CHALMERS

Concept development and facelift of an electric walk-with towing tractor

Bachelor of Science Thesis within the Design Engineering Program

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden, 2012

Preface

This thesis work has been carried out within the Design Engineering Program at Chalmers University of Technology in Gothenburg. The Design Engineering Program is a three year bachelor education which concentrates on product development and design. A key part of the education has been to work in project groups and handle the different phases in a design project, from a need or a problem to a concept idea which is presented with the aid of sketches and 3D models.

The thesis work is made in collaboration with Toyota Material Handling Europe (THME), where the Product Design Manager, Magnus Oliveira Andersson, has been a tutor. Olof Wranne, who is an Industrial designer at Chalmers University of Technology, has operated as the examiner and a tutor as well. The thesis work has been done in Gothenburg with regular visits to Mjölby for supervision, evaluation and presentation.

Special thanks to Magnus Oliveira Andersson for giving us the chance to do this interesting and challenging thesis work. Furthermore, thanks for all the time you have given us and all great feedback. Thanks to Olof Wranne for being a wonderful tutor who has given us lots of useful information and scoops concerning the design development process. Thanks to Kjell Melkersson and Sune Olsson for supervising within construction and mechanical issues. Last but not least, thanks to TMHE and Science Park, for giving us desks and a peaceful inspiring atmosphere to work in.

Summary

In this project an electric walk-with towing tractor, BT movit TWE100 from Toyota Material Handling Europe (TMHE) has been further developed as a future concept and a facelift, which is an updated version of the current product. Today, the towing tractor is used for towing roll cages, shopping trolleys, garbage bins and special made carts for production industries. The aim of the future concept is to find more areas of applications which would result in increased sales of the product. Furthermore, the future concept is going to have a design which suits the new users, looks futuristic and expresses the brand's design language. The point of the facelift is to make the tractor more aesthetically attractive through redesigning the cover and update the other parts. In addition, the facelifted version is going to fit into the current product range.

A key part of the work has been the development process of new forms which are confined by several limitations. Besides, the usage of the current product has been analysed and new areas of application have been investigated. Furthermore, a research of similar products from competitors has been carried out, to see if there are any functions which can be applied on the future concept and the facelift. The brand's design language has been studied and decisions have been taken regarding the form elements, which can be used on the updated versions of the product. In addition, new functions which will be added to the future concept and the facelift have been worked through.

The environmental effects of BT movit TWE100 have been analysed. The results of the analysis were to exchange the current batteries and minimise the material used in the product to decrease the environmental impact. This information was used during the development process of the future concept and the facelift.

The work has two results. The first is BT movit Future Concept, a concept idea which has three new areas of application: trailers, heavy goods and airplanes. For each area of application there is a special configuration, the four different ones are called Pulley, Lift, Aero and Tug. The model Tug is used for the current usage: moving trolleys. The product has a completely new form, functions and inbound components. The second result is BT movit Facelift, an updated version of BT movit TWE100. BT movit Facelift has a new cover and the other components as the frame, the steering arm and the wheels have been changed. The design of the facelift follows the brand's design principles to fit into the current product range.

The results will be used as idea inputs in further development of BT movit TWE100 by THME. Hence, no regards concerning: technical aspects of function and components or ways of manufacture and production costs, have been taken for BT movit Future Concept.

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1 Introduction

In this chapter the background and the purpose of the project is described. Furthermore, the delimitations are stated and the specific questions are listed.

1.1 Background

Toyota Material Handling Europe (TMHE) was established in 2005 (TMHE, n.d.) and is a part of the Toyota Industries Corporation (TICO). TMHE manufactures and sells material handling equipment in the three brands: Toyota, BT and CESAB. The production system in TMHE's factory in Mjölby is based on TPS (Toyota Production Systems) and the factory has no store-keeping. TMHE has an electric walk-with towing tractor called BT movit TWE100 (see fig. 1.1). BT movit TWE100 (from now on referred to as "TWE100") was designed by Wernsen Engineering (Oliveira Andersson & Senneryd, 2012)[1] in the last decade, to provide a safe and ergonomic handling of heavy roll cages and mobile containers with a weight up to 1500 kg. It is powered by an electric motor with a battery to minimise the user's manual effort. However, the design of TWE100 has not changed significantly since it was created, except the handle, therefore it is now out-of-date. Design and styling of material handling equipment has been increasingly important in recent years. Hence, TMHE strives to unify the product range in their BT brand with their newest design principles which was designed in the year of 2008. The company uses a specific design language as a part of their branding. They have several reasons to use specific design principles in a product range as their branding. Firstly, to help the customer identify that the product is part of the BT brand. Secondly, to emphasise the product values of BT design which are safety, durability, driveability[2], simplicity and productivity. Since TMHE wants to increase the sales of TWE100 the product is under evaluation if it should be redesigned, to fit the current line of BT's design principles.

Fig. 1.1 - BT movit TWE100 (THME, 2012)

[1] Magnus Oliveira Andersson, Product Design Manager & Magnus Senneryd, Senior Applications Manager (at TMHE, interviewed by the authors 16 January, 2012).

[2] TMHE's own expression for driving comfort.

1.2 Purpose

The purpose is to make a concept study of a new generation of TWE100 with new areas of application in the year of 2017 and to make TWE100 aesthetically fit into BT's current product range through a facelift with a main focus on the cover.

The goal is to have new areas of application and a design of TWE100 that fits into the 2008 product range and can be used as a base for further development of the TWE100 by THME. This will be presented with the aid of sketches and illustrations showing the usage and a CAD-model with renderings.

Since there are two certain parts: a concept study and a facelift, the project will be divided into two phases referred to as BT movit Future Concept and BT movit Facelift.

1.3 Delimitations

1.3.1 BT movit Future Concept

The first part is going to result in a concept which will be used in further development of TWE100 by THME with the focus on form and new applications. Therefore, there are certain delimitations stated below that will not be dealt with:

- Design for markets outside Europe – Because certain regulations and design aspects can differ between the worldwide market and the European market a product needs to be adapted to the different markets (Oliveira Andersson, 2012)[1]. Since this would result in several models of one product the Future Concept will be designed to suit the European market only.

- Technical aspects of function and inbound components – Because this assignment is focused on the aesthetics of design, no calculations or detailed design of any construction components will be done. In addition, the Future Concept is an idea concept which is not aimed to be a complete product.

- Ways to manufacture and production costs – Will be excluded because the Future Concept will be further developed before it is ready to be produced. Furthermore, the number of products which are expected to be manufactured are not defined due to that it

[1] Magnus Oliveira Andersson (Product Design Manager at TMHE, interviewed by the authors 16 January, 2012).

is a completely new product with new customers. When the production volume is not given the production method can not be chosen and no production costs can be calculated.

1.3.2 BT movit Facelift

The second part will result in a CAD-model which can be used when TMHE is going to make a facelift of TWE100. A facelift means that something is restyled to make it look more modernised (Britannica Online Encyclopedia, 1934) and it is not a redesign of a whole product. With this definition as a basis the following parts of TWE100 will not be changed significantly:

- Inbound components or their layout – Change of the components can lead to increased costs for development and manufacture.

- The frame - Material can be added to the frame but not cut off, to maintain the current strength.

- The handle - Hence the handle is recently changed.

- Brackets for hooks - Because there are several hooks which fit on the current brackets, a change of the brackets would lead to that the hooks need to be redesigned.

- The manufacturing process of the cover - The new cover is going to be produced in the same way as the current one, through a hand laid fiberglass technique. This is the most cost effective way when manufacturing small production volumes (Oliveira Andersson, 2012)[1].

Furthermore, the facelift will be done on model TP 4.1 (see chapter 2.3.1 BT movit TWE100), because it got the largest cover. BT movit Facelift can be used for the smaller models as well, by placing their components inside the new larger cover.

[1] Magnus Oliveira Andersson (Product Design Manager at TMHE, interviewed by the authors 16 January, 2012).

1.4 Specification of questions

To reach the goal the following questions are going to be answered:

1.4.1 BT movit Future Concept

- What do the applications for TWE100 look like today? Where can new areas of application be found and what needs do the new users have?

- Are there any current products from competitors in the new areas of application? What do their products look like? Do these products have any functions which can be applied on BT movit Future Concept?

- Which form elements from the 2008's design language can be applied on BT movit Future Concept? What can be added to make the design more modern than today?

1.4.2 BT movit Facelift

- Which form elements from the 2008's design language can be used to make the facelift fit into BT's 2008 current product range? How can the form elements be adapted to this product with a smaller size and other proportions than the other products in the range?

- Which function/-s can replace the current folding system on the steering arm to ease the adjustment of the handle and to make the product fit more users at their elbow height?

- Are there any competitors? What do their products look like? Do these products have any functions which can be applied on BT movit Facelift?

2 Theoretical frame of reference

In this chapter theories and tools are described to give a better understanding and then explained in chapter 3 how they are used in this project.

2.1 Concept Development in the automotive industry

This theory has inspired the work flow of this project. The development of a new car model often starts with a concept car which is going to inspire the design of the finished car model and the following facelifts. Franklin[1], Manager for the Digital Concept Modeling unit at Volvo Cars, says that the development process of the V40 begun with fast concept sketches, describing several feelings. The Design Manager selected a few expressions which were further developed as sketch models made in Autodesk Alias. One of the models was chosen as the final concept and then built as a clay model in natural size which was modified to find the perfect design. A concept car was later built as a result of the design concept. The complete car model of the V40 was inspired by the concept car but has a completely new design. A concept car is never built for production its aim is to express in which direction the design language is heading. Coming facelifts of the V40 will have influences from the concept car as well, says Franklin[1]. SAAB also used this development process (Chase, 2005). For example, the rear and front styling on the facelift of the 9-5 model from 2006 was inspired by the 9X concept car.

2.2 Form and aesthetics

There are theories about how the human being perceives product form. In the following text the Syntactic theory is described and how proportions can give different expressions. Syntactic means "the way in which linguistic elements are put together to form constituents" (Britannica Online Encyclopedia, 1574).

2.2.1 Visual form syntactics

"The aim of product styling designers is to achieve the desired visual effect, by creating a suitable syntactic functionality, carried by the product form." claims Warell (2004), where product form is defined as consisting of geometrical shape, dimensions, compositional structure, and surface characteristics. All elements of a product form are part of a visual system, according to the design syntactic theory. If one design element is changed, this

[1] Rickard Franklin (Manager for the Digital Concept Modeling unit at Volvo Cars, held a presentation watched by the authors, 18 April 2012).

will affect the visual estimation of the whole system and the appreciation of the product. In addition, every element has syntactic functions, which gives visual effects to the whole product, as perception of balance, groupings and continuity in product form. The form syntactics methodology can be used to create the correct visual effects which transmit the purpose of the design. This means that the most important elements of the design are identified and conclusions are made about the product's appearance.

2.2.2 Proportion and expression in design of vehicles

Proportions are substantial for the expression in the design of a vehicle, according to Franklin[1]. A good example to show this is to change the proportions of a car. In fig. 2.1 a Volvo s80 has been modified with bigger wheels, shorter front and higher shoulder line. By making these changes to the vehicle's proportions a new expression has been created. A family car has transformed into an aggressive sports car.

Fig. 2.1 - Example of a Volvo s80 with new proportions (Motorauthority.com, 2012)

2.3 Electric walk-with towing tractor

Towing tractors are used for horizontal transporting of goods in environments as warehouses (TMHE, 2006). The goods can be loaded on various kinds of trolleys and in linked series of loads. Towing tractors increase the productivity and reduce the cost of moving goods. Furthermore, the physical effort can be reduced significantly by using a towing tractor.

2.3.1 BT movit TWE100

BT movit TWE100 is an electric walk-with towing tractor within the product family called BT movit and the w-series (TMHE, 2011). The product is used for towing roll cages, shopping trolleys, garbage bins and special made carts for production industries (Oliveira Andersson,

[1] Rickard Franklin (Manager for the Digital Concept Modeling unit at Volvo Cars, held a presentation watched by the authors, 18 April 2012).

2012)[1]. TWE100 has changeable hooks which suit these different areas of application. To fasten the hooks in the towing object, TWE100 has to be angled forward by lifting it in the handle to lower the hooks, which makes the product balances on the two driving wheels. TWE100 is manufactured by Wernsen Engineering BV, who has developed and designed the product as well. It is manufactured manually since it is a low volume product. All parts are assembled by hand which enables a high flexibility.

There are six models of TWE100, TP 2.0, TP 2.1, TP 3.0, TP 3.1, TP 4.0 and TP 4.1 (see fig. 2.2). The models got different total pulling weight, travel speed, motor drive power and size of inbound components and cover. TP 4.0 and 4.1 have a differential gearbox which increases the manoeuvrability and shortens the turning circle. The following data is the maximum capacity for the strongest model:
Pulling weight: 1500 kg.
Travel speed: 1.9 m/s (6.84 km/h)
Motor drive power: 600 W.
(TMHE, 2011).

Fig. 2.2 – Four of the six models of TWE100 (TMHE, 2011)

2.4 Hand laid fiberglass production technique

The cover on TWE100 is made of hand laid fiberglass (Seger, 2012)[1], which is a cost effective way when manufacturing small production volumes (Oliveira Andersson, 2012)[2]. Firstly, a coating of resin is applied to a mould (Hankinson, 1997). Secondly, sheets of fiberglass made

[1] Magnus Oliveira Andersson (Product Design Manager at TMHE, interviewed by the authors 16 January, 2012).
[2] Magnus Oliveira Andersson (Product Design Manager at TMHE, interviewed by the authors 16 January, 2012).

from yarn are placed at the mould surface and pressed by hand into the mould. Resin and yarn are alternated, one layer at the time. There are certain form limitations, when moulding in one single mould (Seger, 2012)[1]. The mould needs to have a minimum draft angle of 2 degrees, to enable disengage of the cover from the mould. Furthermore, if the product has in or outward bends on the sides parallel to the pulling direction it will get stuck in the mould. Therefore, bends can only exist on surfaces normal to the pulling direction.

[1] Magnus Seger (Design Engineer at TMHE, interviewed by the authors, 1 Mars 2012).

2.5 Important tools

2.5.1 Interviews

There are different marketing analysis tools that can be used to get deeper information (Bergman & Klefsjö, 2008), one of them is interviewing. This is a qualitative method which can be used with success in certain situations which require information from user experience of one or more individuals. Interviews can be structured in different ways, either more as a discussion with open questions that requires explanations or with closed questions were the answers are focused on yes or no or different scales that measure the agreement to different statements.

2.5.2 Study visits

To create a better understanding of a specific object or place a study visit can be made, where information about the point of interest is investigated and recorded with a medium suitable for the visit (Glosbe.com, n.d.). The study visit can be further developed with the aid of interviews (see paragraph 2.5.1) to get more specific and deeper knowledge from people that are in some way linked with the point of interest.

When a study visit can not be made there are other ways to investigate a point of interest, some companies use youtube.com as a medium to show an overview of their production pipeline, some show their products and their uses (Youtube.com, 2012). Sometime these materials are sales material for marketing their business, therefore it is important to stay critical to the information. The same kind of information about products and their uses are also sometimes available on the websites of the manufacturing companies or their distributors.

2.5.3 Moodboards

Moodboards are collages of images, colours, textures, patterns and other mediums which can influence, assist in analysis and help idea generation when working with design (Garner, 2001). A moodboard is a tool that not only helps solving design problems it can also perceive problems.

2.5.4 Function analysis

A function analysis is a tool which can, in a structured way, divide a general function of a product into smaller functions described with verbs and substantives (Landqvist, 2001). An example would be a main function for a towing tractor, “simplify towing” and then “be ergonomic” and so forth. These functions describing the product are then categorized with the functions which are needed, desirable and unnecessary. The function analysis eases the problem solving by structuring the problem instead of having to solve a total problem (Johannesson, Persson & Pettersson, 2004), there are smaller more manageable part problems to solve. The categorizing terms: needed, desirable, unnecessary can be exchanged for: main function, support function and part function and unwanted functions.

2.5.5 List of demands

A list of demands is a detailed list of standards which are to be applied on a product (Johannesson, Persson & Pettersson, 2004). Each standard has its own unique number and is categorized under a label e.g. production or safety. This is marked with a numbering system containing a cell number 2.2, 2.3 etc. Each standard is then defined as “required” or “wanted”, also if the standard is bringing function or if it is limiting it. An example of how a standard could look is seen in fig 3.2.

Standard nr	Cell	Standard	Required (R) or Wanted (W)	Function (F) or Limiting (L)
1	1.1	Be 100% recyclable	W	L

Fig. 3.2 - Showing an example of a list of demands

2.5.6 Digital sketch modeling

Sketch models are simple three-dimensional physical models representing a sketch to give a better understanding of the shapes and dimensions (Johannesson, Persson & Pettersson, 2004). Sketch models are often made with materials that are easy to work with such as kapa board and styrofoam.

Digital sketch modeling is creation of a digital three-dimensional model which represents a sketch or a design proposal, in the same way as a physical model (Almius, 2012)[1]. The difference is that it exists in a digital environment, not in a real form, unless it can be printed with a 3D printer. There are several modeling techniques, which can be compared to the physical way of either working with clay, kapa board or styrofoam. These modeling techniques are nurbs, polygonal modeling, subdivisional modeling and solid modeling. Subdivisional modeling is not used in this project, but it is described to give a better understanding of the different techniques.

[1] Håkan Almius (Lecturer in Design & Human factors, held a lecture watch by the authors, 9 May 2012).

Nurbs modeling is based on paper-thin surfaces that are created with the aid of curves (Johannesson, Persson & Pettersson, 2004). These curves are placed interactively by placing points in an xyz-coordinate system which the curve will follow. More curves are then created that intersect each other and these paper-thin surfaces are then created with different tools, most appropriate for the given surface (see fig. 2.4).

Fig. 2.4 - The process of nurbs modeling

Polygon modeling is based on manipulation of vertices, edges and faces in an xyz-coordinate system (Johannesson, Persson & Pettersson, 2004). Through extruding, splitting and using other tools to create the desired shape. As seen in fig 2.5, the middle figure is a basic flat plane with four corners. The right edge is then selected and moved to the left in the z-direction, thus creating a rectangle shape and then extruded to the right. The top right vertex is moved upwards in the y-direction. The edge furthest to the right is then re-selected and moved in the x-direction away from the camera, making this a three-dimensional polygon from just a two-dimensional plane, which this model was created from. The complete model can be seen in the fig. 2.5 to the right.

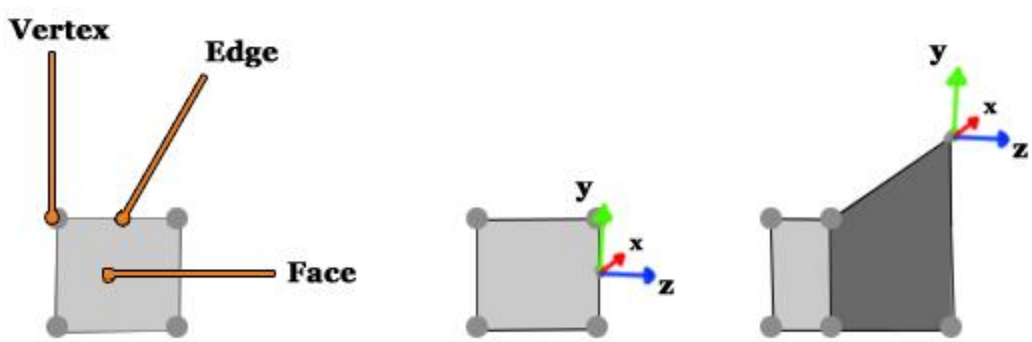


Fig. 2.5 - The process of polygon modeling

Subdivision modeling is based on a similar mathematic as in polygon modeling (Johannesson, Persson & Pettersson, 2004), in fact subdivisions are a subdivided polygon controlled by the same shape which is not subdivisioned. A polygon cube have four vertices which are the corners and six surfaces which create a cube, instead, the subdivision has a smaller more sphere like shape it the bounding area of the four vertices. The interesting part is that it is still these four vertices which control the shape of this soft shape in the middle, this means that the model is always modified in a soft way (see fig. 2.6). This technique was developed to model more organic shapes such as CG (Computer Graphics) characters in the movie industry. Similar tools to those used in polygon modeling are also applied in subdivisional modeling.

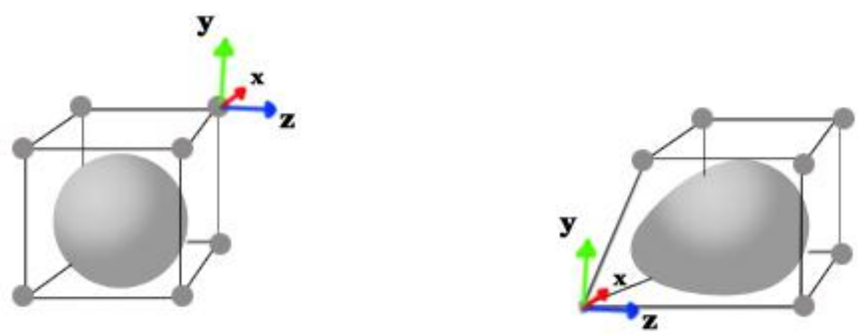


Fig. 2.6 - Subdivision modeling showing the four vertices controlling the soft shape in the middle

Solid surface modeling is a technique mostly used by the manufacturing industry as it is based on technical drawings with detailed measurements and tolerances (Johannesson, Persson & Pettersson, 2004), which are vital to the end result. A technical drawing is made on a two-dimensional plane e.g. xy-coordinate system, this drawing is then padded or extruded in the z-direction, thus creating a three-dimensional object (see fig. 2.7). The basic workflow of solid surface modeling is drawing a two dimensional shapes and then use a tool which can add or remove material in the current shape worked with.

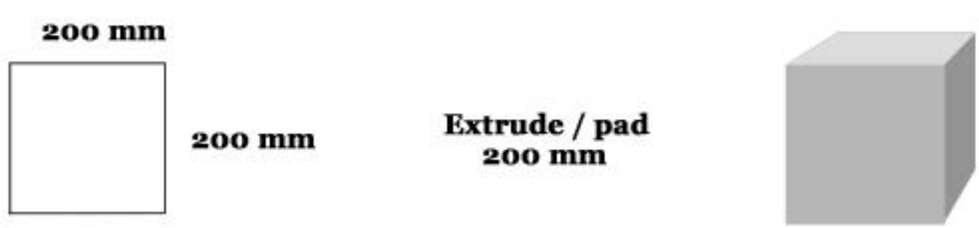


Fig 2.7 - Showing the principles of solid surface modeling

For all these modeling techniques there are different softwares, some can be used to model in one or more of these above mentioned techniques. The following softwares can be used for the different techniques (Almius, 2012)[1] :

- Nurbs modeling - Alias, Maya, CATIA.
- Polygon modeling – Maya, 3ds Max
- Subdivision modeling – Maya, CATIA
- Solid surface modeling – CATIA

2.5.7 Morpological matrix

A morphological matrix is a concept evaluation method were part functions are lined in a table (Johannesson, Persson & Pettersson, 2004). Each part function have an own row where several different solutions are presented. By combining one solution from each part function a total solution to the whole problem is created. These different total solutions are marked out with a polygonal line through the table, showing which part functions a total solution consists of.

2.5.8 The ABCD method

The ABCD method is used when making an environmental analysis of a product (The Natural Step, 2012). It is based on the four system conditions (ABCD) from the organization Natural Step. It is a method that uses back casting, which means that a vision of the company in the future is made. From that point it is a process of going backwards and determining all the steps that are involved in reaching the goal which the company envisioned. ABCD stands for:

A= Awareness and visioning – The company defines its visions and goals.

B = Baseline mapping –The company’s activities are analysed and compared with sustainable guidelines.

C = Creative solutions – Solutions for the most critical impacts are generated.

D= Decide on priorities – Define the most important activities to deal with in a priority list.

[1] Håkan Almius (Lecturer in Design & Human factors, held a lecture watch by the authors, 9 May 2012).

2.5.9 SLCA

With a Sustainability Life Cycle Assessment (SLCA) the sustainability of a product can be defined, assessed and communicated. SLCA is a process which gives an overview of the social and ecological sustainability in the product's life cycle effects (The Natural Step, 2012). The result shows the major impacts of the product through the whole lifecycle in relation to principle requirements of sustainability. The result is shown in a table and the impact is described by colours, where green is low impact and red is high impact. The process is an aid to create plans for decreasing environmental.

3 Method

The workflow is inspired by the concept development process in the car industry. The development of a new car model often starts with a concept car which is going to inspire the design of the finished car model and the following facelifts (see chapter 2.1 for more information).

An overview of the method used is shown in fig. 3.1. Since there are two separate parts: a concept study and a facelift the project will be divided into two phases referred to as BT movit Future Concept or the Future Concept and BT movit Facelift or the Facelift. The Facelift will partly be based on information from BT movit Future Concept which is developed first.

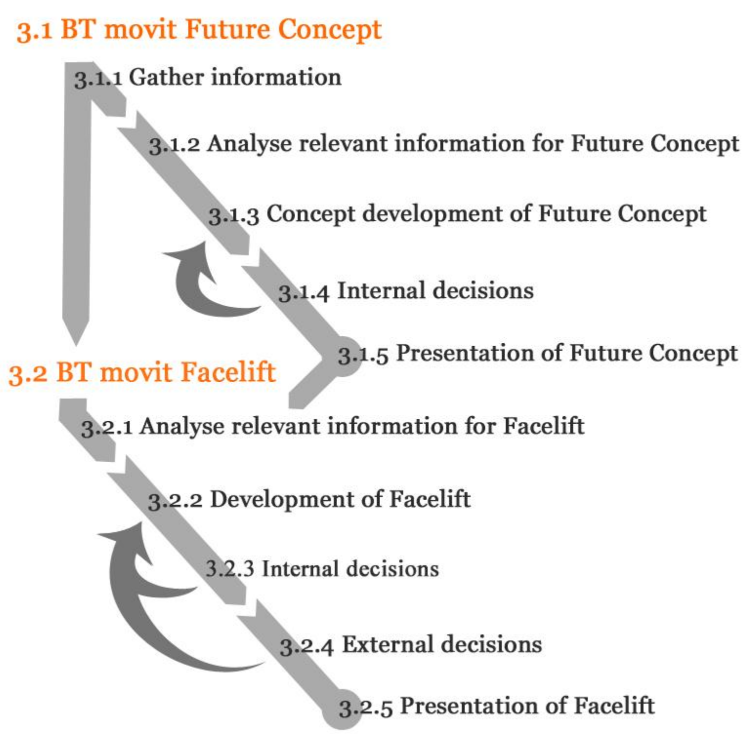


Fig. 3.1 - describing the workflow and the order of the methods used

The methods used in the analysis of the environmental effects of TWE100 are described in chapter 3.3.

3.1 BT movit Future Concept

3.1.1 Gather information

This phase is strictly focused on gathering useful information for both the Future Concept and the Facelift. Useful information meaning technical information about TWE100, how it is used, where it is used and by whom. Other important information needed is information about the design language of the BT brand and the core values (see chapter 4.1.1) which TMHE uses.

3.1.1.1 Find potential Areas of Application

Specific businesses in the welfare system, the production industry and the service sector were systematically structured in columns. Then the entries in the columns were researched one by one to see if there were any potential areas of application. The research was done using Google's picture search on the internet, watching documentaries at youtube.com and looking at companies' home pages. The most promising applications were evaluated through study visits and interviews to find out if a product can solve their problem.

3.1.1.2 Study visits

These study visits are carried out:

- Study visit to TMHE's Factory to increase general knowledge of the BT brand and to get a apprehension of design language from 2008.
- Study visit to a TWE100 customer to get a better understanding of how the product works, is used and the customers thoughts about it.
- Study visits to points of interest that are potentially new areas of application for the TWE100 product.

3.1.1.3 Interviews with employees

Interviews with employees in areas which are found to be potential new areas of application are carried out in combination with a study visit to get a better understanding of difficulties which exists or can occur within the area of application. The interviews also give a good insight into problems that the employees experience which a study visit could potentially miss.

The interviews are created for each individual study visit, with relevant questions. The focus of the interviews are to get a better understanding of experienced problems that occur, desired improvements or needs which the interviewed person feel would benefit the product or ease their work task.

The structure of the interviews is mainly open questions, without giving direct guidelines in which direction the question will be answered. Some closed questions with answers yes and no are used.

3.1.1.4 Inspiration from other trades

To increase creativity when generating ideas, inspiration is very helpful. This inspiration does not have to come from the same trade or similar trades as the product. The perspective can be broadened if taken from a different trade. Inspiration can be gathered or acquired through different mediums such as the use of internet, art exhibitions, nature, personal communication and countless of other ways.

A trip to Stockholm Furniture & Light Fair 2012 is made to get inspiration from the interior design market with the newest furniture fashion trends. Trips to other sources of inspiration are also made, this information is later used when creating moodboards.

3.1.1.5 Competitor analysis

Information about the competitors is gathered to create a better understanding of the market and the different areas were similar products are used. Furthermore, to get ideas of functions which can be added to BT movit Future Concept and Facelift.

3.1.2 Analyse relevant information for the Future Concept

Information relevant to the Future Concept is analysed, most significant is information acquired about potential areas of application and the inbound components of TWE100.

Areas of application

The areas of applications affect how the Future Concept is designed and therefore the data collected from different potential areas of application is evaluated in detail, to get a good insight if the areas of application are applicable on the Future Concept. This is done through analysing the documentation and interviews held on the study visit to each of the areas of application and making conclusions based on those facts.

Inbound components required for the Future Concept

To be able to design the Future Concept an understanding of the inbound components of TWE100 is required and an analysis of dimension of these components is carried out.

3.1.3 Concept development of the Future Concept

3.1.3.1 Moodboards

Moodboards describing the chosen areas of application and inspirational content to aid the idea generation and sketching phase are created. These are based on inspirational materials gathered.

3.1.3.2 Function analysis

A function analysis based on the requirements which each of the new areas of application demands of the product is made, to enable that the Future Concept can fulfill the need of these new areas of application. These functional analyses are then combined into one final to define the requirements that the Future Concept has to meet. Instead of using need, desirable and unnecessary, the term main function, part function and support function is used to describe the functions.

3.1.3.3 Interpretation of the function analysis to form

Interpretation of the function analysis to form is where the core values of the BT brand, dimensions, limiting components and design language are translated into aesthetic design criteria. This is done through defining the requirements in a way which the products design expresses, radiates or reflects the requirements. This means that a person seeing the product for the first time should get a feeling that the product is e.g. robust or fast.

3.1.3.4 Idea sketching

Firstly, the sketching focuses on finding the basic proportions and shape of the Future Concept. To help the sketch process, small scale cardboard models of a human driving the product is made. More cardboard models, of products which is going to interact with BT movit in the found areas of application, are made to ease when making the Future Concept adapt to the requirements these areas have. When the basic shapes are defined, more details are added to the sketches. Various techniques are used, hand sketches with ballpoint pen, pencils, prisma color pencils, markers and other techniques.

3.1.3.5 Mockup model

To understand some of the critical components and their functionality on a very basic level a mock-up model is created of the handle. This allows fast testing and verifying the design features of these critical components. The material used are Styrofoam and wooden bars.

3.1.3.6 Sketch modeling

Because of the short 16 weeks' time frame, the use of physical sketch modeling is omitted for digital sketch modelling, as a tool to understand and evaluate the design from different perspectives. The advantages of working with a digital sketch model are that it takes less time to make changes and it is much more flexible than a physical model. However, the downside is that the digital model does not give as good feedback of the actual size and is harder to relate to, than a real model. To compensate the downside and increase the understanding of the relationship between the actual size of the product, a 3D model of human being of the 50 % percentile is standing next to the digital sketch model.

The tool which is used for sketch modeling is Autodesk Maya 2012 and the modeling technique is polygonal modeling (Autodesk, 2012). The choice is based on earlier experience of this technique, but even with very small or no experience at all this is an easy technique to learn for the purpose used in this case.

The workflow is an interaction between sketching and digital sketch modelling, where promising designs are modeled and evaluated. Then the interesting ideas which come from the sketch model are re-sketched and then re-evaluated in a new sketch model. This iteration goes on until a specific design proposal is worked out in detail. This is done with several different ideas. When a number of design proposals are transferred to sketch models, these are evaluated against each other and the criteria from e.g. a function analysis or list of demands.

3.1.4 Internal decisions

Decisions are taken on an internal basis, meaning that no interaction with TMHE is influenceing the decisions about design, only discussions about the progress are held with TMHE.

The decisions are based on the criteria from the interpretation of the function analysis to form that specifies the requirements the Future Concept has to meet. The result of the decisions taken is in some cases forcing iterations of some parts of the development of the Future Concept were certain areas are redone to give a better end result.

3.1.5 Presentation of BT movit Future Concept

For presentation purposes the final sketch model is further refined and detailed to a level which is usable in rendering software. The detail level of the model imply no hard edges, meaning that if a cube has six surfaces the edges between these surfaces has to have a radius, otherwise the edge can not pick up any light. In terms of real life there are almost no completely sharp edges.

This model is finally rendered with the rendering software Autodesk Showcase to visualize the result and make it easier to understand the idea of it. Furthermore, to create a realistic representation of the Future Concept and the materials which are used. To present the Future Concept, detailed images are created describing functions which are important for the functionality of the concept, to give the viewer a better overall understanding of the design and its logical choices. These pictures and technical descriptions are put together to create collages and then printed on A3 paper.

3.2 BT movit Facelift

This section describes the facelift of the current product, TWE100.

3.2.1 Analysing information relevant to Facelift

3.2.1.1 Analyse of TWE100

The data collected about TWE100 is analysed in detail to understand how the product is manufactured and used. Additionally, the inbound components are studied and dimensions are measured.

3.2.1.2 Analysing the result from the Future Concept

The design and functions from the Future Concept are analysed to see if it is possible to integrate some of them into the Facelift of TWE100. The integration does not have to be total, in a sense that modifications might have to be made, to make it match the rest of the Facelift. However, the general idea of the integrated design stays the same.

3.2.1.3 Understand the BT design language

The design language of the BT brand is analysed to understand all the different products and how their form is distinguished from each other. This is vital to be able to create a product which fits into the range of products the BT brand has to offer.

3.2.2 Development of Facelift

3.2.2.1 Moodboards

As for the Future Concept, moodboards are created, with the same purpose as in the Facelift phase. The difference is that instead of illustrating the areas of application, the focus is to describe the design language of the BT brand and TWE100. Moodboards containing inspiration are created to aid the form development.

3.2.2.2 List of demands

A modified version of a list of demands is used where the aim is to establish what is to be changed in the Facelift. The list of demands uses limitations and potential changes instead of the normal syntaxes of a normal list of demands, described in the previous text. The list of demands consists of what will, what is allowed and what will not be changed on the Facelift and is made to define the Facelift. The list of demands splits TWE100 in parts and every important part is checked with the delimitations and it is evaluated if the Facelift affects it or not. The list of demands shows in detail what is changed to every particular part.

3.2.2.3 Reference model

To speed up the development of the form a reference model of TWE100's base frame is created with CATIA V5 to ease the creation of the perspective sketches in terms of proportions.

3.2.2.4 Mockup models

A physical model of the frame is also created with kapa board to give a good understanding of the real size of the product, because of the absence of an actual TWE100 product. In addition, a mockup model representing the steering arm is built when deciding the accurate inclination in relation to the frame.

3.2.2.5 Idea sketching

The idea sketching in the Facelift starts with working out technical functions which affect the design of the Facelift. Then the focus is to define the direction of the product, the basic shape and proportions which are explored through fast sketches. This is iterated every time a new design proposal is made. Detailed renderings with shading made with colour pencils are created to strengthen the perception the surfaces and their curvature give.

3.2.2.6 Sketch modeling

The same method as in the Future Concept is adapted on the Facelift (see chapter 3.1.3.6).

3.2.2.7 Morphological matrix

To test different combinations of the Facelift's components in a structured way, different parts are evaluated in relation to each other in a morphological matrix. The end result of this matrix is the proposals of the Facelift. One of these is then chosen as the final Facelift.

3.2.3 Internal decisions

The decisions in the Facelift phase are both taken internally and externally. The internal decisions are based on how well the concepts meet the requirements of the list of demands, how the expression of the Facelift form reflects the core values of the BT brand and how well the design fits into the BT product range.

3.2.4 External decisions

Phone meetings are held where the design proposals are discussed and evaluated together with TMHE. Since the Facelift is a refinement of the current TWE100, in contrast to the Future Concept which is a concept of a future product, it is important that TMHE opt in and approve or disapprove decisions which will give a better end result of the Facelift.

3.2.5 Presentation of BT movit Facelift

A final digital model is built using various softwares which include CATIA V5, Autodesk Alias, Autodesk Maya. CATIA V5 is used for parts which are easy to create with technical drawing and Autodesk Maya is used for parts which do not necessarily have to have perfect dimensions while Alias is used to create the cover of the tractor. To visualize the final result of the Facelift the digital model is rendered with aid of Autodesk 3DS Max design and the external renderer Vray. Several shots are made to show the whole design.

3.3 Environmental Effects of TWE100

An environmental analysis is carried out to understand what can be done to decreases the product's environmental impact. The work flow in this analysis is based on the ABCD method (see chapter 2.5.8 for more information). The results of the analysis are used when designing and developing the Future Concept and the Facelift.

3.3.1 Stakeholder's analysis

To find all those who are interested in the product a Stakeholder's analysis is made in the beginning of the product development. The stakeholders either have an opinion or an interest of the product under its lifecycle.

3.3.2 Material flow chart

To determine the out and inflow of materials, energy and emissions of a product, a material flow chart is used. It shows the result in a good overview with all the correlations between the different flows.

3.3.3 SLCA

SLCA is an assessment tool to evaluate a products whole lifecycles environmental impact in relation to a sustainable future (The natural step, 2012) (see 2.5.9 for more information). The result is presented with the aid of colors to give a good overview of how the current situation is, in terms of environmental effects.

3.3.4 Product Ecology

This is a tool accessed on the website www.productecologyonline.com, which evaluates the emissions, water use and waste output from the product's whole lifecycle (Product Ecology, 2012). Input of material, weight and production process results in an output of the amount of CO_2 (Carbon dioxide) emissions, water use and waste output. The tool also takes transports and energy consumption under use into account.

3.3.5 Functional analysis

To break the construction down into workable pieces, a function analysis is done to show what the product have to accomplish and what functions it is going to. See chapter 3.1.3.2 for more information.

3.3.6 List of requirements

With the aid of the stakeholder's analysis, system perspective and the result of the SLCA, a list of requirements is made to show the suggested changes to make the product more environmentally friendly (The natural step, 2012).

4 Development of BT movit Future Concept

In this chapter the results from the concepts study about BT movit Future Concept is described.

4.1 Background research

To understand the principles of BT's form language, how TWE100 is used by current customers, TWE100's technical functions and the inbound component's layout a background research was carried out.

4.1.1 BT's form language from 2008

There are design elements which are specific for BT's form language (see fig. 4.1). The BT logo is located on the lip in an immersion. The family name is written on the side of the frame, growing upwards. The lip is a plastic cover which is placed on the orange body, it can also be inverted if the body is a cover, moulded as one part. Loop fillets are edge fillets which run in a continuous loop, they appear on orange covers and dark grey plastic parts. The BT wave is the s-formed shape which appears in the corners of the steel frame.

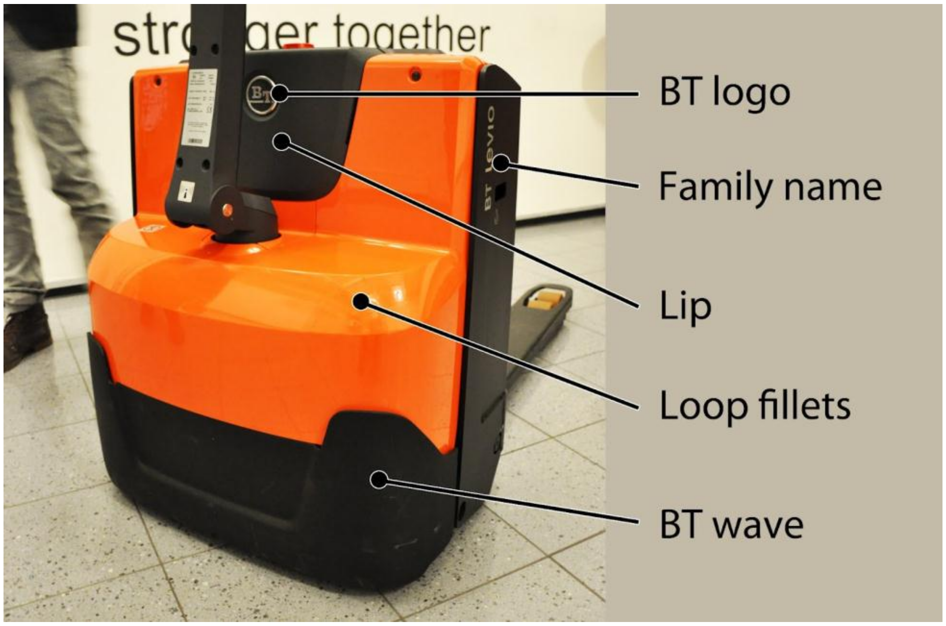


Fig. 4.1 - Design elements in BT's form language from 2008

In addition, there is a specific colour scheme where every single colour is used on certain places. A high gloss Orange is always used on plastic covers and hoods. A black colour with the fine texture MT11020 appears on protective parts as steel frames. Plastic function parts used for storage of personal things etc. are dark grey with the rough texture MT8762 M. Light grey with the rough texture is used on interaction parts such as buttons.

TMHE have core values which are represented in the design of the BT products:

- Safety - The products are designed to be safe for the driver through emergency stop buttons and hidden wheels.
- Durability - The product has to express quality and be designed to last for many years.
- Driveability - The driving comfort as well as ergonomics is important when designing BT products.
- Simplicity - The products needs to be easy to understand for the user and the design is stylistically pure with few details and clean surfaces.
- Productivity - The function rules the form, the aim of the product is to ease a duty for the customer.

4.1.2 Competitor analysis

There are two current competitors in the same product segment as TWE100: Movexx and Jungheinrich (Oliveira Andersson, 2012)[1]. Movexx have six walk with towing tractor models, three of them seen in the figure below. They have a total pulling weight between 1000-1500 kg (Movexx.nl, 2012). Comparing with TWE100 they have an upright form which gives an expression of a good manoeuvrability, according to the authors.

Fig. 4.2 - Models from Movexx (Movexx.nl, 2012)

[1] Magnus Oliveira Andersson (Product Design at TMHE, interviewed by the authors 16 January, 2012).

Jungheinrich have one product in their range called EZS 010(Jungheinrich, 2009), which is similar to TWE100. EZS 010 has a total pulling weight of 1000 kg. Comparing with TWE100, EZS 010 has covered wheels and can not be pushed downwards to fasten the hooks in the towing object. Instead, the hooks have a construction which allows them to snap to the attachment on the trailer. Furthermore, EZS 010 has a foldable steering arm as an optional function (Jungheinrich, 2011), which enables storage in compact places. However, the proportions resemble TWE100's and express strength and durability, according to the authors.

Fig. 4.3 - Jungheinrich EZS 010 (Jungheinrich, 2009)

4.1.3 Functionality analysis

A study visit to a customer using TWE100 was done to learn how TWE100 works, what TWE100 is used for and identify technical functions and inbound components. Dimensions were measured which later was used when building the reference model of the chassis (see fig. 5.3). Reference photos of the exterior and interior of TWE100 were taken to be used in the Facelift phase (see chapter 5). Interviews were done to understand how TWE100 can be improved.

The customer is a supermarket store in Skårer, in the outskirts of Olso, Norway. They use TWE100 to tow shopping trolleys from the garage to the entrance of the store. TWE100's hooks are attached to the first trolley's wheel frame (see fig. 4.4) and more shopping trolleys are collected from several places in the garage, the furthest one is around 500 meters away. This is a two man job when one person is driving TWE100 and the other one is steering the trolleys in the other end (see fig. 4.5). This is done one time every day and between 30 and 35 cats are picked up and it takes 30 minutes. Furthermore, some carts are collected in the evening but only near the entrance and TWE100 does not need to be used.

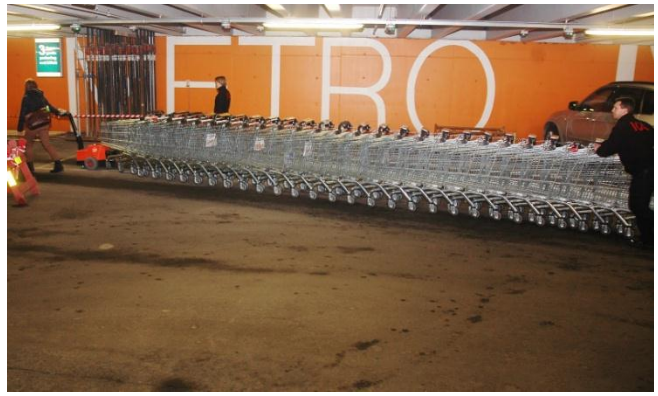


Fig. 4.4 - TWE100 is attached to the trolleys

Fig. 4.5 - One person drives and one steers the end

Before the store bought TWE100 this was very heavy for the staff members, one of them injured her back and had to be signed off. They had to collect trolleys many times every day and each took about one hour.

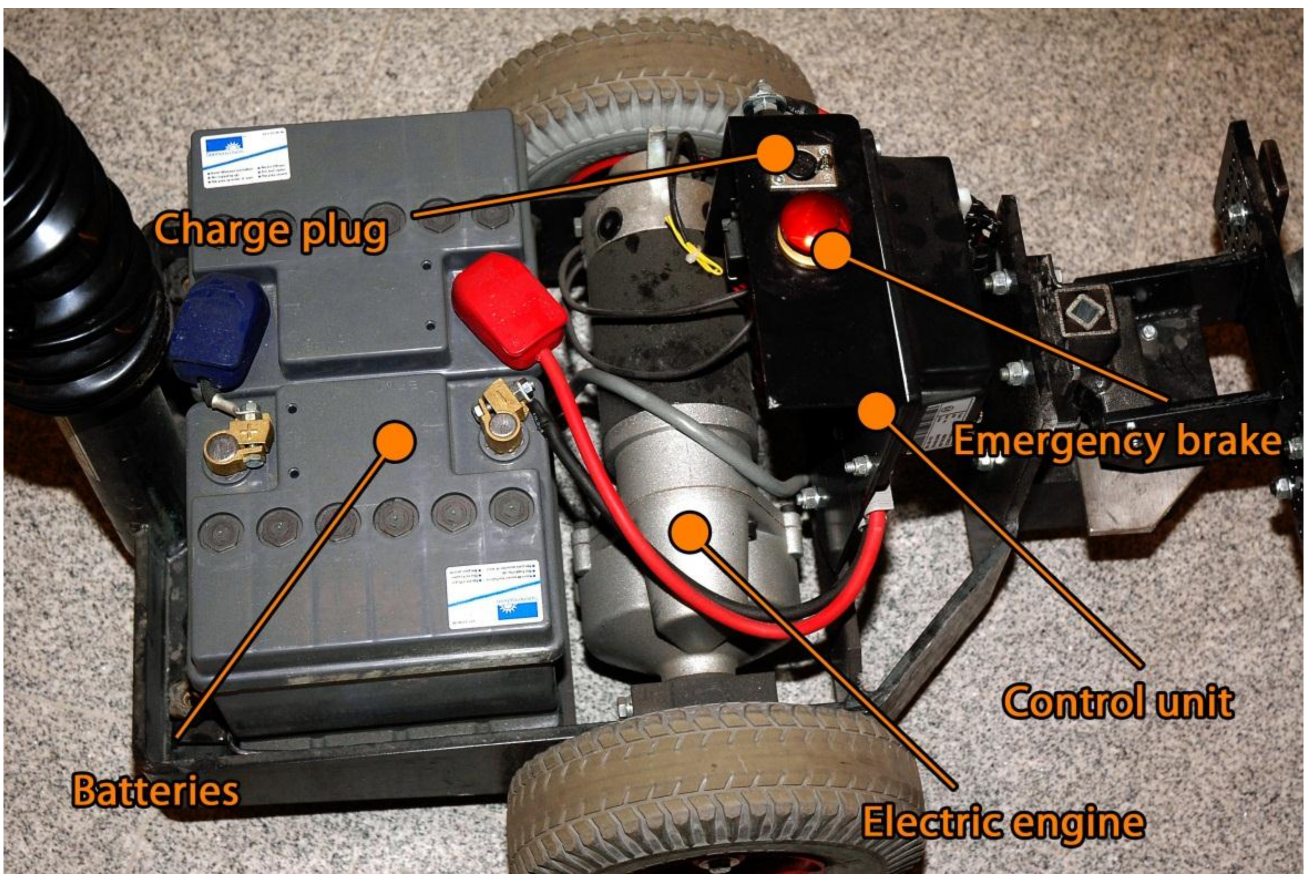


Fig. 4.6 - Showing the inbound components of TWE100

The staff mentioned areas which they would like to have improved:

- The cover does not fit perfectly on the frame and sometimes slides off.
- The adjustment system on the steering arm is difficult to understand an use.
- The wheels spin when riding on wet floor.
- Higher speed when TWE100 is not towing.
- TWE100's motor is too weak to tow the carts in a small uphill slope

The three first issues were later evaluated and solved in BT movit Future Concept and the Facelift. The two last points were not further developed due to the delimitations concerning technical aspects of function and inbound components (see section 1.3).

4.2 Areas of Application

To broaden TWE100's market new areas of application have to be found. The new areas of application will influence the design of BT movit Future Concept.

4.2.1 Trolleys

There are needs for an aid to help moving various kinds of trolleys such as the examples below:

Roll cages (RC) transporting goods for the food industry and grocery stores. According to one of the author's previous experiences from working in a super market, some of these RCs are heavy to move when they are fully loaded, especially if the floor is uneven. Another aspect is to use an aid to make the handling more efficient by towing several RCs in a procession.

Trolleys transporting laundry used in the laundry industry. These trolleys are very big and heavy to move, referring to one of the author's experience when working with laundry trolleys. This can also be more efficient if they are towed in a procession.

Special made carts for different production industries producing:

- Beams (Movexx, 2010)
- Windows (Movexx, 2011)
- Engines (Movexx, 2011)
- Furniture (Movexx, 2010)
- Bread (Movexx, 2011)
- Paper (Movexx, 2011)

There is a great variety among these carts, every factory has their own designed ones. Hence, the aid has to be specially developed to suit these customers.

Trolleys transporting flowers at plantations. There are often big processions with many flower trolleys, which are heavy to tow (Movexx, 2011).

Large garbage bins on wheels (see fig. 4.7). The garbage bins have to be towed a longer distance because the truck is unable to get close to the garbage station. The ground is often uneven and the bins are heavy when they are fully loaded. The workers have to move several bins per day and this duty has a big impact on their bodies (Geng, Adolfsson and Torén, 2003).

Shopping trolleys (see chapter 4.1.3 and fig. 4.8).

Fig. 4.7 - Garbage bins on wheels

Fig. 4.8 - Shopping trolleys outside grocery store

4.2.2 Airplanes

An interview, with the pilot Orhaug[1] at Säve airport in Gothenburg, confirmed that it is a need for a tool that can ease the transport of small airplanes at airports. The airplanes weigh around 1000 kg and common types are the small Cessna planes. The pilots move the planes from the hangar to the airstrip by manual power and a tow bar (see fig. 4.9). The tow bar attaches to the airplane's front wheel (see fig. 4.10) and enables manual steering and towing. There are several attachments depending on the airplane manufacturer which results in different tow bar types. Sometimes the pilots have to fly by themselves. This leads to a complicated situation with a heavy strain, when one person has to tow the airplane, especially if the airstrip consists of grass.

Fig. 4.9 – Pilot moving a plane with a tow bar.

Fig. 4.10 – The tow bar attaches to the front wheel.

4.2.3 Trailers

There are needs for an aid to help moving various kinds of trailers as the examples below:

Delemark[2], an employee at GPL trailer hire, said that it is hard to move a fully loaded trailer and he would be pleased to have an aid to help him do it.

Jacobsson[3], marketing coordinator at the caravan manufacturer company Solifer Polar, said that the company already uses a machine to help the production workers to move the largest bogie caravans during the assemblage process. These caravans weigh from 1300 kg to 2400 kg, due to their weight, size and bogie construction there is a difficulty to tow and steer them, especially in narrow spaces. The machine is called Stringo (see fig. 4.11) and the maximum load for this product is 1800 kg. There are several different models from Stringo which have maximum loads

[1] Mattias Orhaug (Pilot, interviewed by the authors, 23 Feb. 2012).
[2] Mattias Delemark (Employee at GPL trailer hire, interviewed by the authors, 23 Feb. 2012).
[3] Iva Jacobsson (Marketing coordinator at the caravan manufacturer company Solifer Polar, (Interviewed by the authors, 15 Feb. 2012).

from 1200 kg to 3000 kg (Stringo.se, 2012). When moving a caravan one person drives the machine and another person has to control the caravan’s rear.

There is also a need for a product to help moving caravans at caravan retailer companies (Lennerbert, 2012)[1], because there are little space between the caravans in the showroom and it is difficult to move them as seen in fig. 4.12.

Fig. 4.11 - Stringo 450 (Stringo.se, 2012)

Fig. 4.12 - Caravans in a showroom

Moving boat trailers in tight and narrow places where a car is too big to use (Parkit360, 2011).

4.2.4 Heavy Goods

An interview with Petterson[2], the logistic manager at Markokaj Moving AB which is a delivery firm that has delivery service of appliances such as refrigerators, freezers, dishwashers, washers and other heavy products showed that the delivery sector needs better tools, to ease the physical strain involved in the job. The issue that Petterson described is the transportation of products in stairs which is burdensome and ponderous and is a two person job. Today a small manual

[1] Bengt Anders Lennerbert (Manager at the caravan retailer company Campia, interviewed by the authors, 15 Feb. 2012).
[2] Linus Petterson (Manager at Markokaj AB, interviewed by the authors, 15 Feb. 2012).

powered cart is used with one person dragging from top and one helping to lift it from underneath, it is very common that injuries occur in these situations. There are tools today such as Powermate (Powermate.info, 2011) which aid in this kind work. However, Petterson and his co-workers find them to slow and ungainly.

4.3 Moodboards

Six Moodboards in A3 size were made (see fig. 4.13) from photos which were taken during several study visits. The moodboars are called: BT Brand, Inspiration, Trolleys, Trailers, Heavy Goods and Airplanes. They were used as references in the sketching phase and as help when developing the function analysis.

Fig. 4.13 - Moodboards (see appendix 1-6 for A4 size)

The aim of “BT Brand” was to describe the design elements, form language and the product values in the BT brand. It was made from the pictures taken at the first visit to the factory in Mjölby. To have photos of the design elements was a great source of inspiration when creating sketches of the Future Concept.

“Inspiration” consists of pictures from other trades than tractors as furniture, cars and gardening tools. The photos which were taken at Stockholm Furniture & Light Fare 2012 give influences from the 2012 design trends. To express TMHE’s core values pictures were taken of powerful cars, construction equipment and gardening tools.

The four last moodboards were made from visits to the potential users (described in chapter 4.2). Each one describes the areas of application and its needs and problems.

4.4 Concept Development

4.4.1 Function Analysis

A Function analysis for each of the four application areas was made to define main (M), part (P) and support(S) functions. Where the main function is the aim of the product, the part functions are necessary to enable the main function and the support functions are not required for the main function but good to have. The four separate analyses were combined to one (see fig. 4.14) which clarifies how BT movit Future Concept will be applied to suit the different areas of application.

Fig. 4.14 - Function analysis for BT movit Future Concept

Verb	Noun	Supplements	Class
Move	Airplanes, Trailers, Trolleys & Heavy goods		M
Minimise	Physical effort		P
Bring	Productivity	For buyer & user	S
Radiate	Safety		S
Radiate	Durability		S
Radiate	Simplicity		S
Radiate	Drivability		S
Offer	Changeable fastening	For airplanes, Trailers, Trolleys & Heavy goods	P
Offer	Attachment	Easy, fast and safe	P
Offer	Securing of the goods	Easy, fast and safe for ”Heavy Goods”	P
Offer	Stair climbing	For ”Heavy Goods”	P
Provide	Electrical drive		P
Offer	Handgrip	For the driver that suits all the areas of application	S
Offer	Steering		P
Be	Easy to handle		S
Provide	Throttle		P
Provide	Ergonomic driving position		S
Provide	Adjusting	Of the handle	S
Provide	Emergency break		P
Be	Stable		S
Be	Reliable		S
Provide	Changeable wheels		P
Provide	Traction	In all seasons and on all surfaces	P
Ease	Storage	Of the product when it is not in use	S
Show	Battery status		S

4.4.2 Interpretation of the function analysis

Guidelines for the design of the future concept were made using the function analysis.

- A bounding box consisting of the inbound components results in limitations in form and dimension. The product needs to have an upright form as a cart, since it has to carry goods. When it has an upright form the centre of mass has to be low, which results in that its components has to be placed in the bottom.

- The product has to radiate and provide the core values below:

  Durability - The construction needs feel robust, stable and reliable. This can be expressed through a steel frame which protects the product from scratches and buckles.

  Driveability - The product has to be easy to drive and suit all kinds of drivers. Less buttons and functions make the product easier to understand. A handle which is height adjustable will suit all drivers. In addition, while having two different throttle controls the driver can choose the most suitable one.

  Simplicity - The form will consist of simple shapes and clean surfaces to radiate simplicity. Additionally, the product has to be easy to understand with simple symbols and forms which indicate how the functions work.

  Productivity - The buyer's acquisition of the product will result in productivity for the company and the user by easing the processes. It is important that the tractor can be used when the driver needs it. Hence, it will easily be recharged anywhere by having a cable in a flex winder which can be plugged in to the nearest power point.

  Safety - The product has to be safe for the user and radiate safety. Furthermore, the product has to be designed due to safety regulations. An emergency brake is needed so the driver can not reverse the truck into him/her self. A key ignition to ensure that no one else than the driver can start the tractor.

- The product is going to be modular, consisting of a body with changeable wheels and customised configurations such as hooks and tow bars.

- The product's design language is going to follow BT's design principles from 2008, but with a hint of new influences.

4.4.3 Idea sketching of BT movit Future Concept

Firstly, the layout of the inbound components was defined and used as a bounding box when sketching. Secondly, reference pictures were made of users and products interacting with BT movit Future Concept (see fig. 4.15). A person holding in the back of a chair was photographed from a side view. The chair was equal to the accurate handle height of 1100 mm (see chapter 4.4.10). Pictures of a trailer, an airplane, a fridge, a garbage bin and a staircase were found on the internet and modified in Photoshop. All the pictures were later converted to grey silhouettes, printed and glued on cardboard.

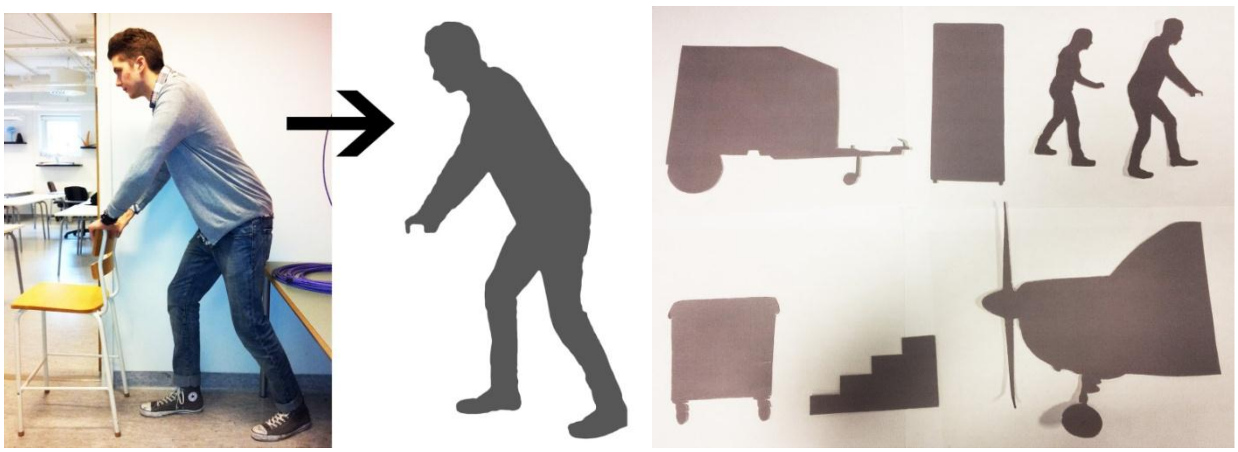


Fig. 4.15 - Reference pictures in cardboard

With the aid of the bounding box and the reference pictures, 2D sketches were made using prismacolor pens and A4 paper, illustrating front and side angles which show ideas built on the guidelines (see fig 4.16). The most interesting sketches were combined and resulted in new ideas.

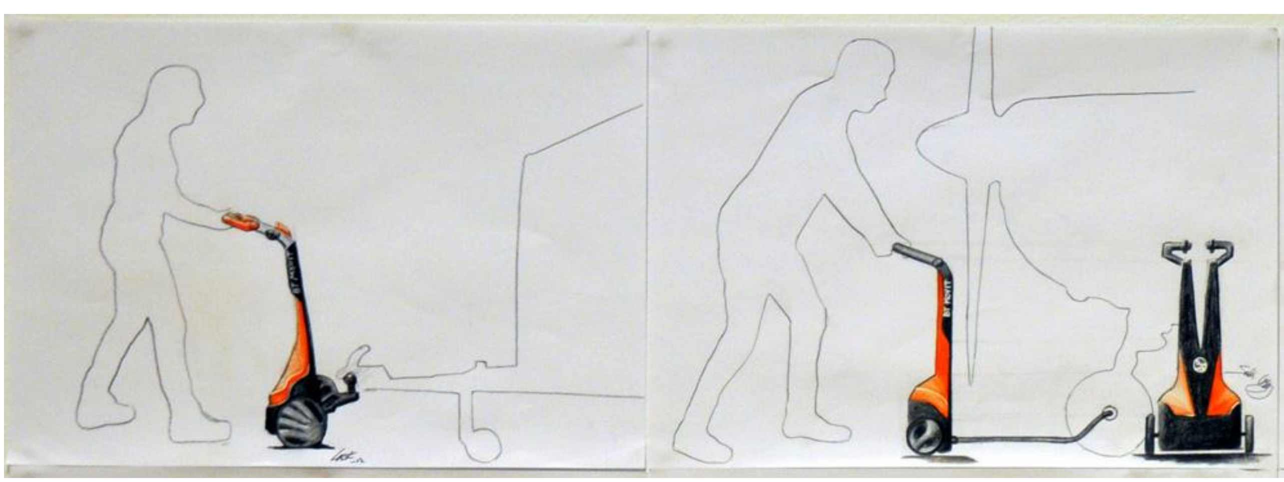


Fig. 4.16 - Sketches made with the aid of the reference pictures and the bounding box

Fig. 4.17 shows the sketches which were combined to one idea which later was created to a sketch model (see chapter 4.4.5). The first row shows concepts for the application Trailers, the middle row is designed for Heavy Goods and the last row is for Trolleys and Airplanes.

Fig. 4.17 -Idea sketches of BT movit Future Concept

4.4.4 Mockup model of the handle

Of wooden bars and cellular plastic a quick and dirty mockup model was made (see fig. 4.18). The model was used to determine the shape and size which are most ergonomic for different hands and the button types which are going to be used for controlling the throttle. Several people with various hand sizes tested the handle with and without gloves.

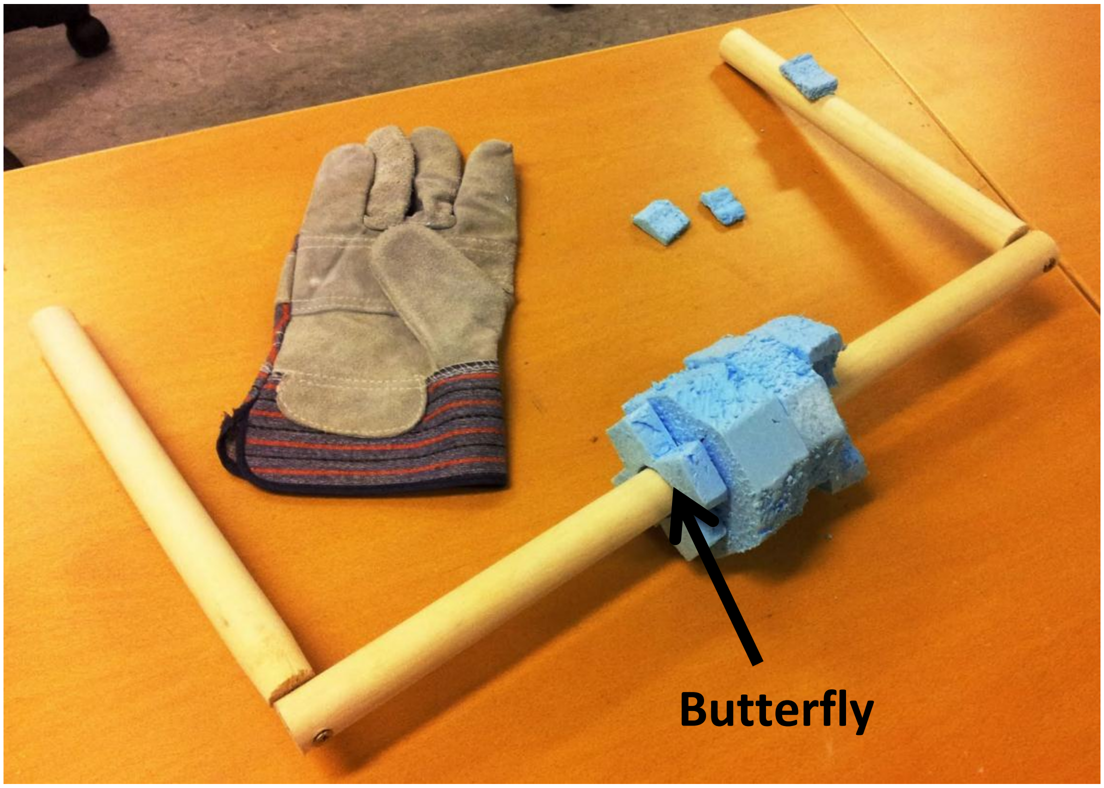


Fig. 4.18 - The mockup model of the handle

The tests with the mockup model resulted in proportions which made the handle fit to many different hand sizes. The dimensions were decided to a width of 450 mm, a depth of 200 mm and a diameter of 35 mm. The space between the butterfly[1] throttle and where the handle bends is 150 mm, to enable that it is enough space for a large hand wearing a glove when the thumb is laid on the throttle control. According to Hägg, Ericson & Odenrick (2008), the hand width for men in the 95th percentile in Sweden is 95 mm, which means that the handle is designed to fit everyone's hands. The most ergonomic shape of the buttons and the throttle (see fig. 4.29) were also set using the results from the test.

[1] BT's name of the ergonomic throttle (see fig 4.18)

4.4.5 Sketch modeling

A model of the final concept idea was built in Maya. The model was further developed by minor variations in shape to find the desired form of BT movit Future Concept. The figure below shows changes in form elements as the lip, the top of the frame and the branding.

Fig. 4.19 - Sketch modeling of form element details

4.4.6 Renderings in Autodesk Showcase

The Maya model was imported to Showcase where renderings were created showing parts of the product, inbound components, the size in proportion to a human and the product in use (see fig 4.20). Free to use 3D models of a man, an airplane, a garbage bin and a lorry were downloaded, adjusted and put in scenes together with BT movit Future Concept to show how it interacts with the user and other products.

Fig. 4.20 - Renderings from Showcase with a free to use 3D model

4.4.7 Shape

The shape of the Future Concept, seen in figure 4.21, is greatly limited by the areas of application which are quite different from the original use of TWE100. For each area of application there is a special configuration, the four different ones are called Pulley, Lift, Aero and Tug. Because of the model BT movit Lift (seen in fig. 4.26), the shape was limited to the requirement of stability and support for tall and heavy objects and therefore the concept has an upright tall form, instead of having a recumbent compact form as the TWE100. By having an upright form the concept also takes less place than TWE100, during storage when not in use.

The shape is wider in the bottom to express the feeling of stability and the narrower top also makes it feel less heavy and easier to manoeuvre. To be able to adjust the handle to the maximum height and avoiding jamming a hand in between the tractor and a heavy object, there is a distance created with a 90 degrees angle seen from a side view, where the handle meets the frame, to increase the distance from the handle to the flat front.

The front of the tractor is flat to give the best loading capacity and is inspired by the carts used to move large objects. The orange plastic is protected by the black metal frame to ensure a durable product with a long lifespan. Furthermore, the metal frame is going to keep the plastic from scratches.

To increase the feeling of driveability, the tractor's middle section has a big opening to give the tractor a feel of lightness and an overview for the driver. The opening also minimizes material use and is beneficial in terms of lowering the product's impact on the environment (see chapter 6).

Fig. 4.21 -BT movit Future Concept

4.4.8 BT design language

To identify that BT movit Future Concept is a part of the BT brand, the design has to follow the design principles. Important form elements are described in chapter 4.1.1.

Colours and textures

To follow the design principles, BT's specific colours and textures has been used in BT movit Future Concept in the same way as on existing BT products. The high gloss orange is used on the plastic cover. The steel frame is black with fine texture. Dark grey plastic with rough texture has been applied to the lip, the handle and the handle adapter. Light grey plastic with rough texture has been used on the throttle controls, push and slide buttons.

Steel frame

As all BT products the Future Concept also has a steel frame. The BT wave has been taken to a new level with sharper corners, more looking as a Z than an S (see fig 4.22).

Loop fillets

These can be found on the orange covers on all products from the 2008's design language. In BT movit Future Concept the fillets are applied to the plastic cover at three places: from the rear part up to the handle, in the back and in the front of opening (see fig. 4.22).

Fig. 4.22 - Fillets

Plastic lip
The lip is an important design element, BT movit Future Concept has a lip on the top (see fig 4.23) to express the brand's design language.

Fig. 4.23 – Plastic lip

Branding
The BT logo has been applied to the lip and is located in an immersion (see fig. 4.23). The family name is placed on the side of the frame (see fig. 4.25).

4.4.9 Inbound components

Most of the inbound components in BT movit Future Concept (seen in fig 4.24) are equal to TWE100's components, with the same size and capacity (see fig 4.6 of TWE100's components) except for the battery, the drive shaft and the flex winder.

The battery is an Li-ion battery which has the same capacity at high discharge as the Lead Acid batteries in TWE100, but is only one-fourth of the size (lithium.web.officelive.com, 2010). A smaller battery is beneficial in terms of form limitations and minimising the material. The Li-ion battery enables a slim and upright form with a low centre of gravity. Furthermore, an Li-ion battery has full capacity until it is discharged while a Lead Acid battery has only 60% of its full capacity in one hour discharge rate. Additionally, Li-ion batteries have longer lives, up to 2 000 charge cycles comparing with Lead Acid Batteries which have up to 800 charge cycles. Furthermore, a Li-ion battery is better than a Lead Acid battery, in terms of environmental effects (see chapter 6). With the Li-ion battery, the product weights 70 kg instead of 99 kg which is the weight of TWE100.

The drive shaft is directly connected to the electric motor by a driving belt. This construction enables various placing of the drive shaft, in front of or behind the motor, which is beneficial when the product needs to be modular for the different areas of application. The models Tug and Pulley have the wheels placed in the front while Lift and Aero have them behind the motor (see fig. 4.26 and 4.27).

To facilitate the charging, BT movit Future Concept has a flex winder and can be plugged in to the nearest power point and charged in the same way as a vacuum cleaner.

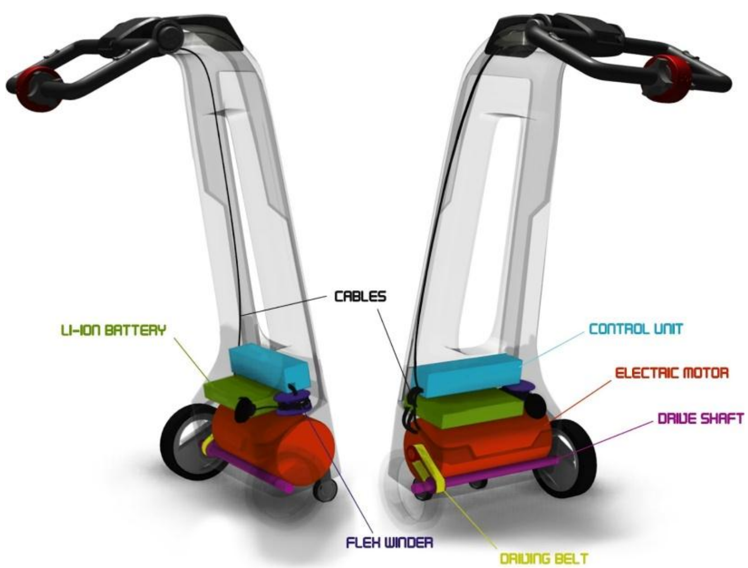


Fig. 4.24 - Inbound components

4.4.10 Dimensions

BT movit Future Concept's design is based on dimension limitations seen in fig 4.25. The height of 1100 mm is the average elbow height for men (Hägg, Ericson & Odenrick, 2008). This means that the product suits an average man when the handle is parallel in relation to the ground, as in the figure below. The handle can be adjusted (see fig .4.30) to the maximum height of 1420 mm and the minimum height of 900 mm. The maximum elbow height for men is 1181 mm and the minimum elbow height for women is 957 mm, which means that the product is designed to suit everyone.

The width is 450 mm to fit the motor which has the width of 378 mm, the depth is 200 mm and the height of the rear part is 250 mm to have enough space for the inbound components seen in fig 4.24.

Fig. 4.25 - Dimensions

4.4.11 Modularity

To enable that the same product can be used for all of the four areas of application it needs to be modular. A modular product is environmentally friendly when one single product can be used instead of buying several different products (see chapter 6 for more information). The same body can be used to all models while wheels and configurations will differ. Lift has a plate which is joined with the steel frame which can carry the goods (see fig. 4.26 and 4.27). Tug has the same brackets as TWE100 which is assembled on the frame. Aero has a tow bar which can move in all directions with the aid of a ball joint, the construction is assembled to the steel frame. Pulley has a tow hitch with dimension and location within the European standard where the ball is 50 mm in diameter (Towbarfactory.co.nz, 2003) and the towing height is 350 mm from the ground to centre of the tow ball (Leicestertrailers.co.uk, n.d.).

Fig. 4.26 - Configuration: Lift, Tug, Aero and Pulley

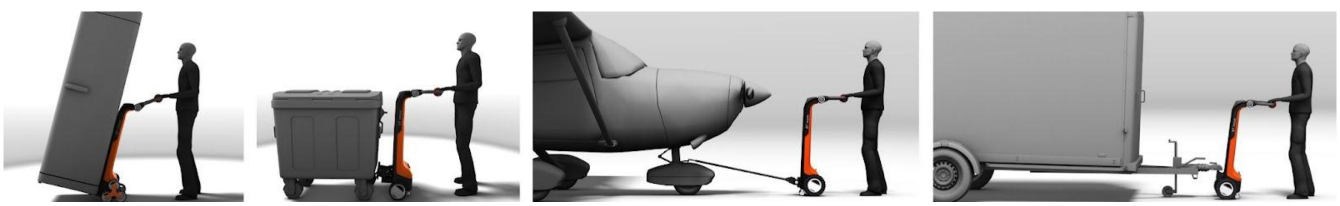


Fig. 4.27 - BT movit Future Concept used in the different areas of application

4.4.12 Steel frame and plastic cover

One of the BT brand’s core values is simplicity, to express that the Future Concept has a design which is simple and clean without unnecessary elements that have no function. The whole structure of the product is based on the steel frame (see fig. 4.28). To increase the rigidity of the frame it is bent in a shape of an L-beam. The frame’s function is also to support tall and heavy objects (see fig 4.27). The frame’s enfoldment of the plastic cover gives the product a feeling of robustness and strength and expresses durability. To give a contrast to the round top of the frame and to give the product a sense of direction, there are sharp corners inside the opening in the frame, creating a piece of a conic shape.

The plastic cover (see fig 4.28) is made of injection moulded PP (Polypropylene). This is much more environmental friendly than fiberglass, which is used in the current cover (For more information see chapter 6). The cover is designed with looped fillets to give it a feeling of harmony where the designed lines are continuous. The main inspiration comes from the 2008 BT design language but has been evolved into a new approach. The design has no visible screws instead these are placed under the top to be invisible from a standing point of view.

Fig. 4.28 - Steel frame and the plastic cover

4.4.13 Handle

The handle is based on the most efficient dimension from the testing of the mockup model (see chapter 4.4.4). The function and ergonomics are most essential and therefore the main focus of developing the handle was put into testing on the mockup model.

There are two ways of controlling the throttle (see fig. 4.29) one with the butterflies and one with the sliders on the sides. The sliders on the sides are mostly used in the area of heavy goods, to give more stability and lower the strain on the wrists, through the use of the whole arm and shoulder instead of only the wrist. However, it also gives users a possibility to alternate between the two ways to decrease the chance of static attritional wear. The layout of the throttle controls is based on a hand truck with the purpose to move heavy goods.

The emergency brake button is pin-jointed in a circular way which enables it to be pressed from different angles (see fig. 4.29). This ensures that the button works regardless of the handle's adjustment. The purpose of this button is stop the tractor, but not turn it off.

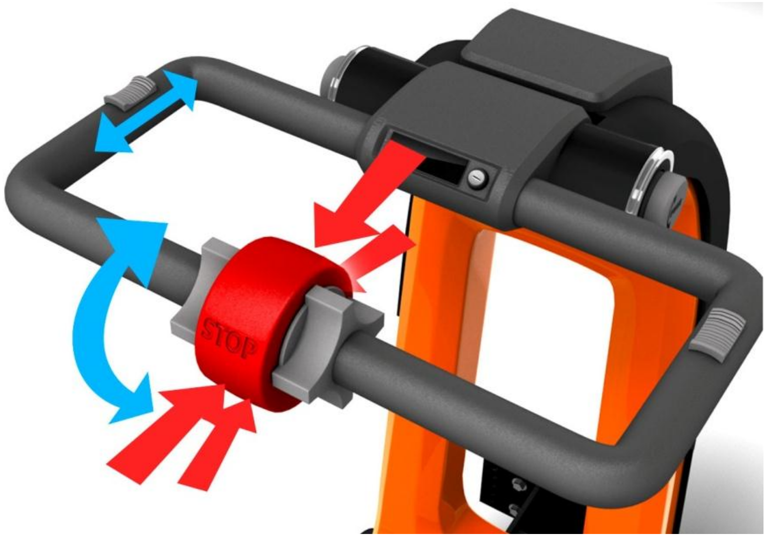


Fig. 4.29 - How the emergency brake and throttle controls work

The handle is height adjustable, by pushing the PUSH button (see fig. 4.30) the handle can be rotated up or down to the demanded height. When the button is released the handle stays in position.

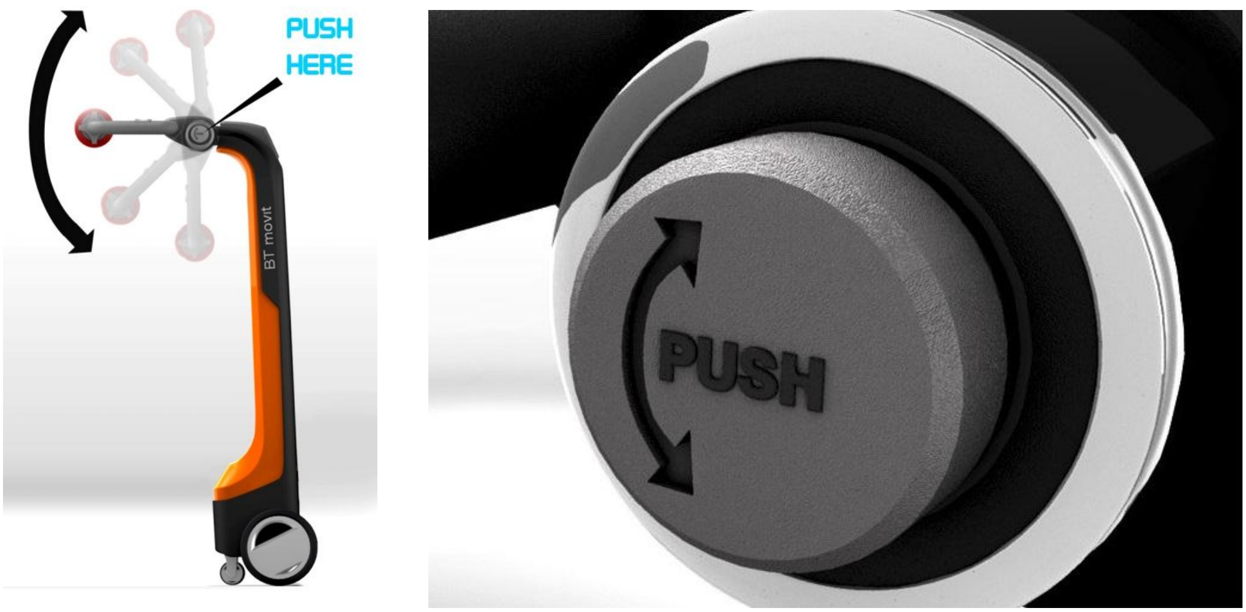


Fig. 4.30 - The adjustable height of the handle

A display of the battery indicator is placed on the handle (see 4.31). This position makes it easy for the user to see the battery status. A key ignition is placed beside the display, in the area where the user keeps the hands. When removing the key the tractor is locked and can not be used until the key is inserted.

Fig. 4.31 - Battery display and key ignition

4.4.14 Charging

BT movit Future Concept can be plugged in to the nearest power point and charged in the same way as a vacuum cleaner (see fig. 4.32). The cable is pulled out and connected to a plug. When the charging is finished the cable is pulled back by a flex winder, using the same technique as in vacuum cleaners.

Fig. 4.32 - Charging

4.4.15 Wheels

Different types of wheels (see fig. 4.33) enable BT movit Future Concept to be used in various environments. The tri-wheel is used in the model BT movit Lift for stair climbing. The wheels is driven by the driving shaft and is rotating around the centre axis. The three wheels rotate around their own axes with the aid of gears from the driving shaft. The gears are hidden behind the orange plate. To increase the turn ability the tires consists of rubber cylinders which rolls sideways.

The terrain wheel is useful for configurations which are used outdoors as the models Pulley and Aero. The indoor wheel can be used on all models when driving indoors or on even ground.

Fig. 4.33 - Three wheel types: Tri-wheel, Terrain wheel and indoor wheel

BT movit Future Concept also have supporting wheels (see fig. 4.32) as TWE100. The supporting wheels are placed in the front or rear part of the frame depending on the placing of the driving wheels, which differ between the configurations. The attachments which are holding the supporting wheels in place have various sizes depending on the driving wheel type. As seen in the figure above, the distance from the ground to the centre of the wheels differ between the wheel types. This leads to a greater ground clearance when the tri-wheels and the terrain wheels are used, due to uneven grounds as steps and terrain.

The rim has a form which is inspired by the BT logo (seen I fig. 4.1). The middle section in the rim represents the line below the letters in the logo. Instead of having the logo on the rim, the rim itself expresses the form of the logo. Hopefully, the rim is going to be a form element in the design language and it can be used on all BT products with visible wheels.

4.4.16 Presentation of the Future Concept

Posters for presenting the idea of BT movit Future Concept was made (see fig. 4.34), consisting of the renderings, describing texts and related pictures. The posters were used to present the concept idea for the Product Design Manager, the Senior Application Manager and the Marketing Manager at the office in Mjölby.

Fig. 4.34 - Presentation posters (see appendix 7-12 for A4 size)

The listeners gave their opinions about BT movit Future Concept during an open discussion, which resulted in theses following improvement proposals:

- A radius instead of a fillet on the lip at the edge close to the handle, to give form continuity.
- Place an emergency stop button on top of the handle or the lip. An emergency brake button is not enough to meet the safety regulations. The product must have a function which can turn off the engine quickly at any time.

4.4.17 The final BT movit Future Concept

The improvement proposals in chapter 4.4.16 were made to achieve a well elaborated concept. The form of the lip was changed at the edge closest to the handle to create form continuity and an emergency stop button was inserted to meet the safety regulations. The emergency stop button is taken from the current range and was already designed by THME. It is placed on top of the lip, since it is the easiest accessible place when it is the highest point on the product in elbow height. The accurate BT logo, the new rims and tires which are used in the Facelift (see chapter 5.10) replaced the previous parts used in the presentation material of the Future Concept, to make the Future Concept more elaborated.

Fig. 4.35 – The updated lip with the emergency stop, changed edge and the accurate BT logo

Fig. 4.35 – Rims and tires from the Facelift

5 Development of BT movit Facelift

5.1 Inspiration

A moodboard describing each bullet below was made (see fig. 5.1), to inspire the design phase:

- TWE100, made from photos taken during the functionality analyse (see chapter 4.1.3)
- BT's design elements from 2008, consisting of photos taken during several visits to TMHE's factory in Mjölby. The moodboard of the BT Brand which was made in the concept study (see appendix 1) was used again and an additional one was made.
- Inspiration from the concept study, with pictures from the presentation material (see chapter 4.4.16).
- Inspiration from different trades. The inspiration moodboard from the concept study (see appendix 2) could be used again. An additional one was made, concentrating on lawn mowers. This was made from pictures taken during a study visit to a lawn mower store.

Fig. 5.1 - Moodboards (see appendix 13-16 for A4 size)

5.2 List of Demands

A List Of Demands was written to clarify how TWE100 will be redesigned to fit into BT's product range (see fig 5.2). In the List of Demands TWE100 has been divided into parts, where each part's limitations and potential modifications are described.

Fig. 5.2– List of demands

Part	Limitations	Potential modifications
Cover	• Fit to frame (low tolerances). • Space for inbound components. • Incorporate with steering arm. • Incorporate with brackets. • Incorporate with wheels. • Place for charging input. • Place for emergency stop button. • Lockable with chassis. • Producible through a fiberglass hand worked process. • High gloss surface with the BT orange colour code.	• New shape. • New split lines. • Spray lacquered with the high gloss BT orange. • Add the BT logo. • Change the emergency stop button to the current button in use. • New integration with the charging input. • Add lip.
Frame	• Same frame. • Same dimensions. • Space for CE plate and machine specification plate.	• Add laser cut material or change the current material to achieve the “BT wave”.
Frame adapter	• Fit frame. • Fit steering arm. • Detachable.	• Hooks for transportation.
Handle adapter	• Enable height adjustment of minimum 27.5 cm. • Adjustable for driver. • Fit the handle. • Fit the steering arm.	• Insert a handle adapter.
Folding system	• Durable. • Stable. • Easy to handle. • Fit the overall design.	• New folding system.
Steering arm	• Use a steering arm from the current hand pallet trucks. • Fit to handle adapter. • Fit frame adapter. • Height adjustable. • Enable dissemblance. • Foldable.	• Insert a height adjustment system. • Insert a folding system. • Change handle attachment.
Handle	• Same handle. • Be placed at a height of 1100 mm from the ground.	• Change colours of the plastic materials to: BT black, dark grey, light grey and red. • Remove the sticker with the BT logo from the handle.
Wheels	• Fit on the drive shaft. • Tire dimensions.	• New rims, with new colour - grey/silver. • New tires for all weather. • Change rubber colour to black.
Branding	• Family name. • BT brand logo. • Follow the current design language.	• Free placement.
Inbound components	• Same components. • Same layout.	• No modifications.
Brackets for hooks	• Same brackets.	• No modifications.

5.3 Reference Model

A simple CATIA-model (see fig. 5.3) of the existing chassis and inbound components was built to use as a base reference when redesigning the parts in the List of Demands.

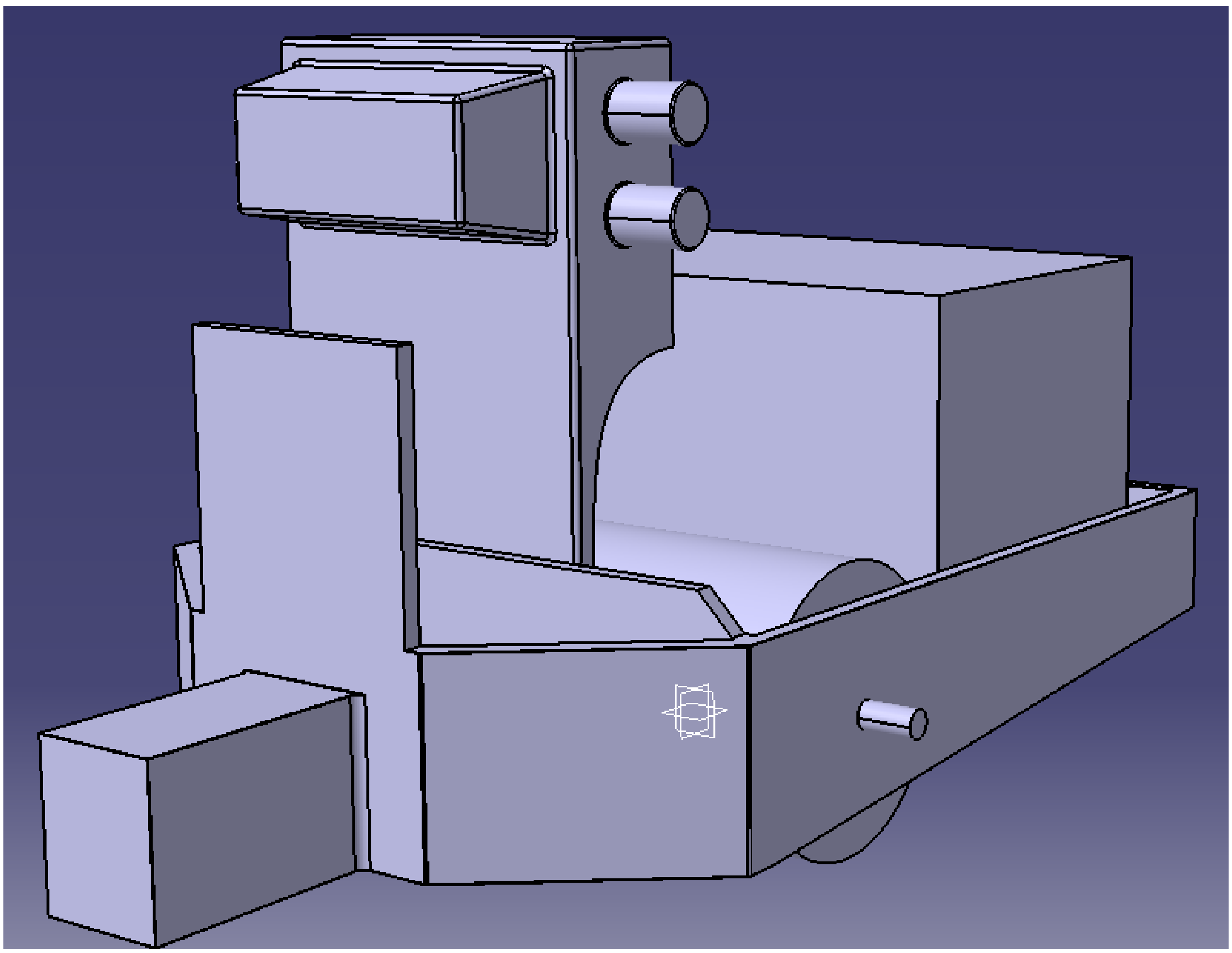


Fig. 5.3 -Reference model

5.4 Idea sketching

A number of idea sketches were created, illustrating the handle adapter, the folding system, the frame adapter and the cover.

5.4.1 Handle adapter

The idea of the handle adapter is described in fig. 5.4. The construction consists of a cylindrical part which is attached to the handle and circular plates which are welded to the steering arm. These parts are assembled with a bar involved by a spring. The bar has to plates with spikes which fit in the holes in the steering arm's plates. When pressing the push button, the spikes slide out from the steering arm's plates and the handle can be adjusted to the requested height. When the push button is released the spikes will slide into the holes again, pushed by the spring and the handle is fixed.

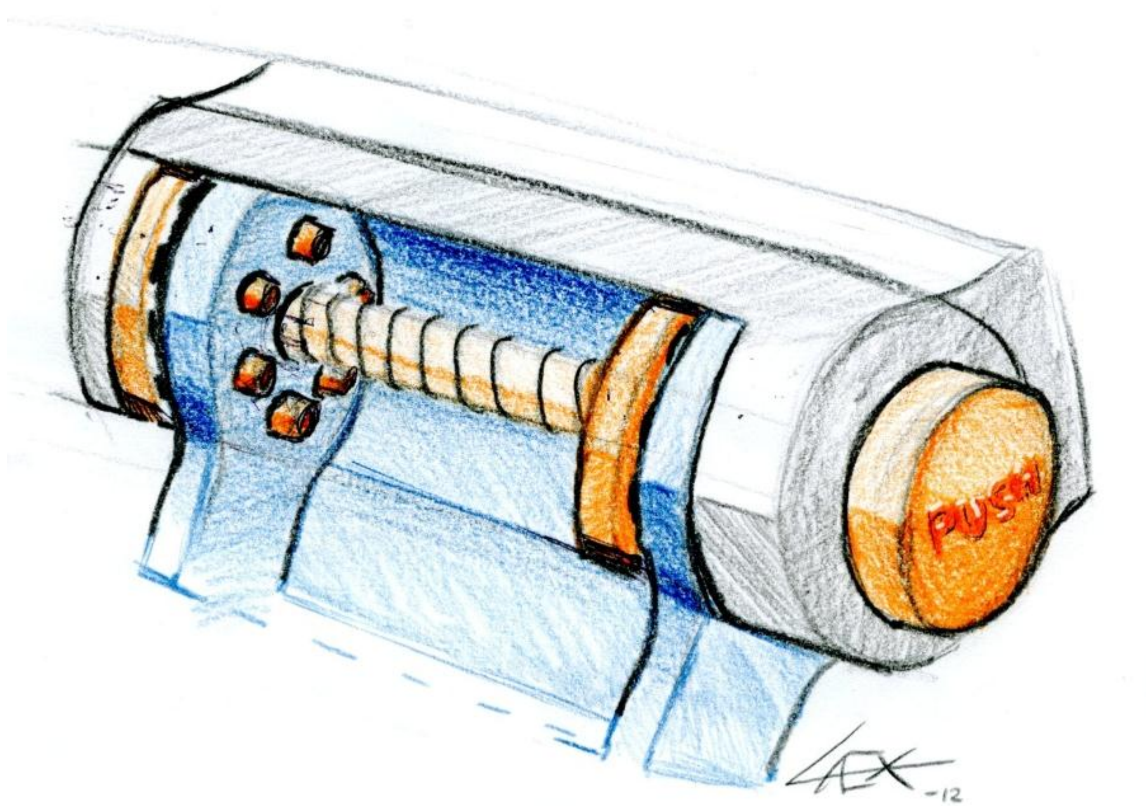


Fig. 5.4 - The construction of the handle adapter

In fig. 5.5 there are some ideas of how the handle adapter can incorporate with the steering arm and the handle in an aesthetic way. Material can be added to the steering arm to achieve a better form transition.

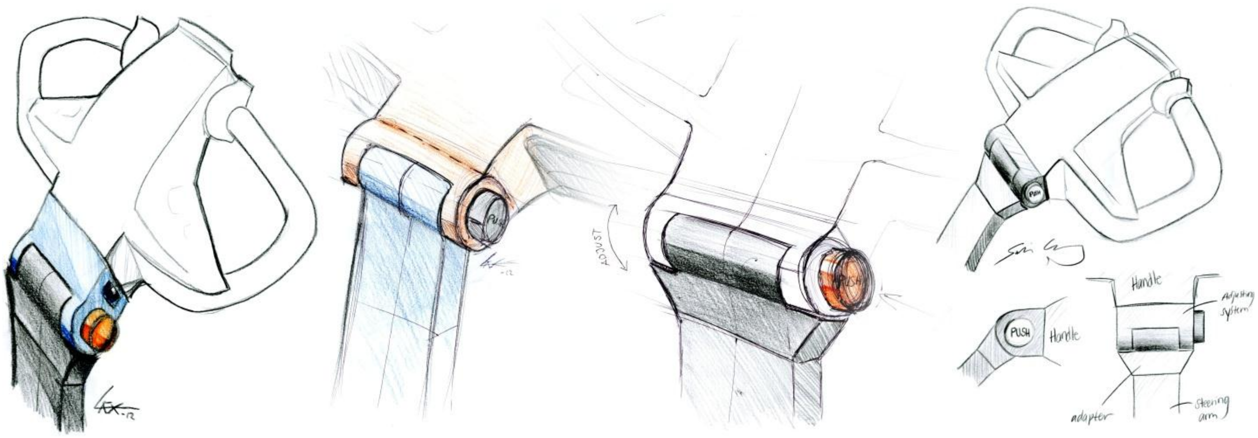


Fig. 5.5 - Different designs of the handle adapter

5.4.2 Folding system

Three different solutions were created, illustrated in fig. 5.6, each one described in the following text.

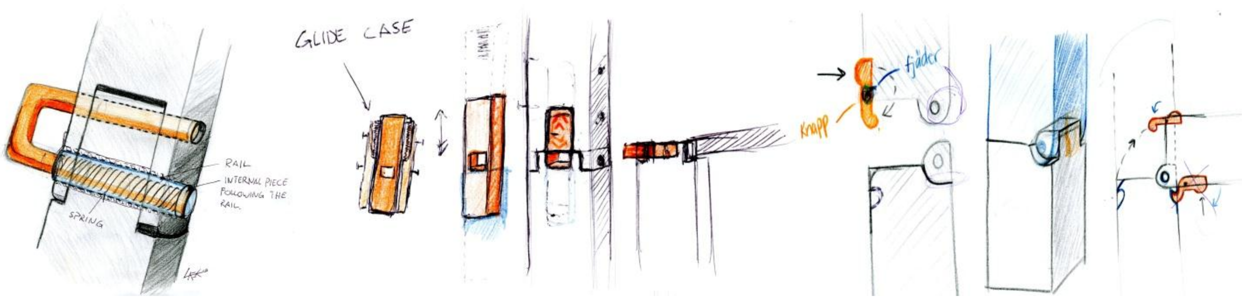


Fig. 5.6 - Folding system

The idea illustrated in the left sketch in the figure is a bent steel bar which holds the two beams of the steering arm together. When the bent bar is pulled out, the shorter top end can be slid out from the holes in the beams and the steering arm can be folded. The bottom end of the bent bar is involved by a cylinder and a spring. When the steering arm is unfolded the bent bar is pushed into the holes in the beams by the spring, to secure the construction.

The middle sheet in the figure describes another folding system. It consists of a block which can slide inside a groove and the two beams are foldable with a hinge. The block locks the steering arm in an unfolded position with the aid of a spring, pushing the block down. When the block is pulled upwards, it slides out from the bottom beam and the steering arm can be folded.

In the third solution, in the sketch to the right in the figure, the two beams are hinged and locked in an unfolded position with a button. The button is attached to one of the beams and is pushed into a slot in the other beam by a spring. When pushing the button with a finger it releases from the slot and the steering arm can be folded. When the steering arm is turned to an upright position again the button snaps into the slot and the steering arm is fixed.

5.4.3 Frame adapter

The frame adapter will consist of four metal plates which are welded to the backside of the frame. One pair of plates are vertically placed (see the two upper sketches in fig. 5.7) and got various numbers of holes. The holes which are marked with blue in the figure is where the stereogram's axis will be inserted to hold the lowest part of the steering arm in place. The holes marked with orange hold the upper part of the steering arm's assemblage part in place. By making two or more of these holes in each plate the steering arm can be adjusted to achieve a changeable angle. The vertical plates are fixed and strengthen with another pair of plates, horizontally placed (see the two lower sketches in fig 5.7) at the frame.

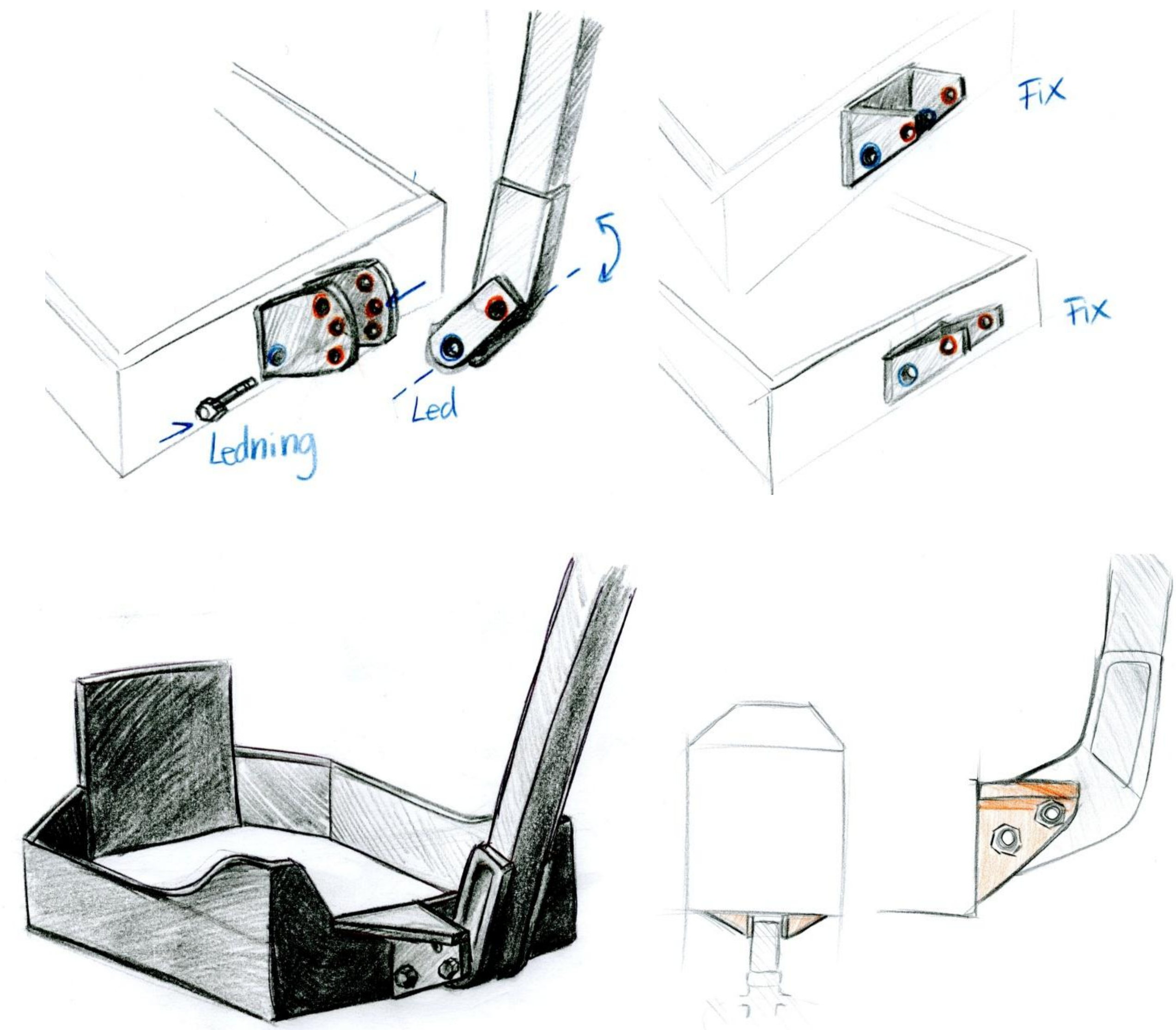


Fig. 5.7 - Frame adapter

5.4.4 Cover

Several sketches were created to find forms which incorporated with the frame and the inbound components. The covers in the picture in the upper left corner and in the centre picture in fig. 5.8 do not have the accurate height to enclose the inbound components. The other sketches were made with the aid of the reference model (see fig. 5.3) as an underlay. The most interesting ideas were modelled in Autodesk Maya to get feedback about the forms (see fig. 5.16).

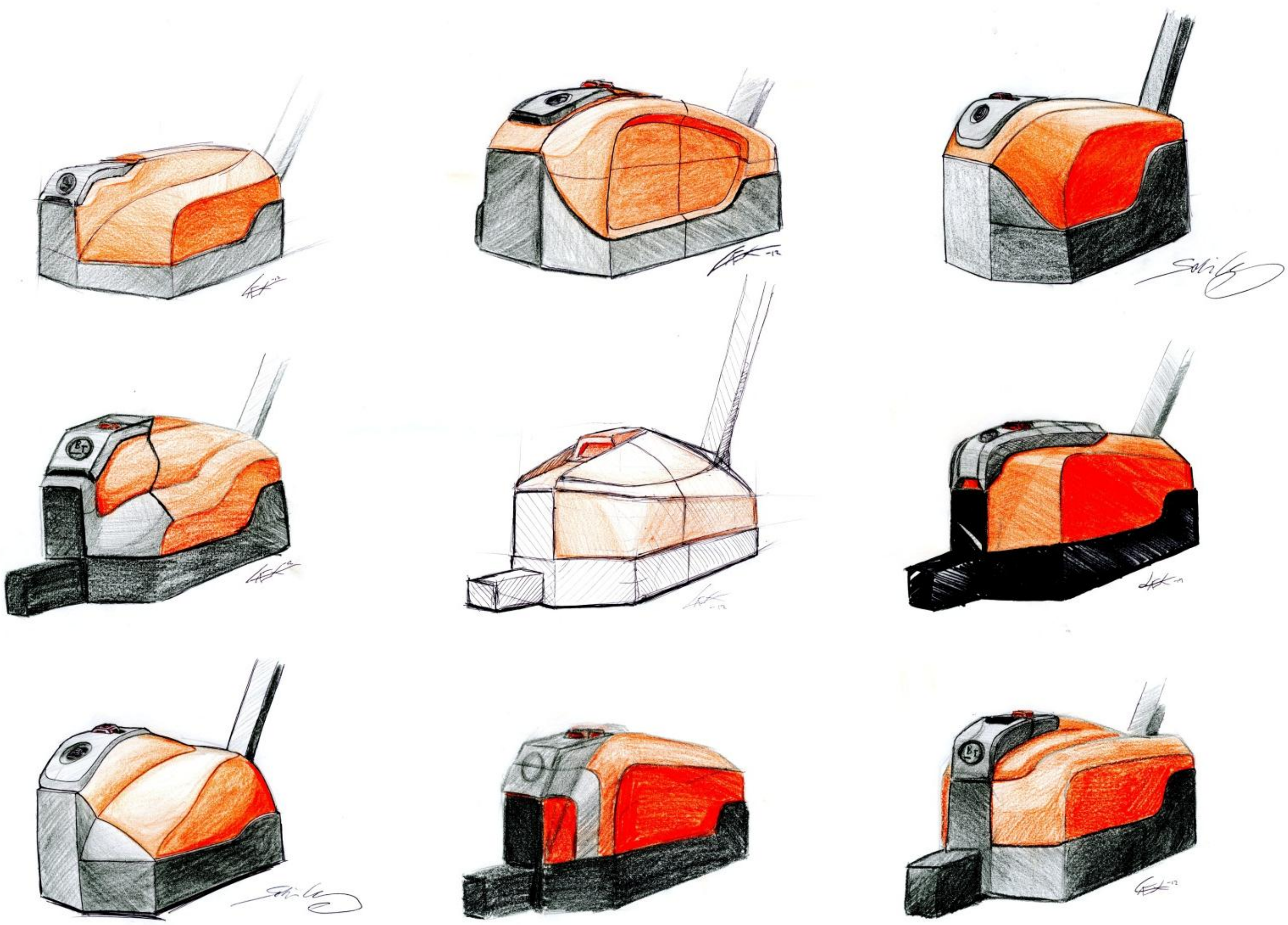


Fig. 5.8 - Early sketches of the cover

The modeling in Autodesk Maya resulted in one idea seen in fig. 5.9 and 5.10.This form was further developed with the aid of sketching to decide form details. This result was presented as Facelift 1.

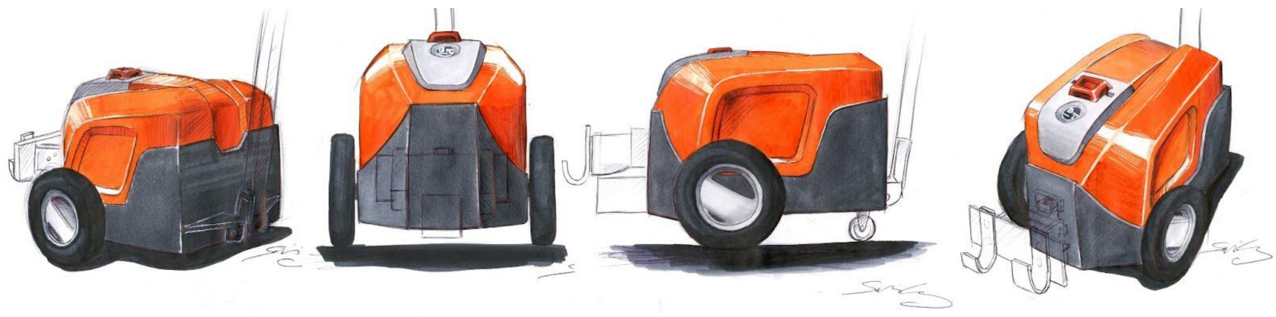


Fig. 5.9 - Sketches of Facelift 1 made with markers

Fig. 5.10 - Sketch of Facelift 1 made in Photoshop

After discussions with Oliveira Andersson and Wranne about Facelift 1's design a decision was made about trying to minimize the material used in the plastic cover, elaborate with the placing of the lip and experiment with the form direction. Sketches were created to find new basic shapes (see fig. 5.11). The aim was to find a new form with less space between the cover and the inbound components. Furthermore, the product's main direction was discussed, because BT movit can be driven both forwards and backwards during usage. An attempt to make the product bidirectional was worked out.

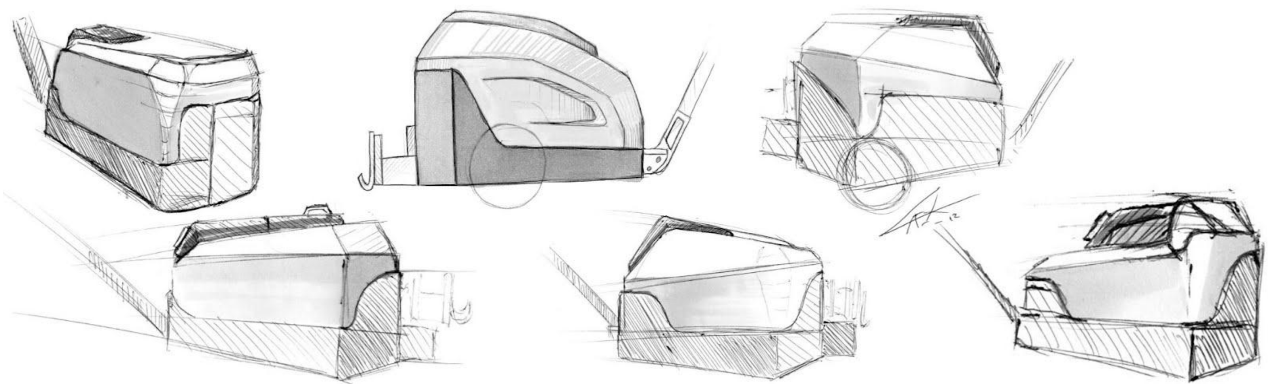


Fig. 5.11 - Sketches to find basic shapes for Facelift 2

The sketch in the lower right corner in the figure 5.11 was further developed. Fig. 5.12 shows how form elements can be changed to elaborate with the expression and the continuity in the form. These ideas were tested in Autodesk Maya and resulted in Facelift 2 (see fig. 5.17).

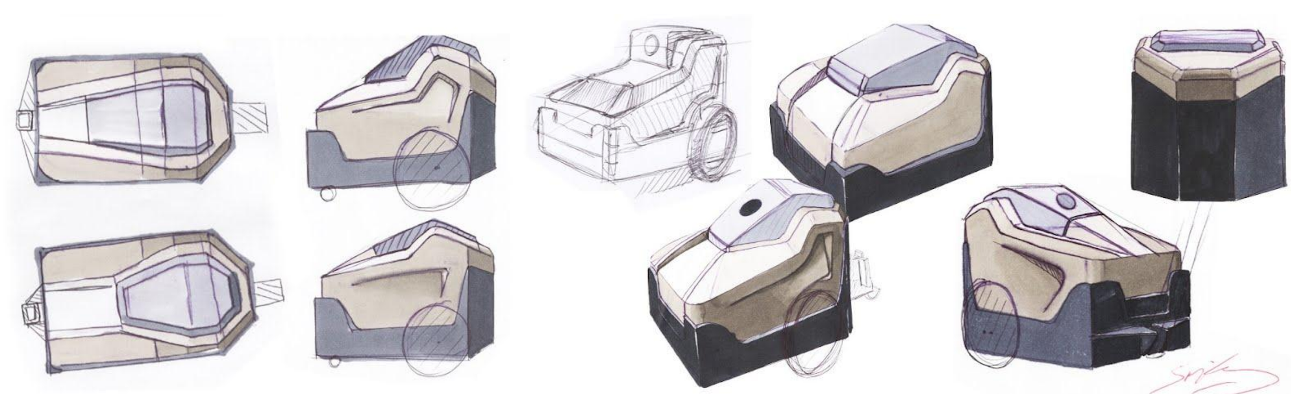


Fig. 5.12 - Sketches of Facelift 2

After a second discussion with Oliveira Andersson it was decided that the frame was going to be kept and the cover had to be redesigned due to the reason that the design had to be cleaner with less elements. Furthermore, to enable that the facelift can be produced in fiberglass to an acceptable price, the lip has to be integrated in the same part as the cover. Sketches were created to try new ideas such as an inverted lip, fewer design elements and a rounder form. The idea was also elaborated with the aid of a sketch model. Fig. 5.18 shows the development in form from Facelift 2 to Facelift 3.

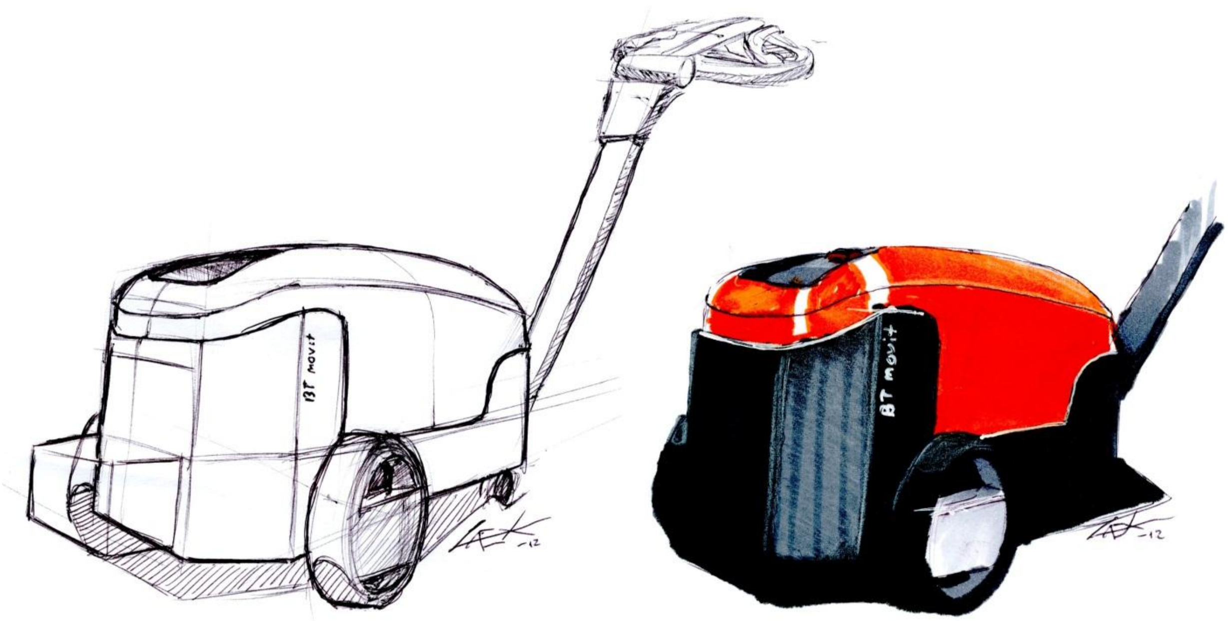


Fig. 5.13 – Sketches of Facelift 3

5.5 Mockup models of the frame and the steering arm

Mockup models were created to get an understanding of how the parts work and look in reality.

5.5.1 Frame

To get the real proportions of the frame a mockup model was built (see left picture in fig 5.14), in natural size with black kapa board. By cutting out several shapes and try on the model, ideas of frame modifications could be tested (see right picture in fig 5.14). Furthermore, the branding in terms of the placing of the family name could also be tested.

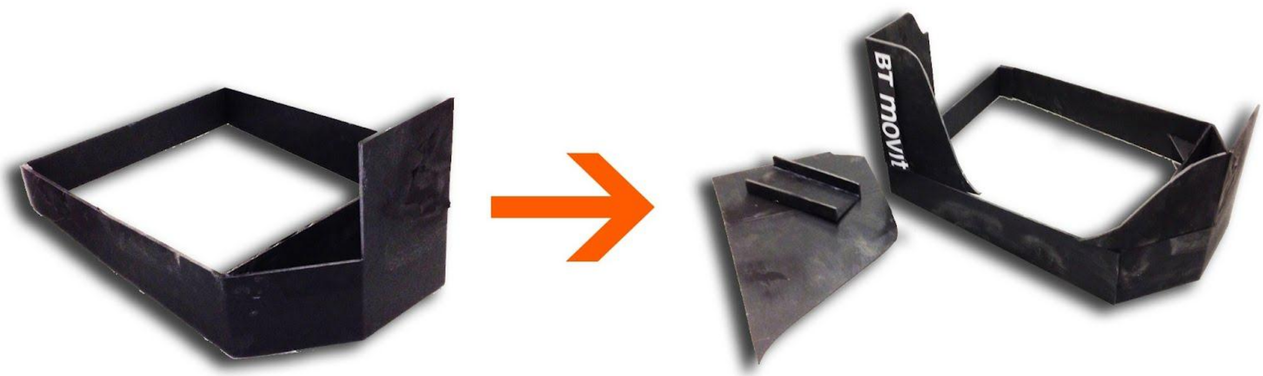


Fig. 5.14 - Mockup model of the frame

5.5.2 Steering arm

A mockup model was created (see fig. 5.15) to analyse the length and inclination of the steering arm. The minimum distance from the driver's feet to the frame adapter need to be 60 cm, to prevent that the driver walks into the frame. When having a distance of 60 cm from the drivers feet to the frame adapter, the steering arm need to be 115 cm when the height is set to 110 cm (see chapter 4.4.10 Dimensions). This results in an inclination of 73 degrees, between the ground and the steering arm.

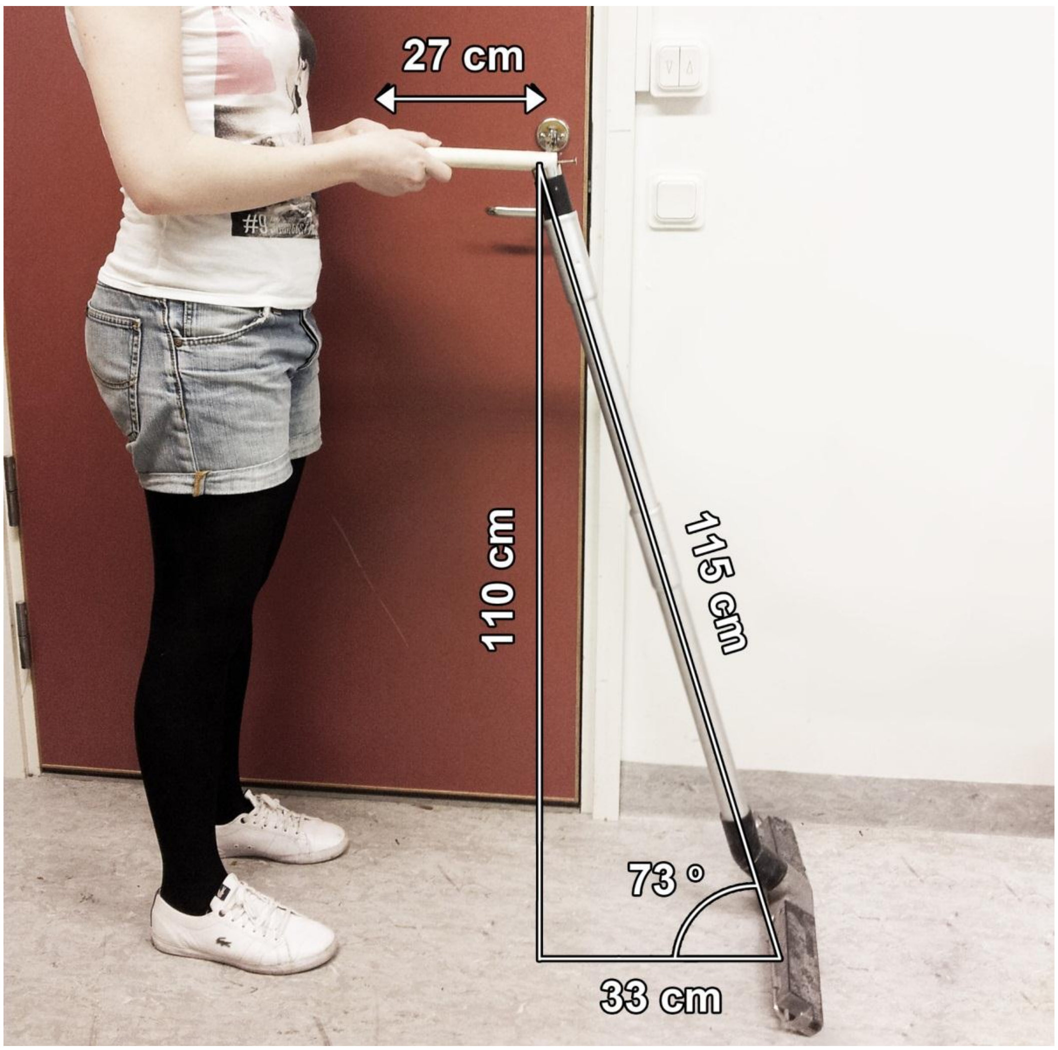


Fig. 5.15 - Mockup model of the steering arm

5.6 Sketch modeling

Models were made in Autodesk Maya to evaluate the idea sketches (see chapter 5.4). Fig 5.16 shows models made from the sketches in fig. 5.4 – 5.8, which resulted in Facelift 1.

Fig. 5.16- Sketch models before Facelift 1

After the decision to redesign Facelift 1 (see chapter 5.7) ideas were tested again through sketch modeling, which resulted in Facelift 2 seen in the figure below. The three variants of Facelift 2 differ in terms of small form details as the loop fillet and the rear part of the cover.

Fig. 5.17 - Sketch models showing variants of Facelift 2

After the decision to redesign Facelift 2 (see chapter 5.7) new ideas were tested with the aid of sketch modeling. Several changes in form led to Facelift 3. The figure below shows the form development from Facelift 2 (see the uttermost/left model) to Facelift 3 (see the nearest/right model). The form elements which differ are the lip, the loop fillet, the rear part of the cover and the metal plate on the frame where the family name is placed.

Fig. 5.18 - Sketch models showing the development from Facelift 2 to Facelift 3

5.7 Morphological matrix

The most interesting ideas of the different parts in the List of Demands were created as sketch models and put into the matrix to find different concepts.

Fig. 5.19- Morphological matrix

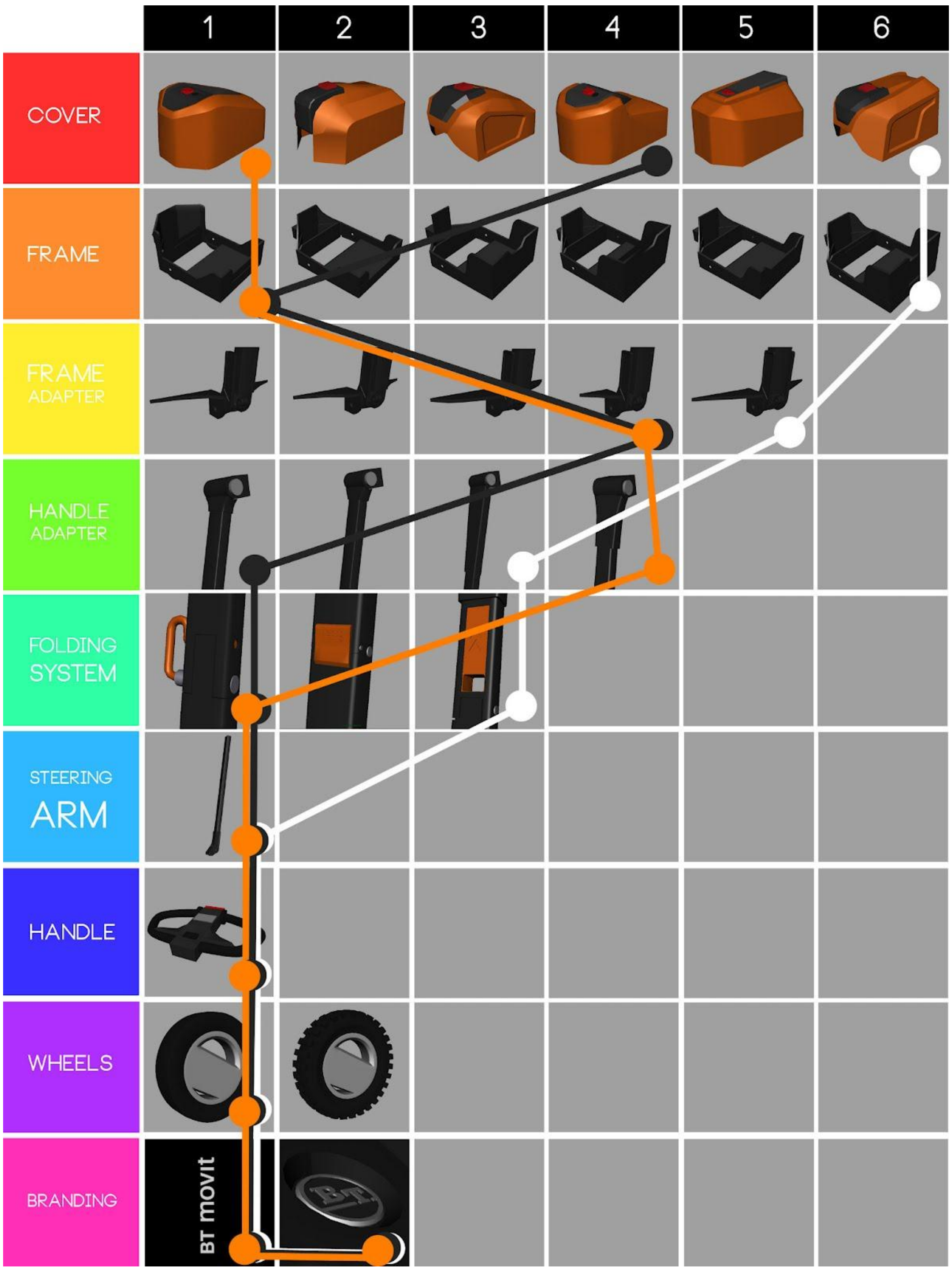


Fig 5.19 shows the morphological matrix which was used to generate ideas. There are three paths describing different concepts. The white path represents Facelift 1 (see fig. 5.20) which was the first facelift concept. After the decision about changing Facelift 1, in terms of trying to minimize the material used in the plastic cover, elaborate with the placing of the lip and experiment with the form direction (see section 5.4.4), the design was changed.

Fig. 5.20 - Facelift 1 *Fig. 5.21 - Facelift 2* *Fig. 5.22 - Facelift 3*

This development resulted in Facelift 2 (see fig. 5.21) which is illustrated by the black path in the matrix. The design of Facelift 2 was inspired by BT levio (see fig. 5.23). The following design elements have been taken from BT levio:

Fig. 5.23 - BT levio

- The S-formed shape in the orange cover which can be seen from a side view.
- The BT wave in the rear part of the frame.
- The higher plate in the front part of the frame containing the family name BT movit.
- The grey plastic lip on top of the orange cover which has one surface parallel with the top of the cover and a second surface facing the driver and containing the BT logo.

When it was decided to change Facelift 2 (see section 5.4.4), the cover's design was changed.The third facelift (seen in fig. 5.22) which is represented by the orange path in the matrix was an attempt to simplify the design of the cover. In addition, the lip is inverted as on BT vector (see fig. 5.24) which enables that the cover can be produced in the same mould.

Fig. 5.24 - BT vector

5.8 CAD-model

A CAD-model of Facelift 3 was built using CATIA V5, Autodesk Alias and Autodesk Maya. The frame and the rims were built in CATIA V5, hence the frame had to have accurate dimensions and the parts were easy to build in this program. The reference model and the sketch model of Facelift 3 were used as an underlay when building the frame. The cover was built with the aid of Autodesk Alias, since it was the most effective way to get surfaces with a good quality. The sketch model was used as an underlay and the surfaces were exported to CATIA V5 to give the model thickness and create fillets and rounds. The emergency stop button, the BT logo and the steering arm were already built by TMHE. Remaining parts were built in Autodesk Maya. All parts were assembled in Autodesk 3DS Max design, where renderings were created.

5.9 Visualization

Renderings were made in Autodesk 3DS Max design and the external renderer Vray, showing different angels of BT movit facelift. The pictures were retouched in Photoshop (see fig. 5.25) and used when presenting the result for TMHE.

Fig. 5.25 - A picture of BT movit Facelift with the aim to market the product

5.10 BT movit Facelift - description in detail

5.10.1 Cover

The cover has a clean design with simple shapes and an inverted lip (see fig. 5.26) which enables that the cover can be produced in one single mould, through a hand laid fiberglass production. There is a loop fillet (see chapter 4.1.1 for description of the term) sweeping round the top of the cover to express the BT brand. The vertical corners have rounds which give distances between the cover and the frame, hence the frame has sharp corners. These distances are undesirable, but since the rounds are important design elements and the frame can not have rounds with a greater radius than 10 mm, due to the limitations (see chapter 5.2, List of Demands), the distances have to be kept.

Fig. 5.26 – BT movit Facelift

On the lip the emergency stop button, the cover lock and the charge plus is placed (see fig. 5.27). The components are moved within the limits of the top plate where the current stop button and charge input are placed in the inbound construction. The stop button is placed in the centre, it is larger than the current stop button and need more space beneath the top plate. This is not a problem when looking at the inbound components of TWE100. The charge input is moved from the centre to make place for the stop button. The cover lock is placed on the other side of the stop button instead of the current placing behind the emergency stop. The lock is used for holding the cover in place and prevent that no unauthorised person can open the cover. When the key is inserted in the lock and turned the cover is fixed with the top plate. However, it is a hole in the cover around the stop button which leads to that water can pour in. This problem occurs on the current model of TWE100 as well. It can be solved by slanting the top plate where the components are fastened and insert a drainage tube which leads the water away to keep the electrical components dry.

Fig. 5.27 – The inverted lip with the charge input, emergency stop button and the cover lock

5.10.2 Frame

Laser cut metal sheets have been added to the frame (compare fig. 5.26 with fig. 1.1). The two parts will be welded to the frame and have a thickness of 6.5 mm. The current frame has a thickness of 10 mm which gives an edge of 3.5 mm. The edge is used as a support for the cover. The frame's front part is high to protect the plastic cover from scratches and damage. The aim of the thin part on the side of the frame is to wear the family name. The rear part of the frame has the BT wave and an immersion taken from BT levio (see fig. 5.29), to use design elements from BT's design language. The machine information plate is placed on the rear part (see fig. 5.28), it includes: model, number, year of manufacture, capacity, weight and battery voltage.

Fig. 5.28 - The placing of the machine information plate

Fig. 5.29 - The immersion on BT levio

5.10.3 Frame adapter

The frame adapter consists of four metal plates which are welded to the backside of the frame (see fig. 5.26 and fig. 5.28). One pair of plates is vertically placed and got 3 holes in each plate, one with a larger radius and two with smaller. The steering arm's axis is inserted in the two greater holes closest to the frame. The user can choose between two inclinations of the steering arm (see fig. 5.30), either a vertical position or an inclination of 73 degrees, by insert the screw with a nut in the requested pair of holes. The vertical position suits environments with narrow and small passages. The inclination of 73 degrees between the steering arm and the ground is chosen to prevent that the driver walks into the frame when driving the product, due to the test with the mockup model (see chapter 5.5.2). The vertical plates are fixed and strengthen with another pair of plates, horizontally placed at the frame. The Horizontal plates have the same width as the immersion in the frame to give form continuity.

Fig. 5.30 – Changing between the two inclinations of the steering arm by moving the screw

Fig. 5.31 – How to adjust the handle

5.10.4 Handle adapter

The construction consists of a cylindrical part which is attached to the handle and circular plates which are welded to the steering arm (see fig. 5.33). These parts are assembled with a bar involved by a spring. The bar has to plates with spikes which fit in the holes in the steering arm's plates. When pressing the push button, the spikes slide out from the steering arm's plates and the handle can be adjusted to the requested height. When the push button is released the spikes will slide into the holes again pushed by the spring and the handle is fixed. The form of the handle adapter is designed to link the handle and the steering arm together. To create a smooth transition a concave curvature is used, see fig.5.32.

Fig. 5.32 – The handle with the handle adapter

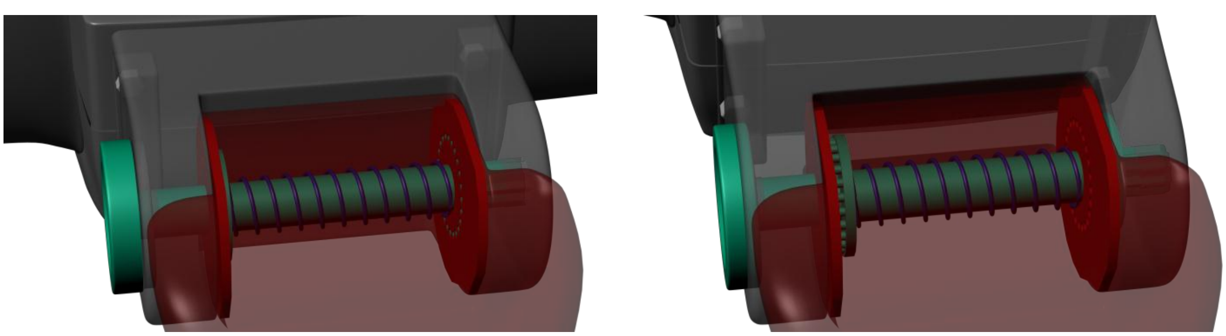


Fig. 5.33 – The function of the handle adapter, the right picture shows when the push button is pressed and the handle is adjusted

5.10.5 Folding system

The handle is a bent steel bar which holds the two beams of the steering arm together. When the handle is pulled out, the shorter top end can be slid out from the holes in the beams and the steering arm can be folded. The bottom end of the bent bar is involved by a cylinder and a spring. When the steering arm is unfolded the bent bar is pushed into the holes in the beams by the spring, to secure the construction, see fig 5.34.

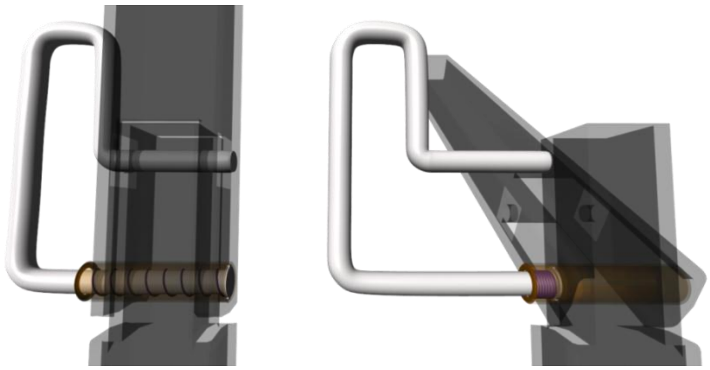


Fig. 5.34 – The function of the folding system

This system was chosen because it is more cost effective, durable and simple than the other two folding systems (see chapter 5.4.2, fig. 5.6 and fig. 5.19). System no. 2 (according to the Morphological matrix fig. 5.19) can be less durable due to the construction, which in the long term can be loose between the button and the slot. The radial clearance results in an unfixed steering arm. System no.3 has strength in terms of the aesthetics, it looks futuristic and innovative. However, this system is only a concept and is not further developed due to potentially high productions costs (see chapter 7.2).

The folding system is needed when the user has lack of room when storing the product or during transportation of the product. The picture below shows how the steering arm is folded.

Fig. 5.35– The steering arm is folded

5.10.6 Steering arm

The steering arm is taken from current hand pallet trucks. The reasons are to shorten the development process and decrease the costs for making new equipment for producing a new steering arm. The steering arm is adapted to BT movit Facelift through the handle adapter and the frame adapter. The folding system is applied to the steering arm by cutting the beam into two pieces and two holes in each end are drilled. As seen in fig. 5.35 the ending surfaces of the folding steering arm are rounded to decrease the gap needed for smooth movement.

5.10.7 Handle

The handle is the current handle used on TWE100. However, changes have been made in terms of new colours on the plastic parts (compare fig. 2.2 and fig. 5.25). Since the handle has to be as similar as possible to the current handles on BT products as BT levio. A plate informing of maximum drag weight of the TWE100 is placed on the handle, see fig 5.32.

5.10.8 Wheels

New tires and rims have resulted in completely redesigned wheels (see fig. 5.25). The rims are taken from BT movit Future Concept and are further developed in detail. There are two models of tires, one for indoor use and a terrain wheel for outdoor use in all weather.

5.10.9 Branding

To follow BT's design language the branding, consisting of the family name and the BT logo, is placed in the current way (see chapter 4.1.1 and fig. 5.26). The family name is located on the frame, at the flat surface at the side in the front part of the frame (see fig. 5.25). The text size is adapted to coincide in proportion to the size of BT movit Facelift. The BT logo is placed in the lip, facing the drive to express the feeling of the brand.

Fig. 5.36 – Comparison between TWE100 and BT movit Facelift

6 Environmental Effects of TWE100

The aim of this analysis is to identify the environmental effects of TWE100 under its whole lifecycle. The suggested solutions can be used to lessen the environmental impact and will be taken in consideration when designing BT movit Future Concept. The ABCD method has been used when making this environmental analysis.

6.1 Step A

THME have an Environmental Action Plan which they use when developing products by design-in environmental improvements in the products (TMHE, n.d.). This limits environmental impact throughout the four product life cycle stages: development, manufacturing, operation and recycling. There is no certain vision for howTWE100 is going to be developed and therefore the authors assume that the goal for the product is in line with the Environmental Action Plan.

6.2 Step B

Step B is a situation analysis of TWE100.

6.2.1 Stakeholder analysis

The most important and most involved stakeholders for TWE100 are the following:

- Clients
- Manufacturer (external)
- Companies working with certification
- Suppliers
- Companies working with recycling
- Organizations such as Greenpeace
- Logistic sector
- Transportation companies
- Sales department at TMHE
- Marketing department at TMHE
- Other internal departments at TMHE
- Retailers

These stakeholders are all in touch with TWE100 in one way or another. They have interest in productivity, durability and the environmental impact of the product. TMHE spends a lot of effort on keeping their products as environment friendly as possible (Seger, 2012)[1]. Their newest Optio series are recyclable up to 99%, where the TWE100 is less recyclable. This is mainly because of that TWE100 is handmade, which requires other materials and manufacturing processes. Another factor is that it is produced by an external manufacturer and not by TMHE.

6.2.2 Function analysis

The following function analysis shows the function of TWE100 and what it offers to the customer. The main function (M) and the part functions (P) required to fulfill the main function and the support functions (S) which increase the customer experience, are explained (see fig. 6.1).

Fig. 6.1 - Function analysis

Verb	Noun	Supplements	Class
Move	Trolleys		M
Minimize	Physical strain		P
Be	Easy to understand		S
Be	Electrically propelled		P
Offer	Grip		P
Be	Easy to manoeuvre		S
Offer	Steering		P
Offer	Speed control		P
Offer	Ergonomic driving position	For the driver	S
Offer	Height adjustment		S
Offer	Emergency brake		P
Be	Stable and level		S
Be	Reliable		S
Offer	Traction	Indoors & outdoors	P
Show	Battery status		S
Ease	The storage	Of the product	S

[1] Magnus Seger (Design Engineer at TMHE, interviewed by the authors, 1 Mars 2012).

6.2.3 Ecological aspects

TWE100 is an active product with an electric engine (TMHE, 2011). This means that it does not release any CO_2 (Carbon dioxide) while in use, but could indirectly release CO_2, when charging through an electricity supplier that uses fossil fuels. The product itself has a life cycle of about eight to ten years (Seger, 2012)[1], depending on use and within that time the batteries is changed once. However, with the right maintenance and repairs it can last even longer.

TWE100's cover is made of fiberglass reinforced plastic. It is not toxic as a finished product, but the dust from sanding and cutting when manufacturing is bad for the health. The life span of this material is very long and does not require maintenance .

A high-impact component in TWE100 is the 40Ah (Ampere hours) lead acid battery. This component is maintenance free which means that no leakage should occur. Since it is extremely hazardous there is a developed recycle system for this battery.
The parts with the greatest impact in the engine are the copper details used which are also found in the wiring of the electric components. The amount of electric components is sparse since the function of them is to control the speed and to enable battery charging, which are basic tasks. The steel frame is made of normal steel and not any super alloy that is made from rare materials, which is beneficial in environmental terms.

The product is heavy, it weighs 99 kg (TMHE, 2011) which means that the power consumption is high. The problem is that the weight has a function in this case it gives the tires enough pressure to have good traction when towing heavy trolleys. The weight comes from the frame, battery and the engine.

[1] Magnus Seger (Design Engineer at TMHE, interviewed by the authors, 1 Mars 2012).

6.2.4 Social aspects

6.2.4.1 Fulfilling the need of customers

It is important that the customer feels satisfied with their product because it will directly have impact on their opinion of the company selling it. If the customer is happy with their product they will probably use the product for a longer time which is important for a sustainable future, since there will not be a need for as many new products.

6.2.4.2 Environment care

Many of TMHE's customers ask about the environmental impact of the products. Therefore it is a growing importance not only to create a sustainable future but also to reach the markets expectations on being environmentally friendly.

6.2.5 Economical aspects

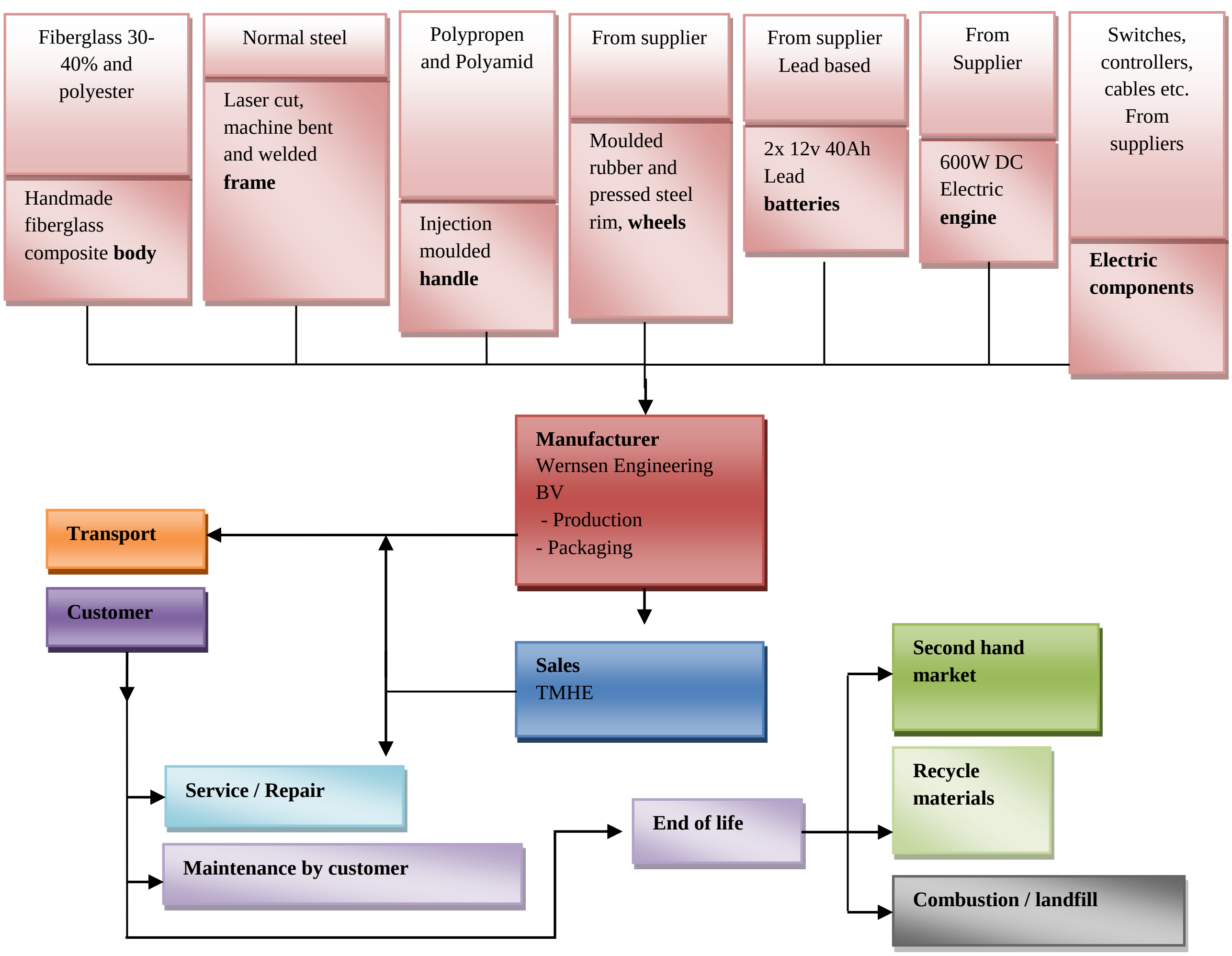
The TWE100 is an expensive product due to it being a low volume product compared to other pallet trucks from TMHE. This means that the product is mainly handmade because of it being too expensive to have machinery tools for all its parts. It is therefore important that the product is of high quality to satisfy the customer which will then use it for a long time.

6.2.6 Material flow chart

Here is a schematic overview of the production process of TWE100. The production processes were assumed together with the design engineer Magnus Seger from TMHE. The product itself is of a simple design with few parts. Nothing is known from where the raw materials are bought or how they are transported. TMHE only sales TWE100 and the transport to the customer goes from the manufacture not passing through TMHE.

TMHE supports the second hand market of their trucks and are able to provide spare parts for very old trucks. This is a good approach for a sustainable future even if a cradle to cradle would be even better (Thomas Nyström, 2012)[1]. This principle means that a product can be reused instead of being disposed. They do have cradle to cradle system on their leasing trucks, when these reach end-of-life they are renewed with some components and then ready for new leasing.

Fig. 6.2 – Material flow chart



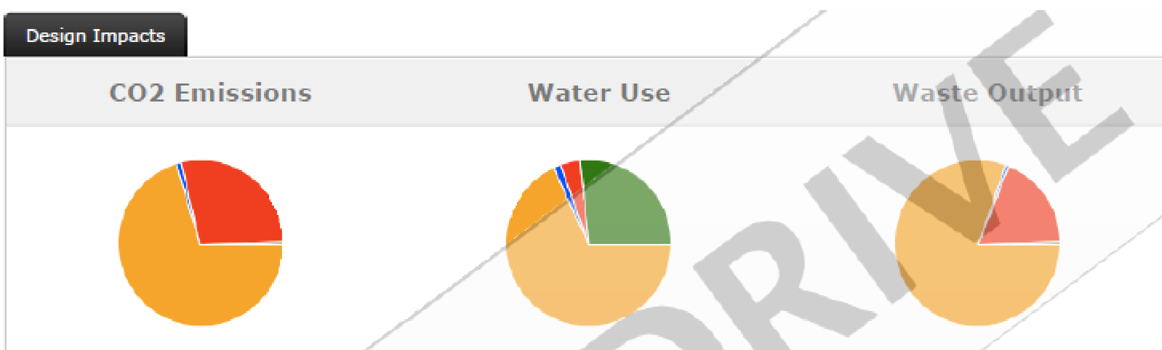
[1] Thomas Nyström (Lecturer at Design & Human factors at Chalmers, held a course about sustainable design in the spring of 2012 for the authors.)

6.2. Product Ecology

The lifecycle report tool shows that most of the CO_2 emissions by this product is from the raw materials and production (see fig.6.3). The next biggest part is from the use of the product and this is through using electricity to charge the batteries twice a week for 18 hours each time for 8 years. 2(two batteries) x 18(h charge time) x 100(days) x 8 (years) x 30 (Watt used by charger) = 864 kWh for the products life span. The greatest difference on the CO_2 emissions depends on which kind of electricity is used. For example, Norwegian fossil free or European fossil powered makes all the difference if this product releases CO_2 under the use. Only a small piece of the CO_2 emissions come from transport which is calculated to be around 1300 km for every product. The water use is mainly used by production and by the end-of-life of the product and small amounts by the distribution and the consumption. The waste output is also mostly from the production and the consumption. This once again is due to the electricity provider. Huge differences were seen if changed to a renewable energy source.

A problem of this tool was that many of the components did not have their corresponding material in the database which means a similar material had to be chosen. Another problem is the lack of information since the product is neither constructed nor produced by TMHE, which means there is not much information regarding the weight of the components, the weights were therefore assumed. Overall the greatest impact from the production is the batteries.

Figure 6.3 – LCA : product ecology results



	CO2 Emissions (t CO_2 eq)	Water Use (m^3)	Waste Output (kg waste)
Materials & Processes	1.555	2.404e+2	1.178e+1
Distribution	2.067e-2	2.133	8.754e-2
Consumption	6.272e-1	5.671	2.698
End Of Life	8.642e-3	3.946e+1	6.236e-2

6.2.8 Material inventory

TMHE uses mostly PP, PA and ABS plastic (Seger, 2012)[1] and all of them are recyclable even if they are not disposable by nature. ABS plastic is often used for the body parts of the trucks but on TWE100 it is a fiberglass composite. The fiberglass reinforce polyester is very durable but more expensive to produce and harder to recycle due to it being a composite of two different materials. (See fig. 6.4 for material locations).

Plastics

- PP (Polypropylene)
- PA (Polyamide)
- Rubber

Metals

- Steel
- Other metals in electric components as copper and aluminium

Other

- Fiberglass composite with polyester

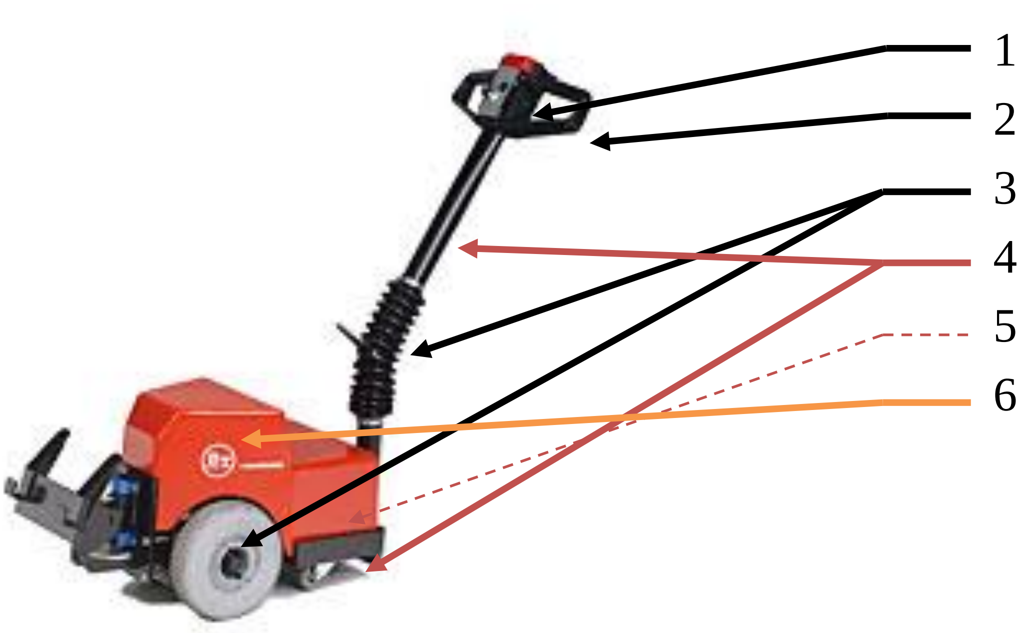


Figure 6.4 - Material placements

[1] Magnus Seger (Design Engineer at TMHE, interviewed by the authors, 1 Mars 2012).

6.2.9 SLCA

The SLCA shows good results in production, packaging and during use. The raw materials and end of life are steps which would require more effort to be more environmentally friendly. A big issue when the SLCA was carried out is the lack of information which means that the term "don't know" had to be used in cases where a good assumption could not be made, for SLCA result see fig. 6.5. The function unit used was TWE100, weight 99 kg.

Figure 6.5 - Result from SLCA

	1. Raw Materials	2. Production	3. Packaging, distribution & retail	4. Use	5. End of Life
Sustainability Principle 1	1	5	4	4	2
Sustainability Principle 2	1	4	2	3	1
Sustainability Principle 3	2	5	5	6	2
Sustainability Principle 4	3	5	5	6	3

Colour key

7 yes / NA	Very Good	All answers positive. Sustainability Principle is met.
6 yes / NA		Mostly positive responses. Sustainability Principle mostly met.
5 yes / NA	Good	Mostly positive responses. Sustainability Principle mostly met.
4 yes / NA		Some positive responses.
3 yes / NA		Quite a few negative responses.
2 yes / NA	Bad	Mostly negative responses. Sustainability principle mostly not met.
1 yes / NA		Mostly negative responses. Sustainability principle mostly not met.
0 yes / NA	Very bad	All answers negative. Sustainability principle not met.

Sustainability Principle 1:
Does the product life cycle contribute to the build-up of substances from the earth's crust?
(e.g. metals, minerals, fossil fuels, etc)

Sustainability Principle 2:
Does the product life cycle contribute to the accumulation of substances produced by society?
(e.g. persistent chemicals, natural compounds produced in volumes that nature cannot handle, etc)

Sustainability Principle 3:
Does the product life cycle contribute to physical degradation of nature?
(e.g. overfishing, land destruction, erosion, etc)
Sustainability Principle 4:
Does the product life cycle contribute to any conditions that undermine people's capacity to meet their needs?
(e.g. unsafe working environments, health issues, financial stability, freedom, etc)

6.2.10 Conclusion of the environmental impact of TWE100

TWE100 is a durable product, but could be more environmentally friendly. The LCA (fig. 6.3) shows that the biggest impact of this product is the production phase which is both good and bad. Since the production is a short period of time in the life span, it is positive that it has the greatest impact. If the user uses environment friendly electricity the impact of the use is minimal. The biggest problem of the product is the lead batteries which have an high-impact on the environment. On other hand, there are recycle systems which are well developed over the world. However, a lead battery only have a lifespan of about five years, which means that under a normal lifespan of the product they have to be changed once. Another problematic part is the handmade fiberglass reinforced polyester cover, which under manufacturing is bad for the health. The positive thing with the composite is that it has a lifespan that outlives the rest of the product a few times and does not require any maintenance.

6.2.11 Specification or requirements

The following requirements are categorized under administrative and technical requirements. These requirements are made by the authors as a recommendation to TMHE.

6.2.11.1 Administrative requirements

- The product shall have both quality and environmental certification.
- The product shall have a manual that describes to the customer how to perform maintenance on the product to maximize its lifespan.
- The suppliers of parts for TWE100 will have to have environment certification and use materials in their product that do not compromise quality but are as environment friendly as possible.

6.2.11.2 Technical requirements

- Use recyclable materials only, not necessarily biodegradable but materials that are easy to recycle.
- The use of material should be minimal but keeping a balance between traction and weight.
- The product should be constructed in a way that makes the recycling of the product easier.
- The product should have an electric motor to match the customer's needs to minimize the use of energy.
- The manufacturer should provide both description of how to dispose the product correctly and an option to take the product back when it reaches the end-of-life.
- The product shall use Lithium-ion batteries instead of lead acid to have better performance and be more environmentally friendly while keeping the weight down.

6.3 Step C

In step C, ideas and solutions are created to decrease the environmental impact of TWE100.

6.3.1 The eco strategy wheel

Optimize the function
The towing function could be integrated with another function to increase the areas of application of TWE100. This should be done with care, as this is a very simple product and forcing more functions on it could render it less usable and more environmentally unfriendly since a new function could require more materials or/and electric components.

Lower environmental impacts during use
Since TWE100 is an active product and consumes electricity through a battery, the most logical change would be to lower the energy consumption. This can be done through choosing an electric engine suitable for the task of the customer. If the task is to tow trolleys with the weight of 500 kg it is not necessary to have a towing capacity of 1500 kg, because it will most likely just consume more electricity.

Another way of lowering the consumption is through weight shredding. Make the towing tractor as light as possible. However, this will lower the performance due to less traction on the wheels in some cases.

Lower the amount of material used
To lower the amount of material used has big drawbacks as stated above, less weight gives less traction. Although, it would lower the consumption and ease the handling of the truck. A better balance between traction and weight could probably be accomplished by using less material.

Choose the right materials
The cover of TWE100 could be made of a more environment friendly plastic like PP or similar which is more environmentally friendly and easier to recycle (Greenpeace, 2012).

Optimize the service life
The product's life span can be extended, through changing parts that wear out. Since TMHE keeps spare parts for their products for a very long time.

Optimize the production
Since the product is mainly handmade, the production process could be reworked to be more efficient, but that does not necessarily mean it will be more environment friendly. As there is not enough information about the production process more than general techniques used, this can not be assessed.

Optimize end-of-life management
The end-of-life has a big impact and changes could be made, today it is all up to the customer to dispose the product as best they can. When many of these products finally meet their end-of-life, they end up at either a recycle station or at a landfill. The product could instead be sent back to the manufacturer who could do the necessary repair and exchanged used up parts and then sell it on a second hand market.

Optimize distribution
Although this is a low volume product, an efficient distribution system could be developed. An effort to use fewer transports and combine transports over different trades going the same way should decrease the amounts of transport needed.

6.3.2 Change of battery type

Lead acid batteries as stated above are very heavy and toxic. They have a low power to weight ratio and are limited to around 800 charge cycles (Schuman, 2012). Their performance also decrease when their charge rate decreases, see fig. 6.6. Their biggest advantage is the price.

Fig. 6.6 - Lithium (2012)

Discharge	**Actual Capacity**	
Rate (hours)	**Lead Acid**	**Lithium ion**
20	100%	100%
10	95%	100%
5	80%	100%
1	60%	100%

A change to the latest generation of lithium-ion batteries would decrease the battery weight by four times since the ratio between power and weight is four times higher than the lead acid batteries (Lithium.web.officelive.com , 2010). The lithium batteries can also withstand around 2000 charge cycles, which is almost three times the amount of lead acid batteries. The most important aspect is that they are environmentally friendly and fully recyclable (Romero, 1996). The negative aspect of changing to Lithium-ion batteries is that they do not have the same lifespan like lead acid have which means for TWE100's whole life the battery would have to be changed twice compared to lead acid, once. They are also more expensive.

6.4 Step D

The conclusion and priorities.

6.4.1 Recommendations for next steps

The next step would be to evaluate the impact of changing batteries to Lithium-ion, how this changes the product weight and therefore the traction when towing heavy objects. It is also important to see how this affects the price of the product since the Lithium-ion batteries are more expensive than the lead acid and how the lifespan of these batteries looks like.

Another step is to change the fiberglass composite to a recyclable plastic such as PP and use injection moulding instead of handmade composite material, to minimize the unhealthy conditions for workers and to simplify the recycling process.

7 Conclusion

In this conclusion experiences are described and the results are discussed concerning BT movit Future Concept and BT movit Facelift.

7.1 Discussion of BT movit Future Concept

In the beginning of the development process of BT movit Future Concept sketches were made, illustrating concept ideas expressing roughness and durability. After a presentation for Oliveira Andersson and Wranne decisions were made to iterate the process and start with basic forms, work structured with form and design the concept with regards to the function. This work flow was effective and resulted in several interesting ideas.

The areas of application are new and it is important to benchmark those areas against the Future Concept and also against the current TWE100. The areas found are potentially new markets where TWE100 can operate in, except for the area Heavy Goods, where TWE100 has limitations because of the form. If TWE100 is adapted through smaller modifications it can fit to the areas of application: Trolleys, Trailers and Airplanes. A wider study would have to be done to estimate if the need is as big as expected. Furthermore, if the pricing is at a level where an investment of a TWE100 is beneficial, in terms of giving value for money, for the customers in these areas of application. Since the new areas of application offer a potentially big unexplored market, the Future Concept can possibly sell enough to drive the prices of it to a level where it becomes a consumer product, which can be sold on an ever broader market. However, the production techniques of TWE100 can also be changed to decrease the price, if sold in higher quantities.

The Future Concept can also be sold as a leasing product to companies such as gas stations, where consumers can hire it for a certain amount in the same way as hiring a trailer or car. This is an environmentally sustainable approach with service company thinking, when products are leased instead of owned by consumers.

The Heavy Goods area is unique in a sense that it changes the way of how the towing tractor is used, instead of towing the load, it carries it. This puts other strains onto the product which need more calculation to develop a construction which is durable. Another issue with the Heavy Goods area is that the Future Concept is to be able to climb stairs, with the aid of the tri-wheel solution. This would need intelligent software helping the driver keep the product on a good angle, in a similar way as a Segway functions with a gyroscope. Furthermore, a special drivetrain which can handle two different axles simultaneously, to drive every individual wheel will be needed. In addition, the brackets holding the wheels to aid in stair climbing has to be developed. However, regarding to the interview with the staff from the delivering firm, Markokaj Moving AB (see chapter 4.2.5), the speed has to be high enough for making the product beneficially during usage.

In the area Trolleys it was found that there are many unexplored markets, which used specially designed carts or containers on wheels. A good market to get into is garbage collection and create an universal and easy system were the Future Concept or TWE100 can be used to collect heavy garbage bins. This system would need to consist of both a hook with an easy attachment system on the garbage bin and an easy way of transporting the product on the garbage truck. This is important because the workflow when using the product can not be much slower or more complicated than towing the garbage can manually, since this would lead to that the product most likely would not be used.

Much likely BT movit Future Concept is going to be purchased by airports. Regarding to the research done at Säve airport in Gothenburg (see chapter 4.2.2), there is a need for a machine as an aid when moving small airplanes. If members in aviation clubs request a product as BT movit Future Concept the club or the airport can invest in an aid helping their members and staff. However, the Future Concept needs to be tested in a real situation with an airplane and detailed calculations have to be done to determine the relations between traction and weight in the situation.

The configuration used in the area Trailers fits perfectly for the idea described above concerning leasing or hiring of the product. BT movit Future Concept can be hired when a customer needs to move a heavy loaded trailer, place the boat in the narrow garage or move the caravan. The product can also be bought by campings to offer their customers the service to easily move their caravans at the hardstand. Concerning the market for the caravan manufacturing industry, there are already products in use as Stringo 450 (see fig 4.11). These products have more capacity with a greater maximum load than BT movit Future Concept, up to 3000kg. This means that this market can be difficult to reach with the current product. As mentioned in the paragraph above, the configuration for trailers also needs to be tested in real life to elaborate with the weight ratio between the towing tractor and the trailer.

The Future Concept is designed to be on the market in the year 2017, which is in 5 years. Regarding to that the design has new forms which can not be found in the current range. The basic shape, consisting of an elongated form with a hole, and the proportions are totally new. However, the used design language is an updated version of the design language from 2008. Since BT has a rather conservative, clean and simple design language due to the products are made for the industry and not private customers. The consideration between a futuristic look and BT’s current design language was a challenging task. Especially, when no information about in which direction BT’s design language is going to be developed was obtainable. However, hence BT movit Future Concept can be used by private customers as well, the design could be more futuristic. The next step, if BT movit Future Concept is going to be further developed, is to elaborate with the placing of the branding and find more new design elements, to make the product look even more futuristic.

BT movit Future Concept fits into BT's current product range, because several design elements has been used from the current BT design language. It is a completely new product which is closest related to the pallet trucks, in terms of size and user segment, since the product can be a consumer product as well as used by industries and companies. In terms of form, BT movit Future Concept is not similar to any product in BT's current range. The proportions are different when it has an upright form. However, one of the competitors to TWE100 also uses an upright form, Movexx (see fig. 4.2), this means that the proportions is going to work during use. Furthermore, the design elements which are used can not be found on BT products in the same size, only on larger products. If the product would be further developed with the aim to be produced shortly, it can be further developed through concentrating on making the design more BT. By changing details in the design elements to follow the design language even more.

The handle's shape is not aesthetically worked out in detail, because of the time frame due to the focus on developing the buttons and controls on the handle. The dimensions of the handle are elaborated through testing and fit both small and large hands with comfortable grip with the two different grip styles. However, in terms of aesthetics, the handle needs to be further developed to perfectly fit into the rest of the Future Concept.

7.2 Discussion of BT movit Facelift

Problems which occurred during the facelift phase were several iterations within the development process of the facelift ideas, which resulted in the three ideas Facelift 1, 2 and 3. The reasons were long intervals between meetings and that the work was done in distance from Mjölby. When questions appeared there were no chance to ask them directly and the work kept going, which led to over-elaborated ideas which later had to be changed after the next meeting. A solution for this would be to work at the office in Mjölby or have more meetings with shorter intervals.

Form elements from BT movit Future Concept and current products in the BT product range were used on BT movit Facelift. However, it took several weeks to develop the final idea of the facelift which in the end looks like a BT product and fits into the product range. The hardest part of the development process was to adapt the form elements to a relatively small product. Hence, the design language was seen on larger product than BT movit Facelift. During the development of the form, sketches and digital sketch models were created, no physical model due to the time frame. A physical model would have been a good way to understand the proportions and the size of the product which probably would have led to a shorter process for developing the form and adapt the form elements to the small product.

Another aspect which made the form development of BT movit Facelift to a challenging task was that no more information than a short presentation of the design language was obtainable. The rest of the information came during the process or were figured out through pictures of the BT products. This resulted in lack of information concerning the design language which led to several iterations in the form development process.

The folding system of the steering arm on TWE100 is changed from one point on the old TWE100 to a total of three folding and adjustment points. The first is on the handle adapter to customize the height for every driver in an easy and accessible way. The middle folding system folds the steering arm in half, thus to take less place or be able to store TWE100 in small places as the concurrent from Jungheinrich (see chapter 4.1.2). The third and last way is on the frame adapter where two different settings are available, these are changed rarely. It regulates the angle between the frame and the steering arm, being able to have a vertical or 17 degree angle. This is a versatile and ergonomic system which can be a sales point for the product, compared to the competitors.

For the middle folding system there are different solutions, the one chosen is robust and easy to manufacture, but folding systems number three in the morphological matrix (see fig. 5.19) is more futuristic and fits better to the overall design of the Facelift. However, it requires more development and is probably more expensive to produce. If TWE100 becomes a greater volume product, this folding system can replace the chosen one.

The cover is designed to be manufactured through a hand laid fiberglass production, but can also be produced with compression molding. Regards were taken to this aspect because BT movit Facelift can be a high volume product if the new design increases the sales. Compression molding is more cost effective than hand laid fiberglass production with greater production volumes.

The next important step in the development process of BT movit Facelift would be to evaluate if the frame can be changed to a design that fits better to the new cover, in terms of aesthetics. A suggestion is to change the frame’s corners and make them rounder, to achieve continuity in the form.

7.3 Environmental Effects of TWE100

TWE100 is in the right direction of being more environmentally friendly. The use of the product is friendly as long as the electricity comes from renewable sources. It is mainly the production and the disposal of the product that should be further investigated to see how the areas could have less impact. The use of lead acid batteries increases the weight of the product and has low power to weight ratio which means that energy consumption is increased because of the battery weight. They are also very unfriendly to the environment and toxic.

The biggest problem while evaluating the environmental impact of this product has been the lack of information about production, suppliers and datasheets with information about the product. Most of the viable information gathered have been with the aid of engineers at TMHE and they had to make guesses and assumptions most of the time. This led to the many "don't knows" and missing information on why some material choices were made.

BT movit Future Concept has been designed with regards to the environmental analyse. The Lead Acid batteries have been changed to a Li-ion battery and one of the main goals when developing the form was to minimise the material. The open form results in less material used in the cover. Furthermore, the Future Concept is a modular product which is good for a sustainable future. Instead of having four products one single product can be used by changing wheels and configurations. It was harder to implement changes on BT movit Facelift. However, minimising the material was a requirement in this development process as well. The cover was developed to have a form which is as close to the inbound components as possible.

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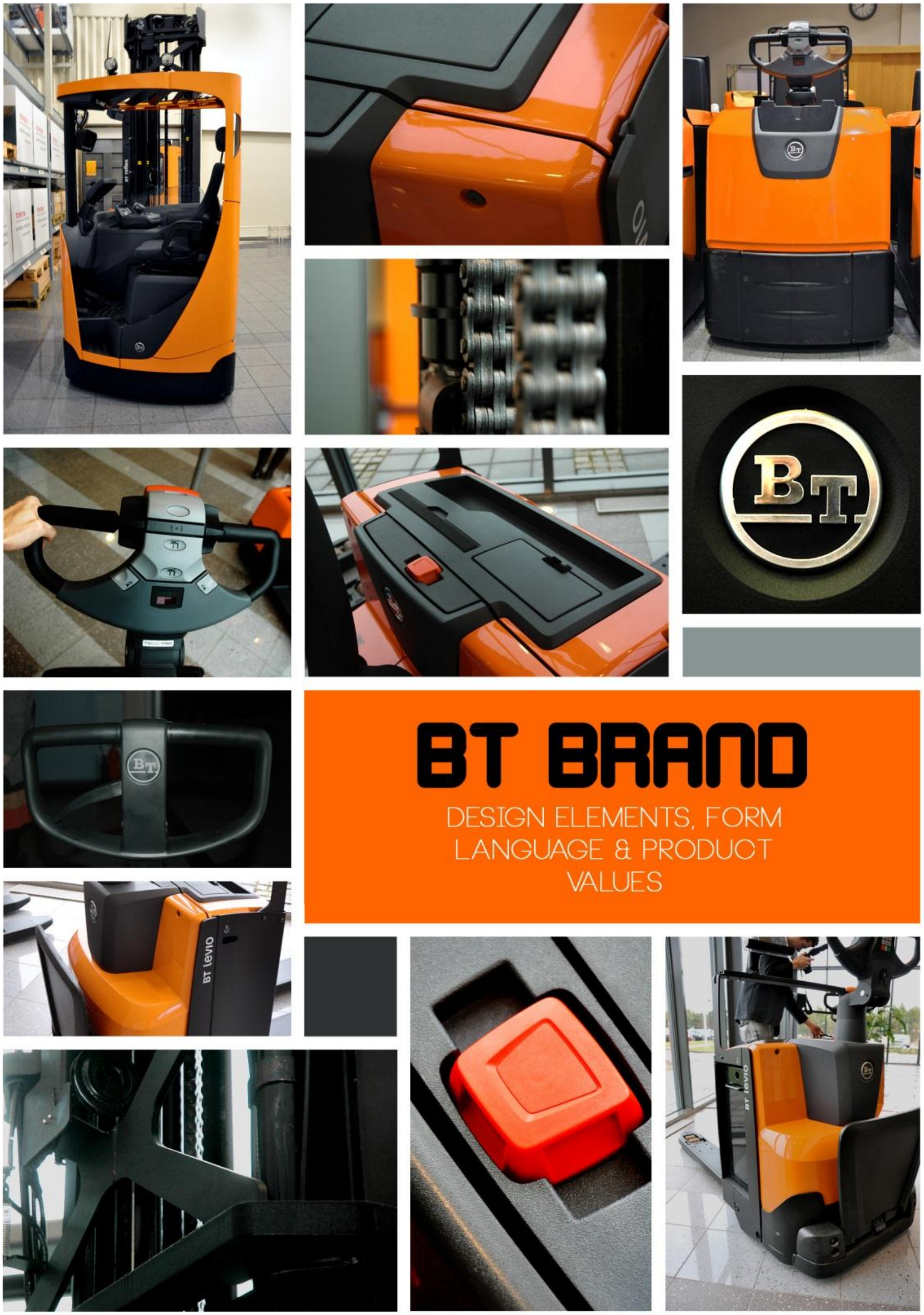
Fig. 2.2: TMHE (2011) *Unimover - Product specification.* Mjölby: THME.

Fig. 4.2: Movexx.nl (2012) Elektrotrekkers. www.movexx.nl (18 May 2012).

Fig. 4.3: Jungheinrich (2009) EZS 010. http://www.jungheinrich.se/sv/se/index-se/produkter/industritruckar/jhproducts/10098/500.html. (18 May 2012).

Fig. 4.11; Stringo.se (2012) Products, http://www.stringo.se/products.4.77645ab6114b5422c548000375.html (21 May 2012).

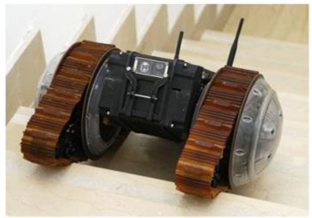
Appendix


BT BRAND
DESIGN ELEMENTS, FORM LANGUAGE & PRODUCT VALUES
BT levio


STIHL
EW 160D
INSPIRATION
HEAVY VEHICLES, FURNITURE,
CARS & GARDENING TOOLS


HUSK
P
BILLETT
TROLLEYS
ROLLCAGES, SHOPPING TROLLEYS,
GARBAGE BINS & SPECIAL CARTS
LandLearn
NSW


TRAILERS
BOAT TRAILERS, CAR TRAILERS,
CARAVANS & HORSE TRAILERS
KNAUS
GPLSTORE.COM
MAGASINERING
031 - 52 42 10
STATOIL


HEAVY GOODS

TRANSPORTATION OF HEAVY GOODS OUTSIDE, INSIDE & ON STAIRCASES.





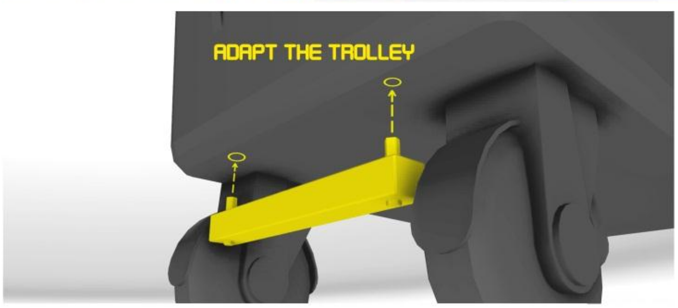

N258CC
AIRPLANES
MOVING SMALL AIRCRAFTS
ON THE GROUND


PUSH
PUSH HERE
BT movit
For higher flexibility BT movit has two throttle controls and an emergency stop button which can be used from any direction.
BT MOVIT
BT MOVIT FUTURE CONCEPT
BATTERY INDICATION
MODULARITY
One body, different configurations
EASY CHARGING
As easy to plugin as your vacuum cleaner
FEEL LIGHTNESS
The design focuses on simplicity and functionality. The movit concept feels both light and stable with wider bottom then top. The versity and drivability are the keys features.


WHEELS
Three types of wheels for different purposes: stairs, terrain and even floors.
TRI-WHEEL
TERRAIN WHEEL
INDOOR WHEEL
STEEL FRAME
Made of black powder lacquered steel and protects the plastic parts from being damaged.
PLASTIC SHELL
Made of injection molded PP.
BT movit
1100
250
200
400
CABLES
LI-ION BATTERY
CONTROL UNIT
ELECTRIC MOTOR
DRIVE SHAFT
FLEX WINDER
DRIVING BELT
PRODUCT SPECIFICATION
Dimensions: as seen above
Inbound components: as seen to the left
Weight: 70 kg
CONFIGURATIONS
Customized hooks and tow bars to make BT movit fit the users needs perfeclty in the four areas of application: heavy goods, trolleys, air-planes and trailers.

BT MOVIT TUG

CONFIGURATION: TROLLEYS



BT monit Tug can be used for towing all kinds of trolleys as rollcages, shopping trolleys and garbage bins. The hooks can be customised to fit every trolley.

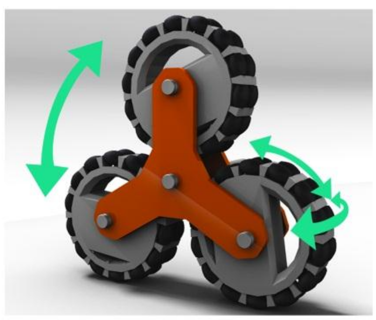
BT MOVIT PULLEY

CONFIGURATION: TRAILERS

Insead of carry heavy goods in staircases by manual power BT movit Lift can be used to ease the heavy work. Then the goods are placed at the fork and fastened with a strap and the tri-wheels will climb the stairs. BT movit Lift can also be used as an electric cart for transporting goods.

BT MOVIT LIFT

CONFIGURATION: HEAVY GOODS



TRI-WHEELS

The tri-wheel is driven by the driving shaft and is rotating around the centre axis. The three wheels rotate around their own axes with the aid of gears from the driving shaft.

To increase the turnability the tires consists of rubber cylinders which rolls sideways.


With BT movit Aero it is easy for one single person to move an 1000 kg air-plane at the airport. Today the pilots move the planes from the hangar to the air-strip by manual power and a tow bar. Two people or more are required to move one aiplane. BT movit Aero saves time and hard work for pilots.
TIP-UP CONSTRUCTION to minimize storage space and ease the driving.
BT MOVIT AERO
CONFIGURATION: AIRPLANES
The tow bar is attached to the front wheel
CUSTOMISABLE
- Tow bar
- Terrain wheels
- Indoor wheels
BT movit


TWE100
THE CURRENT PRODUCT

BT BRAND

DESIGN ELEMENTS, FORM LANGUAGE & PRODUCT VALUES


BT movit
FUTURE CONCEPT
INNOVATIVE IDEAS
AND NEW FORM


INSPIRATION
LAWN MOWERS AND FURNITURE