cognition and are executed both as serial and parallel processes, meaning that we can receive information at the same time as we handle and process information (Bohgard, et al., 2008).

The quality of the information differs depending on how much information that is presented at once and is dependent on surrounded disturbance of different kind. Despite bad quality of the information the human could still make the right decision by using the power of deduction and experiences, but consequently with higher effort. This is made possible because of the use of sensory modalities and because of the fact that some processes are executed unintentionally. Furthermore the brain often uses simplified models because of the limitations of the cognitive capacity. Examples of this could be patterns recognition, grouping and rule of the thumb, just to decrease the mental effort (Bohgard, et al., 2008). The cognitive process is consequently close related to, and affected by the concept of the gestalt laws and semiotics that were presented in chapter XX Industrial Design, Gestalt aspects and Semantic aspects.

It is important to understand how the human cognition process actually works in order to create a good design. A user interface should present the right information at the right time and by doing so give cues to the user of how to act and ease the mental workload. It is also important to minimize and organize the information that is presented to the user, since the memory only can process 7 +- 2 "information chunks" at the same time (Bohgard, et al., 2008).

The following design principles should work as guidance in the product development process. The principles are divided in to four categories (Bohgard, et al., 2008);

Awareness

- Minimize the time and effort for finding information
- Closeness, present related information near each other
- Utilize multiple sources of information

Perception

- Develop displays with good readability
- Avoid too many information levels in order to be able to make a decision
- Avoid processing of data that only refers to special knowledge
- Utilize redundancy
- Avoid similarity between objects

Memory functions

- World knowledge, minimize the information that puts unwanted burden on the memory
- Predict system status
- Coherent presentation, match a new design with the users experiences

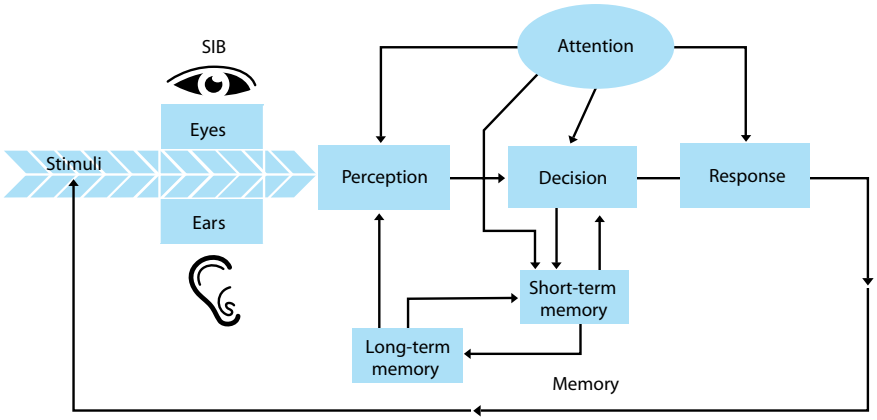

Figure 3.4 Wicken's model for human process of information

Mental models

- Illustrate the real system
- Animated object should match the mental image

3.3 Technical aspects

3.3.1 Frame

Motorcycle frames can be made of aluminium or steel and are generally constructed by tubes, pressed metal sheets or a combination of both (Motorcycle Mechanics Institute, 1994). Metal sheet frames are also called monocoque frames where the outer parts of the construction are used for carrying the load instead of having a traditional tube frame (Davies, 2003).

3.3.2 Steering

Two factors that affect steering the most are rake and trail. Rake is the angle of the steering head axis relative to a vertical plane. Trail is the distance between the point where the wheel touches the ground (i.e. vertically below the centre of the wheel) and a point on the ground where an extension of the steering head axis would hit. The two work together and affect the handling of the motorcycle. Smaller rake allows for faster turning but reduces high speed stability while large rake and trail make the turning slower but more stable at higher speeds (Motorcycle Mechanics Institute, 1994).

3.3.3 Suspension

The engineering of a suspension system is to a large part based on a vehicle's sprung and unsprung mass. Sprung mass include all parts of the vehicle that are supported on springs and unsprung mass are all parts not supported on springs, typically the wheels and other parts that are between the suspension and the ground. More unsprung mass in a vehicle requires heavier springs to return the suspension to its home position after driving over a bump. The suspension system also affects the handling of the vehicle (Motorcycle Mechanics Institute, 1994).

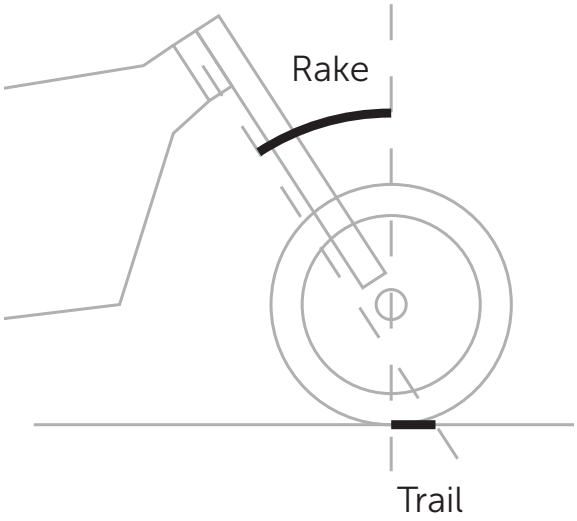

Figure 3.5 Rake and trail described

Front suspension

Telescopic suspension systems are the most commonly used among mopeds and motorcycles (Motorcycle Mechanics Institute, 1994), however this is unfavourable with sidecar designs because of the dive effect when braking. The leading link suspension system on the other hand provides an antidive effect and is common among sidecar motorcycles (Grundevik, 2010). The system is however more expensive to produce and leads to more unsprung mass (Motorcycle Mechanics Institute, 1994).

Figure 3.6 Leading link and telescope forks

Rear suspension

The rear wheel is most often connected to the frame via a swing arm. The swing arm allows the wheel to move up and down and the movement is controlled and dampened by springs and shock absorbers (Motorcycle Mechanics Institute, 1994).

3.3.4 Powertrain

The powertrain in this report in defined as the electrical propulsion system on the vehicle and consists of motor with transmission and energy package.

Motor and transmission

Green Team conducted a study of different types of electrical motors with the purpose to find the best solution for their concept. The different motor types were evaluated using a Pugh matrix where different characteristics were compared between alternative motor types. The characteristics that were evaluated were (Green Team, 2010).

- Weight
- Cost
- Ease of maintenance
- Complexity
- Assembly cost
- Modularisation
- Reliability
- Volume
- Efficiency
- Development feasibility

A motor that is directly connected to the wheel was put as a reference in the matrix and was compared to a motor connected to the wheel by a chain, a motor connected to a driveshaft and a hub motor (Green Team, 2010).

The result showed that a hub motor was rated somewhat higher compared to the reference. However, the decision from the Green Team was to go with the reference motor since this technique is more mature and optimized for its use (Green Team, 2010). However, since the hub motor still could be a suitable alternative it was decided in collaboration with the CSE team that this project should include the hub motor as propulsion device.

Energy package

The information presented here is based on a technology report provided by the CSE-Team who did a study with focus on different energy package systems (Nilson, Ahmad, & Mårtensson, 2010). This chapter will present the conclusions of that study and present the chosen energy package that should be carried by the vehicle.

The study shows that battery technology is the most suitable energy package for the vehicle when comparing to Internal Combustion Engine Technology, Fuel Cell Technology and Compressed Air Technology. The main reasons are:

- Mature Technology which is available on the market
- Renewable energy (electricity) is used and many batteries can be recycled
- Flexible range depending on the size of battery
- Highest well-to-wheel efficiency
- Cost effective, and prices are dropping further
- Positive future trends, due to rapid technology development
- Customizable in shape

The technology report further investigates the critical users of the vehicle in order to identify the battery performance that is needed. The mail distribution segment was identified to have the highest requirements regarding battery performance. A thorough investigation of the battery industry and different types of battery packages show that the most suitable battery type for a vehicle with focus on postal distribution is Lithium-Iron-Phosphate battery.

Lithium-Iron-Phosphate, LiFePO4, is recently commercialized and a relatively expensive battery type when looking at price per kWh. However, for the distribution industry it is the total cost that is of importance. A long battery lifetime is consequently of great importance and when comparing price per cycle it is shown that Lithium-Iron-Phosphate has a very good ratio. The research also showed that large investments are made in this technology, which implicates that there could be lower prices in the future.

Performance facts:

- Charging time: fast 0.5 hour slow 3 hours
- Recharging cycles: <2000
- Operating temperature: -20 to 60 degrees Celsius
- Cost per cycle: around 30 SEK (for an effective capacity of 200 Ah)
- Volume around 0.160 m3

Keys

There are several ways of controlling the ignition on a vehicle. The most common way is to have a mechanical key that controls the ignition. Alternatives are transponder keys and remote controlled keys. A transponder key consists of electronic coded transponder chips of a passive type, which means that it does not need a battery. The ignition socket reads the code of the chips when the key is placed in the ignition and starts the engine. These kinds of keys are very secure but could be expensive to replace if broken.

Remote controlled units utilize infrared or radio transmission to communicate a coded signal to a receiver. The code is interpreted by the receiver, which in turn signals to the system what to do. These kinds of remote controlled systems are very common on cars to remote control the locking mechanism on doors.

3.3.5 Materials and production methods

This chapter will present material and production alternatives that could be suitable for the project. The purpose of this material and production mapping is to understand the different properties in order to develop a product that could be configured to suite these processes. The different material and production methods are possible candidates after the material and production screening (see chapter 4 and Appendix B). This information should however not been seen as finalized and optimized, but rather as a foundation to work from when taking the development process into finalization stage.

HSLA steel

High Strength Low Alloy steel is a strong, lightweight and low cost material compared to standard mild steel. The material is not suitable for heat treatment and needs corrosion protection if it is exposed for more demanding environments. The material is used for pressed sheet vehicle bodies, bumpers and chassis parts. It could also be found as material in welded pressure vessels, truck bodies, mechanical shovels and scrapers, railway goods and wagons (Taylor, 2007).

Steel is reused and recycled to a very large extent all over the world. Recycling of steel is very economically advantageous since it requires less energy and material resources than using virgin iron ore from the ground (EnviroMetal).

Possible production processes that could be suitable for steel are:

Profile draw bending is suitable for different types of profile pipe constructions that require quite small radius. The pipe bending procedure could both be done manually and as an automatic process (Gustavsson, 2006). Before sealing a hollow pipe it should be flushed with hot linseed oil to prevent inside corrosion (Taylor, 2007).

Sheet metal press break forming is suitable when a surface should be formed as a single curved element. Fastening the material to fixtures and using a press can easily bend the sheet metal. This kind of tooling is very simple and adaptable to a wide variety of shapes (Nikhil, 2009).

Stretch forming is an alternative method to press break forming where the sheet metal is clamped around its edges and stretched over a die or form block. Stretch forming is primarily used within aircraft and automotive industry (Nikhil, 2009).

Hydraulic pressing is suitable when a more complex surface is required compared to bending procedures that produces a curve in one direction. The process however has a quite high initial cost (Taylor, 2007). The sheet metal is pressed between two tool halves to shape the material and the benefit with the method is that it will be able to produce parts with small radius (Prototal).

Flex forming is as hydraulic pressing suitable when a more complex surface is required. The method allows for undercuts, double curved faces and deep values. It could also shape pre-painted metal parts. The process produces very smooth surfaces which require minimal post-treatment and it only requires one tool half. The process consequently reduces both lead time and tooling costs. (Prototal).

Polypropylene, PP

Polypropylene is a thermoplastic that is lightweight and rigid. It has very good chemical resistance as well as good mechanical properties such as fatigue and impact resistance. It is also a low cost material (Taylor, 2007). PP is also a recyclable plastic (Bruder, 2009). However the material needs to be UV- and oxygen stabilised to be applicable outside. The material has been applied on various products, some examples are; garden furniture, car battery cases, car trim and car bumper cores (Taylor, 2007).

Acrylonitrilebutadeine-styrene, ABS

ABS is a tough strong material with good impact and scratch resistance. It is furthermore a lightweight material with high finish and produced within a medium-pricing segment (Taylor, 2007). ABS has additionally good recyclable properties (Bruder, 2009). It does however require UV-stabilisation. Example of usage could be vacuum cleaners, car bumpers and dashboards and kitchen appliances (Taylor, 2007).

Suitable production processes for PP and ABS are:

Vacuum forming is a common way to process thermoplastics. The plastic is heated and a mould tool is raised to form the plastic material in a sealed vacuum container. This process is not suitable for high precision parts as it has a positional tolerance of +- 1.0 mm. It is a relatively cost efficient method where the tool cost varies from 5000 SEK to 50000 SEK. The method is suitable for volumes of 10 to 10000 pieces. The cycle time is about 5 minutes (Taylor, 2007).

Injection moulding is the most common process for achieving complex parts in plastic materials, the tolerance is +- 0.1 mm. Plastic pellets are melted and injected under pressure into a water-cooled steel mould. The pressure is maintained until the part has cooled off and has solidified. Set-up costs are high and vary from 50000 SEK to 350000 SEK depending on size and complexity of the part. The process is suitable for volumes of 5000 to over 10 million pieces (Taylor, 2007).

TELENE, Dicyclopentadiene DCPD

TELENE is a highly engineered thermoplastic with low weight and very high impact resistance even at low temperatures. The material also allows for very high freedom in the design work and the surface is very smooth and enables for very high painting quality (Bourghardt, 2010). The material has furthermore very good corrosion and chemical resistance. The combustion of the material is defined as clean, letting out CO, CO2 and H2O and the ash content, HCI, is only <0.3% with no heavy metals included. Possible application areas are vehicle casings and bodies, pools and housing equipment (RIMTEC corporation).

The material is moulded in aluminium forms and it is possible to integrate different types of fittings to minimize finishing work and ease assembly. The method has short lead times and relatively price efficient tools since the method doesn't require high pressure (Bourghardt, 2010).

The production method is cheaper compared to injection moulding and a finalized painted detail has approximately the same cost as a detail that only is injection moulded without finishing work. The forms are somewhat more expensive compared to vacuum forming. However, vacuum forming does not allow for integration of fittings and the detail cannot vary in thickness. The price of a finalised painted detail that is vacuum formed is higher compared to a finalised part in TELENE (Bourghardt, 2010).

High Density Polythene, HDPE

HDPE has very good chemical resistance and high elasticity. The material also has very good elastic properties and a very low cost. The properties for tensile strength and stiffness are not that good and the material is difficult to paint but it is easy to ink the plastic during production. The material is easy to recycle either as material in new products or as environmental friendly energy (Bruder, 2009). Typical usage is barrels, water tanks, ski boots and kayaks (Taylor, 2007).

Rotational moulding is suitable for PE plastics and simple hollow parts. The plastic is melted and put inside a mould that rotates. The rotational force spreads out the melted plastic in the mould until the coat is evenly distributed. The mould is then chilled and the solidified component removed. The cost for the moulds is relatively low since there are no demands on high pressure and the method is suitable for volumes between 10 to 10000 pieces. The method is not suitable for fine sharp details and the production cycle time could take up to 20 minutes for larger parts (Taylor, 2007).

Polycarbonate, PC

PC is a very strong, stiff, hard, tough and transparent engineering plastic and has excellent mechanical properties. The plastic has limited chemical and scratch resistance and has a tendency to yellow upon long term exposure to UV light. These constraints could however be solved by adding the right additives (Alliance Polymers, Inc. , 2007). PC does however have a quite high price tag (Ida Fritzon, 2006). The material can be reused both mechanically and chemically (Bruder, 2009). The material is used in product such as helmets, lamp lenses, shatterproof windows and sunglasses (Taylor, 2007).

Polymethylmethacrylate, PMMA

PMMA is a hard, brittle and crystal clear transparent plastic. It has very good outdoor properties and is easily machined (Taylor, 2007). The material has very good optical properties and is light and heat resistant. The plastic is harder compared to PC and is therefore less sensitive to scratches. It is also a cheaper alternative compared to PC but does not have the same high mechanical properties as PC. PMMA has very good recyclable properties and should primarily be recycled as material. It could however also be used as energy recycling as it only turns in to water and carbon dioxide (Bruder, 2009). Examples of different products where PMMA could be found are; taillights, illuminated signs, laminated bulletproof windows, and lenses (Ida Fritzon, 2006).

3.3.6 Environmental product development

The environmental impact of a society is largely decided by the products that are made, how they are used and how they are discarded. To decrease the environmental impact it is important to consider these aspects early in the development process. In practice it involves creating cleaner and less material demanding products and processes, creating products that consume little energy and have a small impact during use and creating products that are easy to disassemble and recycle (Persson & Antonsson, 2001). General principles regarding low environmental impact design are presented in Appendix C.

3.3.7 Cradle to cradle

Cradle to cradle is a strategy that does not stop at trying to minimize impact but instead strives to achieve a positive impact of products instead of being less bad. The core idea is that all materials that are to be used shall be safe for humans, animals and nature and that they should fit in either a biological or a technical metabolism. The basic concept is to use truly recyclable materials that can be separated from each other at the end of the lifecycle, and to put them back in their respective metabolisms afterwards. Biodegradable materials will be returned to decompose in nature and technical materials will be recycled for reuse in the production of new products. Waste in one process becomes food in the next, just like in nature (Braungart & McDonough, 2009). Implementing cradle to cradle is a very thorough and difficult process, therefore the concept is mostly used as inspiration for ideas during the development and to help push the development in this direction.

3.4 Constraining aspects

3.4.1 Legislations

When vehicles are to be used in traffic, many rules regarding traffic safety needs to be taken into account. Regulations relevant to this project are presented below. The information in this section is referenced from ”Vägverkets föreskrifter om mopeder och släpvagnar som dras av mopeder (VVFS 2003:24)” (Vägverket, 2003) unless otherwise noted.

Structure and propulsion

A moped is defined as a two-, three- or four-wheeled vehicle with a maximum velocity of 45 km/h and a motor effect of maximum 4 kW if it is electrical. The propulsion system shall be protected to avoid injuring users. The battery shall be fastened and placed or protected to prevent foreign objects to come in contact with the poles or other sensitive parts. Batteries should not be placed in the driver area, but if this is done, adequate ventilation and protection from battery acid must be provided. A connector for trailer electricity is to be present when it is possible to tow trailers. The vehicle cannot have protruding parts that may cause damage or injury in a collision.

Driver area

The moped shall have a driver area that is spacious and allow a proper riding position. Passenger seats are not allowed in front of the driver seat. The seat must be at least 450 mm wide. The steering shall be designed to minimize the risk of injuries or malfunctions. It must provide good course stability and precise steering. An envelope of free space must be provided around the steering device; 50 mm in the driving direction and 80 mm elsewhere.

Pedals must be reliable and be provided with an anti-slip surface. The throttle shall be handled safely and easily and be manoeuvrable with the right hand or foot. Brakes shall be controlled by hand or foot. Hand controlled brakes must be manoeuvrable without moving the hand from the steering device. Brakes shall be able to decrease the speed of the moped and make it stop quickly and safely. Three- and four-wheeled mopeds require a parking brake to hold the vehicle even if the driver has left the vehicle. Gear controls must be useable in a comfortable, easy and safe way.

Controls for lights are to be placed to enable quick and comfortable use without risk of turning on the wrong lights or turning off the headlights. Mopeds must be equipped with an approved horn, speedometer and rear view mirrors. Drivers of three- and four-wheeled mopeds with bodies can use seat belts instead of a helmet. A body is a rigid construction that can take up forces in a crash (Transportstyrelsen, 2010). Helmets are not mandatory when the vehicle is used within company compounds, parking lots, cemeteries or parks (Transportstyrelsen, 2010).

Lights

Lamps or reflexes that are used in pairs are to be placed on the same height and on the same distance from the centreline of the vehicle. On asymmetrical vehicles this should be fulfilled as much as possible. Red light is prohibited in the front of the vehicle and white light is prohibited in the back, except for license plate lamps, backing lamps and such.

The moped can have one or two headlights that can provide two levels of light intensity. Three- and four-wheeled mopeds must have one or two positioning lights in the front and back, placed no further than 400 mm from the outer edges of the vehicle and between 350 and 1200 mm from the ground. The moped shall have one or two red brake lights in the rear that indicate when the brake is being used. The distance between two brake lights cannot be less than 600 mm or 400 mm if the vehicle is narrower than 1300 mm.

Two direction indicators showing orange light must be placed in the front and the back. They cannot be placed more than 400 mm from the outer edges of the moped and must be at least 500 mm from each other. Three-wheeled moped direction indicators can be placed between 350 and 1500 mm above the ground. They must be visible 80° outwards and 20° inwards

Three- and four-wheeled mopeds are allowed to have a white backing lamp in the rear. They should also be provided with reflexes that show the width of the vehicle from the front and back. The reflexes can be included in other lamps.

3.4.2 Intermodal containers

The possibility to have production of the vehicle abroad could be a cost efficient alternative for the business. In order to not exclude this possibility the measurements of intermodal containers were gathered. Since cargo vessels are a very common and cost efficient way of shipping goods between continents one could try to optimize the vehicle measurements in order to fit these containers.

The intermodal container from Maersk has the following inner dimensions (Softtruck):

Length: 5.906 m

Width: 2.35 m

Height: 2.393 m

Volume: 33.3 m3

4. Methods

This chapter describes why and how different methods have been implemented during the project. The descriptions will provide an introduction to each method and sources are provided if more information is required. The methods are presented in alphabetical order under each main section.

4.1 Requirement gathering methods

The requirement gathering methods are used to aid the requirement specification process and consist of gathering, processing and presentation methods.

4.1.1 Competitor analysis

To obtain an overview of the main competitors to this type of vehicle, a brief competitor analysis was conducted. Based on information from the CSE Team, further information was gathered from websites, brochures, images and direct observations of the different vehicles. Data regarding performance, functionality, appearance and usability was identified and summarized. This method was created by the project team.

4.1.2 Focus group

A focus group is a group discussion where six to ten people discuss a set of predetermined topics. The discussion can cover e.g. a product, a work method, a system or how a task should be performed. Mediating objects (images, photos or physical products) can be used to start the discussion. It is a time efficient method that mainly provides qualitative data (Bohgard, et al., 2008).

4.1.3 Interview

An interview is the most basic way to gather information about what a person thinks. A semi structured interview is an interview where questions are prepared beforehand to serve as support for the interviewer. The questions are used as guidance but also allow the discussion to evolve based on what is said during the interview. It is important to consider that the interviewer and the situation can affect the answers; the interviewee can adjust the answers depending on who else is in the room or what organization the interviewer is affiliated with. The semi structured interview enables gathering of both qualitative and quantitative data but should be used in combination with observations to see how people really behave in use situations (Bohgard, et al., 2008).

4.1.4 KJ analysis

The KJ analysis enables sorting of complex data through a bottom-up approach. Each piece of information is placed on a board one at a time, if the current piece of information is related to something that is already on the board they are grouped together. This is done until all information is placed in a group. Each different group is then given a name that describes the content of that group (Karlsson, 2007).

4.1.5 List of functions

A list of functions aims to define the functions that a product has to be able to perform. The functions are stated as a verb plus a noun and appropriate limits. The functions should not be solution oriented but instead as abstract as possible. First the main function is identified, then all the sub-functions required to perform the main function. All functions are then rated on a scale from one to five regarding how important they are to the user (Wikström, 2004).

The method was expanded to include categories (Happian-Smith, 2001) to make it easy to see which focus areas are perceived to be of most importance.

4.1.6 Literature review

Literature reviews are used to gather background information about a subject. Information can be found by searching in databases and on the internet to find articles, books, guidelines and regulations within the current topic. The method can be used to describe how much is known about a certain subject or to gather domain related knowledge (Bohgard, et al., 2008).

4.1.7 Observation

Observation is a way to learn how people behave in real use situations. It provides information about e.g. how a product is used and how a task is performed. Observations can unveil user behaviour that they are not aware of themselves, information that therefore is hard to acquire through interviews. The method enables gathering of both qualitative and quantitative data (Bohgard, et al., 2008).

4.1.8 Product breakdown analysis

In order to grasp what parts the current product were made of and to understand the structure of the vehicle, a product breakdown analysis was created. The vehicle was divided into different functional areas and the components of these areas were defined to a certain level of detail. This can be done from photographs or by investigating a physical product. The parts are sorted to form sub-groups to show the relation between different elements. The result is then visualized in a graphical way. The method was used with the purpose of visualizing the complexity and to create awareness of all the things that need to be included. An additional purpose was also to utilize these functional areas as starting points in the development process in order to more easily build a new design. This method was created by the project team.

4.1.9 Requirement specification

The requirement specification serves as a control document for the development process and specifies what the product must be able to do (Baxter, 1999). The final requirement specification structure was provided by the CSE Team and consisted of a matrix where each requirement had a set of properties. The properties; Metric, Weight, Type, Area and Comment, all help to specify the requirement or aid in sorting the requirements. Metric defines measurable limits for the requirement, Weight states the importance between 1 and 5, Type specifies if the requirement is a basic, desired or unspoken one, Area divides the requirements into different categories and the Comment field contains extra information when needed.

4.1.10 Segment matrix

Based on the customer segment matrix presented by Karlsson (2007) the method aims to find possible market segments and to estimate the needs of each segment regarding a few key aspects. A brainstorming session generated a large set of potential areas of use for the vehicle. The use areas were then sorted through a KJ analysis. A set of critical performance aspects were defined, e.g. cargo amount, compactness and operating time. The performance requirements for each area of use were then estimated. The results were colour coded to identify users with high demands.

4.1.11 User profiling

User profiling is a method to describe users' characteristics, abilities and limitations. Aspects that are important for how well the user can use the product are described in the profile. The focus should be on diversity of the users and present their background in terms of what kind of user they are (primary, secondary, side- or co-users), their education and levels of knowledge regarding use of the product. The profile should also include how often the user uses the product, what type of influence the user has on the choice of product or how it is to be used. It should include emotional aspects such as if the user owns the product, if the user wants to send signals to other people when using it. The purpose is to generate a comprehensive image of the users and their qualities (Bligård, 2009).

4.2 Development methods

The development methods are meant to aid different parts of the product development process and consists of creative, framework, evaluative and validating methods. The chapter is divided in to two parts. The first six methods presented below were used within the creative process and the last seven methods, starting with concept scoring, are related to engineering processes.

4.2.1 Brainstorming

Brainstorming is a common method for quickly generating many ideas. A group is presented with a problem and asked to find as many solutions to the problem as possible. It is important to keep an open minded atmosphere, therefore no criticism or negative comments are allowed and divergent thinking and crazy ideas are encouraged. The moderator can propose a number of crazy ideas in order to lower self-censoring among group members. All ideas are documented during the session and evaluated afterwards (Bohgard, et al., 2008).

4.2.2 Image board

An image board is a collection of images and/or graphics put together in a composition to represent an intended mood or emotional response of a design. The method allows designers to express themselves and communicate beyond the limitations of written text. It can be used to confirm a design brief and to help make a team work towards the same goal. The images can be literal or abstract and can be used both to generate ideas and to evaluate different designs later in the process (McDonagh, Bruseberg, & Haslam, 2002).

4.2.3 Persona

Personas offer a way of focusing the development of a product to consider the needs of different users. It enables developers to avoid designing the product for themselves and at the same time avoid creating a general solution that "fits everybody" but that in the end nobody wants. Based on research and knowledge of real users, personas are created and described precisely in terms of whom they are and what they wish to accomplish (Cooper, 1999).

4.2.4 Product character definition

The product's own characteristics were defined in order to reach a consensus about the desired expression of the product and to serve as a starting point for the mood board development. A list of possible words were generated through brainstorming and divided in thematic groups. A first selection with the best candidates was made, and from this selection, the words were combined in order to find a set that

best matched the intended expression. The core values and main message of the Tugger Project were also taken into account to avoid too much overlap and three words were chosen in the end. This method was created by the project team.

4.2.5 SCAMPER

SCAMPER is short for Substitute, Combine, Adapt, Magnify or minify, Put to other uses, Eliminate or elaborate and Rearrange or reverse. The words make up a checklist of possible modifications that are used to generate ideas. It is a way of forcing the developer to go through many possible alterations which might lead to a solution of the problem (Baxter, 1999).

4.2.6 Sketching and visualizations

Sketches and images are used in different stages of the development process and for different reasons. Images are used for both exploration and communication; for the individual, within a team and to external stakeholders. An initial sketch can describe a fuzzy idea of something that requires further development while a more finished rendering can help sell a concept to a client or business partner. Sketches can be made traditionally and digitally in 2D as well as in 3D (Pipes, 2007).

4.2.7 Concept scoring

Concept scoring offers a way of ranking different concepts against an existing solution or a fictive baseline solution. The method is based on the concept scoring method presented by Ulrich & Eppinger (2000). In order to start ranking, a set of criteria is needed and were chosen as follows. A subset of the requirement list was created, containing the requirements which were perceived to be most important and most influential in this project. Their mutual importance was calculated by comparing a criteria to all others, stating if it is more, equally or less important than the other criteria. This generated an internal ranking that was divided in steps from 1 to 5 to set the weight of each criterion.

When this framework was created, the original product and the concepts were rated on each criterion on a scale between 0 and 5. The rating multiplied with the weight formed the score and all scores added together gave the total score. The total score of each contender was divided by the optimal score (rating 5 on all criteria) to achieve a normalized final rating. According to Wikström (2006) a concept is worth pursuing if the normalized rating is above 0,75. The different ratings were colour coded to identify the strong areas of each concept, to quickly find out what to take further from each concept. In the end the final concept was also added to the matrix to see how it compared to the earlier concepts.

4.2.8 DFX methods

During later stages in the development process, it is sometimes hard to link the requirements and needs to specific design problems. Because of this, teams practice DFX (Design for X) methods, where X can be one of multiple quality criteria such as serviceability, environmental impact or reliability to name a few (Ulrich & Eppinger, 2000). DFM and DFA are presented briefly below, further guidelines can be found in Appendix D.

DFM

The most common is design for manufacturing (DFM) that involves manufacturing costs. DFM requires a cross functional team to be applied effectively and should be started at the concept development phase. The DFM process comprises five steps; Estimate the manufacturing costs, Reduce the costs of components, Reduce the cost of assembly, Reduce the cost of supporting production and consider the effect of DFM decisions on other factors (Ulrich & Eppinger, 2000).

DFA

Design for assembly (DFA) is a part of DFM that minimizes the cost of assembly. The process involves keeping the number of parts down and maximizing ease of assembly. The latter is achieved by following the ideal characteristics of a part for an assembly; part is inserted from the top, is self aligning, does not need to be oriented, requires only one hand for assembly, requires no tools, is assembled in a single linear motion and is secured immediately upon insertion. Letting the customer assemble the product is also something that should be considered (Ulrich & Eppinger, 2000).

4.2.9 Finite element analysis

Finite element analysis (FEA) is a structural analysis technique that can accurately predict stress and deflection in a component by carrying out calculations on a CAD-model. The stress can be caused by for instance forces or heat. Before the calculations, the CAD geometry is divided into smaller segments which form a so called mesh. The density of the mesh determines how accurate the calculations are; high density means greater accuracy but also longer cal-

culation times. Conducting accurate simulations demand skill and experience, therefore this project will only perform basic simulations to find potential problem areas in the design (Hodkinson & Fenton, 2001).

The analysis was carried out in Catia V5 with the purpose to find weaknesses in specific parts and optimize the construction for good strength. It was an iterative process that included parallel processes such as how the assembly and manufacture process would be affected in several different configurations.

4.2.10 Material and production screening

A systematic screening of different materials and production processes was conducted in order to create a framework of possible materials and processes with suitable properties. The purpose of the screening was to create a foundation of possible materials and processes that could work as a starting point for the future finalization of the vehicle. The method does consequently not provide finalized and optimized solutions. The screening was divided into four plus one steps.

- Decide required properties of the materials for different parts
- Specify possible materials that fulfil the different properties. Collect both the best and worst solution so this information can give guidance later in the process when trade-offs need to be done.
- Match the possible materials and their properties to find good combinations. Further investigate these materials or material groups to find a first round of materials with acceptable properties and production methods.
- Study the chosen materials more in detail. How well do they meet all the requirements? If they are not of total satisfaction try to find new alternatives. This should be an iterative process.
- Optimize the selection by talking to production engineers and material experts. Also scan the market for applied versions of materials and production processes. (This step is not applied in this project since the product still is on a conceptual level)

This method was created by the project team.

4.2.11 Rapid prototyping

Rapid prototyping is a collection of technologies that enables creating physical models directly from 3D computer models. This enables "three-dimensional printing" of CAD models and the resulting parts are often plastic, but other materials are available as well. When working with prototypes it is important to define the purpose of the prototype and to establish the level of approximation in relation to the final product (Ulrich & Eppinger, 2000).

4.2.12 Target costing

Target costing is a methodology for developing products that need to be produced to a certain cost. It covers defining and realizing the total cost that is required to make the product profitable at its expected selling price in the future. To let the final price set boundaries early is in contrast to the more common approach to set the final price at the end based on the cost of production plus a defined profit. The whole process involves defining the product, setting the target, achieving the target and maintaining competitive cost. Since incorporating target costing fully is very extensive, this project only briefly incorporates the method (Clifton, Bird, Albano, & Townsend, 2004).

4.2.13 Turning radius simulation

Turning radius simulation is used to calculate how much the front wheel needs to turn to achieve a theoretical turning radius. The method was conducted using a spreadsheet program, trigonometry and linear algebra. The idea is to estimate the movement of the wheels during a turn by numerically calculating how the vehicle moves and plot the positions of the wheels during the turn. The angle of the front wheel can then be calculated and provide a rough estimate of how much the front wheel needs to turn.

The position of the rear wheel is set and the two other wheels are positioned relative to this using basic trigonometry. The difference between the positions of the front and rear wheels represent the direction of the vehicle. An increment size for the forward movement and for the vehicle's change of direction in degrees is decided. The vehicle is then moved incrementally by moving the rear wheel in the direction of the vehicle and rotating the vehicle around the rear wheel, since this is the pivot point when the vehicle turns. This requires the increments to be small compared to the size of the vehicle. The wheel positions are continu-

ously plotted in a graph and the increment values can be altered to reach the desired turning radius. The turning angle of the front wheel is then calculated through the angle between two consecutive positions of the front wheel. This method was created by the project team.

4.3 Project management methods

The project management tools are used to support the project itself and to increase the possibilities of it being successful.

4.3.1 *Weekly schedule template*

In order to plan in more detail than the original Gantt chart, a weekly schedule template was developed. This enabled planning of each week as the project progressed. Repeating and continuous activities were given a predetermined space in the schedule and check boxes to tick off when they were complete. This would ensure that less enjoyable but important tasks would be performed over time. This method was created by the project team.

4.3.2 *Gantt chart*

Gantt charts provide a way to illustrate the relationships between different activities and time. The simplest form is a horizontal bar chart, but this can also be developed to incorporate activity dependencies and completion rate. In order to construct a Gantt chart, the activities need to be identified, their sequence needs to be determined and an estimation of resources needs to be made. The activities are then drawn as bars and occupy a certain time on the X axis. This type of chart is widely used and common in project management software (Maylor, 2005).

4.3.3 *Work Breakdown Structure*

The purpose of a work breakdown structure is to divide large activities into small manageable units, thereby creating a hierarchical series of independent activities which are still part of the whole. The breakdown can be made in different ways and focus on activities, functions or deliverables. The breakdown is made until the parts are small enough for a person or a group can manage that part independently. It is important that interfaces between groups or persons with different responsibilities are taken into account to ensure that issues do not end up between different parts (Maylor, 2005).

4.3.4 *Risk analysis*

Risk analysis consists of three parts; identification, quantification and mitigation. Identification defines what risks there is that could affect the project. Quantification means estimating the likelihood of an event and how severe the effect would be if it occurred. Both aspects are rated from 0 to 4 and placed in a matrix with four severity areas; low, medium, high and critical as shown in Figure 4.1 (Maylor, 2005).

4.3.5 *Stakeholder analysis*

The stakeholder analysis aims to identify important project external people and organizations and rate their influence and involvement in the project. This is done to make sure that key stakeholders are not missed out or overlooked during the development. A list of stakeholders is generated through brainstorming, each stakeholder is then rated regarding their interest in the project and their power to influence the project. They are plotted in a matrix that shows how to handle them (Figure 4.2) (Chalmers Teknologkonsulter AB, 2009).

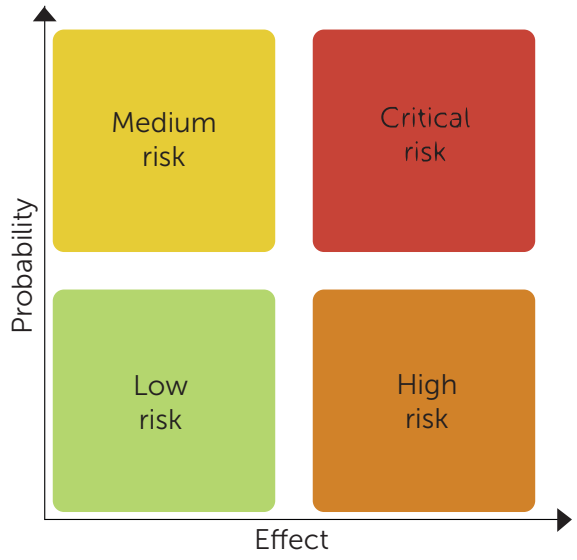

Figure 4.1 Risk severity matrix

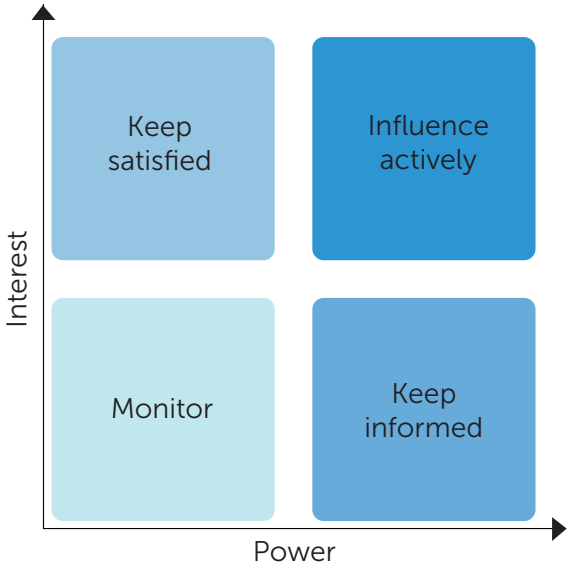

Figure 4.2 Stakeholder matrix

5. Process Description

This chapter gives an overview of the development process that was used in the project. An introduction to the different phases is given, while leaving the details of each phase for the coming chapters.

5.1 Process overview

The project work is divided into four main phases as described in Figure 5.1; one requirement gathering phase, an ideation phase resulting in three initial concepts, a refinement phase leading up to the final concept and finally an evaluation of the final concept. Each phase is described in detail in the following chapters. The project management methods described in chapter 4 have been used throughout all phases in an effort to keep the project on track and on schedule.

During the entire project there has been a lot of interaction and collaboration with Green Team and the CSE Team that has enabled the project to use information and build on ideas originating in their respective projects.

The process could be illustrated by the model shown in Figure 5.1. The model highlights the iterative development process where all the phases affected each other. The work within each phase gave input to the final result but in the same time provided new input to the other phases. The process therefore needed to be repeated several times in order to find suitable end results that were optimised for the product.

The project has also been influenced by external factors that continuously have added new information to the project. These factors are placed outside the dotted circle and was identified as:

Legislations – Most of the legislations were identified in the beginning of the process but new ones were discovered continuously and considered different parts of the vehicle and its structure.

Competitors – The competitor analysis provided information regarding performance and looks. However new information were added when new types of vehicle were revealed.

Users – User requirements were added to the project during the whole process

Old Tugger – New facts about the Tugger were added at some points during meetings with Douglas and the CSE-team.

Technology – Technology research around structures, parts, batteries and functionality was done during the whole process and added new information continuously.

CSE-Team business plan – The business development around the project was done in parallel to this project and gave new input at some stages. New input concerned important features of the vehicle and different types of user needs. It also gave feedback of other projects that the CSE team handled.

CSE-Team focus and scope – New findings in the business development changed the scope and focus of the CSE team business model. The outcome resulted in a shift of focus to mainly centre around the mail distribution segment.

Green Team powertrain research – Green team conducted their research parallel to this project and new information and ideas were added through meetings and contact throughout the project.

The external factors have consequently added complexity to the process and required the project to have a flexible development structure in order to adjust to new requirements.

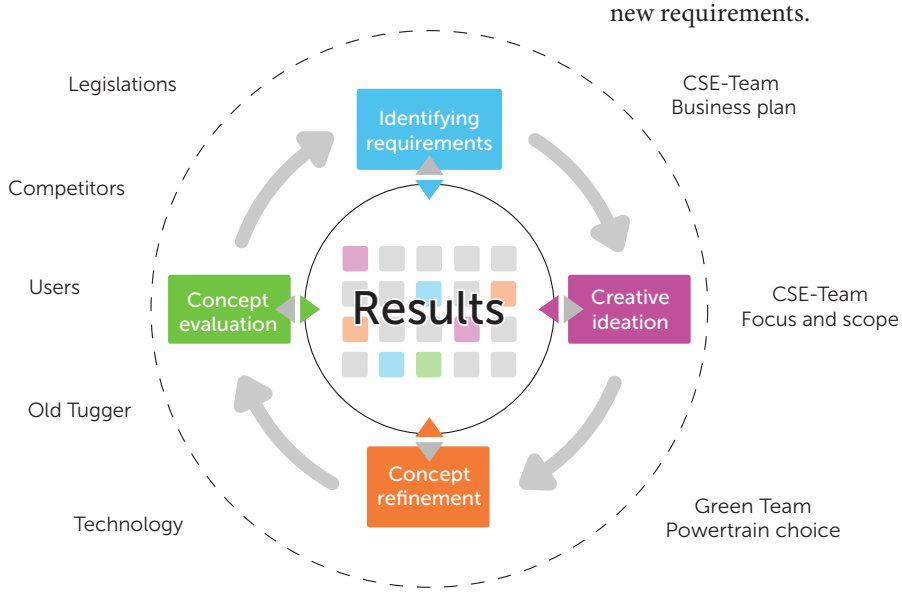

Figure 5.1 Process overview

6. Identifying Requirements

This chapter describes how the requirement gathering phase was conducted, where the information was collected and finally presents the resulting requirements from the work.

6.1 Introduction

In order to get a comprehensive picture of both intended and potential users and their needs, information was gathered in various ways from multiple sources. Literature, interviews, observations and focus groups have given the project team an understanding of the current situations a vehicle of this type can be exposed to. Furthermore, unexplored application areas have been analyzed in order to broaden the possibilities of the vehicle.

6.2 Information gathering

6.2.1 Literature

A market study conducted by Green Team during the fall of 2009 provided an initial understanding of the benefits and problems regarding the old Tugger from different users', a reseller's and a purchaser's perspective. Furthermore, internal documents from the CSE Team have been reviewed regarding brand and market strategies. The literature also provided a basic understanding of different aspects of developing a vehicle. Regulations from different Swedish authorities were also reviewed to find legal requirements mainly regarding vehicles in traffic.

Most of the results from the study are presented in the knowledge base, but an interesting finding is that people who have used the old Tugger have been very satisfied with its performance and reliability.

6.2.2 Interviews

Eight end users were interviewed during four sessions; five postal workers from Posten and Bring Citymail and three park workers from the Gothenburg Botanical Garden and the Church in Kållered. In order to get a basic understanding of the powertrain, a specialist at ETP Kraftteknik was interviewed and to clarify some legal requirements, mail conversations were carried out with the Swedish Road Administration (Vägverket). Interviews with Douglas Grundevik resulted in many insights regarding the old Tugger. Continuous interviews and discussions with the CSE Team also gave a lot of input during the development.

Besides providing a good understanding of who the users are and what their situation looks like, some interesting facts were discovered. There are a lot of problems with the competing vehicles that are used today, which shows that there is much room for improvement. The working environment is very important to the users, but costs are sometimes a limiting factor for improvements. All interview transcripts are available in Appendix E. The visit at ETP Kraftteknik provided an initial overview of possible powertrain alternatives and important measurements of the old Tugger, in particular the placement of the three wheels which affect the turning radius and the handling of the vehicle.

6.2.3 Observations

The interviewed end users, their use context and the vehicles were observed and photographed during the visits to the four previously mentioned places. The CSE Team provided a promotional video from 1994 that showed the Tugger in action. Furthermore the Club Car and Norsjö Carrier have been observed briefly when they were encountered in the streets.

The most important findings were to see what context the products are used in and to get a brief image of how the current vehicles are used.

6.2.4 Focus group

One focus group meeting was conducted to gather information. The focus was on specifying requirements, where the CSE Team, Green Team and Douglas Grundevik were present. This resulted in a common requirement specification for both development projects to ensure that everybody worked toward the same goal.

6.3 Defining the user and areas of use

To define who the intended users are, user profiling was used and personas were created. The segment matrix was used to find more possible application areas than the two primary ones presented by the CSE Team; mail distribution and park administration. The segment matrix also gave an estimation of what needs different segments have regarding key issues. It furthermore clarified what kind of different contexts a vehicle could be used within.

6.3.1 Segments and context

The following segments were identified as possible user segments, the full segment matrix can be found in Appendix L. The highlighted segments are the focus for this development process with a main focus on fulfilling the needs of mail delivery to a high extent. This is according to a market study the largest market for this type of vehicle and the market with the highest demands regarding performance and ergonomics (Nilsson, 2010).

Simple City transportation

- **Mail delivery**
- Pizza delivery
- Grocery transportation
- Sausage-man
- Ice-cream sales

Personal transportation

- Within city transportation, commuting
- Islanders
- Transportation for elderly
- Handicap transportation

Rough/Off-road usage

- **Cemeteries**
- **Parks / Gardens**
- Military
- Towing

Special/diverse cargo transportation

- Sports arenas, medical vehicle
- **Logistics, company internal (outdoor and indoor)**
- **Timber-yards**
- Warehouse
- Airports
- Train stations

Recreational

- Racing
- Amusement park attraction

6.3.2 User profiling

The information gathering results are used in combination with estimations as input for the user profiling. The results are presented below.

Primary users

Primary users can be divided into two different main segments; Postal services and Park & Industrial services. As the CSE Team aim to introduce a new kind of vehicle on the market, both segments of primary users are considered to be domain experts, meaning that they will have much knowledge of the task they should perform but little knowledge about the vehicle itself.

Primary users within the postal service segment need to have an appropriate driver's license in order to drive in traffic. However, users that will use the vehicle on private or restricted areas do not need a driver license. In general, the primary users are familiar with some kind of vehicle as a working aid within their job, electrical and/or petrol driven. It could consequently be said that a new type of electrical vehicle would not be a totally unfamiliar concept for the primary users. However, there are also users that have not yet come in contact with vehicles within their work but could still be potential customers.

The users are both male and female and the age spans from 16 to 65 years. The vehicle is going to be introduced on the Swedish market at first but the ambition is to spread the concept within Europe (Nilsson, 2010). The knowledge and experience of handling and interacting with the vehicle could subsequently vary quite a lot between different primary users. The primary users have a mental model of this kind of vehicle as a tool that helps them do their work rather than a transportation vehicle. The vehicle is used more or less throughout the whole day 5 days per week and the users interact with it both while driving and standing still.

Secondary users

The manufacturer, assembly workers, service technicians are all users that in some situation will come in contact or interact with the vehicle. The requirements from these users are somewhat different compared to the primary users since they will interact with the vehicle in a different way. These users are classified as power users since they have much knowledge about how the vehicle works but little knowledge about the tasks that are being done with the vehicle.

Side-users

People who do not use the product but still could be affected by it are other road users, pedestrians, park visitors and office personnel. These users can for instance be affected if the vehicle is parked somewhere, by sound and appearance or if they are hit by the vehicle.

People who do not interact with the product but benefit from its existence are retailers, managers and co-workers, people who visit parks or similar areas, people who are sending and receiving mail. These users are affected by the vehicle's efficiency and ability to perform when the primary users carry out their tasks.

6.3.3 Personas

Three personas were created to show the breadth of potential primary users. Below is a brief summary of each persona, the full descriptions can be found in Appendix F.

Sara Johnsson, 21

When Sara finished high school, she was fed up with studying and wanted to start working. She started working as a mail carrier at Bring Citymail and has been there for two and a half years now. She knows the routines very well by now and likes to be as efficient as possible because it enables her to work out or meet up with her friends sooner. She likes to travel and is saving up money to travel the world for at least a year.

Jim Davis, 37

Jim moved to Gothenburg from the USA in 1995 when he married a Swedish woman. He quickly managed to get a job at a cemetery when he got to Sweden and since he had been working in a mechanical workshop before, he became responsible for maintaining all the different vehicles used by the team. Jim enjoys the variety of his job and his three colleagues but also wants to get home to his family. Jim likes old cars and coaches his daughter's soccer team.

Bengt Hellner, 58

Bengt has been working at Posten for 27 years and is looking forward to an early retirement. Since he was appointed safety representative, he has learned a lot about how to improve the working environments of mail carriers and this has become a great concern. Bengt is still single and has no plans on finding a partner but if the right person comes along anything can happen. He likes walking in the forest by his country house in Dalarna where he enjoys photography and bird watching.

6.4 Identified requirements

The information gathered was used to create a list of functions for the new vehicle. This list (found in Appendix G) was used as input to the final requirement specification, which was defined during a meeting with the CSE Team, Green Team and Douglas Grundevik. The resulting specification was then used both in this project and by Green Team in order to create a common foundation to base the development on.

The activities described earlier in the chapter and the information presented in the Knowledge Base chapter have all contributed to the final requirements specification. Presented below is a subset of the full list that is available in Appendix H. The weight is rated on a scale between 1 and 5 where the steps are; 1 - Insignificant desirability, 2 - Small desirability, 3 – Desirable, 4 - Much desirable and 5 - Essential requirement. Some demands are rated Basic instead of a number, this means the requirement has to be fulfilled. This subset contains the requirements that are most central within the scope of this project and subsequently also focused mostly on. There are more requirements that are important than the ones presented here, many of which are basic requirements that naturally also have been taken into account during the development.

6.4.1 Form and functionality

Image/Identity

Image and identity requirements are important to consider in order to make conscious decisions regarding the brand identity.

Requirement	*Weight*
Appear environment friendly	4
Appear professional	4
Appear robust	3
Appear stable	3
Communicate message star	5
Allow customer branding	4
Communicate brand essence	4

Functional

Functional requirements cover what the vehicle should be able to do and the features it should have. This is largely connected to how the vehicle is used.

Requirement	*Weight*
Customization using different components (pre-sales)	4
Ability to carry tools/working equipment (rakes, ladders)	4
Ability to pull trailers	3
Allow entry and exit from the right hand side	4
Reach light cargo area from the driver's position	5
Weather protection for cargo	5
Allow mail delivery from driver's standard position	5
Avoid damage of vehicle	4
Possibility to more than one person onboard	3
Protect driver from rain, wind and snow	4
Allow entry and exit from both sides	2
Allow entry and exit from the left hand side	2
Offer drink holder	4
Offer helmet storage	3
Offer storage to personal belongings	3
Reach heavy cargo area from the driver's position	2

6.4.2 Ergonomics

Working environment

The working environment requirements ensure that the vehicle is made to fit humans and to ensure that the vehicle can be used for an extended time.

Requirement	*Weight*
Adequate vision from seating position	Basic
Fit different body sizes	4
Perception of being safely seated	4
Shock absorbtion for the driver	3
Dirt protection of the driver	3
Ergonomically sound loading/unloading of cargo	3
Offer flexibility to adjust working environment to driver's own needs	4

Usability

Usability requirements deal with creating a product that is easy to use and easy to understand. With professional tools it is also important that they are used correctly since they are used extensively.

Requirement	*Weight*
Use semantics regarding use, load and maintenance of vehicle	4

6.4.3 Technical aspects

Technical

Technical requirements cover technically oriented functions and specific criteria that are decided upon such as the vehicle is to be electric and use a battery. The border between the technical and functional areas is not very precise and sometimes certain requirements might fit in both areas.

Requirement	*Weight*
Replace battery while loaded with cargo	4
Offer easy cleaning	4

Manufacturing

Manufacturing requirements are naturally related to aspects regarding the manufacturing of the vehicle.

Requirement	*Weight*
Use as few materials as possible	Basic

6.4.4 Constraining aspects

Performance

Performance requirements define the limits regarding driving range, load capacity, speed and other performance related topics.

Requirement	*Weight*
Small turning radius	5

Legal

Legal requirements need to be fulfilled in order for the vehicle to be approved for use.

Requirement	*Weight*
Minimize injury in a collision	Basic

Further categories

The full list also contain economical, environmental and security requirements that are essential for the product to fulfill. These have also been taken into account during the development.

7. Creative Ideation

This chapter describes the process for the creative ideation phase. The resulting ideas are presented as well as three concepts showing possible directions to take.

7.1 Introduction

With the user and context defined and with the requirement specification in place, the development work started. A development framework was created in order to make the ideation easier and more focused.

7.2 Development framework

The development framework consists of guidelines that will support the development phase of the project. The purpose is to define aspects of the requirement specification that are needed during ideation, such as intended expression and anthropometric measurements.

7.2.1 *Form and functionality*

In order to identify desirable attributes which correspond to the desired characteristics of the vehicle, the following image boards were created;

Brand board

Based on the core values of the CSE project; Creativity, Sustainability, Honesty & Reliability and Personal leverage (Nilsson, 2010), a brand image board was created. The board helped set a general direction for the expression of the vehicle. The core values need to be taken into account, but does not need to be explicit in the product.

Product mood board

The product characteristics were defined as "Nimble, Refreshing and Confident" (the full result of the method can be found in Appendix I). From these words, a product mood board was created.

The purpose with the product mood board in this project was to work as a complement to the core values and the message star. It should in a concise manner express the characteristics as the final vehicle should possess. A formal connection between the expression of the mood board and the final product should be apparent in the end product.

The core values are present during the project as an overall value-system, whilst the message star grades somewhat more explicit properties that should be represented in products from the company. However, the product mood board exclusively focused on the current product and its characteristics.

Figure 7.1 Brand board

Figure 7.2 Product mood board

Figure 7.3 Inspiration board

Inspiration board

A large set of inspirational images were collected. The aim was to find ideas and solutions in similar products as well as totally different products. A number of images were gathered in a collage of products that support the characteristics described earlier was created as an inspirational poster. The products inspire through form or function or both and are also an aid during the ideation.

7.2.2 Ergonomics

In this part of the development process basic ergonomic guidelines were applied in order to adapt the vehicle in a good way. In practise this information consisted of basic anthropometric measurements that were defined to be able to create sketches of vehicles that are adapted to the required percentile. CAD mannequins of humans were also printed and used as sketching underlays.

7.2.3 Technical aspects

Battery size and placement

Different battery types require a different amount of space for the same energy output. The total volume of the battery pack is estimated at 160 litres and the exact dimensions are dependent on the battery supplier that is chosen. (Focus group meeting, 2010)

Standard parts

A list of parts that may be chosen as standard parts, bought from suppliers, was created. This was done in order to help focus the development on parts that will be custom made. The full list can be found in Appendix J.

Cost

To incorporate target costing it was important to consider the end price even at the beginning of the ideation. A target price range and volume was provided by the CSE Team and helped focus the ideation on feasible designs regarding cost.

Material and Manufacturing

The material and manufacturing methods are closely connected to the cost. The material configuration of competitors as well as the current vehicle was briefly evaluated by investigating different pictures. The information that was gathered in this stage of the development process was used an overview with the purpose to create awareness of how low-cost vehicles are constructed

7.3 Creative ideation

The ideation aimed to create a wide range of possible solutions to the different functions and problems that the requirement gathering had discovered. The final material was gathered in an idea library that was used as a framework when putting together different concepts.

7.3.1 Free sketching

Sketching sessions were conducted that concentrated on the different functional areas or how to solve certain problems. A set of focus areas were defined and sketches were created to visualise the whole vehicle as well as part solutions. Silhouettes, orthographic views, form elements, functions and different concepts of an overall structure of the moped were explored.

7.3.2 Brainstorming sessions

A number of meetings and brainstorming sessions were conducted with Green Team to find and share ideas and keep everybody updated on the progress of both projects.

7.3.3 Form development process

The process of finding suitable forms, expressions and functionality of the vehicle did not consist of a pre-defined work structure since it was important to be able to explore ideas on different levels of freedom throughout the whole process (example sketches can be found in Appendix M). The process could however be seen as involving five different parts:

- A quick sketching phase where a lot of small sketches of different silhouettes were developed in order to search for interesting overall shapes.

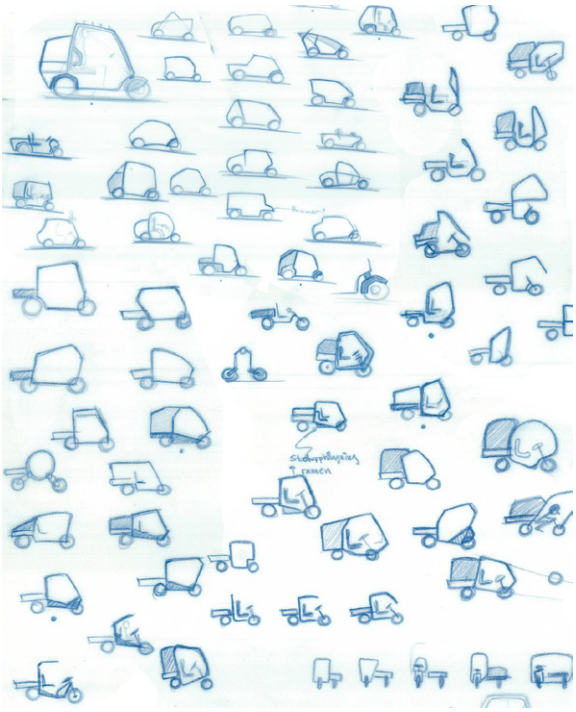

Figure 7.4 Quick sketches

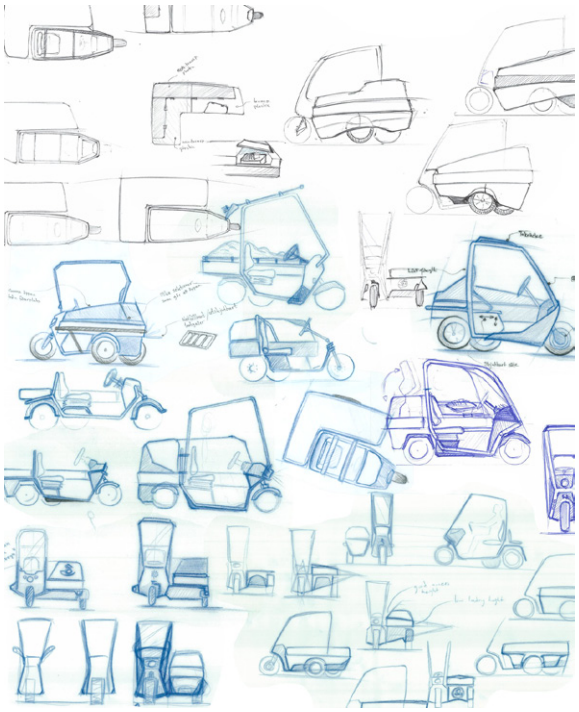

Figure 7.5 View sketches

- A somewhat more detailed sketching phase where ideas were further explored in larger sketches and from different 2-dimensional views. Sketch underlay's consisting of printed side, front, back and top views of mannequins in relation to a wheelbase were produced to guide the development.
- A third phase where the vehicle was explored through perspective sketches in order to investigate surface transitions and search for how the vehicle expression was perceived in different angles. The sketches were still on a quite basic level and did not include all details of a finished concept.
- There were also a lot exploring of certain details and functionality through sketches but also by writing down ideas and describing them by words on a basic level.
- A fifth phase consisted of a continuous evaluation of the different ideas to match them to the different visual boards and comparing how well they fulfilled the desired expression. The evaluation was also done on the different functional ideas to confirm functionality and if they were valid to include in the vehicle. The evaluation was carried out through discussions within the project team.

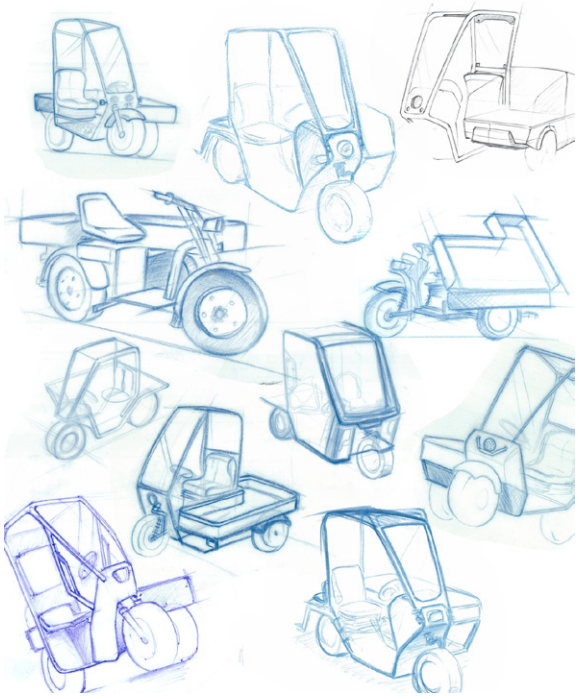

Figure 7.6 Perspective sketches

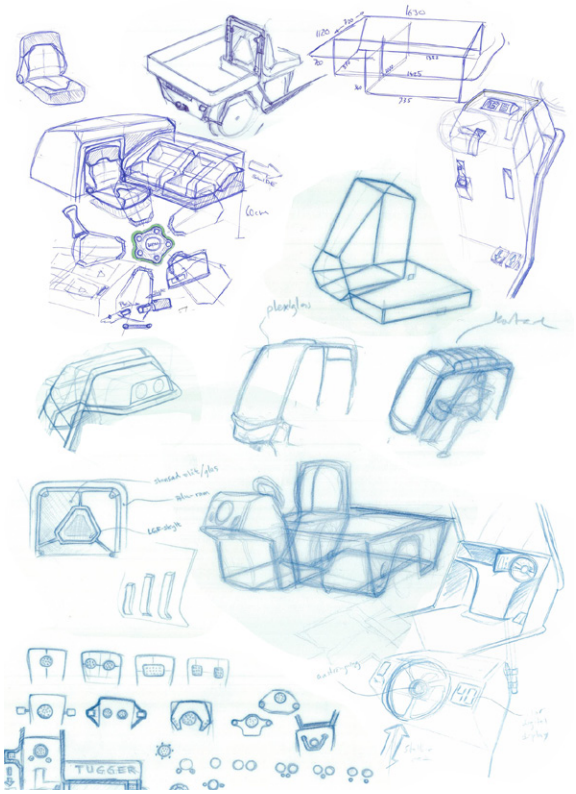

Figure 7.7 Detail sketches

7.4 Three concepts

Combining different designs and functional solutions from idea library into three concepts.

7.4.1 Concept 1

Form and functionality

Concept 1 is a face-lift of the original Tugger where the front has been applied with a casing that covers the steering wheel mechanism and includes the front light in order to create a more unified appearance of the vehicle. The front module furthermore stretches back towards the driver and creates a control panel that faces the driver. The bottom part of the front is created by a single surface in order to create a uniformed expression of the undercarriage and protect the driver from dirt. The side of the undercarriage is tilted to create a less heavy form and make the vehicle look more nimble.

The driver area is surrounded by a frame structure and a windshield to offer some weather protection while driving. The frame structure has a high front that should give the vehicle an alert and confident expression while the rough dimension of the frame should give an expression of a protected driver area.

The frame is also visible around the undercarriage of the platform and should enhance the robust and confident expression in the same time as it is a part of the functional structure of the vehicle. The frame connects to the frame that surrounds the driver area to bring the two parts of the vehicle together.

The platform is surrounded by a frame that offers the possibility to strap down the cargo or to fasten additional modules on the platform to customize the platform for special needs. The platform is tillable both backwards and to the side, which contributes to flexible cargo handling. The sidewalls in the front, on the left side and in the back of the platform are foldable which gives the user a freedom in what kind of cargo that should be carried.

Ergonomics

Both the seat and the backrest are adjustable in vertical and horizontal direction to adjust the interface to different users. The steering wheel is also adjustable in height and angle towards the driver. The different displays are mounted on the surrounding frame so the driver easily can see the information they provide.

Technical aspects

The battery is placed underneath the platform and is connected to a motor that in turn is connected to the rear wheel via a gear to provide the right amount of torque. The motor is placed so that the axle is directly connected to the wheel without any cogwheels or chains in between. This configuration offer low maintenance since it minimizes movable parts.

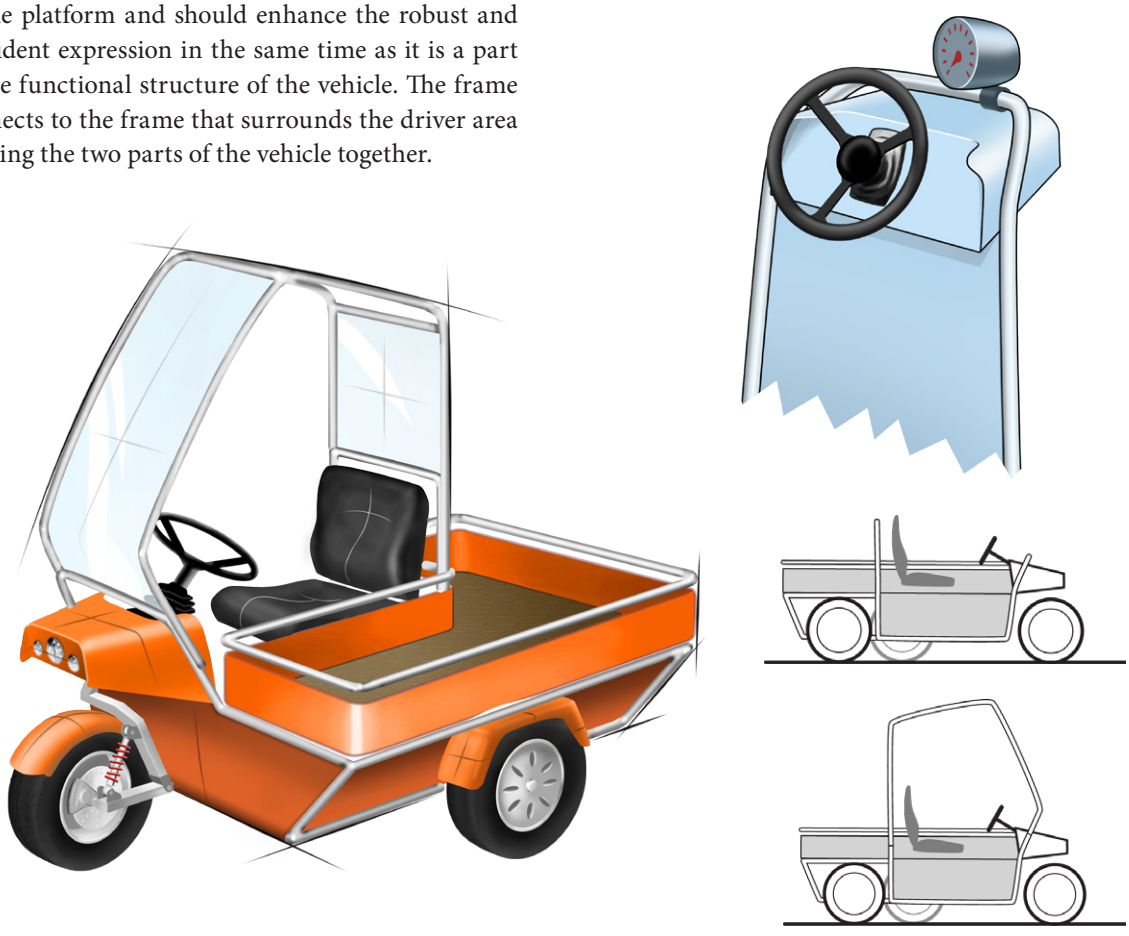

Figure 7.8 Concept 1 exterior and driver interface

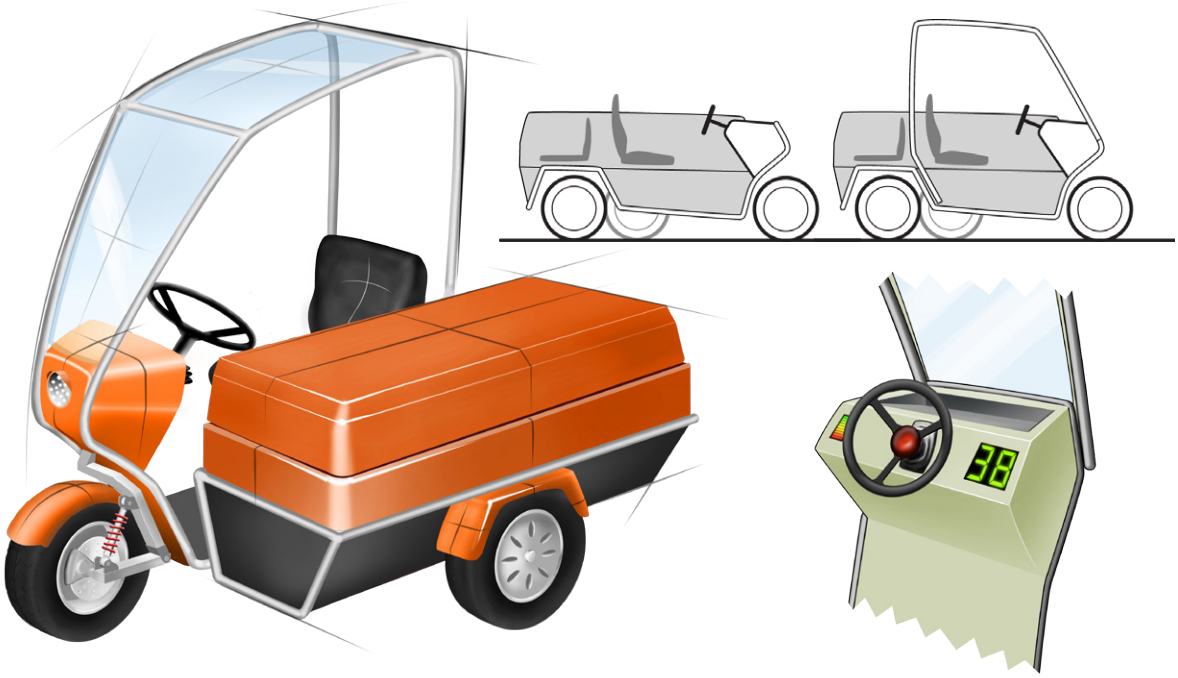

Figure 7.9 Concept 2 exterior and driver interface

7.4.2 Concept 2

Form and functionality

Concept 2 is also based on the same wheel configuration as the old Tugger but the design separates the platform from the driver area.

The front casing is a separate part that covers the steering mechanism and includes a single headlight. The front offers some dirt protection and stretches back into the driver area where the casing exceeds to a dashboard. The front should create a focal point in the design and enhance the driver focus.

By dividing the vehicle into two parts it is obvious that there are two functional areas, the driver area and the platform, which is the working area. The driver area should get more focus in order to enhance the expression of a driver-focused design and similar to concept 1 the driver area is therefore surrounded by a protecting frame and windshield. The silhouette of the surrounding frame is somewhat forward tilting to create a confident and forward striving appearance.

The frame underneath the platform is also visible and should indicate that it is a robust and rigid construction that can carry a heavy load. The undercarriage of the platform and the platform itself should however have a more discrete and toned down appearance compared to the driver area.

The platform configuration offers the possibility to modularise the area depending on the user needs. To meet these needs the platform could be configured as an I-shaped platform leaving the area behind the driver free to utilize as an extra seating area or perhaps for adding a locker where tools and equipment could be stored or it could be configured as the traditional L-shaped platform. The flexibility increases the market possibilities since it could be adjusted to several types of usage.

The concept furthermore illustrates that the platform could be covered with a casing if the cargo is weather sensitive, for example mail.

The front casing also offers a storage surface in front of the steering wheel. This area could be used by mail carriers to put mail on that soon are going to be delivered. The mailman could then drive the vehicle in the same time as he or she prepares the mail, which improves the efficiency.

Ergonomics

The seat is adjustable in the same way as concept 1. The driver interface does however differ. The steering wheel is positioned in the middle of the front casing and the controls and display are positioned on both side of the steering wheel, mounted on the dashboard.

Technical aspects

The battery is placed underneath the side platform and is connected to a hub motor that is positioned within the rim of the rear wheel. The configuration allows for even less maintenance work compared to concept 1 and also offers an easy solution to have suspension on the rear wheel. Since the motor is included in the rim it is possible ton put suspension on the whole rim and motor assembly.

7.4.3 Concept 3

Form and functionality

Concept 3 has a symmetrical design where the rear wheels are positioned on the same axle and the front wheel is positioned on the centreline of the vehicle. The configuration associates the vehicle to a car and offers the possibility to design a symmetrical vehicle. The driver is however positioned on the right side of the vehicle.

The front provides a very good dirt protection where the single front surface is combined with a dashboard on the top. The steering mechanism is hidden inside the dashboard that also includes two round headlights that should give an alert and nimble feeling to the form.

As in the previous concepts the frame is utilized as both a construction element as well as a characteristic design element to increase a robust and confident expression. The side silhouette of the frame goes over the driver and ends just below the headlights and lets the front surface connect the upper an lower part of the frame. The combination of the front casing and the forward striving silhouette creates a characteristic form expression, which enhances the confident and robust feeling of the vehicle.

The frame separates the cargo area from the driver area to indicate that these are two different functional areas. The platform of the vehicle is smaller compared to concept 1 and 2 but gives room for an extra seat inside the driver area. However if an extra seat is not necessary it could be substituted to a secondary cargo area that could be suitable for mail delivery carriers. The platform is moreover tiltable backwards and could be covered with a casing to protect the cargo.

Ergonomics

The seat has the same adjustment possibilities as in concept 1 and 2. The driver interface is inspired by modern cars where the dashboard is swept towards the driver to easily manoeuvre controls and get an overview of the different displays.

Technical aspects

The configuration implicates that the steering needs to be horizontally projected since the steering wheel is positioned to the right and the wheel in the middle. The battery is placed underneath the seats and is connected to an engine that in turn is connected to the rear wheel axle via a driveshaft. This means that the motor propels both the rear wheels to create a uniformed movement of the vehicle.

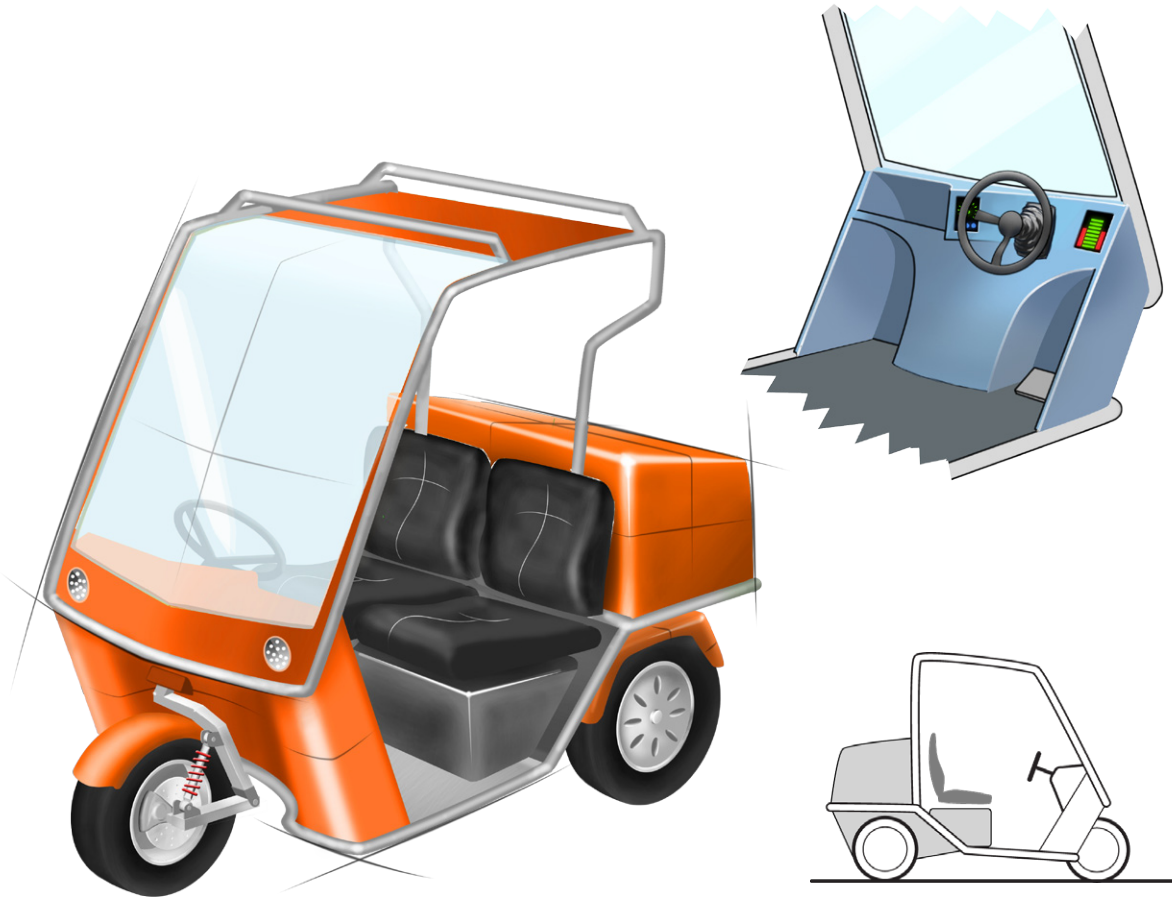

Figure 7.10 Concept 3 exterior and driver interface

8. Concept Refinement

The chapter describes the development process between the three initial concepts and the final concept. The evaluation and the results from the evaluation are presented as well as different aspects of the refinement process. This chapter focuses on the process and contents of the refinement, while chapter 9 presents the results of the refinement.

8.1 Introduction

The refinement process involves an evaluation of the three concepts and further development and analysis of different aspects leading to the more defined vehicle presented in the next chapter. The concept evaluation consists of multiple methods that all aim to help decide which concept is most worth developing further and which aspects of the different concepts are strong. The refinement process in turn aims to define the vehicle further and to take the concept one step closer to reality by eliminating uncertainties and making decisions. The process has been iterative and because many components are connected to each other in different ways the work has been somewhat complex.

8.2 Evaluation

Concept scoring and a focus group in combination with comments and opinions from the CSE Team all worked together to give a comprehensive picture of the positive and negative sides of each concept.

8.2.1 Concept Scoring

A concept scoring was conducted using the requirements presented in chapter 6. The original Tugger was rated first in order to set a baseline for the concepts. The concepts were also scored and the final result can be seen in Figure 8.1 (the full concept scoring can be seen in Appendix K). The results show that the original Tugger is strong when it comes to technical aspects such as performance and some functionality, but weak regarding appearance and working environment. The three concepts received very similar total scores but differed somewhat on certain aspects. Concept 1 is slightly better than the others when looking at the working environment because of perceived safety and good visibility. Concepts 2 and 3 are best when it comes to functionality with concept 2 being slightly stronger because of the flexibility it offers. The three concepts are similarly rated regarding identity aspects and are considered to be a big improvement compared to the Tugger, concept 2 is considered to be strongest of the three because of the light and dynamic appearance.

8.2.2 Focus group

The concepts were presented and discussed with a focus group that consisted of a purchaser, a reseller, the CSE Team and parts of Green Team. This was done to see how the different concepts and ideas were perceived by different stakeholders. The general opinion of the purchaser and the reseller was that performance and functionality are the most important factors along with the price of the vehicle. Customizability and modularity was also considered very important since the old Tugger often was adjusted to fit the specific needs of the customer. Design in terms of form was considered less important, but the reseller stated that it of course is easier to sell a good looking vehicle.

8.2.3 Initiator comments

The concepts were presented to the CSE Team and Douglas Grundevik who then gave their opinions and comments on the different concepts. Different aspects of concepts 1 and 2 were appreciated most. The unified appearance of concept 1 and the dynamic look of concept 2 were considered to be worth developing further. The general concept of a visually prominent frame was considered positive. The gap between the sidecar and the driver area was disliked. The modularity of the cargo area and the fact that it is based on a known and well working wheel configuration were also appreciated. Concept 3 was considered to be unstable in sharp turns and look too much like an old three-wheeled golf cart.

8.2.4 Project group opinions

The silhouette of concept 2 was seen as the best one of the three concepts for representing the desired expressions presented by the visual boards. It furthermore had a favourable way of defining and separating the two functional areas of the vehicle, the driver area and the platform. Another feature that should be included in a final concept was the flexibility of the cargo area in order to adjust the vehicle to special user needs and thereby create a versatile vehicle suitable for a broad spectrum of users.

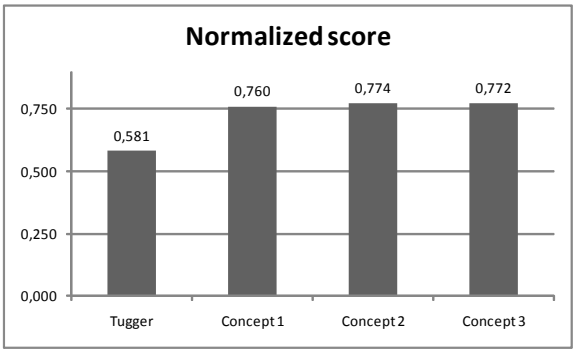

Figure 8.1 Final results from the concept scoring

Other important aspects to consider when developing a final concept were:

- To keep all the positive attributes and functions from the old Tugger but add better functionality and better user experience
- To utilize the frame as a form element and not just a technical structure, this is beneficial for the characteristics of the vehicle and also for reducing costs
- Forms should be simple and easy readable by the observers since it both creates a distinct expression but also since simple curved surfaces are cheaper to produce

8.2.5 *Results*

Concept 2 was chosen to create the base for further development in the refinement phase. The decision was primarily based on the input from the focus group and the initiators opinions but also the opinions from the project group itself. Concept 2 additionally got marginally higher score when comparing the three concepts to each other. However, the decision was not based on these results, instead the focus was to combine all the positive aspects from all three concepts to as high extent as possible. The theories behind the appearance and the flexibility of concept 2 were seen as the two areas that were most positive to bring to a final product.

8.3 Form and functionality

The form and functionality refinement involves applying exact measurements and placements to ensure that things fit where they are supposed to and that parts work and interact in a functional and formally conscious way.

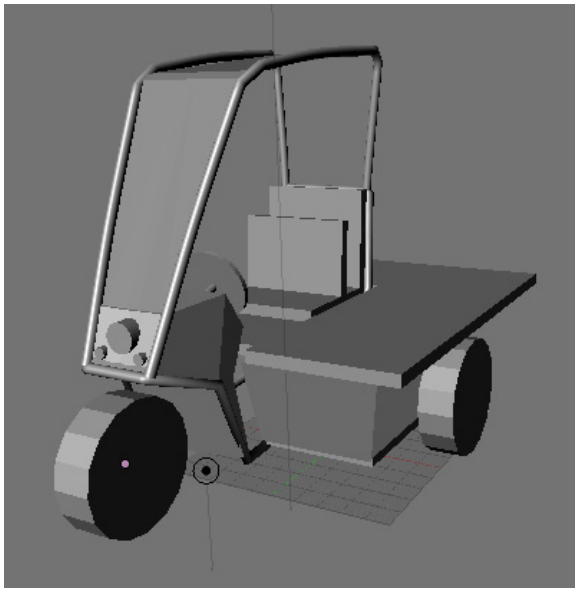

Figure 8.2 The polygon model in progress

8.3.1 *Form language and brand identity*

To ensure that the new vehicle fits well with the intended brand, the development has considered the core values, the message star and the product characteristics. The core values on the most abstract level and the product characteristics the most prominent, with the message star in between. Throughout the development, the characteristics nimble, refreshing and confident were taken into account, striving to make the vehicle express these words.

The corporate identity of the company producing this vehicle was not fully defined, so the findings regarding forms and colours were applied to an initial logo design supplied by the CSE Team and incorporated in the vehicle.

Form development process

The form development process at this stage was similar to the one during the creative ideation phase (see chapter 7.3.3 Form development process) but on a higher level of detail. The purpose was to refine ideas and find detailed form and functional solutions for the whole concept. To define the forms of the vehicle further and examine how different forms work together, a quick and coarse 3D model was created through polygon modelling in the free 3D software Blender. Screenshots of the model was printed and used as underlays to aid and increase the accuracy of the sketch development. Parts of the 3D model were also produced through rapid prototyping in an effort to evolve the form through physical model sketching.

CAD models of the components were later produced using Alias and Catia V5 in order to create accurate geometry. The structural parts and parts with simple geometries were created in Catia while more complex shapes and uncertain geometry were created in Alias. Hypershot was used to create renders of the CAD models.

Colours and textures

Possible colours of different parts have been explored to find a set of colours that work well with the form, that enhance the product characteristics and that is in line with the core values and message star of the CSE Team. Different colours and materials were applied to the CAD model using rendering software and varied further using photo editing software. This generated many possible solutions to choose from and enabled a visual assessment of which colours and material qualities are beneficial for the product's expression.

A neutral colour foundation with accents of slightly subdued bright colours, all in a semi-glossy finish were considered most suitable.

Customer branding

It is considered important to allow the customers to apply their corporate identity on the vehicle. This should be done without losing too much of the own brand identity, and a framework for a conscious customer branding should be encouraged.

8.3.2 Supporting structure

The initial idea was to let the frame be a prominent design feature throughout the vehicle but this intention shifted to make the visible frame accentuate the driver area only and create a stronger focus on this part of the vehicle. The shape of the driver frame was adjusted to enhance the product character and to make sure that a person with a helmet can fit inside. The width in the front was also defined to ensure that the dashboard and storage space in front of the steering wheel was wide enough.

The shape of the sidecar undercarriage is largely dependent on the components contained in it, the supporting structure and certain functionality such as battery replacement and cargo area functions. In order to reshape the sidecar a new supporting structure was developed and verified on a basic level using finite element analysis (described later in the chapter). The overall shape of the sidecar part of the moped was explored and defined further. The aim was to find a shape that interacts with the driver area in a good way and that enhances the product characteristics. The asymmetry of the vehicle made the form development of the sidecar challenging.

8.3.3 Driver area

The driver area has to support the driver's needs in many ways. Regarding functionality it has been considered important to provide a bottle-holder for water bottles of different sizes, storage for personal belongings, access to the cargo and ability to recharge the battery. Possible placements and configurations were explored and briefly evaluated.

8.3.4 Platform

In order to suit the needs from different customers, a certain amount of adjustability of the platform area is required. The aim regarding this is to provide a framework that can accommodate cargo areas that are specialized towards different uses. Different configurations of the cargo area that enable a high flexibility have been considered throughout the development. Examples of how the cargo area can be configured for the main segments were also developed on a conceptual level to give an impression of how it will look.

8.3.5 Additional features

Lights

There are many legal requirements regarding lights on a vehicle (see chapter 3) if it is to be used in traffic. The placement of these lights was explored separately since the vehicle is asymmetrical and consequently has no natural way of distributing the different lights. One idea was to place lights symmetrically around the driver area and front wheel, but this was not possible to a full extent since some lights need to be within certain distances from the outer limits of the vehicle. Another important aspect to consider is that protruding parts often get damaged when this type of vehicle is used, which makes it important to protect the lights somewhat.

Signs

Traffic regulations also include different signs, such as an LGF-sign and a licence plate. These are taken into account during the refinement to avoid ad hoc solutions that do not work well with the overall appearance of the vehicle.

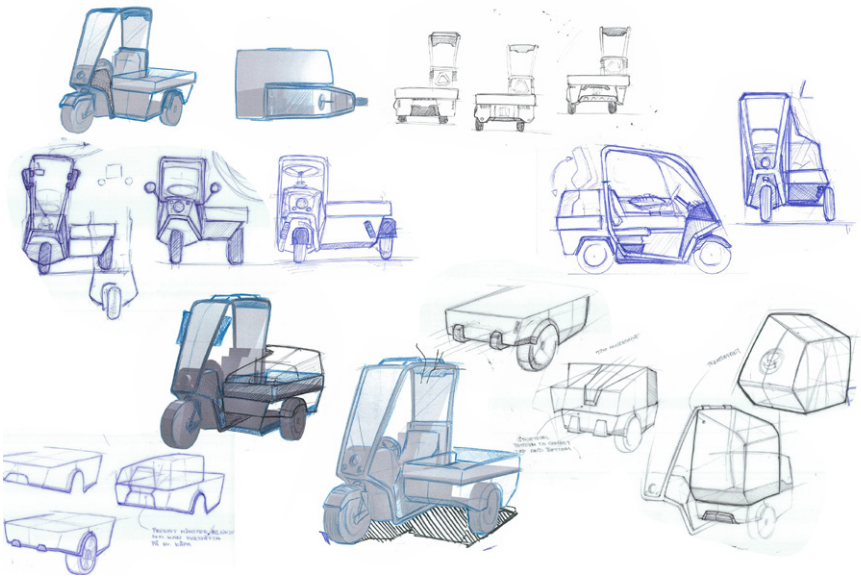

Figure 8.3 Refinement sketches

8.4 Ergonomics

Implementing the ergonomic aspects is mostly about making sure measurements are in tune with existing guidelines in ergonomics literature. Development issues occur when the ergonomic guidelines are in conflict with other aspects of the design.

8.4.1 *Driver area*

To create a driver area that can be used every day, it is important that it is designed with ergonomics in mind. Ergonomic specifications regarding seated work and driving interfaces combined with anthropometric data enabled verification of the size of different parts of the driving area. The most important aspects have been to ensure that people of different sizes can use the vehicle in a good way. In practice this means adjustability of the seat and steering wheel to a certain extent, as well as enough space for e.g. knees and feet to provide good working conditions. Because especially postal workers constantly get in and out of the vehicle, it is important to consider the height of the floor and the shape of the seat.

Regarding cognitive aspects, the driver interface should be as intuitive as possible and provide correct information in the right amount. The controls needed should be unambiguous and placed in a manner that is easy to reach and manoeuvre. The controls and indicators needed were defined and implemented.

8.4.2 *Platform*

Considering how the cargo is handled is also important from an ergonomic perspective. Ergonomic guidelines regarding workbenches were consulted to provide a good working height. The possibility to manually tilt the platform also presents an area where ergonomics need to be considered in order to avoid excess strain.

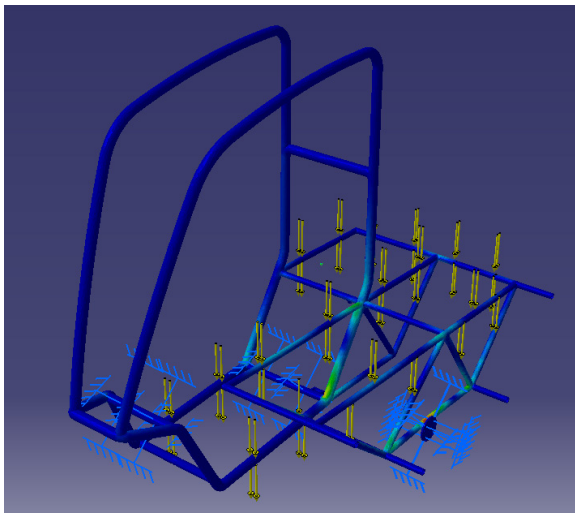

Figure 8.4 Merged frame structure

8.5 Technical aspects

The technical aspects mainly concern validation of the form and functionality exploration to ensure that the chosen solutions are viable.

8.5.1 *Supporting structure*

As mentioned earlier, the packaging and structure of the frame affect the form of the sidecar, in order to verify that the forms would work, a new frame structure was developed. Since it was not possible to test the handling and practical turning radius of different wheel configurations, the placement of the wheels and their relationships were kept from the old Tugger. The battery volume of 160 litres also needed to fit in the frame along with a way to extract and replace the battery in an easy way.

The frame development started with ideas that made sure that the battery and wheel were placed correctly and that the form was satisfactory. This led to a structurally conceptual frame that was developed further using input from mechanical engineers at Dacat to create a strong and structurally sound frame.

At this stage, the frame design had to be verified and consequently two main configurations were analyzed. Questions that needed to be answered in the different configurations were:

- Is the frame structure strong enough?
- Is it possible to minimize the material and keep the strength?

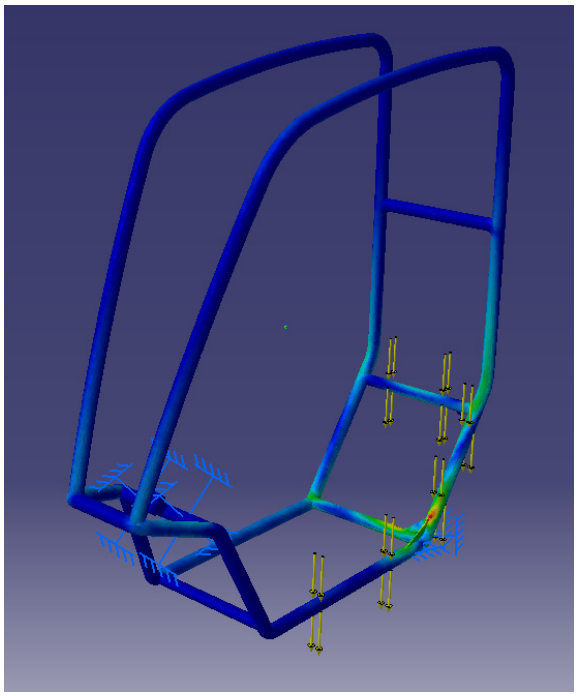

Figure 8.5 Separated frame structure with bolts

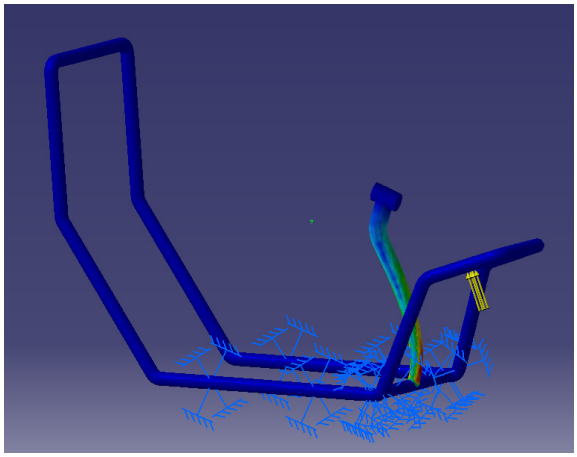

Figure 8.6 Single arm welded to the frame

- Can the construction be optimized for assembly and manufacturing?
- Does the construction fit all the functions needed in the vehicle?
- Does the construction support the exterior design of the vehicle?

The first configuration focused on a merged frame structure where both the driver area and the platform were welded together in a single structure, see figure 3. The second one focused on a concept where the two parts were built separately and then bolted together, see figure 5. The analysis also included some variations of the two frame concepts. Critical areas of the construction were identified and reinforced to reduce the load of these areas.

Suspension and steering

Different front suspension types were investigated and the chosen implemented in a way that is in line with the desired expression. Different alternative configurations of a swing arm for the rear suspension were also explored. In order to validate the attachment of the steering axle to the frame a finite element analysis was conducted here as well.

Two configurations of the front attachment were analyzed. The first was the traditional layout that was applied on the old Tugger. This was a single arm that was welded to the bottom of the frame as figure 6 illustrates. The second configuration utilizes the new outer frame structure and a welded horizontal pipe in the front, see figure 7.

The result of the analysis shows that the double-armed solution is more suitable when comparing the von Mises yield criterion, see figure Error! Reference source not found.. Additionally, this solution has improved material efficiency and it strengthens the total frame structure at the same time.

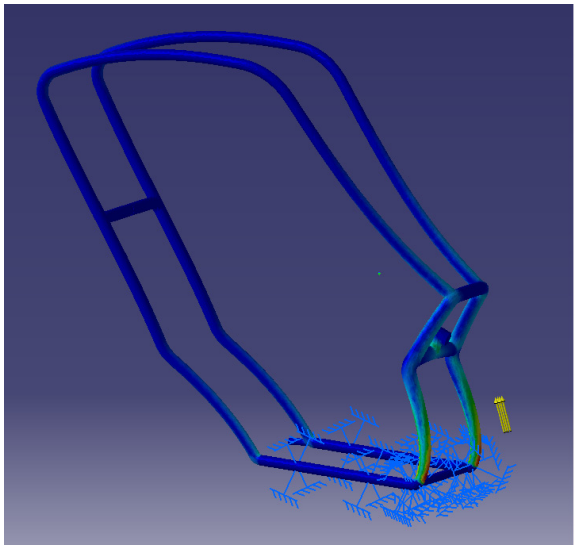

Figure 8.7 Horizontal pipe welded to the frame

Turning radius simulation

The turning radius simulation was conducted to see how much the front wheel had to be able to turn. This was done to ensure that there would be no geometric clashes caused by the rotation of the front wheel and its suspension. The method showed that the front wheel has to be able to turn 60 degrees in both directions to achieve a turning radius of 1.5 meters. This is however only a theoretical number and no real vehicle dynamics have been taken into account.

8.5.2 Powertrain

A study conducted by Green Team resulted in that a hub-motor would be beneficial in many ways. The technology is however not that mature and there are not that many suppliers, this is not considered to be an issue since the concept developed here is supposed to show near future possibilities. Given some time, the technology will be more mature and more manufacturers will be available.

The CSE Team provided information about different battery types, and Lithium-Iron-Phosphate batteries were deemed to be the best option. This battery type is still expensive but in a near future the prices are estimated to be on a better level for this type of vehicle.

8.5.3 Materials and manufacturing

Possible materials and manufacturing processes were investigated to create a framework for the development that shows possibilities and limitations of different combinations. Related costs and environmental aspects were also looked into on a general level.

9. Final Concept

The chapter describes the final concept and end result of the master thesis project. The design of the vehicle is explained and presented in a visual way in terms of form and functionality, ergonomics and mechanics.

Figure 9.**1 The final concept for the Bemo**

9.1 Introduction

The final result is a modular and flexible vehicle that can be adapted to a multitude of uses. The new vehicle Bemo Pro, has a strong visual appearance in combination with a strong driver focused design and functionality. The vehicle construction is adjusted to fit low cost manufacturing methods and utilizes the functional structure as a part of the explicit design.

9.2 Form and functionality

9.2.1 Form language and brand identity

As previously stated (see chapter 7 Creative Ideation) the desired form language should be inspired by he words: nimble, confident and refreshing. In addition to these the corporate brand identity has been put down as a framework for the final design.

Supporting structure

The Bemo has a calm but forward striving silhouette that implies its nimbleness without becoming aggressive. The slightly angled base and the narrow cab create a light and refreshing feel while the robustness of the articulated frame increases the perceived confidence.

Splitting up the vehicle into two parts, the driver area and the cargo area furthermore emphasizes the nimble expression of the vehicle. The driver area becomes the focal point with its high cabin and characteristic silhouette whilst the cargo area has a more discrete form language. Still the total expression of the vehicle is robust and coherent by intersecting the casing of the undercarriage to the driver area. The vehicle is consequently perceived as less clumsy and more nimble.

The front is characterised by the *waist silhouette* (see Figure 9.2) that the frame forms just underneath the headlight. The form creates a confident base of the vehicle but simultaneously lightens up the front and creates a characteristic expression. The waist silhouette is defined as an explicit design element that could be varied in several different ways and is used as a reoccurring form element to create a coherent overall design. As the form element has many possibilities it is suggested that it should be used as a characteristic element for the brand and utilized in other products and vehicles within a product family.

Figure 9.**2 Front view**

The rough dimension of the frame structure, that surrounds the driver environment, is also defined as an explicit design element. In addition to creating a robust and strong expression, it also emphasizes the importance of the driver and thereby the confident characteristics of the vehicle. This is also a flexible element that could be used in different ways within other vehicles in order to create a coherent product family.

By incorporating the structural parts of the vehicle as thought through design elements with both function and design characteristics the Bemo differentiates from its competitors in a creative and refreshing manner. The vehicle thereby becomes a low cost, driver focused vehicle but with a modern and refreshing look.

Driver area

The front casing follows the frame and encapsulates the steering mechanics and stretches back to the driver where it creates a dashboard. By hiding the mechanics in this casing the front becomes more defined and the design is perceived as more thought through and refreshing. The side silhouette angle of the form creates a forward striving direction and gives the vehicle a nimble and confident expression. The side silhouette of the front casing is inspired by the waist form element and an embossed line (see Figure 10.3) on the side of the casing further enhances the form. The line also splits the form in way that should create a more nimble expression. The side of the front casing should also be used as a surface where company logotypes should be placed.

Platform

The casings of the undercarriage of the sidecar have a slanted front that should minimize the static expression and create a more nimble feeling. The wedge shaped form should also create an increasing robust expression in the back of the vehicle. The wedge

Figure 9.**3 Side of the driver area**

Figure 9.**4 Side view**

that the part has a different function than the undercarriage. The chamfers furthermore strengthen the mechanical properties of the sidewalls and make it more rigid.

Corporate identity

The general form language has also been merged with the company's brand values in order to create a consistent design appropriate for the company's core values and message star. The values that have been incorporated in the form are: creativity, sustainability, honesty and reliability, environment friendly, driver in focus and performance.

Creativity is represented in the way the vehicle utilizes the structural frame as a design element and by the somewhat unusual appearance that creates a new type of work efficient industrial vehicle.

Sustainability is represented in the form by the robust and rigid design. It indicates that the vehicle last for a long time and doesn't need a lot of maintenance work. It is also incorporated in the material selection and manufacturing of the vehicle.

Honesty and reliability is expressed by the high front windshield and the traditional round shaped headlight that gives an alert and focused expression. It is also represented by the robust dimension of the frame that surrounds the driver area and the simplicity in the form of the casings. The vehicle also has frame but also in the forward striving silhouette and the characteristic front shape of the vehicle. The confident expression is connected to the performance of the vehicle and creates a distinct yet humble design of a vehicle that is confident in the tasks it is supposed to perform.

Colours and textures

The main parts of Bemo is painted in semi-glossy subtle off-white colour that provides a calm confident expression to the vehicle. The light colour furthermore gives the vehicle a refreshing and modern appearance that differentiates it from its competitors. The undercarriage is given a grey tone to split the large body surfaces into different shapes and by doing so increase a nimble expression in rather static surfaces. The grey tone is somewhat less glossy compared to the off-white paint and gives a good colour balance between the lower and upper part that additionally enhances the confident expression. The form of the grey fields in the front and in the back of the undercarriage is inspired by the waist shape and its position is determined by the battery location. The purpose is to indicate that this part carries special functionality and holds a heavy load. It is also a way of enhancing the feeling of two different functional parts, the driver area and a working area.

The Bemo has moreover been given a glossy orange colour on some details to give the vehicle a more characteristic appearance and recognisable elements.

The orange colour also enhances the refreshing and modern look. The orange sideline is created by colouring the frame which tilts the platform. By enlighten this part it becomes clearer that it is a functional area that is separated from the driver cabin and it also divides the sidecar in a functional upper part and a static lower part. Additional functional details are also colourised in orange in order create a uniformed and coherent appearance.

The platform floor is made out of brown wooden plywood with a discrete semi-glossy texture which should give a feeling of a tough and durable surface. The colour is dark brown in a tone that complements the off-white, grey and orange and gives a modern feeling. A dark colour is also suitable since the platform is going to be worn and dirty.

The robust frame that surrounds the driver area should be coloured so its appearance is similar to anodized aluminium. The difference in structure and the feeling of this part creates an attractive complement to the off-white and grey painting of the casings. It enhances the robust and dynamic shapes and indicates that the area it is surrounding has a special and important function. The frame that surrounds the platform is coloured in the same way with the same reasoning as above to create a consistent design.

Customer branding

When companies want to customize their equipment to fit with their own brand, the Bemo has accommodated this from the start. As mentioned previously there are room for distinct logotypes on the side of the front casing and on the side of the undercarriage. The vehicle furthermore has the possibility to be coloured in company colours on several big surfaces to really stick out among competitors. However, certain parts should be kept in order to preserve the general expression of the vehicle. The first one is the robust frame that surrounds the driver area. This is a very important feature and should differentiate from the colouring of the other parts of the vehicle in order to emphasize the driver focus and the earlier presented properties. The second is the grey base of the vehicle. The differentiation in colour between this area and the rest of the vehicle is important in order to visually split up the vehicle in different functional parts as well as keeping the desired form language. An example of how this could be done for the Swedish Posten is presented later in this chapter

9.2.2 Functionality

Chapter 6 - Identifying Requirements brings fourth diverse sets of user needs as well as legal requirements that need to be fulfilled in this kind of vehicle. The following text will present how the different functions that Bemo Pro offers fulfils these requirements.

Supporting structure

The vehicle is in its original appearance configured as a right steered vehicle with the sidecar mounted to the left of the driver area. The main reason for this kind of configuration is to meet the requirement of mail distribution since the users within this segment wants to be able to be seated on the vehicle and the same time deliver mail to post boxes.

The frame structure that surrounds the driver area is beside a vital construction element also dimensioned so it could be used as a steady handle when entering and leaving the vehicle. This feature is not identified as a requirement stated by users but rather an unspoken one that will enhance the users attitude towards the vehicle. It could for example be suitable for elderly people that use the vehicle as a flexible and safe transportation vehicle. Nevertheless, it could also be used by younger users as a comfortable way of entering or leaving the vehicle.

The overall shape and structure is furthermore designed to minimize protruding parts and thereby minimizing the risk of maintenance due to accidental breakage when hitting obstacles. This was stated as a current problem on the old Tugger and Dobbin.

Driver area

The driving interface is configured with the following controls and displays:

A steering wheel was chosen instead of a handlebar to manoeuvre the vehicle. The functional reason for this was that a handlebar was seen as a protruding part that could get caught in stuff or hit for example mail boxes if the driver is not careful enough.

Throttle is done by pushing the right pedal and braking by pushing the left pedal. By combining a steering wheel and pedals a more efficient driver environment for the mail distributors is created. They now have the possibility to steer and control the speed and still have one hand free for sorting mail and dropping of mail into boxes. This was identified as a quite highly rated requirements when taking to the Swedish Posten and Bring citymail since the users within these segments need to have an efficient workflow around the vehicle.

The gearshift is placed on the right side of the steering wheel as an old fashioned gearshift on cars. The purpose is to further optimize the user interaction and make it easy to manoeuvre the vehicle.

A floor button for tilting the steering wheel is positioned to the left of the brake pedal. The button is supposed to be manoeuvred by the left foot and the reason for positioning the button on the floor is to promote a more efficient way of work that in the same time gives better driving ergonomics. This kind of control of tilting the steering wheel could be found in some forklifts and the idea is to let the driver tilt the steering wheel more or less in the same manoeuvre as he or she leaves the vehicle. This function does not only create a more easily accessible driver area but also promotes a better ergonomic situation and an optimized workflow when the user frequently needs to leave the vehicle for performing a task, which is typical for the mail delivery segment.

The handle on the left side of the steering wheel controls the blinkers when titling it up and down and the full-beam/low beam when pushing it towards the driver. This is also a function that is very similar to cars and thereby an intuitive way of controlling this kind of functions for many users. It is also in line with the legal requirements that state that a moped needs to have blinkers and full-beam/low beam.

The horn is also a legal requirement and this function is placed in the middle of the steering wheel, similar to cars since this function is intuitive for most users.

The ignition is controlled by a remote controlled key, similar to the controls that are used to unlock doors and open trunks on cars. This feature makes it possible for the user to easily and quickly control the vehicle from a distance, which optimizes the workflow for mail distributers but is also a very user friendly and comfortable way for other users to control the ignition. The ignition is furthermore programmed to automatically switch of when it is not in use. If the control should run out of battery or malfunction in any other way there is still a possibility to use the ignition socket that positioned to the left of the steering wheel on the dashboard and controlled by a transponder key.

Since the vehicle has a windshield there is also a simple toggle that activates the wiper and is positioned to the right of the ignition socket.

The battery status is visualised by five lamps that represents how fully charged the battery is and is placed on the dashboard to the right of the steering wheel. In traditional low cost vehicles it could be found a voltage meter that indicated the battery life. However, since many of the users of this kind of vehicle is not familiar to how interpret this kind of display it was found more suitable to have the chosen visualisation.

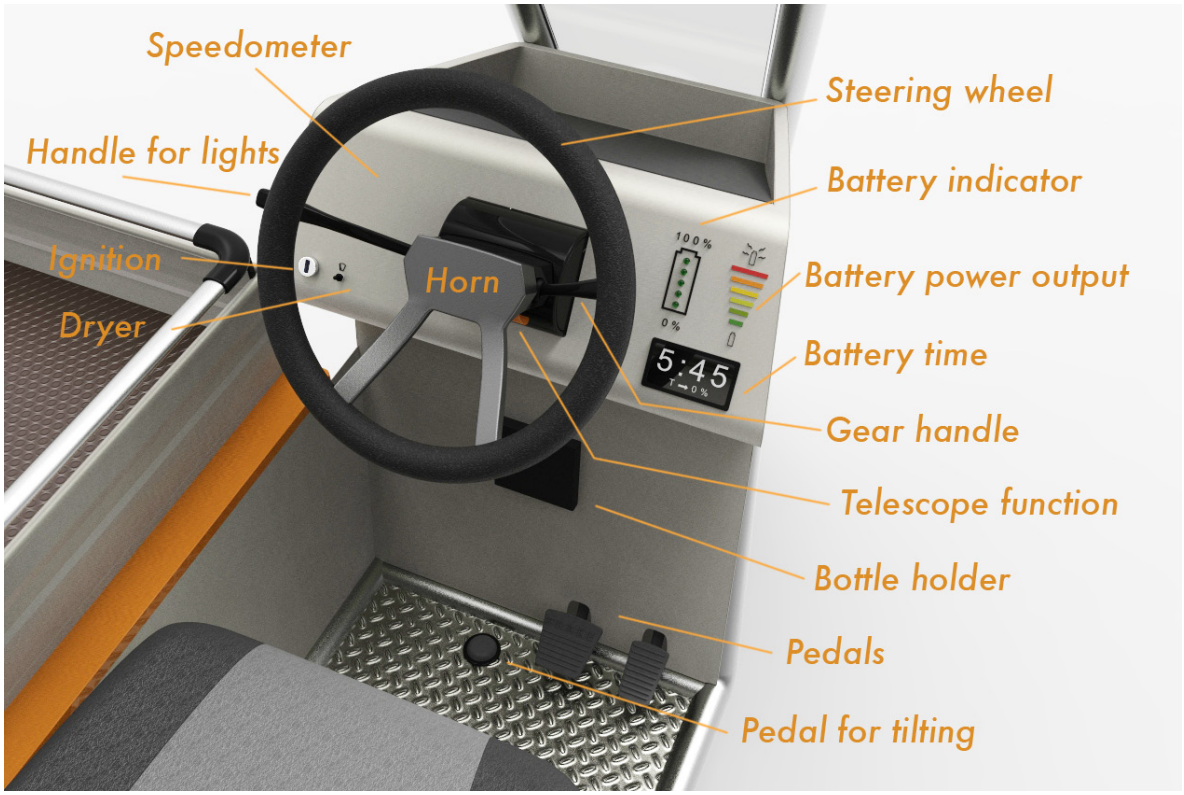

Figure 9.**5 The driver area**

To the right of the battery indicator there is a green-to-red colorized scale where the bars are lit up to indicate how much power that is drained from the battery for the moment. In combination with this scale there are also a display showing how many operating hours and minutes that are left if the current power output is constant. The combination should both give guidance to the driver how to plan his or her activities and upcoming route but should also try to affect the driver to run the vehicle more energy efficient. Even if the vehicle runs on battery one have to consider where the energy originally comes from and how it affects the environment.

The speedometer is a legal requirement but not that frequently used by operators of slow moving vehicles. The speedometer is positioned to the left of the steering wheel and is of standardized type with a needle that indicates the speed. An analogue gauge is chosen instead of a digital since the needle explicitly shows if the speed is increasing or decreasing whilst the user have to have a stronger focus on a digital gauge to identify the change in speed.

The vehicle is also provided with rear mirrors that are attached to the upper part of the windshield frame. The position should give a good and clear view backwards even if the platform is loaded with cargo. To be able to have a clear view backwards when operating the vehicle in narrow areas was stated as an important feature by mail distributors. By positioning the mirrors in an overlapping position with the frame and in the top of the windshield minimizes the area that blocks the visibility in front of the driver. The position is moreover a more subtle solution compared to placing the mirror as protruding parts in line with the frame, which minimizes the risk of hitting obstacles and also creates a form that is less perceived as ears of the vehicle.

The non-driving interface provides a foldable bottle holder for different sizes of bottles. The holder is positioned on the front casing between the legs. This was not explicitly stated as a requirement but identified as a feature that could be useful since several users in different segments explained that they usually carries something to drink while working, especially during summer time.

There is also a personal storage box underneath the seat. The box is accessed by pulling the handle forward and tilting the front of the box. Similar to the bottle holder this was not a feature that was stated as a spoken requirement but many users explained that the often puts a jacket on the seat or somewhere else when the weather is shifting. This kind of compartment box now allows for storing of for example a jacket or an extra sweater in a place where it is not in the way.

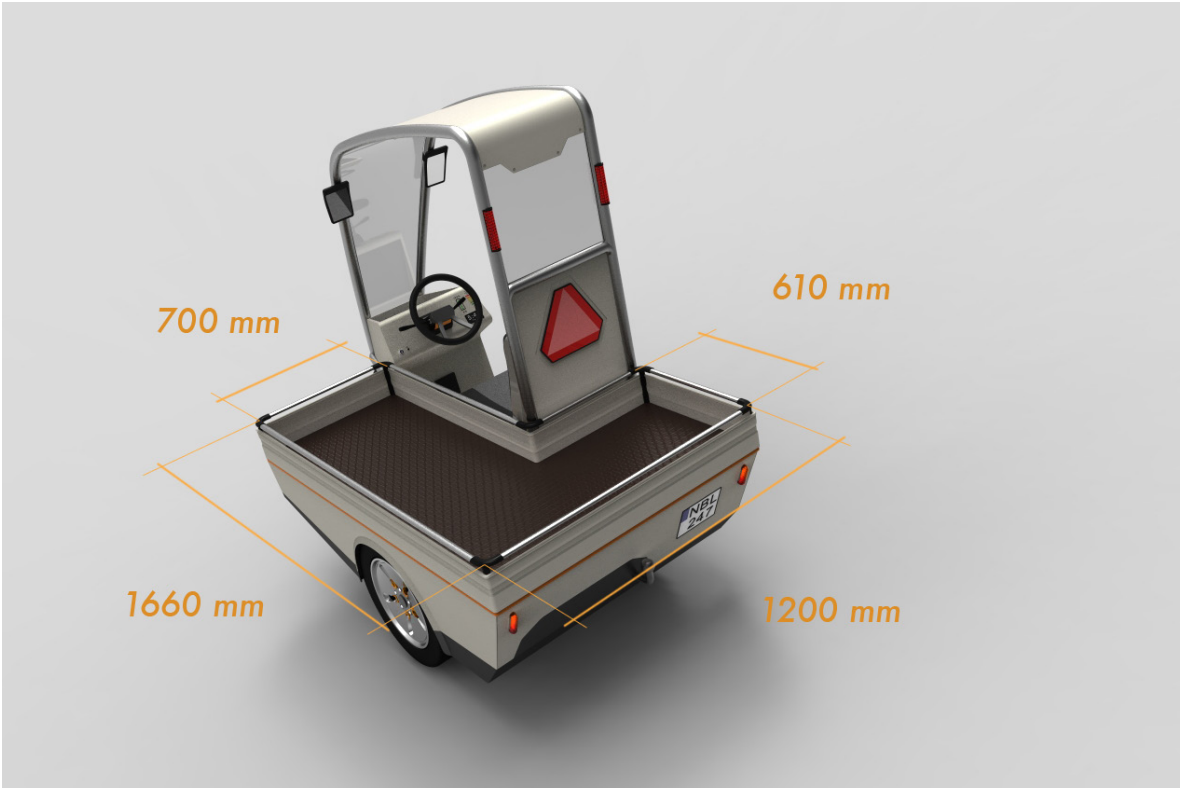

Figure 9.**6 Platform measurements**

An additional storage surface is placed in front of the steering wheel. This storage room is more of a temporary one that for example could be suitable for a pencil and a carrier list, some small tools, a bunch of letters etcetera. The storage in the front is in first hand developed in order to be customizable for mail delivery since many mail men would like to have the upcoming mail in front of them in order to work more efficient. However, the observation studies around more industrial work places identified the need of a temporary storage for smaller thing that could come in hand out in the field.

Platform

The cargo area is designed to be a modular construction where the customer can chose the most appropriate solution for his or her needs. The standard platform is L-shaped and makes it possible for the user to put load on a large surface. The surface measurements could be seen in Figure 10.6 and the vehicle could carry a load of 300 kg, which is the maximum load a moped is allowed to carry. The platform is a flexible construction that allows the user to unload cargo by tilting the platform either backwards or to the side with the help of foldable leverages. A secondary frame that the platform rests on enables the possibility of tilting the cargo in two directions. This frame has additionally hinges in one direction so if the platform is strapped to this frame it could be tilted in a secondary direction (see Figure 10.7). The platform consequently has two foldable sidewalls, the back wall and the side wall. However, in order to load cargo that has long dimensions such as ladders, wood, steel or other ungainly material it is also possible to fold the front wall. This is a feature that has been appreciated in construction areas and wood dealership and also a strong selling point since competitors doesn't have this possibility.

The platform is surrounded by an oval shaped frame that is positioned around 4 cm above the sidewalls of the platform. The idea is that the corners of this frame contain the locking mechanism of the platform walls. When opening a wall one must first release the lock mechanism in the corner then tilt the sidewall together with the oval frame part that is parallel to the side. The main purpose of the oval frame is however to be able to strap down cargo and fasten different types of customized cargo placeholders. For example special holders for rakes, shovels, ladders etcetera. This kind of modularity opens up for an accessory market where customers could buy efficient customized platform add-ons in order to optimize the platform for their special needs.

The whole platform is furthermore exchangeable to other types of cargo configurations. The supporting structure allows for several different modules to be attached on the structural frame. It could for example be a tool cabin behind the driver combined with a platform that only stretches along the side of the vehicle. The area behind the driver could also be fitted with an extra seat if there is a need for that. The modularity moreover provides a very flexible area that could be customized to satisfy the demands and requirements of transportation possibilities and functionality from the mail distribution segment to a high extent. This is a very important aspect since the mail distribution segment is a key customer and also considered to be the main customer of the vehicle. How the vehicle could be adjusted to this segment is explained in the end of this chapter.

Figure 9.**7 Tilting of the platform**

Powertrain

The motor is applied with an automatic parking brake that register if the vehicle is standing still and then secures the back wheel. This function contributes to fewer controls in the driver environment and eases the mental workload of the driver since he or she does not need to consider this function.

The battery weight is around 150 kg and it rests on rails that are welded to the upper part of the platform frame. The frame structure and the way the battery is hanging in the frame allows the user to change the battery without having to tilt the platform and lift out

the battery with a crane. Instead a hatch in the back of the vehicle is opened and the battery could be slide out with the help of a pallet lift. After positioning a new battery in the frame the hatch is closed and the battery securely locked in its position. The inside of the hatch has a locking mechanism that closes the frame structure behind the battery and keeps the battery in position. The locking function is furthermore combined with the battery connector that only provides a connection between the battery and the electrical system if the hatch is thoroughly closed and locked. This is a safety precaution that prevents from driving the vehicle without having the battery securely fastened. The ability to easily change battery is a need of some special segments where the vehicle must be able to run for more than 8 hours a day. It could for example be in logistic areas or industrial workplaces that work in shifts.

Figure 9.**8 Battery handling**

When the user does not have the need of changing the whole battery the vehicle is provided with a built in recharging module that allows the user to plug in the vehicle directly to an ordinary 230 volts power output. The recharging is done by first opening the little hatch in the back on the right side of the vehicle. Behind the hatch there is a cord rolled up on a cylinder with the same functionality as cords on vacuum cleaners have. It is therefore very easy to plug in the vehicle for recharging and when the task is done the cord automatically rolls up on the cylinder by simply tugging the cord. The recharging interface is subsequently portable and the user does not need to find a separate cord to connect to the power socket.

Additional features

The Bemo also has the following additional features:

- The vehicle is equipped with a headlight, blinkers combined with positional lights and reflexes and two brake lights in the back. The legal requirements concerning lights are thereby fulfilled. All of the lights are of LED type to lower the energy consumption and create a modern and refreshing look. The lights are furthermore positioned in a way to minimize damage and are not placed on protruding parts in order to minimize maintenance work due to breakage.
- The legal requirements concerning LGF sign and license plate is also fulfilled and the signs have been placed on surfaces that are clearly visible by other road users.
- The construction allows for high pressure washing which is an efficient a less time consuming way of keeping the vehicle clean and minimize the time of maintenance.
- A roof rack could be welded on the top of the roof in order to carry additional goods such as rakes, shovels, brooms and other tools. This was a function that was observed at the cemetery where tools that always could be good to have nearby where fastened on the roof on a homemade placeholder. This configuration also gives the result that the cargo area could be free from tools and the user could load the vehicle without consider how to fit the tools on the platform.
- Another practical function for users that require electrical driven tools is the possibility to connect electrical tools of 230 volts to the vehicle and use the battery as energy source. This is a special need that could be suitable in example parks and cemeteries where the range of the battery is more than enough to handle the transportation needs for a day. The battery could then work as a portable energy output. The users could have supervision over the power output on the dashboard displays and easily see how many hours or minutes the tool could be used before the vehicle needs to be recharged.
- The Bemo also allows for a towing hitch to be mounted in the back when there are high demands in loading amount. The possibility of being able to pull trailers has been widely appreciated in larger gardens and cemeteries among others.

9.3 Ergonomics

This chapter will present the vehicle ergonomics and the motivation of the chosen solutions. Figure 10.9 illustrates the size of the vehicle in relation to a 5%-ile female and a 95%-ile male.

Figure 9.**9 The vehicle in realtion to humans**

9.3.1 Physical aspects

Supporting structure

It was clearly stated by the persons working in the mail distribution segment that thy wanted an efficient workflow and that the weather was not a big issue since they are provided with efficient clothing that are adapted to the seasons. The same opinions were identified among cemetery workers. The users working in these segments need to wear clothes adapted to the climate since they work a lot outside the vehicle. However, it was favourable if the vehicle could give some protection while driving.

The supporting structure has thereby been designed to minimize the entrance height of the vehicle without creating a too low chassis that could be damaged by sidewalks and other obstacles. The construction is furthermore open and easily accessible without any protruding parts that block the way for the user. The structure still provides some weather protection of the driver without creating a driving environment that differentiates in temperature. The windshield also works as a protection of bugs and insects that could be unpleasant to encounter while driving and the roof works as a sun blocker and provides a shadow area when it is warm outside.

The frame is also provided with suspension both in the front and in the back in order to minimize the possibility of vibrations moving up to the driver position. The frame is also a robust and safe element that creates a surrounding environment of the driver to enhance the feeling of being protected against other road users.

Driver interface

The ergonomics of the driver interface has been a very important part of the vehicle since its users see it as a working tool and the company is going to have a strong driver focus in their products. It was explained by the drivers of mail carriers that they would gladly adjust their working environment if they were given the possibility. To fulfil these requirements the development of the Bemo has followed the ergonomic guidelines stated earlier in the report (chapter 3 Knowledge Base). The seat has a width of 500 mm and a slightly S-shaped backrest that is angled 110 degrees. The following adjustments can be done in the driver environment:

Seat adjustments:

- Horizontal adjustment: 150 mm
- Vertical adjustment: 165 mm
- Backrest sliding range: 100 mm

Steering wheel adjustments

- Tilting angle: 90 degrees
- Telescope range: 100 mm

The seat is also provided with a gas suspension that will ease the impact of vibrations from rough terrain.

A steering wheel was chosen instead of a handlebar since a steering wheel is more forgiving if obstacles hit the wheel. A handlebar does a much larger output and works as a leverage when the wheel changes direction and could cause discomfort or injury. A steering wheel has the same position as before and is thereby a better solution. A steering wheel could furthermore be provided with gear towards the fork that makes it easier to turn the front fork, which is included in the Bemo vehicle.

There is a soft down-light underneath the dashboard that automatically lights up when the ignition is switched on with the remote control. The soft light lightens up the floor of the vehicle to guide the driver when entering the vehicle. This is a feature that should be useful especially for people that has reduced sight, but it could also be useful for mail carriers that during wintertime work in dark hours of the day. It furthermore gives a nice effect and a welcoming feeling.

Displays and controls are placed on the dashboard or connected to the steering column to give the driver easy access to these functions in the line of sight. The temporary storage plane is also placed in the line of sight to give the driver access to this are while driving.

Platform

The platform is placed on a height of 650 mm above the ground that compared to the anthropometric measurements gives a span between the elbow and the platform surface of 255 mm for a 5-percentile female and 530 mm for a 90-percentile male. The height of this surface is however affected by the wheel size and the battery box underneath the platform that needs to hold a volume of approximately 0.160 m^3. The platform however facilitates the loading by offering foldable sidewalls in several directions, which means that the user does not have to lift heavy load as high.

9.3.2 Cognitive aspects

Supporting structure

The different functional areas on the vehicle are clearly defined and guides the user how to handle and interact with them. The supporting structure around the driver area invites the driver to the seat and there are no diffuse implications of how and where the driver should be seated.

Driver interface

The driver interface of controls and displays on the dashboard gives clear and distinct information to the driver. The battery-associated displays are grouped together on the right side of the steering wheel so the driver only needs to glimpse towards this area in order to get a quick understanding of the system status. The information is narrowed down to only sufficient details and is represented by colours, symbols and text to use redundancy in order to clearly visualize their functionality.

The battery indicator is surrounded by at simple battery symbol painted on the dashboard surface and the indicators consist of five green lamps that symbolises how much power that is left. To further enhance the symbolism the battery symbol is provided with percentage signs in the top and in the bottom. This percentage sign are later utilized as symbol in the display that shows the time left to recharging in order to guide the user and create a connection between the indicator and the display.

The symbol T → 0 % that is shown in the display is commonly used in cars and should explain that this is the time until the energy is down to zero percent. The driver could see on the display how the time is updated depending on how much power that is drained from the battery. This is visualised by the colour graded light bars that goes from green to red to indicate the power output for the moment. In the end of the scale there is a battery symbol which has small lightings coming out from it to illustrate effort. The symbol in the bottom is a plain battery.

The handle on the left of the steering wheel, which controls the lights and blinkers, has standardized symbols in the same way as in cars. The handle to the right that controls the gear, communicates its function through its position. If it is pointing forward the forward gear is active and backwards the reverse gear is active.

The windshield wiper is activated through the toggle on the left side and is combined with a symbol of a windshield that is same as the symbol used in cars.

The pedals are placed as in cars and fulfil the legal requirements. The brake pedal is a bit larger than the throttle so it should minimize the risk of not hitting the pedal in a distressed situation. The word "BRAKE" is also padded as a structure on the pedal surface to even further emphasize the function when a user feels unsure.

Platform

The platform has small arrows on the sidewalls that indicate where the leverages for tilting the platform are placed. The arrows indicate where the user should grab in order to fold out the leverage.

Powertrain

The recharging interface is placed in the back of the right side of the vehicle. The placement and form of the hitch should be associated with the traditional way of refuelling. However the symbol that is embossed on the hitch clearly shows that it is rechargeable by electricity.

9.4 Technical aspects

The measurements of the Bemo are illustrated in Figure 10.10. The vehicle dimensions makes it possible to fit five vehicles in an intermodal container if the vehicle needs to be shipped between continents.

Figure 9.**11 The frame structure**

9.4.1 Frame

The FEA resulted in a frame structure that is divided in two parts, one frame for the driver area and one for the platform (see Figure 10.11). The driver area is built of steel pipes with a diameter of 45 mm and a material thickness of 2 mm. A critical part of the construction is the corner closest to the platform. This part takes lot of the load and is therefore reinforced with gussets to spread the load.

The sidecar is built of steel pipes with a diameter of 30 mm and a material thickness of 2 mm. The frame is of a truss structure that distributes the load throughout the pipes. The platform is bolted together with the other frame part. This layout structure facilitates the possibility for parallel manufacturing and some assembly of the two frame parts and also increases disassembly properties. It does however increase the material usage somewhat.

Figure 9.**10 Measurements of the Bemo**

Since the sidecar is produced separately and then mounted on the driving part of the frame it allows to create alternative sidecars for specific user needs without affecting the driving area of the vehicle. The method also facilitates the possibility of a mirrored vehicle when this is requested.

Wheel configuration

The Bemo is based on a three wheeled configuration which gives the vehicle a very narrow turning radius of approximately 1.5 metres. This is an important aspect since it is vital to offer a vehicle that easily can move around on narrow streets and paths. Users within the mail distribution segment find this as a very important performance attribute.

The front and the back wheel are mounted on a centre line that cuts the driver area in two. This is favourable since the two wheels should create a coincidence line in order to minimize friction towards the terrain. The vehicle is furthermore equipped with disc brakes on all three wheels to create a uniformed braking force and a reliable braking system.

Suspension

The suspension of the vehicle is of a leading link configuration that will counteract the diving force that traditional forks tend to suffer from. This kind of configuration is also a very common and recognisable solution on motorcycles with sidecars and used on the old Tugger.

Steering

The FEA confirmed that the steering mechanism could safely be fastened in between the front frame structure on a horizontal beam. The steering column runs from the steering wheel in to the front casing where it is attached to a cogwheel configuration that allows the column to tilt back and fourth. The cogwheel configuration is in turn connected to the steering mechanism that is connected to the leading link suspension arm. The connection between the steering mechanism and the leading link is geared in order to provide a suitable gear ratio so that the driver does not need to apply that much force to the steering wheel when turning. The configuration is furthermore optimized to find a good balance between the rake and the trail.

Figure 9.**12 Hub motor and wheel**

9.4.2 Powertrain

The Bemo is powered by a 48 volts hub motor mounted in the back wheel and provides a power of 4 kW, which is the legal limit for mopeds. A hub motor configuration is a very flexible and easy way to configure the propulsion system since it is prefabricated and only needs an attachment point on the frame and no other additional installation procedures. The solution also facilitates the possibility to have suspension on the back wheel as the whole motor and wheel assembly could be mounted with suspension as one unified part.

The hub motor also includes a regenerative braking system that will recharge the battery when the throttle pedal is released. The motor uses the kinetic energy of the vehicle to recharge the battery. The energy is transformed from kinetic energy to stored energy in the battery and this process decelerates the vehicle speed.

The battery that is included in the Bemo should meet up with the needs stated by the mail distribution segment. As explained in chapter 3 Knowledge Base the battery is consequently a Lithium-iron-phosphate.

9.4.3 Materials and manufacturing

The casing and the frame are made of HSLA steel that was found as the most suitable steel when performing the material screening. Steel is a relatively cost efficient material that can be reused as well as recycled. It is further favourable since recycled steel requires less energy to produce and is thereby also more economically favourable.

The pipe profile of the frame could be produced by using the method profile draw bending that offers the possibility to construct quite small radius and a production process that allows for both manual and automatic production. The steel construction of the frame creates a very rigid construction that can carry high loads. The steel is also suitable since the material can stand quite rough environments and withstand impact of different kinds.

Figure 9.**13 Branded and customized for Posten**

The casings are made of sheet metal and the geometries of the design are developed to be produced using simple and low-cost production methods. The casings could consequently be produced by utilizing press break forming or stretch forming to create the desired geometries. The sheet metal also creates rigid casings that can withstand impact without the need of reparation.

The platform floor is made of wooden plywood sine there has been suggested by users that the sound when loading and unloading goods such as crushed stones and similar creates a very loud and harsh sound. The material is furthermore biodegradable and relatively cheap.

Figure 9.**14 Branded and customized for Posten**

9.5 Vehicle customization

The vehicle is as explained suitable for several different user segments and could be customized according to the user needs. Since the requirements differs quite a lot between the segments the vehicle is divided into two models, a Pro version and a Basic version.

9.5.1 Bemo Pro

The Bemo Pro is in first hand directed towards mail carriers that will use the vehicle a large part of the working day. Because of their extensive use of the product, they will benefit from the outstanding performance and ergonomics delivered by the Bemo Pro. With innovative solutions regarding the mail handling and a unique look, the Bemo Pro will be the tool no mailman wants to be without.

In addition to the performance data, the following advantages could be identified in the Bemo Pro version customised for mail delivery:

- Right steered interface that allows for mail delivering to post boxes while still seated on the vehicle
- Steering wheel and pedals offers the possibility to manoeuvre and controlling the speed while preparing the next mail delivery

- An ergonomic driver environment that cold be adjusted to several different body sizes.
- High loading capacity
- A primary cargo area in the back covered with a casing for weather protection.
- A secondary cargo area on the front platform with weather protection. This area is customized so the driver easily can reach and handle the mail that will be delivered in the nearest future. When the mail is delivered the empty boxes are switched out with new ones from the primary cargo area.
- A third cargo area in the front of the driver where a bunch of mail for the upcoming street or block could be placed in order to create an efficiently workflow when going down a street. This area also offers the possibility to place a customized box in order to protect the mail from bad weather.
- The vehicle offers quick and easy entrance and exit
- Weather protection while driving
- Remote controlled ignition key that makes the interaction with the vehicle more time efficient since the driver does not have to put a key in the ignition switch every time.
- A cargo area that could be customised to fit the standardised boxes that are used by the delivery company

9.5.2 *Bemo Basic*

The Bemo Basic is a somewhat simplified version of the Bemo Pro that is directed towards park and industrial workers that need a flexible and convenient tool for transporting various goods. The Bemo Basic is for users who do not need that extra range and do not use the vehicle as extensively as mail carriers do but still demand high loading capacity and good quality. The basic version is configured to meet the minimum requirements in both performance as well as functionality and customized to fit specific tasks. The details of such concept should be carefully evaluated by the business department so there is a good correlation between the basic version and the pro version on the market.

Figure 9.**16 Bemo Basic**

9.5.3 *Additional equipment*

The frame around the platform offers the possibility to fasten different modules that would enhance the usability and the functional performance of the vehicle. These kinds of modules could be sold as add-ons to the platform. Some examples of such modules are:

- Ladder holder
- Shovel, rake and broom attachment
- Attachment for placing handheld tools

Figure 9.**15 Branded and customized for Posten**

Figure 9.**17 Rear view of the Bemo**

Figure 9.**18 Front view of the Bemo**

10. Concept Evaluation

The chapter presents the evaluation of the final concept and a description of the strong and weak aspects of the design according to the evaluation.

10.1 Concept scoring

The evaluation of the final concept is done through concept scoring using the same criteria as when evaluating the three earlier concepts. The final ranking can be seen in figure 10.1 and it shows that the final concept is rated higher than the initial concepts and a lot higher than the original Tugger. The full concept scoring can be found in Appendix K. The highest number of 5's of the concepts compared was given to the final concept. The concept is considered to be strong (rating 4 or 5) in all functional requirements but three. The identity is rated highly on all criteria. Working environment and usability is also considered to be a strong area with only 4's and 5's across the board. The technical aspects along with manufacturing and performance are rated highly as well. Keep in mind that the scale is relative, so a 5 does not imply an optimal solution. The reasoning behind the rating of each criterion is presented below.

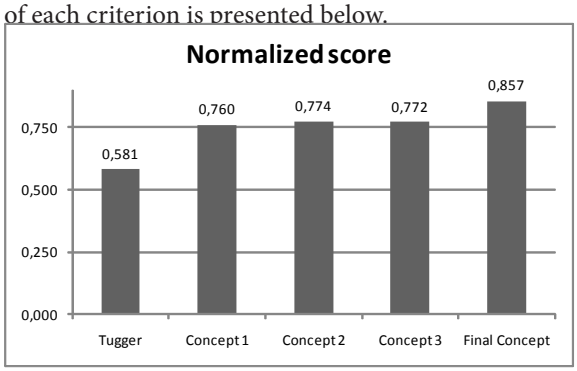

Figure 10.1 Final results of the evaluation

10.1.1 *Form and functionality*

Customization using different components (pre-sales)

The amount of flexibility provided through the platform area and the modular sidecar along with making it easy to mirror the design and providing an opportunity to choose to have a roof have worked together to give the high rating.

Ability to carry tools/working equipment (rakes, ladders)

The rails on the platform provide a natural interface for equipment holders of different kinds.

Ability to pull trailers

This is considered to be equally as good as in the other concepts.

Allow entry and exit from the right hand side

The seat design and height adjustment options provided make it easy for people of different sizes to get in and out.

Reach light cargo area from the driver's position

Since both the platform and the small storage in front of the steering wheel are within easy reach, this has been given a high rating.

Weather protection for cargo

The rails one again provide a good interface for different kinds of hoods that will protect the cargo.

Allow mail delivery from driver's standard position

The right sided driver position in combination with the easily accessible small cargo area in front of the steering wheel will make delivering mail very convenient.

Avoid damage of vehicle

The vehicle has no sensitive protruding parts and is built on a sturdy and robust frame that will endure much.

Possibility to more than one person onboard

There is a possibility to add a seat behind the driver if this is deemed necessary by the customer.

Protect driver from rain, wind and snow

The roof and windscreen provide good protection of the driver.

Allow entry and exit from both sides

This is nonexistent.

Allow entry and exit from the left hand side

The rating is based on that the frame modularity enables a convenient way of mirroring the whole vehicle, thus providing entry and exit from the left hand side.

Offer drink holder

A multi size drink holder is conveniently placed close to the driver.

Offer helmet storage

No dedicated space exists but it is considered possible to store the helmet on the vehicle.

Offer storage to personal belongings

The compartment under the seat provides storage space for personal belongings

Reach heavy cargo area from the driver's position

Heavy cargo can be reached, but it requires reaching over and does not provide good ergonomic conditions.

Appear environment friendly

The fresh appearance and clean surfaces make the vehicle appear environment friendly along with the lack of noise while driving.

Appear professional

The robust and special design of the vehicle makes it look professional.

Appear robust

The large diameter of the visible frame and the sturdy construction makes the vehicle appear robust.

Appear stable

Since the majority of both the visual weight and the actual weight is placed between the wheels, the perceived stability is high.

Communicate message star

Environment friendly is mentioned above, the accentuated frame and user centred design of the driver area makes it look driver focused. The performance is delivered by the chosen batteries and safety and reliability is connected to the simple and sturdy design.

Allow customer branding

Large surfaces are provided for branding along with suggested accent areas that together create a good foundation for customer branding.

Communicate brand essence

The brand essence or core values are expressed in a satisfactory way. The quirkiness of the vehicle is associated to creativity, the environmental and reliable aspects have been addressed and

10.1.2 Ergonomics

Minimize injury in a collision

Not possible to rate in detail but there are no protruding parts to get hurt by.

Use semantics regarding use, load and maintenance of vehicle

The controls and gauges in the driver interface are intuitive and the shape of the sidecar makes it show that it can handle the most load in the middle, which it also can.

Adequate vision from seating position

The driver's seat provides good all around visibility apart from the frame that obscures part of the field of view.

Fit different body sizes

The driver area provides extensive adjustment possibilities to ensure that many people can use the vehicle comfortably.

Perception of being safely seated

The enclosed driver area increases the safe feeling

Shock absorption for the driver

The front and back wheels as well as the seat are all suspended.

Dirt protection of the driver

The front and left side of the driver area are covered to avoid dirt hitting the driver.

Ergonomically sound loading/unloading of cargo

The height of the cargo area offers a good ergonomic working height.

Offer flexibility to adjust working environment to driver's own needs

The driver area can be adjusted as mentioned previously. Multiple storage and cargo areas enable good flexibility in the placement of goods.

10.1.3 Technical aspects

Use as few materials as possible

Steel is used in almost the entire vehicle.

Small turning radius

The original wheel configuration is intact so it should be as good as the old Tugger.

Replace battery while loaded with cargo

The battery replacement system allows removing of the battery in the back of the vehicle.

Offer easy cleaning

The large surfaces are easily cleaned.

10.2 Additional requirements

In addition to the evaluation matrix several other aspects have been evaluated continuously throughout the development process. The full requirement list that can be seen in Appendix H includes several legal requirements and other basic requirements that need to be fulfilled by the concept.

10.2.1 Legal requirements

The legal requirements that are presented in chapter 3 Knowledge Base have been labelled as basic ones and are all taken into consideration in the final concept.

10.2.2 Cost

The requirements regarding cost have been incorporated in the development process when looking at material selection and production methods and by using DFx-methodology in the development. The final concept is however not compared to a detailed budget.

10.2.3 Environmental

The environmental requirements concern the batteries, emissions, materials and recyclability of the entire vehicle. This project has excluded emissions and batteries since these parts have been the focus of the CSE Team and the Green Team. The development of the final concept does however try to adapt the material selection and production to materials that are recyclable and use as few different materials as possible. The environmental aspects have also been considered by implementing the DFx-methodology in the development.

10.2.4 Technical

There are both technical and performance requirements stated in the requirement list that has been important to fulfil in the final concept. Some of these requirements were however not the focal point during the ideation phase where concepts on a higher abstraction level were produced. Some were also at a very basic level and automatically fulfilled. Nevertheless, the following requirements have been considered in the final concept.

Load capacity

Was tested by performing a finite element analysis of the frame

Ground clearance >15 cm

The vehicle has a ground clearance of 20 cm

Turning radius

An analysis was performed in order to concluded that the wheel needs to be rotated around 60 degrees; the construction allows the front fork to reach this angle.

Time to exchange battery, around 2 minutes.

The way the battery is exchanged is built upon a tested concept that earlier have been done in around 2 minutes.

Prevent theft of vehicle

A remote controlled key and a safety transponder key control the vehicle ignition.

Prevent theft of user belongings

This criteria is not fulfilled

Prevent theft of components

The undercarriage hides the parts and makes it more difficult to steel components

Prevent theft of cargo

Different types of cargo protection are offered. It is up to the user to choose a configuration that fits his or her needs

Life length of vehicle (excl. Battery)

The main part of the vehicle is built by HSLA steel that is a robust and rigid material that also has better rust protection properties compared to other steels.

Offer easy cleaning

The robust design offers high pressure cleaning

Stability of chassis at a certain load

Needs to be tested with models. The structure is only evaluated in the computer.

Length 215-235 cm

Final concept length: 235 cm

Height 200 cm

Final concept height: 180 cm

Width 110-135 cm

Final concept width: 120 cm

Wheels (standardized wheels)

The concept uses customized 14” rims but with standardized wheel circle of 100 mm

Should have three wheels

Yes

Replaceable battery

The frame construction offers easy access to the battery from the rear end of the vehicle.

11. Discussion

The discussion presents an evaluation of the thesis project with opinions and comments from the project team. The results, the methods used and the process are all discussed.

11.1 Introduction

We have realized that there are a lot of different aspects to consider when developing a vehicle, especially such a stripped down vehicle as this, where almost any single component affects the appearance and size of the entire vehicle. It has been challenging to battle contradicting demands and a somewhat awkward overall shape with cost limitations and technical aspects. There are of course always more things that can be done and more aspects to consider. Given the scope of creating a conceptual vehicle in compliance with technical and economical limits, and the time frame, we believe we have created a feasible foundation to build on, both from a formal, a functional and a technical point of view.

11.2 Form and functionality

The end result can from one perspective be considered to be very close to the original vehicle, which there is no reason to disagree with. The reasons for this can be many. First of all, the project is about redesigning an existing vehicle. The original vehicle has its inherent strengths and weaknesses, and those strengths are of course connected to the way the vehicle is designed. If all these good properties are to be kept, it is easy to end up in the same type of vehicle, since the reason it has these properties is because it is a vehicle of this type. It becomes a type of circle argumentation. We have explored alternative solutions as well, but nothing strong enough to challenge the expertise and experience from the initiators of the project.

Secondly, we believe it is easy to be locked in creatively by an existing solution. The result would perhaps be different if the purpose would have been to look at these users without taking off in an existing vehicle. This is however something we have been aware of during the development and we have tried to use creative ideation methods to break free. Taking the perspective of the initiators, it is however good to utilise existing technology and knowledge as much as possible to increase the chance of the ideas being implemented, so it depends in which context the project is viewed. From the end user's perspective it is of course better to generate a concept that is good and gets implemented than an excellent result that never leaves the drawing table.

We feel that the area around the driver with the frame and driver interface is more finished when looking at the form, than for instance the sidecar undercarriage which we feel is not as convincing formally. It works and we consider it to be a good start, but another iteration regarding the design of this part would be beneficial. Considering it is a redesign project, the scope and comparing it with the original vehicle and its competitors, we still feel that the result provides a good base to build further development around.

11.3 Ergonomics

The ergonomic perspective of the project is considered a strong point. Many guidelines regarding the physical work environment are implemented and cognitive aspects have been taken into consideration as well. Something that needs more investigation is the actual work situation of the postal worker, for instance the amount of cargo handled and the intervals at which it is handled. This is something that should be looked into when developing the postal platform further.

We are aware of that it is probably not viable from a cost perspective to custom make a seat and the steering column as we have done in the final concept, but the proposed solutions can be used as guidance when choosing which parts to get. The functionality and the amount of adjustability described provide good measurements for a future selection process.

Once again, compared to the original vehicle and to many of the competitors, the thorough ergonomic consideration of the final concept and user centred approach stands out in a positive way.

11.4 Technical aspects

Validating the technical aspects of things connected to the form and functionality has been an integrated part of the work. It has been interesting to work conceptually on a level that is still fairly close to a producible product. The fact that many of the form related aspects have been investigated from a technical point of view is also considered to be a strong positive aspect of the result.

Some aspects of the concept are however still in need of further investigation. It is crucial that the vehicle dynamics and handling properties are tested with a full scale prototype, since these are essential parts to ensure a safe and comfortable ride. The wheel configuration and general structure of the vehicle is only based on the old vehicle and the driving characteristics of that vehicle are not fully known, which makes it important to conduct proper tests of a new vehicle.

11.5 Constraining aspects

The cost of this kind of vehicle is vital since it is going to be competing on a low-cost vehicle market. The principle of target costing was therefore introduced in the beginning of the project and has been influencing the development process. It has however not been applied in detail to compare vehicle details to a pre-defined budget. Cost reasoning has been included when choosing material and manufacturing methods and the supporting frame construction aims for minimizing material and assembly costs. The vehicle has on the other hand been provided with sheet metal casings that will increase the material and production cost compared to the original Tugger. As mentioned in the evaluation chapter the trade-off between increasing material costs and the market advantages that the design bring must be thoroughly investigated and analysed.

The cost reasoning was perceived as quite difficult since it is tricky to now how much the cost variance will be when choosing between different materials and methods or changing a detail in the design. There are several parameters that need to be taken in to consideration and it is often the industrial experts that work with the different materials and production that could give a reliable answer. A closer cooperation with such experts during development will certainly give a more accurate and reinforced decision basis.

11.6 Method

Many different methods have been applied during the project, some existing, some adjusted versions and some own creations. All methods presented have been beneficial in some way, but the results of the different methods have been used to different extents within the project. Below is a discussion regarding the specific methods.

11.6.1 Requirement gathering methods

The requirement gathering methods cover gathering, processing and presentation methods. The results from the methods are used in different ways.

Some were used as a way of increasing our own knowledge in a certain area and since the project team acquired the knowledge the actual method results were not used explicitly after that. These include the information gathering methods such as interviews, observations and the product breakdown analysis for instance. There is of course a risk of forgetting certain aspects of this information so to avoid this, more time could have been spent visualizing the results and findings to allow for wall mounting to give the information a greater presence during the development. This was done to some extent through the list of requirements, but could be improved further.

The product breakdown method was a good way to get an overview of the product at hand and the different subsystems. It could however be developed further to provide a more consistent result, for instance in which order to focus on parts and different attributes like materials and adjustability for instance.

The KJ analysis is an information processing method that was used frequently as parts of other methods and to sort information from the information gathering methods. It provides a quick and intuitive way of sorting data that we consider being very good.

The list of functions, requirement specification and segment matrix were good ways to list and present important information. The list of functions was good input to the requirement specification and the requirement specification was used during the entire development. It was used to find areas to focus the development on and also provided the criteria for the evaluation of the concepts. The segment matrix provided a way to increase the amount of possible market segments. It was good to use later, during the ideation phase to broaden the focus area and find possible solutions, but the estimations were completely subjective and based only on the knowledge within the project group. Because of this the results of the segment matrix were not used later in the development.

11.6.2 Development methods

The development methods consisted of creative, framework, evaluative and validating methods that aided different areas of the actual development of the product.

The creative methods such as brainstorming, SCAMPER and sketches and visualizations have all contributed to driving the development forward. We do however feel it is important to have a structured approach to the creative phase as well, in order to focus the effort and increase the efficiency. We do not advocate too much or too rigid structures, but rather a framework that directs the efforts of the creativity and does not inhibit it.

The framework methods; image boards, personas and the product character definition have all been used to guide and continuously evaluate the ideas and designs; the image boards and character definition to a larger extent than the personas. The results of these methods should all also be wall mounted to help keep them in mind during the entire process. The image boards were printed and used constantly to evaluate form ideas and the expression of the whole and this worked very well.

Concept scoring was the only systematic evaluation method and it provided a structured approach to assessing a number of criteria. It is important to keep in mind that it is a comparative and subjective method and that the results can only be used to rate the different concepts against each other. The rating is also biased and can sometimes be a bit optimistic when the design is not defined in detail yet, especially when the persons evaluating the concepts are the same as the ones who have developed them. The aspects of the design that are not performance driven are probably always prone to be decided on subjective grounds, this method at least adds a systematic approach to rate the concepts on the same terms. All in all it is considered to be a good way to compare different concepts and find strong and weak points.

The validating methods have been very important in increasing the credibility of the final concept. The finite element analysis and the turning radius simulation have given answers to specific problems while the DFX methods, target costing and material and production screening have provided a more general framework to work within. There is still a risk that the resulting concept does not manage to stay within the boundaries of the framework when looked at in more detail, but since these aspects have been considered from the start, the required adjustments should be smaller and easier to implement.

11.6.3 *Project management methods*

The project management methods all aided the progress of the project itself. In the beginning of the project the Gantt chart and work breakdown structure provided a structured approach to the project planning. During the project the weekly schedule template provided easy detail planning of the current and coming weeks. The weekly recurring activities were however often pushed forward because of other work. This could perhaps have been aided if the reserved time was in the morning instead of the afternoon, to ensure that no work being done before runs over time. The risk and stakeholder analyses were good ways of assessing the importance and severity of these aspects. They could however also have been printed and mounted on a wall to make them more prominent during the project.

11.7 Process

The form development has been somewhat limited by the technical and functional aspects of the vehicle. This has both positive and negative sides, on one hand it may be hard to reach as high formal qualities as possible, but on the other hand, the forms that are chosen and technically verified require less work to be implemented in a real vehicle. The development has still had a starting point around form and functionality, but we feel it has been important to balance this with a fair amount of engineering work to create a believable concept that is valuable to the initiators of the project.

The relative importance between the segments has changed slightly toward the end of the project. The postal segment is deemed much more important from a business perspective, and if this had been the focus from the start, a more directed result towards postal services could have been developed. The vehicle would perhaps look different if there for instance would be no need to tilt the platform or fold the sidewalls. Now, some ideas directed towards mail handling are presented but this is an area that needs a deeper understanding of how the postal workers actually work on a day-to-day basis. Since our understanding of the work situation is based mostly on interviews, we have probably missed some hidden problems that would have been detected through observation. Now our findings are filtered through the minds of the interviewees. Proper observation studies are something that should be done when developing the vehicle further.

The close collaboration with Green Team and the CSE Team have proved very beneficial, since we have been able to take concurrent work into account in this project as well, and build on each other's findings and decisions. It has also been a good experience to see our area of expertise in a larger context and we believe this has made us better prepared for when we leave school and start working.

12. Recommendations

This chapter presents recommendations directed towards the initiators of the project based on the results presented and knowledge acquired during the project.

12.1 Introduction

The basic aspects of the concept presented have been verified to a certain extent, but there is still work to be done in order to implement the ideas in a real product. The aim was to create a concept that gives an image of how version two or three of the vehicle could look and work. These recommendations present actions that should be taken when developing the vehicle further. The final concept presented in the previous chapter should be used as a guideline in many ways when the development continues.

12.2 Form and functionality

If this configuration of the vehicle is considered to be an attractive direction to take, then as many ideas as possible should be taken into consideration when developing the first version. This will ease the continuous development later on. It will also provide a better market introduction since a well-defined product probably would be more convincing to present to possible customer segments right from the start of the market initiation.

If a more basic version will be developed initially, certain aspects are more important to keep than others. The concept with a visible frame around the driver area should be kept, even if the frame itself is implemented in a simpler way. The form of the sidecar undercarriage should be developed further.

The functionality within the driver area will increase the experience for the user and are considered to be fairly easy to implement, so the storage area and drink holder should be kept.

There are more user aspects that need investigation. A first step would be to evaluate the concept on the potential customers, to see if it is appreciated. Observations of users should also be conducted within the interesting market segments. A deeper investigation of how the vehicle can be optimized for postal work should for instance be made.

12.3 Ergonomics

In order to stay credible with a driver focused design it is important to not compromise too much with the driver area. The adjustment possibilities should be kept to an as high extent as possible when investigating standard components for the seat and steering wheel.

It would also be beneficial to build physical mock-ups to find possible problems that are not evident in the computer models and to verify the concept further.

Mail handling should also be looked into in more detail from an ergonomic perspective to ensure that the driver area is adapted to this, especially the platform area that is highly customizable. Investigations can be made on how mail is handled in different types of vehicles to see what is good with each solution.

12.4 Technical aspects

It is important for the credibility of a company that wants to brand itself as environmentally friendly to work proactively with environment issues. A life cycle analysis should be conducted on the vehicle initially and continuous analyses and improvements should be made to make this aspect better.

Since the frame structure is only verified virtually on a basic level, the properties of the frame should be investigated practically as well to see how it performs under load. The effect of where the load is placed should also be investigated, especially how it affects the stability when driving. The influence when towing a trailer should also be looked into.

In order to verify and improve the handling of the vehicle, a prototype with adjustable rake and trail, as well as adjustable wheel placements would be beneficial to be able to try different variations of these aspects.

Detailed design engineering is needed to ensure that all components and electrical wiring can fit within the different hoods.

13. Conclusion

The chapter presents the conclusions that are drawn based on the project described in the report.

13.1 Conclusion

The purpose of the project was to " improve the possibility of a successful product and brand introduction on the market by implementing a methodical re-design process on the Electrical Distribution Vehicle". The following conclusions should subsequently be considered in relation to the original Tugger.

The form language has its foundation in the core values of the company and provides several characteristic elements that form an industrial vehicle that stands out in the crowd of competitors. The design is based on the supporting frame structure and simple single-curved surface elements which allows for low-cost material and manufacturing methods.

The evaluation clearly indicates that the basic user needs are fulfilled to a high level and by additionally incorporating several specialised needs the vehicle is considered to meet the aim of fulfilling user demands and wishes to a high extent. In addition, driver ergonomics has been the core within the development process and is to a high level incorporated in the driver area to enhance the possibility to adjust the vehicle to different users. However, the vehicle still needs some further development in order to define the ideas in detail and evaluate the concept with physical models.

Environmental friendliness has been a general mindset in the development process and decisions regarding the design have consistently been evaluated regarding environmental impact. The vehicle is however not optimized with this aspect in mind since cost is a crucial element for this kind of industrial vehicle. It is nonetheless very important that the company considers the environmental aspect in a lifecycle perspective, as the brand desires to be perceived to have a strong focus on environmental friendliness. This is fundamental in order to strengthen the credibility of the brand and the vehicle.

The concept vehicle has moreover been adapted to low cost manufacturing of rather small series in order to be realisable in the near future. However, the vehicle is probably going to be more expensive to manufacture compared to the original vehicle since the material usage has increased. Nevertheless, the additional cost needs to be evaluated to analyze what kind of market advantages the design will bring.

The summarized conclusion is that the project result presents a redesigned vehicle that surpasses the original vehicle in several ways. The new design utilizes all the strengths within the original vehicle and adds additional value to the vehicle and the brand through a thought through design with a characteristic expression and good ergonomics.

Figure 13.1 The old vehicle

Figure 13.2 The new Bemo

14. References

All cited references used in the master thesis are presented in this chapter.

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15. Appendices

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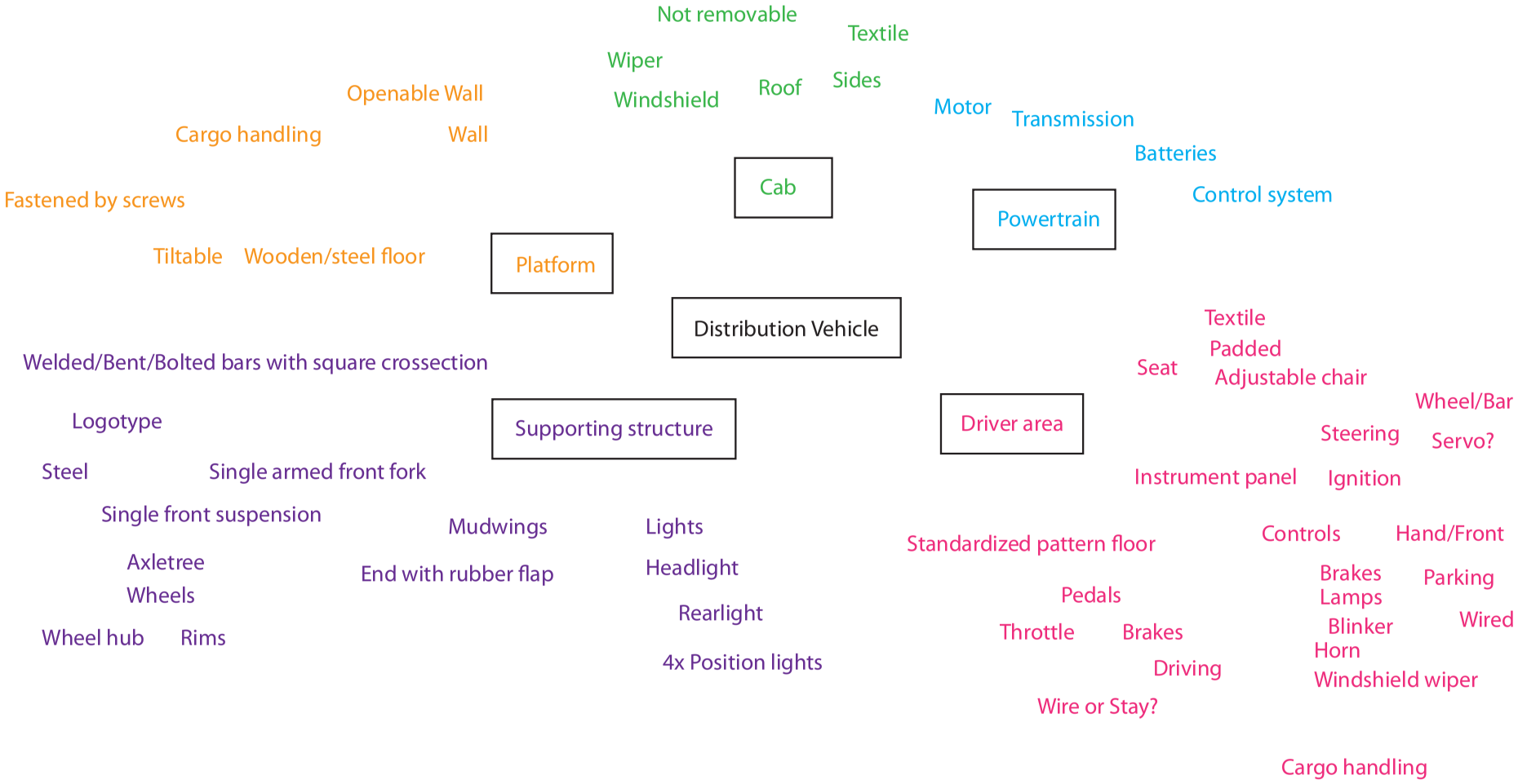
Appendix A - Product Breakdown

Product Breakdown



Appendix B - Material Selection

Material selection

Step 1: Deside required properties of the materials

Step 2: Specify possible materials that fulfills the different properties. Collect both the best and worst solution so this information can give guidance later in the process when trade-offs need to be done.

Desired properties	Best material alternatives	Worst material alternatives
Strong in tension	High tensile steels (HTS):	Cast iron
Parts:	High carbon steel	Solid glass
Frame	Alloy steels	Brittle plastics
Platform	Stainless steel	Ceramics
		Minerals
		Waxes
Strong in compression	Cast iron	Flexible foams
Parts:	Steels	Elastomers
Frame	Many metals in solid form	Soft metals
Platform	Hard minerals and rocks (e.g. granite)	Some plastics
Rigid, stiff component	High carbon and alloy steels	Copper
Parts:	Brasses and bronzes	Tin
Frame	Aluminum	Zinc
Casings	Magnesium and titanium alloys	Lead
Windshields	Many thermoset plastics	Solder
Platform	Composite plastics	Unfilled thermoplastics
	Woods and wood composites	Elastomers
	Glass and ceramics	Fabrics and fibers
Transparent	Mica	Everything else
Parts:	Many solvents	
Windshields	Some adhesives	
	Soda glass	
	Crown glass	
	Flint glass	
	Glass-ceramics	
	Transparent plastics	
Corrosion resistant	Precious metals	Unprotected plain carbon steels
Parts:	Inconel etc	Zinc
Frame	Stainless steel	Most copper alloys
Casings	Alloy steels	Brasses and bronzes
Windshields	Magnesium alloys	Aluminum in marine environments
Platform	Monel metal	Most unprotected woods
	Titanium	
	Marine bronzes	
	Most plastics	
	Plastic composites	
	Elastomers	
	Plated and passivated metals	
	Glass	
	Glazed ceramics	
	Durable woods, WBP and marine ply	
Low material cost	PS	Silicones
Parts:	PE	PEEK
All	PP	PTFE
	PVC	Polyester
	Formaldehyde thermosets	Epoxy composites
	Plain carbon steels	Honeycomb composites
	18-8 stainless steel	Carbon fiber composites
	Commodity rubber	Titanium
	HSLA steel	Ceramics
	Commodity softwoods and general-purpose wood composites	Premium hardwoods and high grade wood composites
		Precious metals
Low ongoing process cost	Injection or compression molded plastics	Minerals
Parts:	Die cast metals	Wood
All	Pressed metal parts	Metals or plastics requiring extensive machining
	Other high volume (fully tooled and automated) processes	Hand layup GRP

Step 3: Match the possible materials and their properties to find a good combination. Further invesigate these materials or material groups to find a first round of materials with acceptable properties and production methods.

Possible alternatives to investigate further:

Part	Material	First round	
Casings	Thermoset plastics	HSLA steel	
	Composite plastics	Thermosets plastics	PP, DCPD, ABS
	Steel		
Platform floor	Durable wood	Wood	Coated plywood
	Steel		
	Aluminum		
	Thermoset plastics		
	Composite plastics		
Windshield	Soda glass	Transparent plastics	PC, PMMP
	Crown glass		
	Flint glass		
	Glass-ceramics		
	Transparent plastics		
Platform sides	Steel	HSLA steel	
	Thermoset plastics		
	Composite plastics		
Frame	Steel	HSLA steel	
	Aluminium		

Step 4: Study the choosen materials more in detail. How well do they meet the requirements? If they are not of total satisfaction try to finde new alternatives, it is an ittarative process.

The possible materials choosen to the first round are further invesigated with focus on:

Environmental impact
Cost for material and production processes

Guidleines for material cost

Low cost (under $2 per kg)	Medium ($2 to $10 per kg)	High cost (over $10 per kg)
Cast iron		
Plain carbon steels		
Alloy steels	Alloy steels	
	Stainless steels	
	Tool steels	
	Copper alloys, brass etc	
	Aluminum alloys	
	Magnesium alloys	
		Titanium alloys
Commodity plastics		
	Engineering plastics	
Clay ceramics		
Softwoods		
	Softwoods	
	Hardwoods	
	Glass reinforced polyester	
		Carbon epoxy composite

Step 5: Optimize the selection by talking to production engineers and material resellers. Also scan the market for applied versions of materials and production processes

Appendix C - Environmental aspects

Extract from Design-Bites regarding environmental product development

Pollution occurring during materials extraction and product manufacture

- Minimize energy use in extraction and manufacture.
- Minimize emissions.
- Minimize use of toxic or polluting materials in processes.
- Minimize toxic or polluting materials in the product.
- Minimize scrap material and general waste.
- Recycle scrap material.

Pollution caused by packaging waste

- Minimize packaging materials use.
- Select recyclable or biodegradable materials.
- Have material types easily separable.

Pollution caused by the product during normal use

- Maximize energy efficiency.
- Mivnimize use of fossil fuels.
- Consider disposal of maintenance waste (e.g. old lubricating oil).

Pollution caused by end-of-life disposal of the product

- Consider viability of component re-use rather than material re-cycling.
- Design for easy disassembly using common tools. Design products as per Design for maintainability. Increase modularity.
- Design for disassembly into single-material pieces for recycling. Use non permanent fasteners instead of adhesives or welds.
- Avoid moulded-in metal components in plastic. Avoid exotic material blends, composites, and metal plating of plastics. Minimize colour variations. Avoid fillers and strengtheners in plastic (e.g. glass fibre).
- Identify component materials by marking with a code.
- Incorporate maximum regrind material into new products, consistent with desired mechanical and other properties.

Appendix D - DFM/DFA Guidelines

DFM and DFA Guidelines from http://www.npd-solutions.com/dfmguidelines.html

1. Simplify the design and reduce the number of parts because for each part, there is an opportunity for a defective part and an assembly error. The probability of a perfect product goes down exponentially as the number of parts increases. As the number of parts goes up, the total cost of fabricating and assembling the product goes up. Automation becomes more difficult and more expensive when more parts are handled and processed. Costs related to purchasing, stocking, and servicing also go down as the number of parts are reduced. Inventory and work-in-process levels will go down with fewer parts. As the product structure and required operations are simplified, fewer fabrication and assembly steps are required, manufacturing processes can be integrated and leadtimes further reduced. The designer should go through the assembly part by part and evaluate whether the part can be eliminated, combined with another part, or the function can be performed in another way. To determine the theoretical minimum number of parts, ask the following: Does the part move relative to all other moving parts? Must the part absolutely be of a different material from the other parts? Must the part be different to allow possible disassembly?

2. Standardize and use common parts and materials to facilitate design activities, to minimize the amount of inventory in the system, and to standardize handling and assembly operations. Common parts will result in lower inventories, reduced costs and higher quality. Operator learning is simplified and there is a greater opportunity for automation as the result of higher production volumes and operation standardization. Limit exotic or unique components because suppliers are less likely to compete on quality or cost for these components. The classification and retrieval capabilities of product data management (PDM) systems and component supplier management (CSM) systems can be utilized by designers to facilitate retrieval of similar designs and material catalogs or approved parts lists can serve as references for common purchased and stocked parts.

3. Design for ease of fabrication. Select processes compatible with the materials and production volumes. Select materials compatible with production processes and that minimize processing time while meeting functional requirements. Avoid unnecessary part features because they involve extra processing effort and/or more complex tooling. Apply specific guidelines appropriate for the fabrication process such as the following guidelines for machinability:

- For higher volume parts, consider castings or stampings to reduce machining
- Use near net shapes for molded and forged parts to minimize machining and processing effort.
- Design for ease of fixturing by providing large solid mounting surface & parallel clamping surfaces
- Avoid designs requiring sharp corners or points in cutting tools - they break easier
- Avoid thin walls, thin webs, deep pockets or deep holes to withstand clamping & machining without distortion
- Avoid tapers & contours as much as possible in favor of rectangular shapes
- Avoid undercuts which require special operations & tools
- Avoid hardened or difficult machined materials unless essential to requirements
- Put machined surfaces on same plane or with same diameter to minimize number of operations
- Design workpieces to use standard cutters, drill bit sizes or other tools
- Avoid small holes (drill bit breakage greater) & length to diameter ratio > 3 (chip clearance & straightness deviation)

4. Design within process capabilities and avoid unneeded surface finish requirements. Know the production process capabilities of equipment and establish controlled processes. Avoid unnecessarily tight tolerances that are beyond the natural capability of the manufacturing processes. Otherwise, this will require that parts be inspected or screened for acceptability. Determine when new production process capabilities are needed early to allow sufficient time to determine optimal process parameters and establish a controlled process. Also, avoid tight tolerances on multiple, connected parts. Tolerances on connected parts will "stack-up" making maintenance of overall product tolerance difficult. Design in the center of a component's parameter range to improve reliability and limit the range of variance around the parameter objective. Surface finish requirements likewise may be established based on standard practices and may be applied to interior surfaces resulting in additional costs where these requirements may not be needed.

5. Mistake-proof product design and assembly (poka-yoke) so that the assembly process is unambiguous. Components should be designed so that they can only be assembled in one way; they cannot be reversed. Notches, asymmetrical holes and stops can be used to mistake-proof the assembly process. Design verifiability into the product and its components. For mechanical products, verifiability can be achieved with simple go/no-go tools in the form of notches or natural stopping points. Products should be designed to avoid or simplify adjustments. Electronic products can be designed to contain self-test and/or diagnostic capabilities. Of course, the additional cost of building in diagnostics must be weighed against the advantages.

6. Design for parts orientation and handling to minimize non-value-added manual effort and ambiguity in orienting and merging parts. Basic principles to facilitate parts handling and orienting are:

- Parts must be designed to consistently orient themselves when fed into a process.
- Product design must avoid parts which can become tangled, wedged or disoriented. Avoid holes and tabs and designed "closed" parts. This type of design will allow the use of automation in parts handling and assembly such as vibratory bowls, tubes, magazines, etc.
- Part design should incorporate symmetry around both axes of insertion wherever possible. Where parts cannot be symmetrical, the asymmetry should be emphasized to assure correct insertion or easily identifiable feature should be provided.
- With hidden features that require a particular orientation, provide an external feature or guide surface to correctly orient the part.
- Guide surfaces should be provided to facilitate insertion.
- Parts should be designed with surfaces so that they can be easily grasped, placed and fixtured. Ideally this means flat, parallel surfaces that would allow a part to picked-up by a person or a gripper with a pick and place robot and then easily fixtured.
- Minimize thin, flat parts that are more difficult to pick up. Avoid very small parts that are difficult to pick-up or require a tool such as a tweezers to pick-up. This will increase handling and orientation time.
- Avoid parts with sharp edges, burrs or points. These parts can injure workers or customers, they require more careful handling, they can damage product finishes, and they may be more susceptible to damage themselves if the sharp edge is an intended feature.
- Avoid parts that can be easily damaged or broken.
- Avoid parts that are sticky or slippery (thin oily plates, oily parts, adhesive backed parts, small plastic parts with smooth surfaces, etc.).
- Avoid heavy parts that will increase worker fatigue, increase risk of worker injury, and slow the assembly process.
- Design the work station area to minimize the distance to access and move a part.
- When purchasing components, consider acquiring materials already oriented in magazines, bands, tape, or strips.

7. Minimize flexible parts and interconnections. Avoid flexible and flimsy parts such as belts, gaskets, tubing, cables and wire harnesses. Their flexibility makes material handling and assembly more difficult and these parts are more susceptible to damage. Use plug-in boards and backplanes to minimize wire harnesses. Where harnesses are used, consider foolproofing electrical connectors by using unique connectors to avoid connectors being mis-connected. Interconnections such as wire harnesses, hydraulic lines, piping, etc. are expensive to fabricate, assemble and service. Partition the product to minimize interconnections between modules and co-locate related modules to minimize routing of interconnections.

8. Design for ease of assembly by utilizing simple patterns of movement and minimizing the axes of assembly. Complex orientation and assembly movements in various directions should be avoided. Part features should be provided such as chamfers and tapers. The product's design should enable assembly to begin with a base component with a large relative mass and a low center of gravity upon which other parts are added. Assembly should proceed vertically with other parts added on top and positioned with the aid of gravity. This will minimize the need to re-orient the assembly and reduce the need for temporary fastening and more complex fixturing. A product that is easy to assemble manually will be easily assembled with automation. Assembly that is automated will be more uniform, more reliable, and of a higher quality.

9. Design for efficient joining and fastening. Threaded fasteners (screws, bolts, nuts and washers) are time-consuming to assemble and difficult to automate. Where they must be used, standardize to minimize variety and use fasteners such as self threading screws and captured washers. Consider the use of integral attachment methods (snap-fit). Evaluate other bonding techniques with adhesives. Match fastening techniques to materials, product functional requirements, and disassembly/servicing requirements.

10. Design modular products to facilitate assembly with building block components and subassemblies. This modular or building block design should minimize the number of part or assembly variants early in the manufacturing process while allowing for greater product variation late in the process during final assembly. This approach minimizes the total number of items to be manufactured, thereby reducing inventory and improving quality. Modules can be manufactured and tested before final assembly. The short final assembly leadtime can result in a wide variety of products being made to a customer's order in a short period of time without having to stock a significant level of inventory. Production of standard modules can be leveled and repetitive schedules established.

11. Design for automated production. Automated production involves less flexibility than manual production. The product must be designed in a way that can be more handled with automation. There are two automation approaches: flexible robotic assembly and high speed automated assembly. Considerations with flexible robotic assembly are: design parts to utilize standard gripper and avoid gripper / tool change, use self-locating parts, use simple parts presentation devices, and avoid the need to secure or clamp parts. Considerations with high speed automated assembly are: use a minimum of parts or standard parts for minimum of feeding bowls, etc., use closed parts (no projections, holes or slots) to avoid tangling, consider the potential for multi-axis assembly to speed the assembly cycle time, and use pre-oriented parts.

12. Design printed circuit boards for assembly. With printed circuit boards (PCB's), guidelines include: minimizing component variety, standardizing component packaging, using auto-insertable or placeable components, using a common component orientation and component placement to minimize soldering "shadows", selecting component and trace width that is within the process capability, using appropriate pad and trace configuration and spacing to assure good solder joints and avoid bridging, using standard board and panel sizes, using tooling holes, establishing minimum borders, and avoiding or minimizing adjustments.

Appendix E - Interview summary

Interview material

Interview Botanical Garden, Gothenburg

Intervju med Martin Jakobsson på Botaniska Trädgården

Har kört Tugger sedan 80-talet sålde de sista till ett gäng Jugoslaver igår. Nu kör de elmopder från Transportel samt två Dobbins.

En Dobbin som är 3-4 år gammal, 3kW AC-motor och 48 volt, blybatterier. Ca 80.000 kr. En lite nyare Dobbin med truckcellsbatteri. De är båda standardutrustade. Batterilådorna för syrabatterier var tvungna att vara helt slutna i botten enligt ny lag? Viktigt att sköta om batterierna annars förlorar de kapacitet snabbt, men samtidigt måste det vara lätt och intuitivt om alla ska klara av det.

De viktigaste funktionerna är att kunna koppla på lastvagnar och att den klarar tung last. Används till att dra försäljningsvagnar, krattor, spadar mindre jordlast, krukor sålådor, lövkorgar, moduler till papperskorgar m.m. De nuvarande motorerna är tillräckligt starka för de uppgifter som utförs på Botaniska.

De väljer oftast andra, större maskiner för att köra jord och elmopeder när de inte drar något.

Problem med Dobbin:

- Svårt att trycka i och dra ur laddhandske, kontakten dras sönder emellanåt
- Påfyllning av vätska till batteri kräver viss uppsikt eftersom ventilerna ibland hänger sig och det läcker ut syra
- Gaspedalen hänger sig ibland när det kommer in smuts mellan öppningen i golvet och pedalen
- Lamporna kring fordonet är inte skyddade och går ofta sönder när man kör in i saker
- Mindre personer har svårt att ställa in en bra sittposition och säkerhetsbrytaren reagerar inte på lättare personer
- Bromsskivorna rostar och gnisslar eftersom de inte används så mycket (man motorbromsar oftast), måste köra dem rena då och då
- Studsar ut saker från flak när vägen är ojämn
- Tungt att lyfta upp och tömma ett lastat flak
- Lite för mycket glapp i ratten, kan bero på kedjeutväxlingen
- Ibland river de upp sätena när de har vassa verktyg i fickor eller bälte
- Väldigt dåligt glid i inställningen av stolen
- Plastkåpor var sådär, inga hade gått sönder ännu, men var skrapade och slitna
- Ibland händer det att man ställer sig på gaspedalen när man kliver på fordonet
- Syran förstör det galvaniserade stålet
- På vintern kan batterierna bli dåliga när fordonet får stå ute länge
- På sommaren räcker det utan problem en hel dag
- Fordonet är sämre på halt underlag pga. sin höga vikt, den glider och spinner lätt på grund av att det bara är drivning på ett hjul
- Flaket kan inte spännas fast riktigt, dålig krok och det slamrar när man åker
- Ett svagt tjutande ljud i elektroniklådan

Önskemål:

- Förarplatsen kan bli mycket bättre
- Känns trångt att sätta sig
- Går ofta på och av så ett lågt insteg samt en svängbar stol hade varit bra
- Fordonet hade eventuellt kunnat vara lite smalare för att få plats på gångar, men inte ta bort för mycket last yta
- Skönare sits och lättare att ställa in
- Det är många ovana förare så det behöver vara en robust konstruktion och känsliga komponenter måste vara väl skyddade
- Det ska vara så tyst som möjligt att arbeta med fordonet
- Hade varit bra att kunna spänna fast saker på flaket
- Siffrorna i elpanelen går inte att tyda, det står alltid någon siffra och varken användaren eller försäljaren vet vad de innebär
- Viktigt att det är tätt in till olika komponenter så att underhåll minimeras
- ”Den ska vara robust som en hockeypuck”
- Hytt som skyddar sitsen mot regna hade varit bra, men det får inte bli för varmt på sommaren

Intervjuformulär Bring 2010-02-08

Datum: 2010-02-08 Man/Kvinna: Ja/Ja Ålder: 23 och 24 Erfarenhet: 1år respektive 3år

Inledning

- Vilka olika typer av fordon har ni använt er av?I vilka situationer?Vilka var bäst? – Varför?

Bil – När det är längre bort och mycket backar

Moped – När det är längre bort och/eller mycket backar

Cykel – Nära och inte så mycket backar

Alla fordon används året om. Det spelar ingen roll vilken typ av väder det är.

- Vad är er allmänna inställning till denna typ av fordon?

Bil – bäst och skönast under vintern. Man kan bli seg av att sitta i bilen en hel dag.

Moped – En Scooter med påbyggnader i stål för att sätta lådor. Lite krånglig eftersom den går sönder då och då, den är för slö i backar. Bra när det är sommar men bökigt på vintern. Soft.

Cykel – Bra på sommaren, aningen jobbigt

- Hur ser en typisk arbetsdag ut? Hur många timmar arbetar ni i sträck? Vilka moment är jobbigast? Fysiskt? Psykiskt?

Börjar vid 07.00 med att sortera brev på lagret. Brukar åka ut vid 10-11 om det inte blivit brev kvar från föregående dag. Då levererar man dessa direkt på morgonen. Slutar vid 13.00 eller runt 15.30. Det beror på hur mycket brev som ska levereras. Man kör vanligtvis en till två rundor á 2-3 timmar. Mopeden är bensindriven och klarar två rundor.

- Hur lastas fordonet? Flera gånger om dagen? Standardmoduler med post som sätts i eller läggs posten i direkt (Ta mått)? Några problem med detta?

Mopeden lastas med 4 lådor i standardstorlek. All post sorteras i denna typ av plastlådor som sedan lastas i ställningar på mopeden. Vikten på lasten varierar mellan 40-85 kg (uppskattning).

- 3-hjulingar hade varit optimalt – kan lasta hur mycket som helst, men då behövs det starkare motor

- Hur ser de olika momenten ut? Hur ofta stiger man på och av fordonet? Vid vilka tillfällen? Vilken ordning tar man posten och stiger av?

Vid villaområden vill man kunna ”dunka”-posten dvs. Lägga posten i brevlådan i farten. Men det går inte med mopeden eftersom gasen sitter på högersidan av styret. Brevbäraren förbereder oftast kommande avlämning i farten. Dvs. han/hon kör samtidigt som han/hon tar fram rätt bunt brev ur lådorna framför sig. Detta är en viktig funktion enligt de intervjuade.

Vid lägenheter stannar man mopeden och tar ut de brev som ska levereras till en trappuppgång. Oftast låter de nyckeln sitta i för det blir ett extra arbetsmoment att dra ut nyckeln och låsa fordonet samt att behöva starta den igen. Hjälmen lägger de i en av de fack där locken till postlådorna ska vara. Brukar gå av och se till att den inte välter (instabilt stöd), sedan ta posten.

Konstruktion

- Finns det saker/detaljer som ofta går sönder?

Bakbromsen är dålig. Den är ofta sönder

- Känns konstruktionen pålitlig och säker? Vad känns bra/mindre bra?

Mopeden har vält att antal gånger och håller relativt bra. Det blir en del repor och småsprickor. Ställningen har lostnat, bultarna har gått sönder.

När den ramlar händer alltid nånting.

- Hur uppfattas storleken på fordonet? Stor/liten/klumpig/smidig…?

Ganska bra. Nästan lika stor som cykeln, lite mindre för lådorna sitter bak på moppen och inte på sidorna som på cykeln.

Så länge den inte blir bredare så vore det bra att kunna lasta mer.

- Hur mycket kan fordonet lasta? Följer man rekommendationerna?

Finns ingen maxlast. Beroende på hur mycket kataloger som ska levereras kan vikten ligga mellan 40-85 kg

- Hur känns det att manövrera med last? Utan last? I hög fart? I låg fart?

Det känns vingligt med maxlast men det är en vanesak. En av de intervjuade välte fyra gånger i början. Kan kännas lite wobbligt i höga farter och med mycket last, är den tom är det ingen fara. Går fortare på sommaren än vintern.

- Manövrering allmänt? Svängradie, storlek, stabilitet, av/påstigning, olika terräng, trottoarer/väg m.m.?

Det är ju inget terrängfordon. Hyfsad manövrering. Inte jättebra svängradie. Man klarar att svänga runt på en normalbred gata utan att behöva backa. Ställningen är lite begränsande av svängningen. Det är väldigt bra däck, dubbdäck under vintern. Men man klara inte snövallar. Trottoarkanter kan man lära sig att ta

Funktionalitet

- Vilka funktioner finns på fordonet? Hur upplevs/fungerar de?
- Förvaring av gods?
- Finns plats för fyra fyllda lådor samt 14 tomma lådor, sju på höjden i facken bakom föraren.
- Finns plats för alla lock i extra fack. Dessa används ibland till stora paket.
- Förvaring av personliga saker?
- Finns ingen. Hade uppskattats om det fanns plats för plånbok, mobil, vattenflaska etc. Ska kunna låsa detta fack.
- ”Man får ha en påse i jackan eller nåt”
- Förvaring av hjälm?
- Finns ingen speciell plats, läggs i en tom låda. Hade varit bra med en krok där man lätt kunde hänga hjälmen, men utan att behöva knäppa den. Det ska gå snabbt och enkelt och de använder inte hjälmen korta sträckor mellan uppgångar.
- Ska man låsa fast hjälmen blir det också ett extra moment.
- Kontroller? Pedaler? Knappar? Reglage? Vad styr vad?
- Standard för scooter-modeller
- Helljus behvös när det blir mörkt.
- Olika typer av skydd? För gods? För förare?
- Finns inget skydd för föraren. De har tillgång till olika typer av kläder. Det finns plastlock till lådorna som används vid dåligt väder. Dessa kan vara lite besvärliga att snabbt öppna och stänga (finns inga gångjärn). Kan hända att de trillar av ner på marken. De kan lossna i farten utan att man märker det och försvinna. Cyklarna har ett specialskydd i tyg för lådorna fram som är integrerat i ställningen.
- Hur lastas gods?-Olika moduler till olika last?
- Standardlådor. Vissa större paket latas provisoriskt i på olika sätt i lådorna.
- Låsfunktioner av gods och fordon, tillhörigheter?
- Låser aldrig mopeden under dagen – tar för lång tid. Det finns låsbara lådor men denna funktion används inte – det blir för krångligt. Inget direkt problem med att saker stjäls – har hänt några gånger.
- Tillgänglighet av gods?
- All post tas från backar framför föraren. Denna plats verkar vara det bästa alternativet enligt intervjuobjekten. När en back är tom byts den mot en full som är placerad bakom föraren. De intervjuade trodde nog att det var bäst att ta saker framifrån istället för från sidan eftersom man då måste vrida sig vilket är mer ansträngande/sämre för kroppen.
- m.m.
- Vilka funktioner används mest frekvent?
- Vilka är de absolut nödvändiga funktionerna?
- Bra/dåliga funktioner – Vad vill ni ta bort? Justera? Lägga till?

Lång sadel för två personer, men man åker aldrig två. På andra mopeder kan man ibland öppna sadeln och förvara hjälm eller annat där, men det går inte på dessa.

- Hur långt kan den färdas?

5-6 timmar

- Är motorn tillräckligt stark?

Nej, måste putta upp den för vissa bakar

- Används fordonet till något annat än post?

Ergonomi

- Har någon råkat ut för några skador? Vibrationer? Utslitning. Vilka kroppsdelar tar mest stryk?

En av de intervjuade nämnde att det ibland kunde kännas i ryggen efter en lång dag – sitter dåligt. De nämnde även att en kollega inte längre kan köra mopeden på grund av vibrationsskador i händerna efter lång användning.

- Hur känns det att sitta på fordonet – avstånd, dämpning, räckvidd, sikt m.m.?

Lätt att glida fram på sadeln eftersom man sträcker sig framför styret varje gång för att hämta post. Ibland kan man få skavsår på insidan låren. Man vrider sig mycket när man delar ut posten.

- Vilka inställningar kan man kunna justera i förarmiljö? Är förarmiljön bra anpassad efter alla förare? Vilka skulle ni vilja ha? Tror ni att man använder dessa?

Kan justera en backspegel, den andra är borttagen för att man lätt ska kunna komma åt posten framför styret. Att kunna justera backhållaren framför styret hade varit bra. De båda tyckte att det hade varit bra att kunna anpassa förarplatsen till sin kropp och trodde at de skulle utnyttja detta i början av ett pass för att kunna jobba bättre/effektivare under resten av passet.

- Vad tycker ni om att sitta på en sadel jämfört med en stolsliknande sits?

Det hade kanske varit skönare med stol – ryggstöd hade varit gött

- Vad tycker ni om styre jämfört med ratt?

Ratt går bort på en sån här moped. Man är ju van vid styre när det är två hjul.

Utseende/Känsla

- Vad associerar ni med fordonet? Vilken typ av känsla skapar den hos er?

Den är helt okej, ”jag hatar den inte i alla fall”. den ser inte cool ut men den behöver inte se cool ut heller. Vill vara en i mängden, vill inte sticka ut för mycket men samtidigt är det bra att se att det är Bring som kommer/äger fordonet. När de blir tilldelade att åka moped känns det gött för då slipper de cykla.

- Hur känns det att åka runt med fordonet? Hur tror ni att andra uppfattar er och fordonet?

Som en i mängden.

- Skulle ni vilja justera något i utseendet? Vad skulle ni vilja associera med fordonet?

Bra om man såg att det var Bring som kom, nu har de bara svarta moppar. Hade varit gött med tak, när det regnar blir man genomsur.

- Hur känns det att använda hjälm? Är den lätt att förvara på fordonet när den inte används?

Varmt å skönt på vintern, svettigt på sommaren. Man använder den alltid i trafik. Känns bra att skydda sig. Är det kort mellan stoppen tar man inte på sig hjälmen.

- Känns det säkert att färdas med fordonet i trafik? Varför/varför inte?

Inte när det är snö och bromsarna är dåliga.

Avslutande

- Om ni fick önska er vad ni vill utan några som helst begränsningar – vad skulle ni då vilja lägga till? Hur skulle ert ”drömfordon” se ut och vilka funktioner skulle ni vilja ha?

3 hjul hade fungerat – mer stabilt men det är viktigt att den är smidig och att man lätt kan komma åt brevlådor. Viktigt att kunna komma nära brevlådor på höger sida. 3 hjul vore bra, då kan man lasta hur mycket som helst.

Svårt att dunka med handgasreglage, då hade pedaler varit bättre så att man kan ”dunka” - man kan använda höger handen att ta post med samtidigt som man justerar farten. Bra när postförvaringen är framför och på höger sida eftersom man kollar där och förbereder posten i farten innan man kommer fram till lådan. Det kan bli krångligt om man måste kolla åt sidan samtidigt som man kör.

Bälte är sämre än hjälm, känns läskigt att vara fastspänd. Bilbälte hade inte varit bekvämt. Det är vanligt att brevbärare kör bil utan bilbälte också för att det begränsar rörligheten. Prioriterar att lätt kunna ta posten och jobba effektivt före ett väderskydd för föraren – det får alltså inte påverka effektiviteten i jobbet.

- Ta kontaktuppgifter om de är intresserade av att hjälpa till längre fram i utvecklingen? – Komma med åsikter och utvärderingar?

Får gärna kontakta igen. De vill se vad det blir av projektet.

Intervju med tre personer på Posten i Frölunda

- ställer höga krav på fordon
- nuvarande moped pallar inte en hel dag - tung last + backar + modd funkar inte, sommar + lite last funkar
- fordonen förvaras inte rätt så de blir sämre
- vissa packar i lådor, andra i buntar med remmar
- buntar lättare att hantera och tar mindre plats
- risk att lasta lådorna för fulla så det blir för tunga lyft
- i regel packar man sin post själv, utom reklamen

Clubcar:

- Clubcar används hela utrymmet till last, sen flyttas det fram till hytten
- bara ett fack, i bilar
- alla har belastningsskador tror en person - har kommit hjälp från posten som visar hur man ska jobba
- finns en plastinsats som man kan använda
- finns många förbättringar att göra i clubcaren: inte bra att kunna komma åt det stora utrymmet, då kommer folk att jobba fel. Sträcka sig och så, bättre att bygga så att folk inte kan göra fel för folk är lata
- finns inga inställningar i clubcaren nästan, går att justera sitsen 10cm typ
- jobbigaste med clubcaren är att sträcka sig ut när man ska lägga i post
- man får inte köra på trottoaren, vissa brevlådor sitter inte bra
- Epton generalagent för clubcar i sverige
- inga problem med lastkapasiteten
- clubcaren känns mer skyddad, där har man bälte också
- det används till och från turerna men inte på själva turen
- svängradie är typ samma, kanske lite bättre på clubcaren
- ratt är lättare att hantera än ett styre
- varit med om två framaxelbrott på clubcaren, den strukturen var för vek
- kan ha varit pga att folk kört upp på trottoarkanter och så
- gaspedalen har fastnat nån gång pga snö och smuts på clubcaren
- de ska förvaras varmt men står i minusgrader
- clubcaren är det ingen större skillnad att köra fullastad för den är så tung i sig själv
- mopederna blir klumpiga, längre bromssträcka, slirar lätt
- bilbältet i clubcaren är en efterkonstruktion och är krångligt, används till och från turen
- ingen återrullning
- hade varit bättre med ett trepunktsbälte
- skjutdörren är oftast öppen när man är ute, till och från turen beror på lägenheten
- finns en dieselbrännare för värme i hytten
- man lägger in posten där bak bara i clubcaren

- hellre en truckpedal på clubcaren, tvådelad för fram o back+broms
- för fram o back har vissa en "blinkerspak" andra en spak nere
- inget servo i clubcar, kan vara farligt om man kör på nåt och har tummarna i ratten
- hanterar man posten i farten? - "det borde man svara nej på va?"
- oftare i bil än elfordon
- ibland måste man plocka lite, annars hoppar man av och tar med sig en bunt
- vanligare med cyklarana
- sällan man lägger i saker direkt i farten från clubcaren
- bra sikt, dåliga backspeglar
- dåligt placerad A-stolpe, ingen innerbackspegel
- clubcaren känns inte lika anpassad för ändamålet, lite klenare i förhållande till storleken
- smidigare med clubcar än bil, lättare att ta sig in och ur

Cykel:

- cyklarna är lite justerade för att passa användningen. frambacken är låg så det blir långt att sträcka sig, det är jobbigt för de som är kortare
- mopederna är klumpiga jämfört med cykeln
- finns elcyklar också
- hellre elcykel än de andra, den är smidigare att hantera
- första elcyklarna kom 2000 typ

Moped:

- jobbigaste på mopeden är att flytta post från stora utrymmet till de små
- vissa kör med luckan öppen för att slippa lyfta fram reklamen hela tiden, men det får man inte, och så ser man inte så mycket
- väldigt svårt att svänga när den är tungt lastad
- kan lasta typ 200 kg, det är inte så mycket
- flytta post varje kvart ungefär om det är mycket.
- men det beror på husen också. stora hyreshus kan svälja en hel moppelåda
- batterikapaciteten är inte den bästa
- drygt att inte få köra på cykelbana överallt, otäckt att köra i trafiken
- känns inte säkert alltid, sitter oskyddad, speciellt nu när det är moddigt
- mopeden går mellan 20 och 35 km/h
- känns bara stressigt till och från turerna, ute på turen behöver de inte gå fortare
- borde vara bra att den är starkare, är det mycket last och brant backe är det jobbigt
- kanske hellre sitter inomhus
- mopeden används på innergårdar där clubcaren skulle bli för klumpig

- många har regnkläder med sig eftersom det kan slå om snabbt
- gångjärnen till plexiluckan skevar ofta till sig, ibland går det inte att stänga
- om det är öppet så regnar det in genom de små facken in i det stora
- dåligt när solen skiner för det reflekteras
- man kör gärna med plexit öppet om det går för att få bort fartvind, inte för effektiviteten skull
- stabilare än de gamla bensinmopederna, de kunde gå upp på två hjul även om man körde långsamt och svängade
- nyckeln som man bryter strömmen med sitter vid golvet, den måste man ta med sig på vissa ställen där stöldrisken är större
- finns fjärrlås på vissa som är bättre än det befintliga iaf.
- pris: 2 till 2,5 moppar per clubcar
- kör inga paket, men "brevklumpar" = stora brev som ändå får plats i brevlådor
- de mått som är, de räcker
- facken fram på mopeden är anpassade för posten och storleken funkar, höj och sänkbarhet vore däremot bra
- hela lådan fram är låsbar
- hjälmfacket finns och är låsbar
- vattenflaska får plats bland breven i småfacken
- lådan fram används till rätt mycket
- hjälmen hängs på styret eller läggs där fram, används bara till och från
- när det ösregnar är det svårt att hålla posten torr i moppen, men sällan så mycket att det blir ett problem
- gasfjädrar som hjälper öppning av lock
- när det är blött på marken stänker det upp på fötterna
- sällan mer än 200 kg, reklamen väger
- batterikapaciteten viktigare, hur mycket kan man ladda upp på en och en halv timme
- 300 kg är jävligt mycket, skulle klara oss definitivt
- bensinmopederna var hemska när det gäller vibration
- elmopparna är inga problem
- smidigare med sadel, men skönare med säte
- jobbigare att ta sig ur säte
- vi sitter inte länge på mopederna, de går bara i trappuppgångar
- mopeden är byggd bra för ändamålet, den känns klumpig

Generellt:

- lite frukt kan man ha med sig
- plånboken har man på sig
- ska visa att posten ligger i framkant i miljöarbete och personalvård och modernt
- robust och smidig men inte klumpig
- likt situationen att köra bil och då är man van att man kan ställa in hela förarmiljön
- inställningsmöjligheter viktigt, arbetsmiljön är A o O
- svårt att säga hur mycket olika funktioner är värda vid inköp
- svårt att säga hur mycket folk har att säga till om

Drömfordon:

- servo
- går snabbt när man kör på större vägar
- tvåväxlad/stark lågväxel
- släde i lastutrymmet, "en släde eller en 'slade'"
- sidodörr på flakdelen
- locket är tungt på mopeden, plåt och vassa hörn
- bättre sikt bakåt
- vi har skitbra kläder "när jag började på posten var byxorna ylle va"
- viktigare att skydda lasten

Appendix F - Personas

Personas

Name: Sara Johnsson

Age: 21

Occupation: Delivering mail for Bring Citymail

Description

Before Sara started at Citymail she studied social science at high school level in Varberg. When she finished her studies she felt quite bored of studying and wanted to start to work.

Sara has now been working for Citymail for almost 2.5 years and has very good knowledge about the different routines in her work and has been able to adapt her work so it will be as efficient as possible. She is happy to be able to work outdoors even if she thinks that some days are less enjoyable when it is cold and rainy at the same time.

Sara likes to be outdoors and has an active lifestyle where she often meets up with friends at the gym or goes for a run at the tracks in the nearby recreation area. Beside her interests in different sports she is also very interested in travelling. Her ambition is to save up enough money to travel the world for at least one year.

Everyday working goals: Be able to work as efficient as possible.

Critical needs: Be able to sit on the vehicle and at the same time deliver mail in mailboxes (dunk the mail). Be able to drive the vehicle for a whole day without having to worry about running out of batteries, even in hilly conditions and bad weather.

Preferable new functions: Personal storage for example water bottles. Could also be good with some kind of automatic key so she doesn't need to put time on stopping and starting the vehicle when delivering mail to apartment buildings.

Name: Jim Davis

Age: 37

Occupation: Park keeper at a cemetery

Description

Jim emigrated from USA to Gothenburg in 1995 when he married a Swedish woman he met in his hometown. He has no collage degree and had been working in a mechanical workshop before he moved to Sweden. When he arrived to Sweden he quickly got a job at a cemetery in the eastern part of the city and has been working there ever since. He really enjoys his job and his three colleagues who always have a positive attitude in a somewhat cheerless environment.

Jim has a fondness of old cars and as he has a background in mechanical work he is the one that is responsible for maintenance of the different vehicles at the cemetery. Jim likes the variety in his job where the tasks differ quite a lot depending on the seasons.

At the side of his interest of old cars and his valuable collection of miniature veteran vehicles he also coaches his daughters' soccer team. It is very important for Jim to take part of his daughters' life since his own dad left the family when Jim was very young. However, he also understands that it will come a time when "dad" is not as welcome all the time.

Everyday working goals: "A structured workshop where tools and vehicles are working and available is sufficient in order to execute the job in a good manner."

Critical needs: Should be able to easily store shovels and rakes on the vehicle. Be able to load and unload soil and sand in a good way – it should be able to carry at least 300kg.

Preferable new functions: It would be really good to be able to connect different power tools to the vehicle.

Name: Bengt Hellner

Age: 58

Occupation: Delivering mail for Posten

Description

Bengt has been working for Posten in 27 years and is looking forward to early retirement when he turns 61. He has witnessed the development of how the distribution efficiency has changed the workflow and how the extensive usage of e-mail has affected the industry. He is using several different vehicles when delivering mail depending of which area and type of mail that is going out.

He has partly been responsible for the working environment over the past four years as he has been appointed to be safety representative for his department. This position has taught him a lot about how to improve the working environment and work in a better way when delivering mail. For about 6-7 years ago his only focus was to deliver the mail as fast he could. Nowadays he is much more concerned about his posture and working more ergonomically right in order to minimize possible attritional wear. He is also very eager to teach his colleagues about this.

Bengt is still single and has no plans on finding a partner but is not unacquainted with the thought of paring-up if the right person comes along. He likes to socialize with his colleagues during working hours but on his spare time he always tries to go to his country house in Dalarna. He likes the quietness and walking in the forest. Another big interest is photography and bird watching. He is a bird collector and sometimes he goes on trips to find special species to add to his collection book.

Everyday working goals: Deliver the mail in time within a good working environment, minimizing the risk of attritional wear.

Critical needs: Be able adjust the driving environment to different individuals. Important with an efficient workflow when moving mail around on the vehicle – but it should still be in a good ergonomic manner.

Preferable new functions: A seat and steering wheel that can be individually adapted considering several ergonomic aspects.

Appendix G - List of Functions

List of Functions - Electrical Distribution Vehicle

Main function: Transport driver and goods

	Function			Assessment							Main type	Rating
Nr.	Verb	Noun	Comments/Limits	5	4	3	2	1	B	U		
1	Fulfill	Vibration limits	Insatsvärde: 0,5 m/s^2 Gränsvärde: 1,1 m/s^2						B		Ergo	6
2	Reach	Cargo	From side						B		F	6
3	Recharge	Battery	While in vehicle						B		F	6
4	Recharge	Battery	Using standard plug						B		F	6
5	Carry	Driver	Given weight						B		P	6
6	Carry	Load	300-400 kg?						B		P	6
7	Clear	Obstacles	Ground clearance, road roughness? Which surfaces?						B		P	6
8	Fit	Seasons	All						B		P	6
9	Manage	Paved roads	All						B		P	6
10	Replace	Battery	Within given time?						B		P	6
11	Comply with	Legal requirements	Bilprovning, Arbetsskydd, Vägverket, Transportstyrelsen, Arbetsmiljöverket, Other?						B		S	6
12	Show	LGF-sign	Clearly in the back						B		S	6
13	Show	License plate	Clearly in the back						B		S	6
14	Show	Light	White forward, red backward, red brake, orange blinker						B		S	6
15	Carry	Motor	Size(s)? Type?						B		T	6
16	Carry	Battery	Size(s)? Type?						B		T	6
17	Carry	Critical components	Size(s)?						B		T	6
18	Fit within	Size limits	L x W x H						B		T	6
19	Run on	Wheels	3 pcs.						B		T	6
20	Run on	Electricity							B		T	6
21	Control	Driving direction	Feeling?						B		U	6
22	Control	Brakes	While parked and driving, automatic? Manual? Front and rear? ABS? Type?						B		U	6
23	Control	Speed	Forwards and backwards						B		U	6
24	Control	Lights	Head, tail, blinker, hel/halv						B		U	6
25	Control	Ignition	how?						B		U	6
26	Allow	Production	cost without electrical components: 20-30 kkr? Volume?	5							$	5
27	Fit	Human	At least given percentile	5							Ergo	5
28	Fit	Different uses	Postal, industrial, park, food? Personal? Other?	5							F	5
29	Reach	Cargo	While parked, driving?	5							F	5
30	Appeal to	Target user	Through design	5							I	5
31	Communicate	Brand Essence	Implicitly	5							I	5
32	Communicate	Core Values	Implicitly	5							I	5
33	Communicate	Message Star	Explicitlty and implicitly	5							I	5
34	Control	Driving direction	Turning radius max 1,5 m	5							P	5
35	Offer	Pleasurable driving	what characteristics are important? At waht speed?	5							P	5
36	Avoid	Injury	of Driver	5							S	5
37	Avoid	Injury	of Bystander	5							S	5
38	Avoid	Injury	of Service personel	5							S	5
39	Utilize	Recyclable Materials	of low environmental implact		4						Env	4
40	Fit	Different people	customizable, adaptable, minimum effort		4						Ergo	4
41	Allow	Loading	Silent		4						Ergo	4

42	Allow	Upgradability	Of which components?		4						F	4
43	Allow	Postal "dunk"	Deliver mail on right side during driving		4						F	4
44	Offer	Weather protection	For cargo		4						F	4
45	Offer	Weather protection	Against rain		4						F	4
46	Offer	Dirt protection	of sensitive Parts		4						F	4
47	Offer	Compatible cargo area	Using standards, Different standards for different post services?		4						F	4
48	Offer	Storage	of personal belongings? (Water bottle)		4						F	4
49	Reach	Cargo	From driver's position		4						F	4
50	Allow	Customer branding	Without loosing own identity		4						I	4
51	Appear	Environment friendly	Safe		4						I	4
52	Appear	Professional			4						I	4
53	Carry	Load	volume?		4						P	4
54	Carry	Load	area?		4						P	4
55	Carry	Load	length?		4						P	4
56	Recharge	Battery	In given time		4						P	4
57	Transport	Load	Given range at given load. (postal: 6h full load)		4						P	4
58	Secure	Vehicle	From theft, easily (without adding extra task) while away a short while		4						S	4
59	Allow	Service	To be perfomed on certain parts at given intervals		4						U	4
60	Allow	View	Around vehicle		4						U	4
61	Avoid	Control contradictions	i.e. Break/Accelerate, Drive away/Charge		4						U	4
62	Allow	Comfortable use	To certain level			3					Ergo	3
63	Allow loading	of Cargo	In an ergonomical way			3					Ergo	3
64	Offer	Dirt protection	of Human			3					Ergo	3
65	Allow	Mail delivery	While seated			3					F	3
66	Allow	Mail handling	While driving, (preferred in front)			3					F	3
67	Allow	entry/exit	From left and right			3					F	3
68	Clear	Loading area	Efficient and easy			3					F	3
69	Carry	Tools	Small hand held, rakes, ladders, etc?			3					F	3
70	Allow	Customizability	of tool placement			3					F	3
71	Offer	Weather protection	For driver			3					F	3
72	Offer	Weather protection	Against snow			3					F	3
73	Offer	Weather protection	Against Wind			3					F	3
74	Offer	220V access	For handheld tools and such			3					F	3
75	Offer	Storage	of helmet			3					F	3
76	Offer	Storage	of helmet, while driving and secure while parked			3					F	3
77	Recharge	Battery	While not in vehicle			3					F	3
78	Replace	Battery	Without removing load?			3					F	3
79	Appear	Robust	Powerful, strong, not easily breakable			3					I	3
80	Appear	Stable	Not tip over			3					I	3
81	Avoid	Damage	On vehicle and surrounding			3					S	3
82	Avoid	Damage	by impact			3					S	3
83	Avoid	Damage	by corrosion			3					S	3
84	Avoid	Damage	by wear			3					S	3
85	Avoid	Damage	by malpractice			3					S	3
86	Avoid	Damage	by rough usage			3					S	3
87	Secure	Vehicle	From theft			3					S	3
88	Secure	Goods	From theft, from falling off			3					S	3

89	Explain	Optimal use	Driving, loading, charging, etc.			3					U	3
90	Explain	Optimal loading	Amount, placement			3					U	3
91	Pull	Trailer				3					F	3
92	Allow	Pulling of trailer	Given specifications				2				F	2
93	Offer	Weather protection	Against Hail				2				F	2
94	Offer	Weather protection	Against Cold				2				F	2
95	Offer	Weather protection	Against Heat				2				F	2
96	Offer	Weather protection	Against Sun				2				F	2
97	Carry	Passenger	1-2?				2				P	2
98	Show	Important information	e.g. Battery status, and such				2				U	2
99												
100												

Assessment criteria:

5 - Essential requirement
4 - Much desirable
3 - Desirable
2 - Small desirability
1 - Insignificant desirability

Appendix H - List of Requirements

List of requirements - BEMO

ID	Requirement	Metric	Weight	Type	Area		Comment
	Price BEMO Pro (for distribution and incl. Battery)	[redacted]		unspoken	economical		
	Component costs (excl. Battery)			unspoken	economical		
	Battery			unspoken	economical		
	Price BEMO Basic (incl. Battery)			unspoken	economical		
	Emissions		5		environmental		estimation from Douglas needs to be checked
	Harmful materials should be recyclable		4		environmental		
	Recyclable				environmental		Batteries should be looked upon separately. Lead-acid batteries can be 99% recyclable
	LCA (life cycle assessment)				environmental		(according to Douglas), Li-ion batteries are different.
	Protect driver from rain		4		functional		Cemetary guys dress for the weather but they have protection
	Protect driver from wind		4		functional		
	Protect driver from snow		4		functional		
	Protect driver from cold		2		functional		
	Protect driver from heat		2		functional		
	Protect driver from sun		2		functional		
	Ability to pull trailers		3		functional		Especially for parks (hard to use in postal delivery)
	Upgradability of components (post-sales)		2		functional		
	Customization using different components (pre-sales)		4		functional		
	Ability for on-board charging, just plug it in (no charging station)		5	basic	functional		
	Ability to exchange battery pack		4		functional		
	Vehicle should brake automatically when the throttle is released		4	unspoken	functional		Further investigation needed!
	Shock absorbing ability of the vehicle			basic	functional		Further analysis needed
	Ability to connect range extenders		2	unspoken	functional		E.g. sun cells, fuel cells, pedals, ICE
	Being able to drive while handling mail		4		functional		Only postal delivery. Safety issue? Check with SEKO, managers at Posten, etc.
	Allow mail delivery from driver's standard position		5	desired	functional		If we have a seat...
	Being able to do the "postal dunk"		3	desired	functional		Driving past the mail box and drop the mail, without having to slow down
	Operatable on different surfaces			basic	functional		dirt, grass, concrete, snow, ice, gravel
	Efficient working cycle		4	desired	functional		Minimal working tasks/events in recurring working cycles
	Allow entry and exit from the left hand side		2		functional		
	Allow entry and exit from the right hand side		4		functional		
	Allow entry and exit from both sides		2	desired	functional		
	Weather protection for cargo		5		functional		Basic for postal deliver, very desired in parks, not so important indoors
	Flexible/detacheable weather protection for cargo		5	unspoken	functional		
	Offer environmental protection for sensitive parts			basic	functional		
	Cargo area should fit with Posten's standard boxes, etc.		5	desired	functional		Investigate this with standard sizes
	Parts that experience a lot of wear should be easily replaced		3	desired	functional		Ease of maintenance
	Offer storage to personal belongings		3	desired	functional		
	Ability to carry tools/working equipment (rakes, ladders)		4	desired	functional		Secondary segment: Small and big, could be a special system
	Offer 220 Volt output		3	desired	functional		Secondary segment
	Offer helmet storage		3	desired	functional		Required to wear helmet to be in traffic
	Offer drink holder		4	desired	functional		
	Reach cargo from the driver's position		5	desired	functional		Primary: basic to have some cargo reach, but not all the cargo.
	Possibility to more than one person onboard		3	desired	functional		Secondary: Legislation.
	Access to cargo		5	desired	functional		Tip platform, open up sides, etc. efficent and easy
	Carry driver	<120kg		basic	functional		
	Avoid damage of vehicle		4		functional		Impact, corrosion, wear, malpractice, rough usage
	Allow customer branding		4	desired	image/identity		without loosing own identity
	Appear environmnetal friendly		4	unspoken	image/identity		Safe
	Appear robust		3	unspoken	image/identity		Powerful, strong, not easily breakable
	Appear stable		3	unspoken	image/identity		Not tip over
	Appear professional		4	desired	image/identity		
	Communicate brand essence		4	unspoken	image/identity		
	Communicate message star		5	unspoken	image/identity		
	Appeal to target customer		5	desired	image/identity		through design and overall impression

Appropriate warning labels must be affixed			basic	legal		
The vehicle must not infringe on existing patents		5	unspoken	legal		
Meet all applicable safety standards and regulations			basic	legal		Bilprovning, Arbetsskydd, Vägverket, Transportstyrelsen, Arbetsmiljöverket, Other?
Shall carry identification mark			basic	legal		producer sign and id number on chassi or frame
Easy removable "speed limitations" not allowed in the electric system			basic	legal		
Cables must be placed so wear is minimized			basic	legal		cables should be sufficently isolted
Sound limit for three wheeled moped	76 dB		basic	legal		
Driving brakes must have front wheel and rearwheel brakes	v^2/110m (v^2/55m with only rear brak		basic	legal		For all requirments on breaks see "mopedhandboken"
Parking brake			basic	legal		Can be combined with driving brake and must be able to hold the vechile on leaning ground
No protroding parts that can inflict injury in a collision			basic	legal		
Passanger seat can not be plaved in front of driving seat			basic	legal		
max offset between central line of seat and the steering	<100mm		basic	legal		
Lights			basic	legal		extensive requriments in "mopedhandboken" chapter 15
Must have half light (can have 1 or 2)	500-1200mm above the ground etc.		basic	legal		
No red light shall be visible from front			basic	legal		within in a hight of 1000mm - 2200mm
No white light shall be visible from behind			basic	legal		
Diving direction indicators	blinking frequency 90-+30/min etc.		basic	legal		even number n each side that shows orange light (placement details in Mopedhandboken)
Back-lights	250-1500mm above ground etc.		basic	legal		red light
1-2 rear reflexes showing red light shall be present			basic	legal		
signal horn	approved		basic	legal		
Carry LGF sign (slow moving vehicle)	250-1500mm above ground etc.		basic	legal		LGF = slow moving vehicle
Rear mirror			basic	legal		
weight (excluding batteries)	<270kg		basic	legal		http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31993L0093:EN:HTML
dimensions	< length 4m, height 2,5m, width 2m		basic	legal		
payload	<300kg		basic	legal		maximum allowed, but it can carry more....
registration sign in the back			basic	legal		
Ability to lift the chassis with equipment (over head cranes)		3		manufacturing		
Allow for assembly/disassembly			basic	manufacturing		
Allow safe transport			basic	manufacturing		
No use of flammable materials			basic	manufacturing		
No use of materials that are of limited supply			basic	manufacturing		
No use of toxic materials			basic	manufacturing		
Use as few materials as possible			basic	manufacturing		
Top speed	[redacted]			performance		
Range				performance		
Power				performance		Klass 1
Load capacity				performance		Legislation?
Operating time				performance		
Acceleration				performance		Tradeoff between, load weight, fun driving, battery drain
Start and stops				performance		
Load capacity	Volume (m3)			performance		Size and length of components to carry
Ground clearance	~15 cm?			performance		Manage average sidewalk edges etc.
Turning radius	<1.5 m	5	basic	performance		performance
Fast charging time (between rounds, lunch break?)	[redacted]			performance		
Slow charging time (overnight, last 20%)				performance		
Time to exchange battery				performance		If exchange function is possible. Hinder hand exchange, need to use pallet truck or similar.
Prevent theft of vehicle		5		security		
Prevent theft of user belongings		5		security		
Prevent theft of components			basic	security		
Prevent theft of cargo		4		security		
Life length of vehicle (excl. Battery)	[redacted]			technical	w	This metric should include appropriate service and maintenance.
Life length of battery				technical		
Offer easy cleaning	high pressure cleaning	4	unspoken	technical		
Efficiency of powertrain (battery to wheel)				technical		
Vehicle weight (excl. Battery and load)	<270 kg			technical		legal requirment for klass 1 moped
Stability of chassis at a certain load				technical		
Length	215-235 cm			technical		

[redacted]

Height	200 cm			technical	
Width	110-135 cm			technical	Fit in standard container, 2 units next to each other. Side walks. Legislation. Car trailer.
Wheels (standardized wheels)				technical	
Wheel pressure				technical	
Wheel friction				technical	
Weights of rotating parts in powertrain				technical	
Powered by electricity				technical	
Should have three wheels				technical	
Replaceable battery		4	unspoken	technical	with or without cargo on the vehicle?
Provide emergency/parking brakes			basic	technical	Non electric
Use semantics regarding use, load and maintenance of vehicle		4	unspoken	usability	Make correct usage clear. Avoid contradictions (brake/speed up or charge/drive for instance)
Show important information			basic	usability	battery status, speed
Allow control of speed			basic	usability	
Allow control of brakes			basic	usability	
Allow control of lights			basic	usability	
Allow control of ignition			basic	usability	
Shock absorbtion for the driver		3		working environment	
Vibrations on handheld devices	at most 0.5 m/s2		basic	working environment	
Limit on driver's perception of shocks/bumps/vibrations	Frequency			working environment	
Limit on driver's perception of shocks/bumps/vibrations	Amplitude			working environment	
Avoid injury of driver		5	unspoken	working environment	
Avoid injury of bystander		3	unspoken	working environment	
Not roll over during normal use	speed, slope, etc.		basic	working environment	
Noise while driving and loading/unloading	Interval?	3	desired	working environment	Arbetsmiljöverket
Working environment dimensions	Vehicle should fit from 5 percenti	5	desired	working environment	Guidance from Nina's master's thesis
Offer flexibility to adjust working environment to driver's own needs		4	desired	working environment	
Ergonomically sound loading/unloading of cargo		3	desired	working environment	
Adequate vision from seating position			basic	working environment	Legal requirements?
Driver protected from electric equipment/system, acids, etc.			basic	working environment	Check regulations, recommendations, etc.
Perception of being safely seated		4	unspoken	working environment	
Dirt protection of the driver		3	desired	working environment	
Offer comfortable driving		4	desired	working environment	
Offer fun driving		2	unspoken	working environment	
Avoid injury of service personnel during maintenance		4	unspoken	working environment	
Moving components and mechanisms should be covered	[redacted]		basic	working environment	prevent injury to the user and damage to the components

Appendix I - Product Characteristics

Product characteristics

Brand:

- Creativity
- Sustainability
- Honesty & Reliability
- Personal Leverage

Message Star:

- 1.Environment friendly
- 2.Performance
- 3.Driver focus
- 4.Reliability
- 5.Safety

Brainstorm after KJ:

- Strong
- Robust
- Masculine
- Stable
- Solid
- Lasting
- Heavy-Duty
- Durable

- Sustainable
- Kind
- Friendly
- Trustworthy
- Proud
- Ergonomic
- Confident

- Distinct
- Quirky
- Agile
- Nimble
- Refreshing
- Lively
- Alive

- Sparkling
- Independent

- Smart
- Diverse
- Cross functional
- Multi functional
- Versatile

- Entrepreneurial
- Novel
- Sharp
- Up to date
- Young
- Fresh
-
- Smooth
- Calm
- Cool
- Humble
- **Selected:**
- Solid
- Durable
- Trustworthy
- Proud
- Confident
- Refreshing
- Independent
- Humble
- Fresh
- Versatile
- Smart
- Nimble

Final vehicle characteristics:

- Nimble
- Refreshing
- Confident

Appendix J - Standard Parts

Standard parts

A list of standard parts that could be bought from different suppliers.

- Tires and rims
- Head lights
- Brake lights
- Rear lights
- Blinkers
- Lights for driver area
- Brake system
- Suspension in front and rear
- Seat and seat suspension
- Tube frame connectors
- Side mirrors
- Remote controlled ignition system
- Battery
- Powertrain
- Towing hitch
- Parking brake included in motor
- Steering wheel and column, adjustment possibilities included
- Controls and displays for driver interface
- Blinker and light (full beam and low beam) handle
- Gear handle
- Ignition
- Switch for windshield dryer
- Horn included in steering wheel
- Battery status by LED-diodes
- Battery power output LED-diodes configured in colorized lamps
- Oled-display for battery time
- Speedometer
- Pedals (brake and throttle)
- Electrical system
- 230V output
- Hinges
- Windshield wiper
- LGF-sign
- License plate
- Lever handles

Appendix K - Concept Scoring

Requirement	Weight	Type	Tugger		Optimal		Concept 1		Concept 2		Concept 3		Final Concept	
Customization using different components (pre-sales)	5	functional	4	20	5	25	4	20	5	25	3	15	5	25
Ability to carry tools/working equipment (rakes, ladders)	4	functional	3	12	5	20	5	20	5	20	3	12	5	20
Ability to pull trailers	4	functional	4	16	5	20	4	16	4	16	4	16	4	16
Allow entry and exit from the right hand side	4	functional	4	16	5	20	5	20	5	20	5	20	5	20
Reach light cargo area from the driver's position	4	functional	4	16	5	20	4	16	5	20	4	16	5	20
Weather protection for cargo	4	functional	3	12	5	20	4	16	5	20	5	20	5	20
Allow mail delivery from driver's standard position	3	functional	4	12	5	15	4	12	5	15	4	12	5	15
Avoid damage of vehicle	3	functional	2	6	5	15	4	12	4	12	4	12	4	12
Possibility to more than one person onboard	3	functional	2	6	5	15	1	3	4	12	5	15	4	12
Protect driver from rain, wind and snow	3	functional	3	9	5	15	4	12	4	12	5	15	4	12
Allow entry and exit from both sides	1	functional	1	1	5	5	0	0	0	0	4	4	0	0
Allow entry and exit from the left hand side	1	functional	3	3	5	5	3	3	4	4	5	5	4	4
Offer drink holder	1	functional	0	0	5	5	3	3	3	3	4	4	5	5
Offer helmet storage	1	functional	2	2	5	5	3	3	0	0	3	3	2	2
Offer storage to personal belongings	1	functional	0	0	5	5	2	2	2	2	3	3	4	4
Reach heavy cargo area from the driver's position	1	functional	3	3	5	5	3	3	2	2	0	0	2	2
Appear environment friendly	2	image/identity	3	6	5	10	3	6	4	8	3	6	4	8
Appear professional	2	image/identity	2	4	5	10	4	8	4	8	4	8	4	8
Appear robust	2	image/identity	4	8	5	10	4	8	3	6	4	8	4	8
Appear stable	2	image/identity	2	4	5	10	3	6	3	6	3	6	4	8
Communicate message star	2	image/identity	2	4	5	10	4	8	4	8	4	8	4	8
Allow customer branding	1	image/identity	3	3	5	5	4	4	4	4	4	4	4	4
Communicate brand essence	1	image/identity	2	2	5	5	3	3	4	4	3	3	4	4
Minimize injury in a collision	5	legal	3	15	5	25	3	15	3	15	3	15	3	15
Use as few materials as possible	3	manufacturing	4	12	5	15	3	9	3	9	3	9	4	12
Small turning radius	4	performance	5	20	5	20	5	20	5	20	4	16	5	20
Replace battery while loaded with cargo	3	technical	3	9	5	15	5	15	4	12	5	15	4	12
Offer easy cleaning	2	technical	1	2	5	10	4	8	4	8	4	8	4	8
Use semantics regarding use, load and maintenance of vehicle	2	usability	1	2	5	10	4	8	4	8	4	8	4	8
Adequate vision from seating position	5	working environment	4	20	5	25	4	20	4	20	3	15	4	20
Fit different body sizes	5	working environment	2	10	5	25	4	20	4	20	4	20	5	25
Perception of being safely seated	5	working environment	3	15	5	25	4	20	3	15	4	20	4	20
Shock absorbtion for the driver	5	working environment	2	10	5	25	4	20	4	20	4	20	5	25
Dirt protection of the driver	4	working environment	2	8	5	20	4	16	3	12	5	20	4	16
Ergonomically sound loading/unloading of cargo	4	working environment	3	12	5	20	3	12	3	12	3	12	4	16
Offer flexibility to adjust working environment to driver's own	4	working environment	2	8	5	20	4	16	3	12	4	16	5	20
		Average Sum	2,639	308	5,000	530	3,583	403	3,611	410	3,778	409	4,056	454
		Normalized		**0,581**		**1,000**		**0,760**		**0,774**		**0,772**		**0,857**

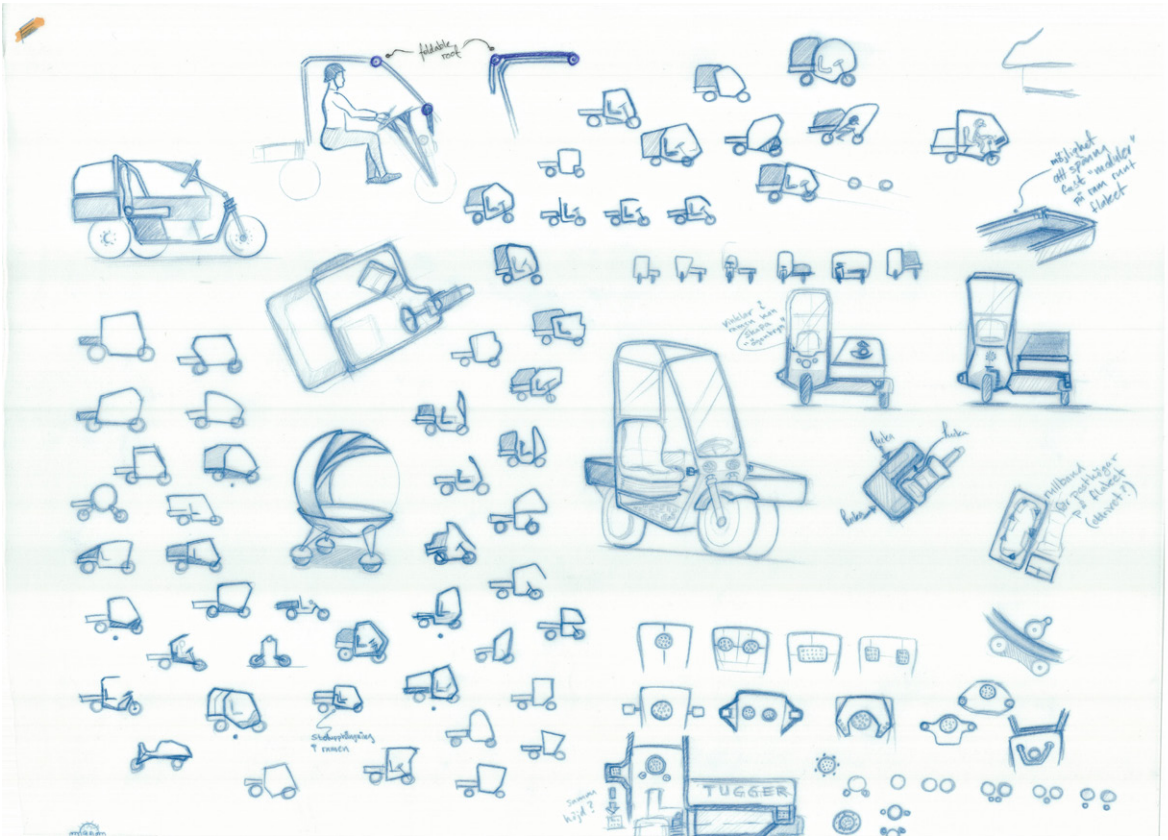
Appendix L - Segment Matrix

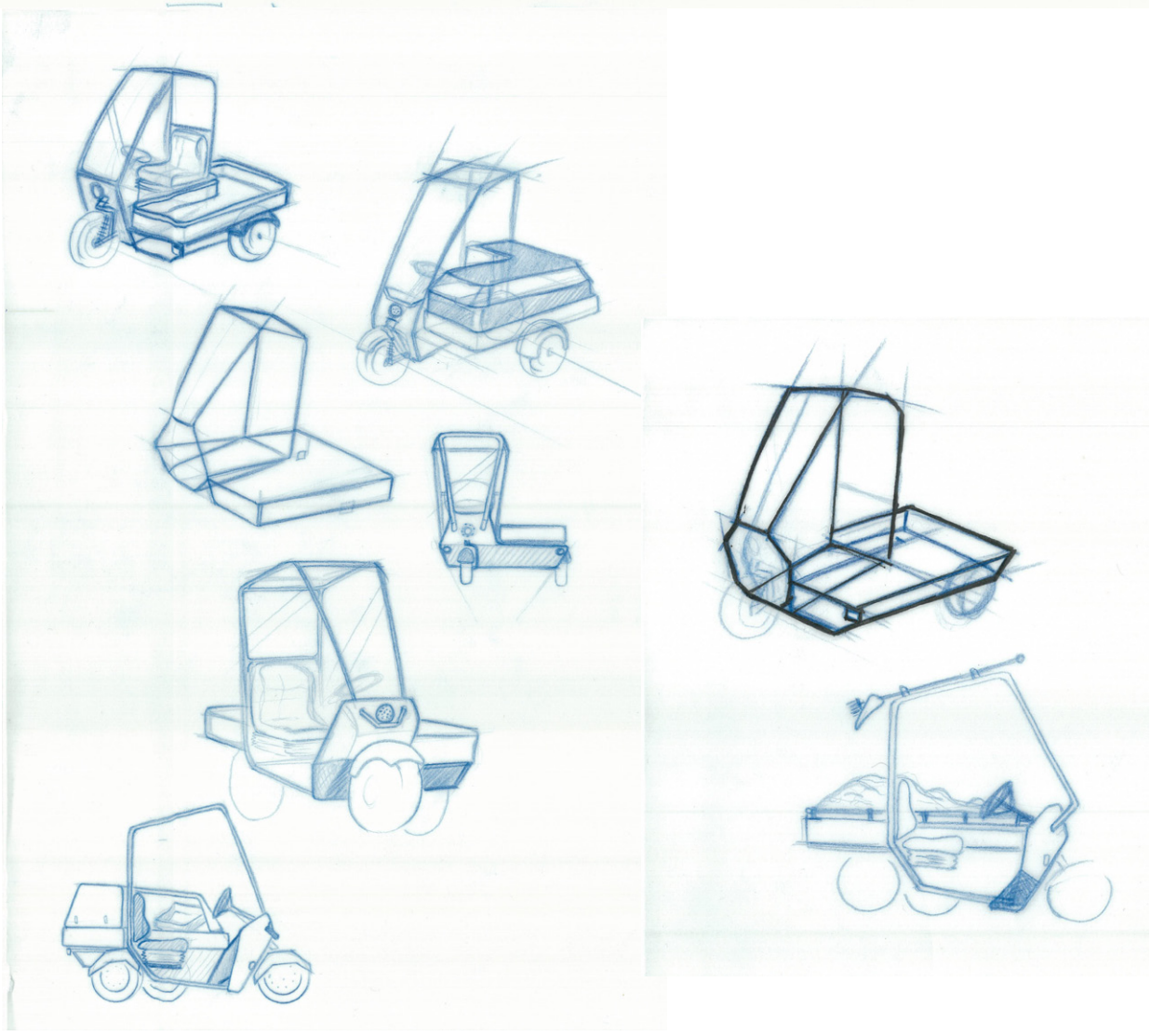
Possible segments - brainstorm

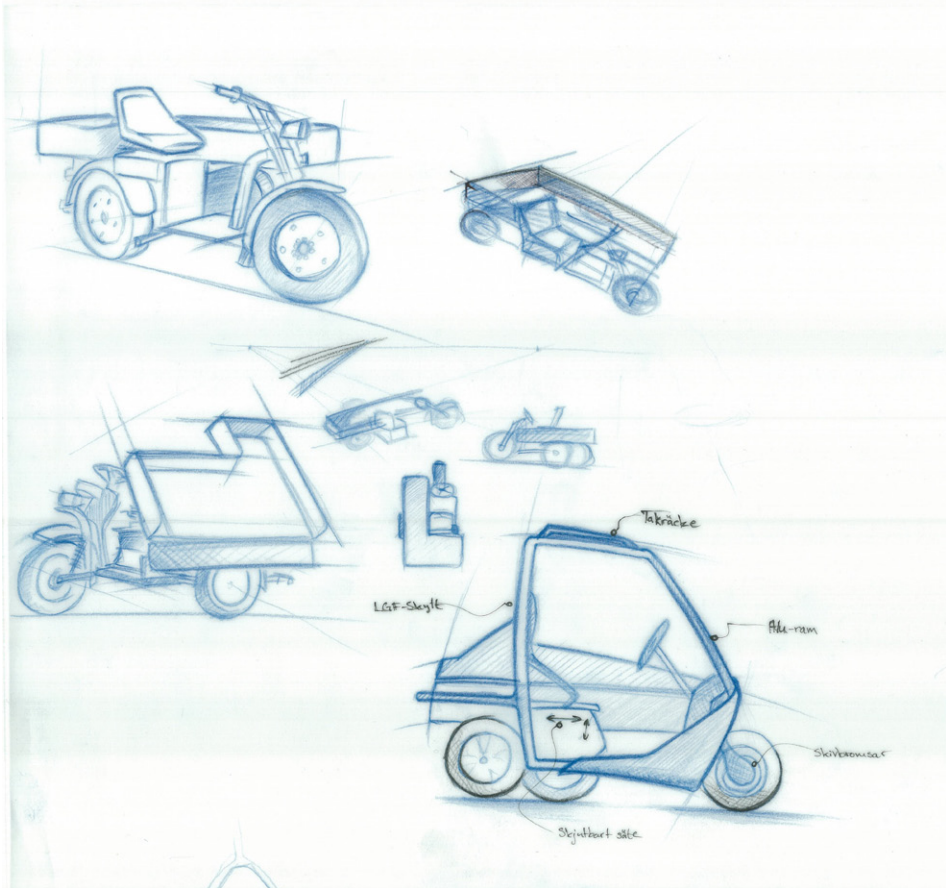
	Cargo size	Cargo amount	Passengers	Compactness	Protection	Degree of protection	Agility	Operating time (hours per day)
Simple City transportation								
Mail delivery	Small	Many	1	High	Both	3	High	6
Pizza delivery	Medium	Several	1	Low	Both	3	High	6
Grocery transportation	Medium	Several	1	None	Both	4	Low	4
Sausage-man	Small	Several	1	High	Both	5	High	6
Ice-cream sales	Small	Many	1	High	Both	5	High	8
Personal transportation								
Within city transportation, commuting	Medium	Few	2	High	Both	5	High/Low	3
Islanders	Large	Several	4	Low	Both	4	High	3
Transportation for elderly	Small	Few	1	Low	Both	4	High	2
Handicap transportation	Large	Few	1	High	Both	4	High	6
Rough/Off-road usage								
Cemeteries	Large	Several	2	High	Personal	2	High	6
Parks / Gardens	Large	Several	2	Low	Personal	2	High	6
Military	Large	Several	2	Low	Both	3	High	24
Towing	Large	Few	1	None	Personal	2	Low	4
Special/diverse cargo transportation								
Sports arenas, medical vehicle	Large	Several	3	Low	Personal	2	Low	4
Logistics, company internal (outdoor and indoor)	Large	Several	2	High	Both	3	High	12
Timber-yards	Large	Several	1	Low	Personal	2	High	4
Warehouse	Medium	Several	1	High	None	0	High	8
Airports	Large	Many	1	Low	Both	4	Low	12
Train stations	Large	Many	1	Low	Both	3	High	12
Recreational								
Racing	N/A	None	1	High/Low	None	0	High	4
Amusement park attraction	N/A	None	2	Low	None	0	Low	10

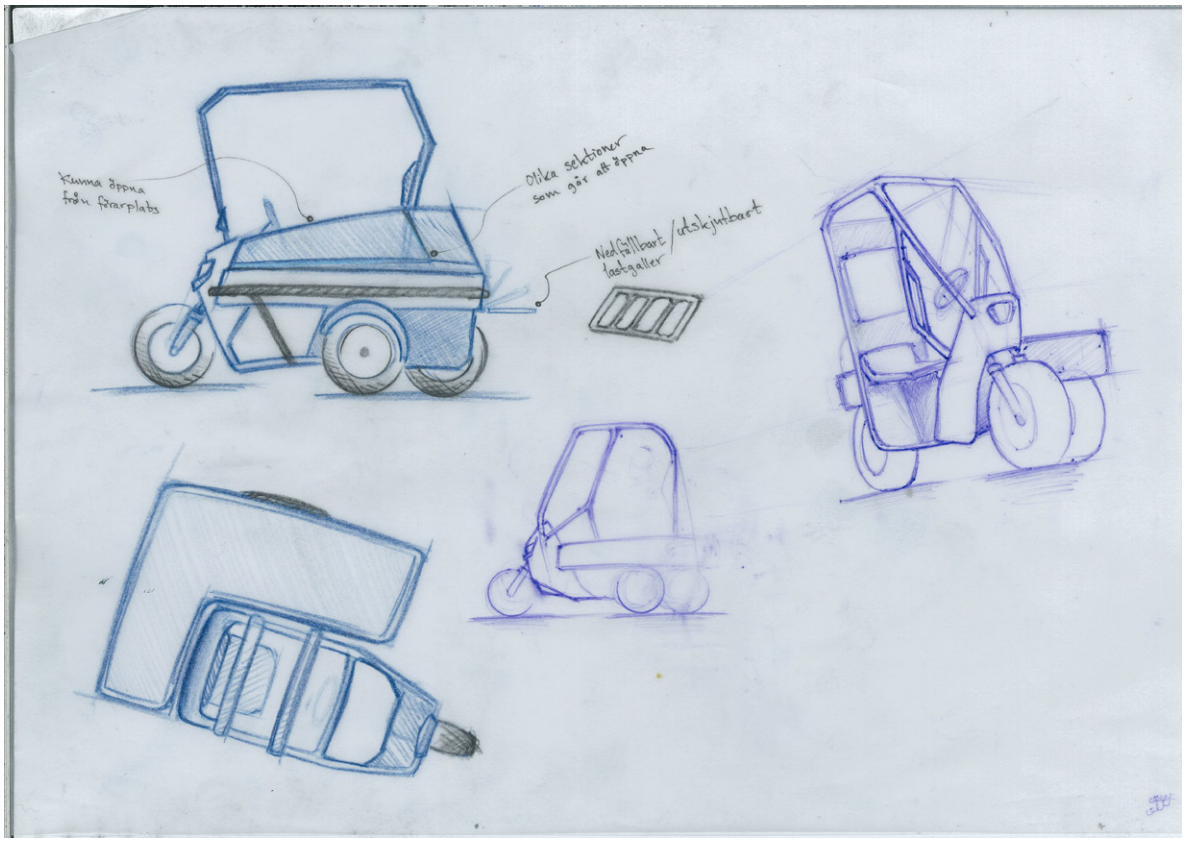
Measurement definition:	Small <30 cm	0-5 few	Low	Cargo	0 Low
	30< Medium <60	6-20 several	High	Personal	1 High
	60< Large	>21 many	None	Both	2 None
Johan/Linus					3
					4
					5

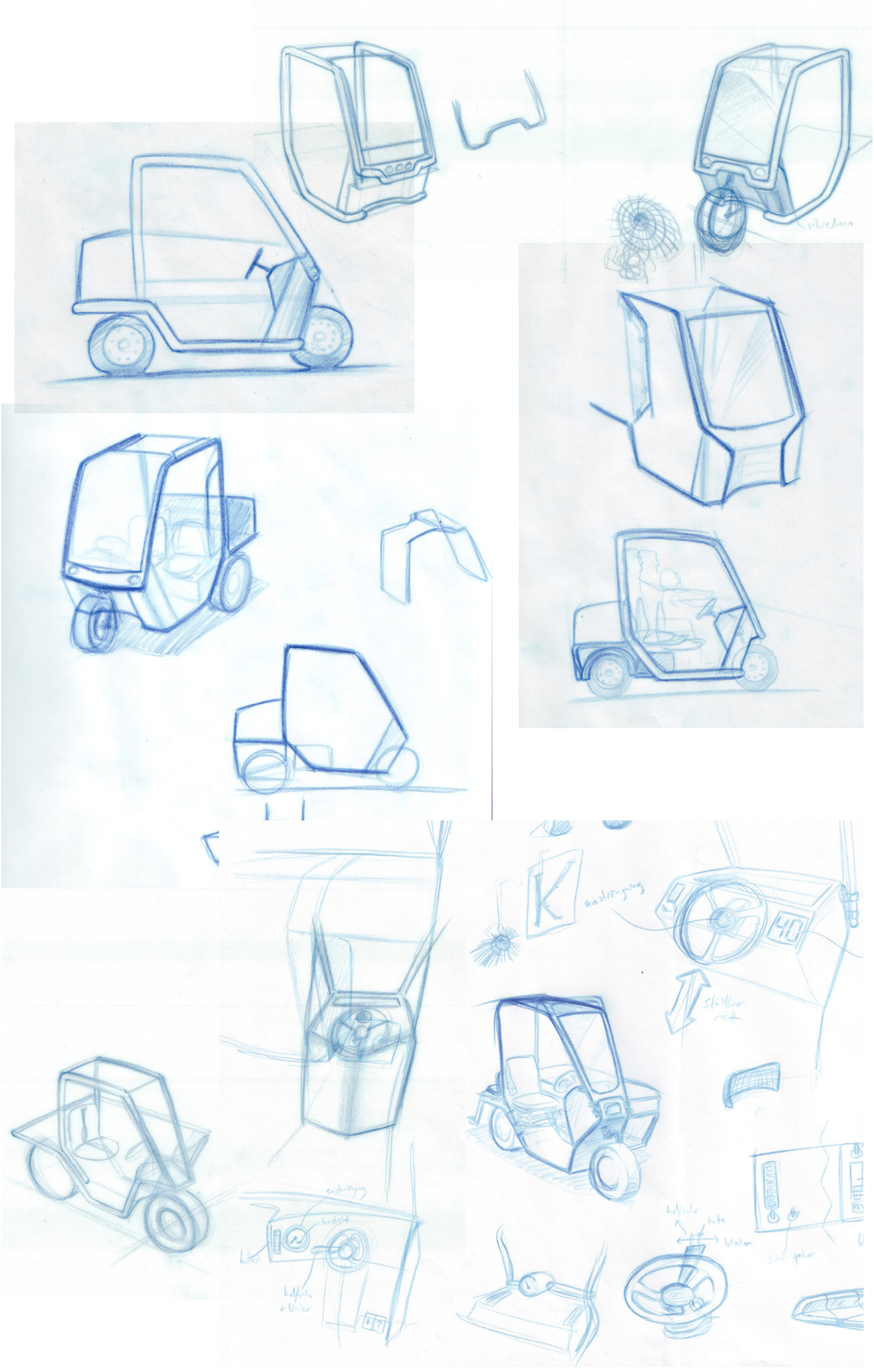
Appendix M - Sketches

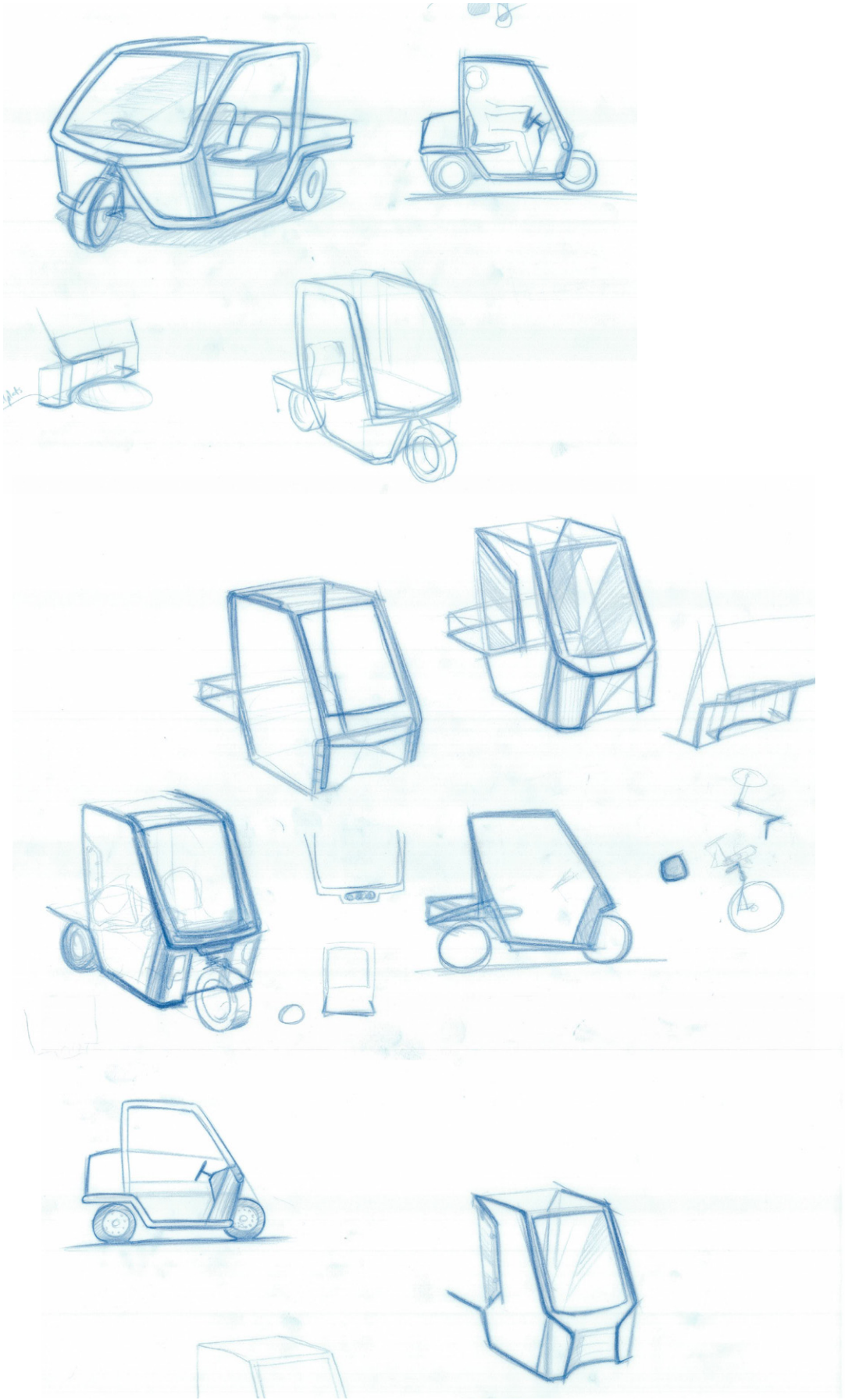


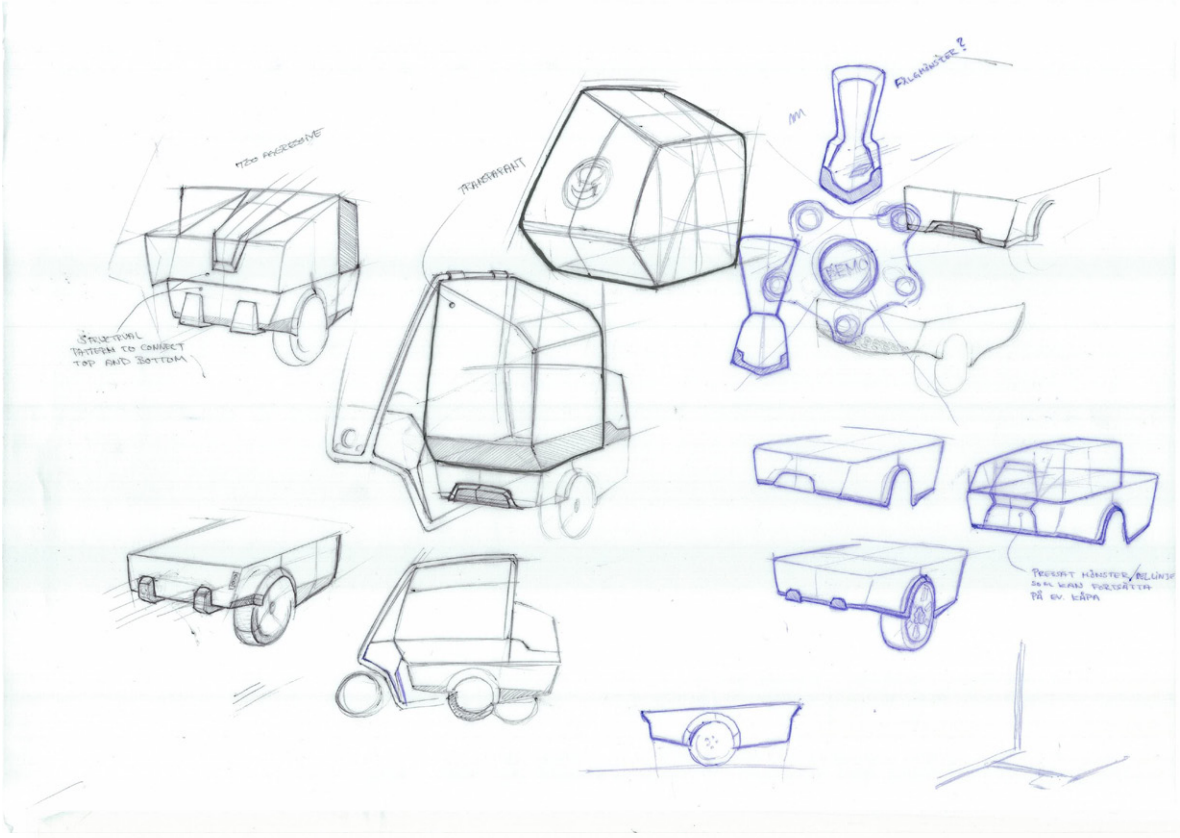


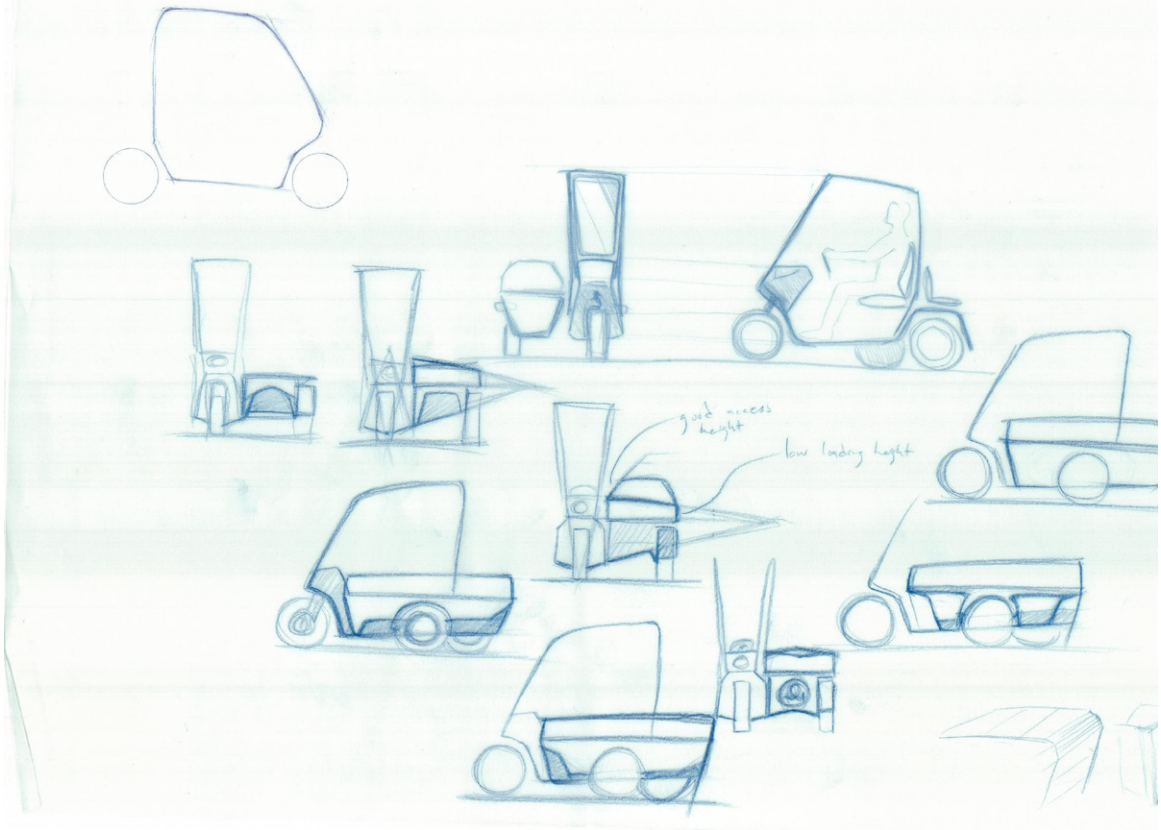

Takräcke
LGF-Skydd
Alu-ram
Skivbromsar
Skjutbart säte

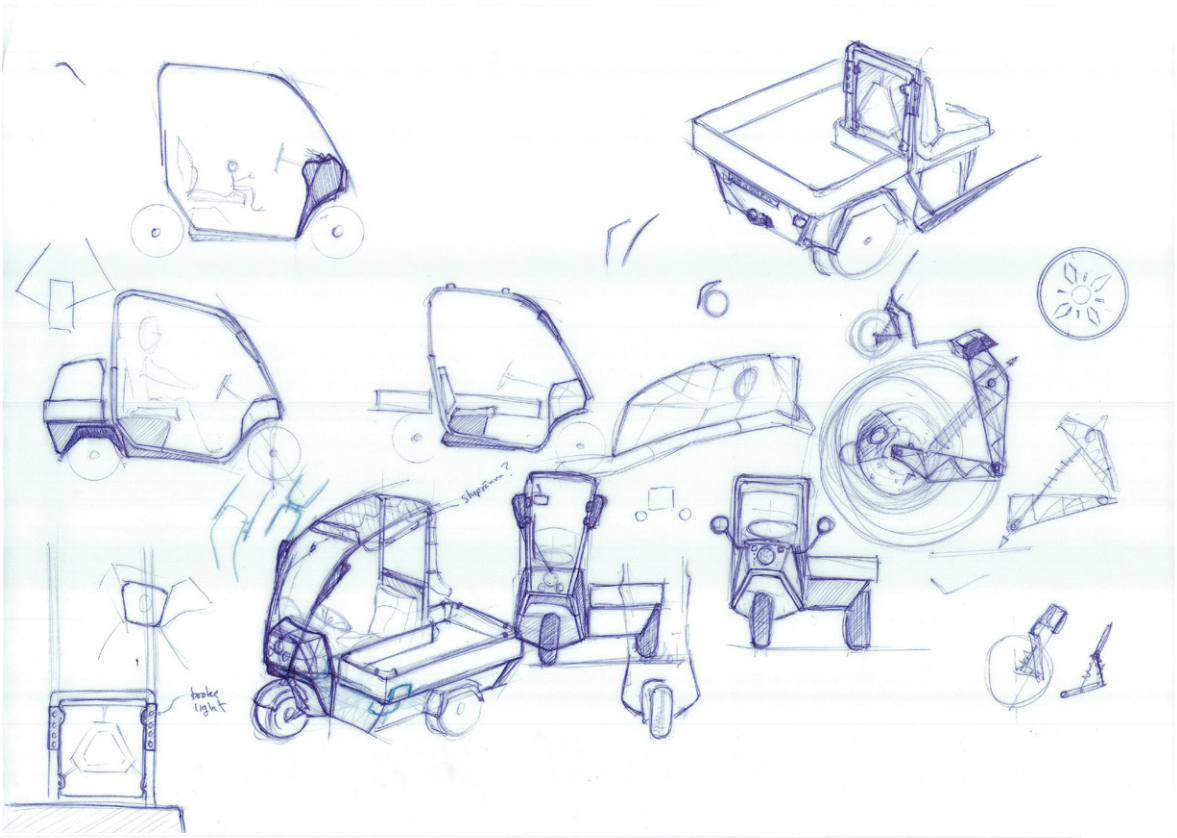

Finns öppna från framplats
Olika sektioner som går att öppna
Nedfällbart/utskjutbart lastgaller

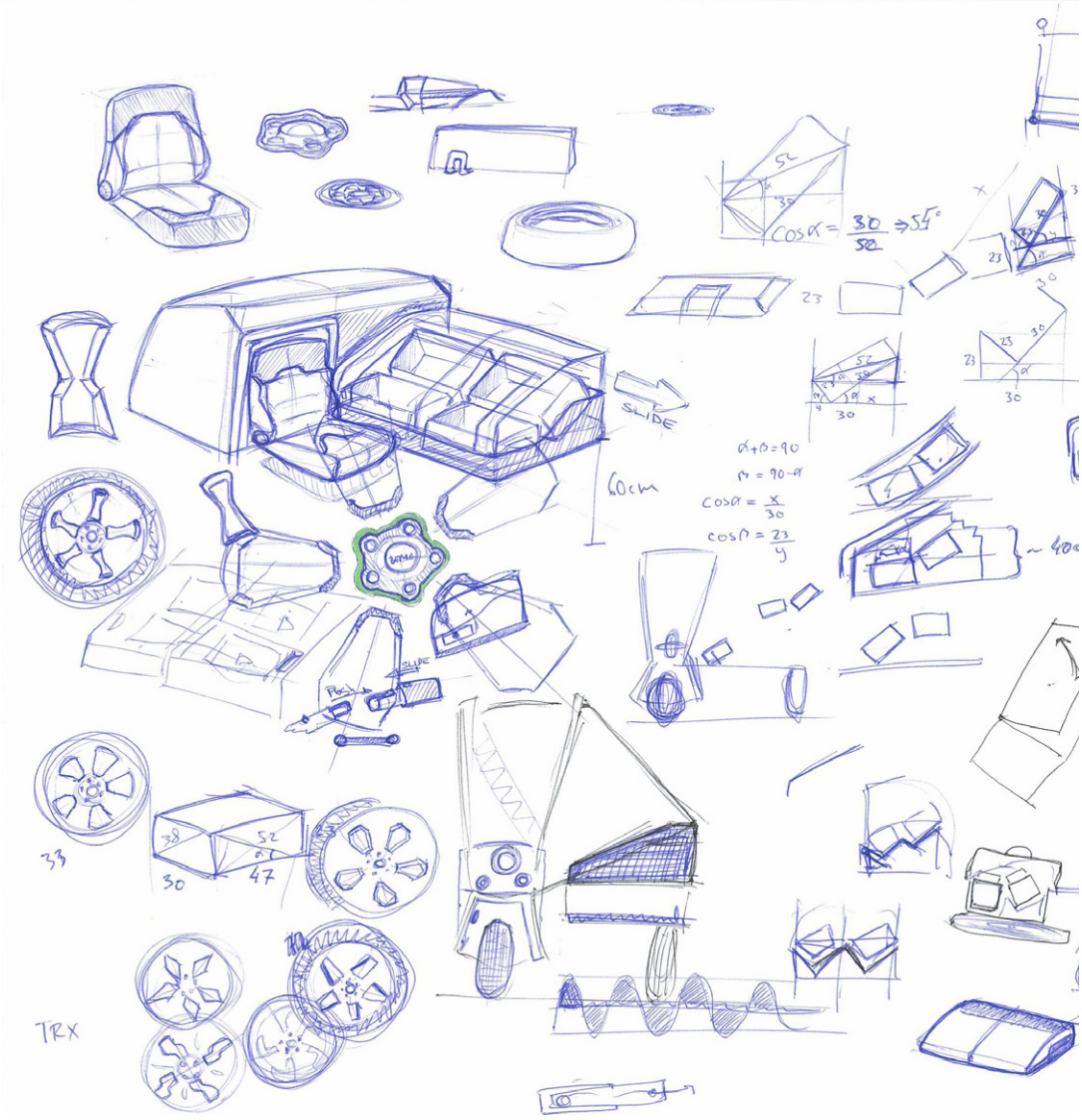

K
40

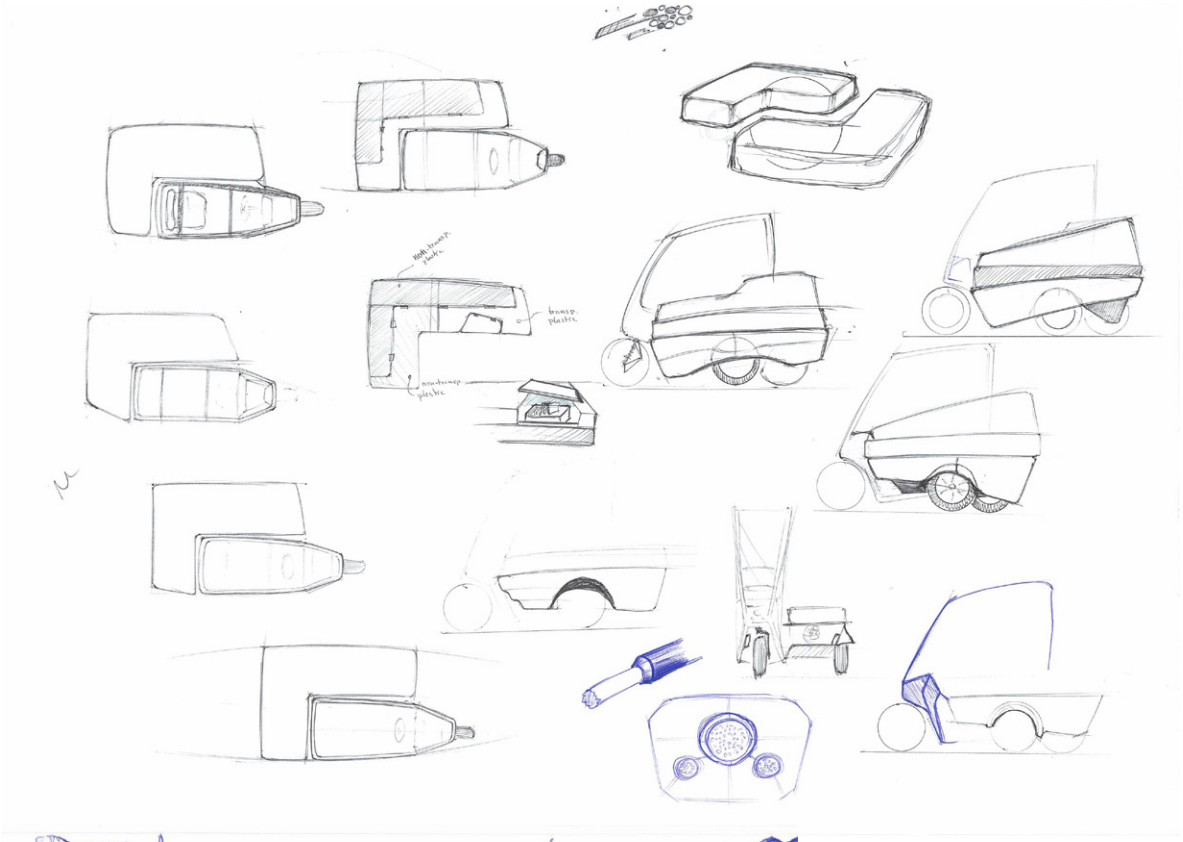


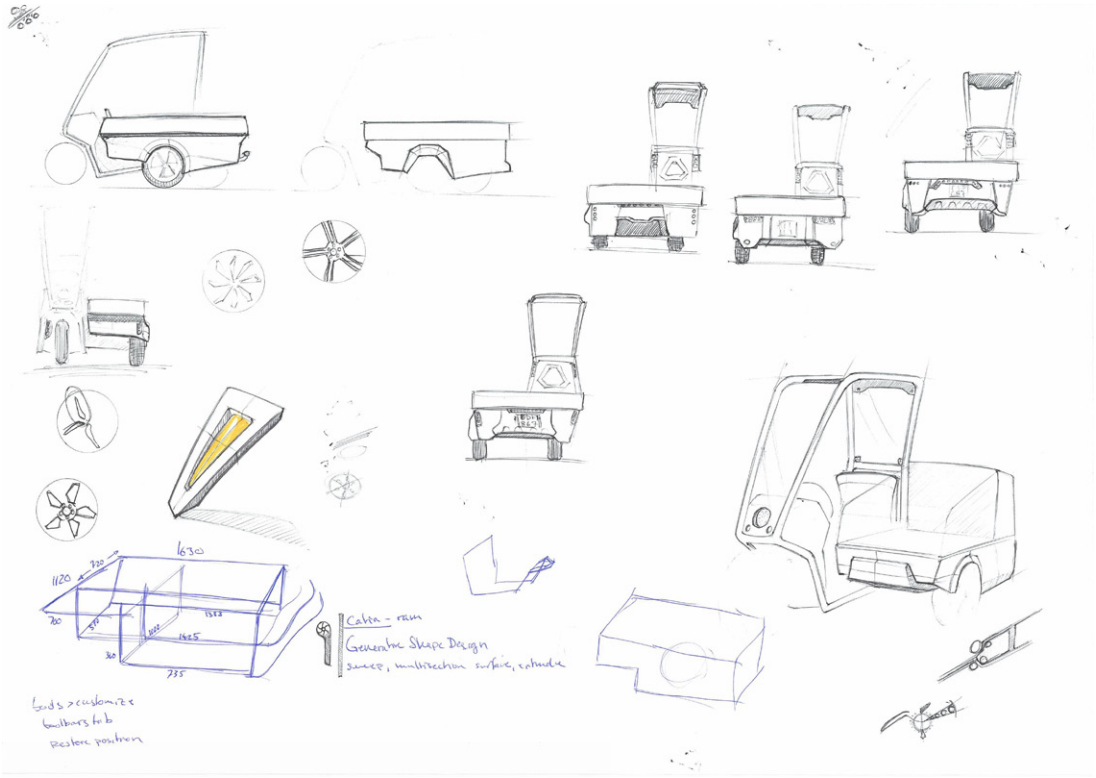

ALTERNATIVE ?
STRUCTURAL PATTERN TO CONNECT TOP AND BOTTOM

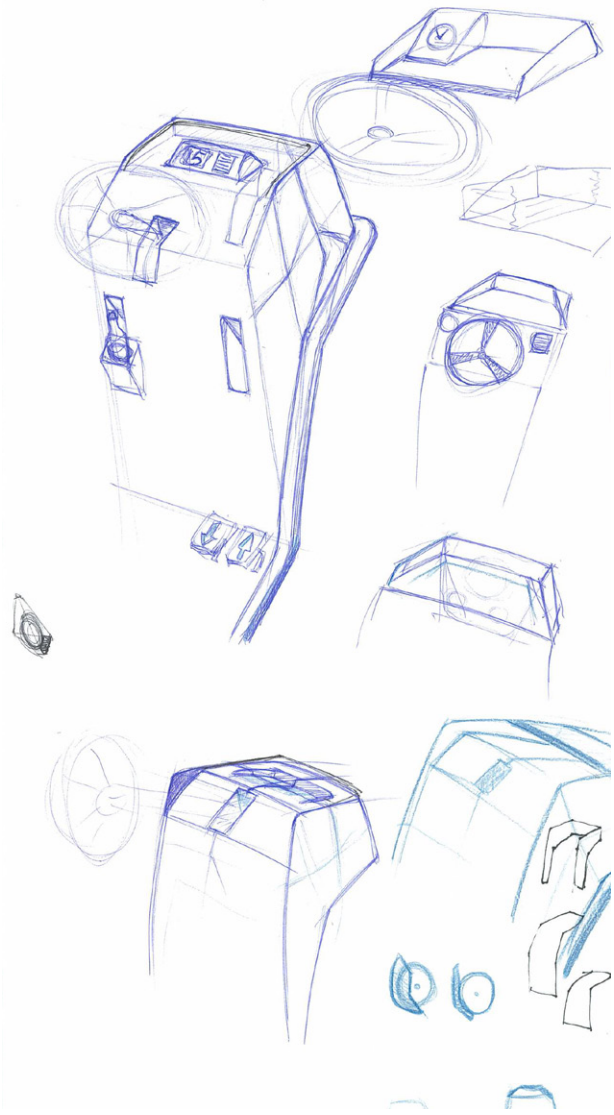

good access height
low loading height

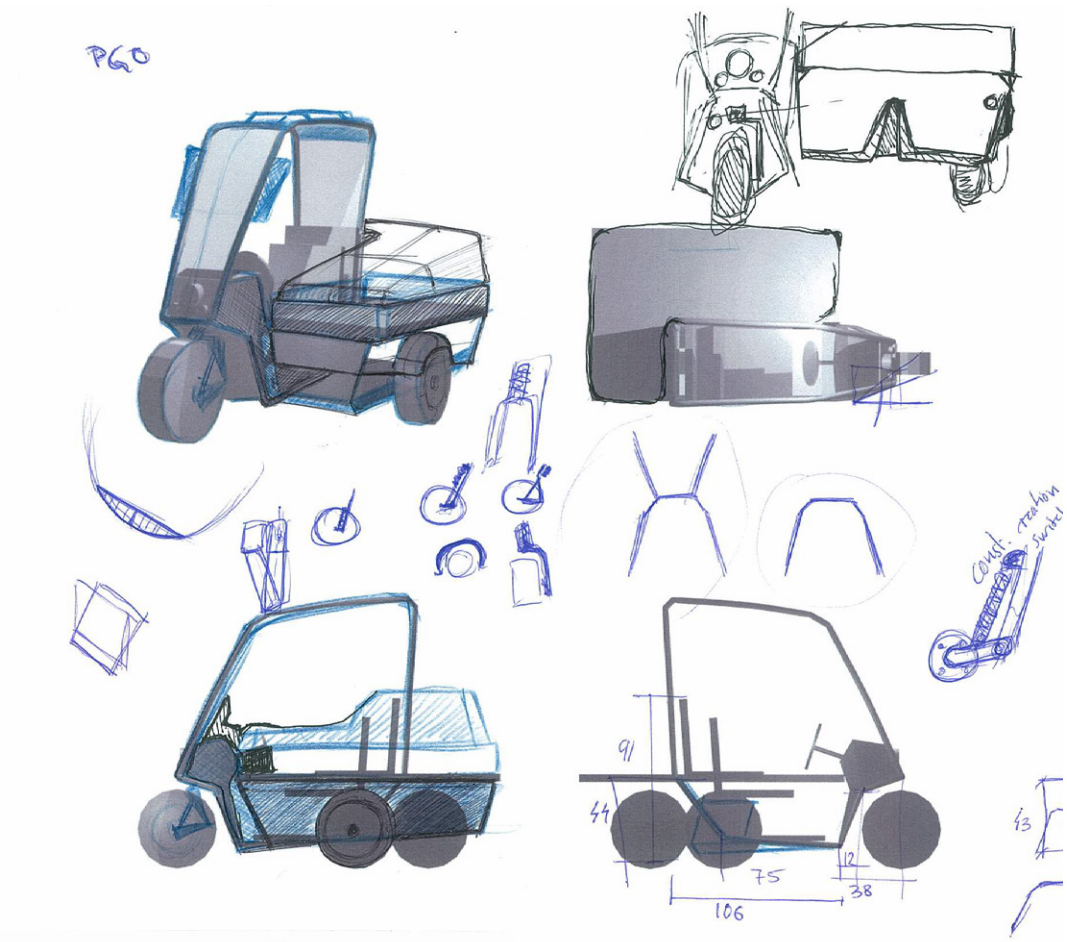

brake light

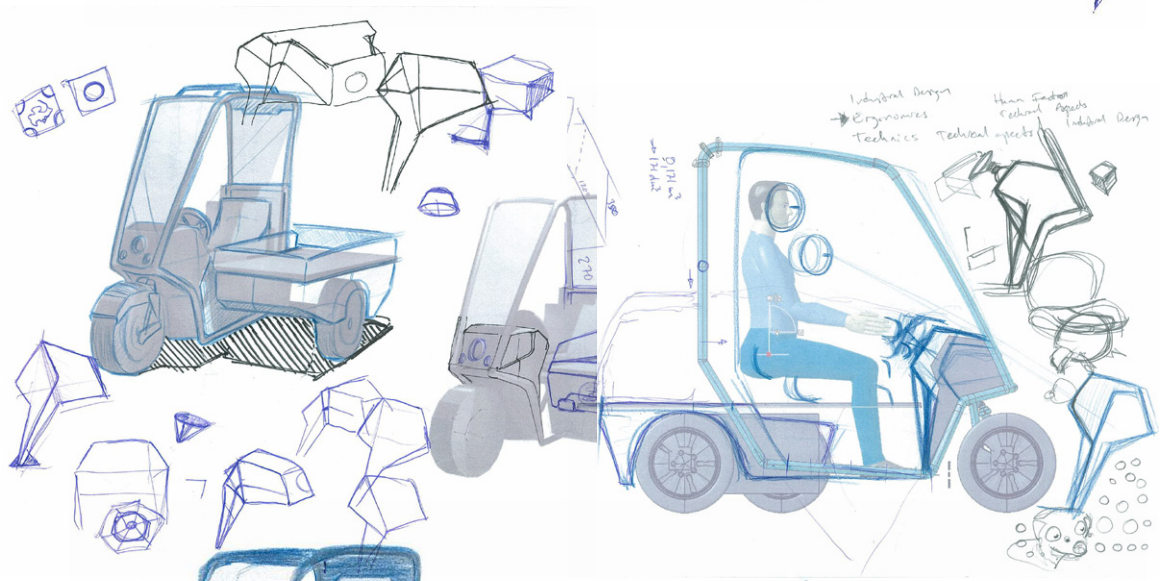

SLIDE
60cm
TRX




1630
1120
720
760
360
735
1583
1625
Catia - run
Generative Shape Design
sweep, multisection surface, extrude




PGO
91
44
75
106
38
12


Ergonomics
Technics