MASTER THESIS PROCESS REPORT

DurO Balance

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DURO LOGO

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ABSTRACT

This report is the main part of the documentation project for the master thesis called Duro. The documentations consists of this report that covers the process of developing the product described in the product report with the technical drawing. Duro is a mobility aid developed for users living an active life style despite of their walking disability. The objective of the project were to challenge current wheelchair manufacturers in their way of designing electrical wheelchair. Duro is providing a new design enhancing the feeling of safety while driving outside.

READERS GUIDE

The structure of the report is based on the iterative circles in the design process. Every chapter will present an essential step in the process. New knowledge gathered during to process will be marked with an exclamation mark and green text. All sources are referred to by the Harvard method and the complete list of references can be found in the back of the report. The appendix is placed on a USB flash drive, in case USB failure a link to a Dropbox containing the appendix is placed together with the USB.

ACKNOWLEDGEMENT

For the project to succeed the project team were highly dependent on the users of the wheelchair in order to gain the necessary insight. We are very grateful for the in times long spent with wheelchair users having interesting conversations and we are overwhelmed by the interest shown for the project. We would like to express our gratitude of the help provided by Poul Lund the workshop manager and his great ideas every time we went to him with crazy thoughts. Finally we wold like to thank the supervisors Christian Tollestrup and Jørgen Kepler for patient supervision and motivation.

CONTENT

This is the first phase of the project, In this chapter the project will be outlined a working hypothesis will be created in order to move ahead with the project. The external factors affecting the design will be described and the focus of the project will be illustrated.

PREFACE

INTRODUCTION

Project Team

The team of this master thesis consists of two industrial designers from Aalborg University, with a special interest in user oriented product development and an urge to improve quality of life. The development of the project is based on the knowledge shared between the project team and Wolturnus A/S who provided the overall project focus. The project will be setting off, after initial research, by looking into the current challenges of electrical wheelchairs. Several challenges, which would give interesting perspectives, turned up.

External Partner

Wolturnus is a company located in Bislev near Nibe in northern Jutland. They specialise in custom made wheelchairs, ergonomically fitted to the individual user. Their main target group is the active wheelchair user, who needs a light and durable wheelchair. They have a great variety of manual wheelchairs, varying according to the intended use and the users needs. Some are extremely light, some are discreet and some are adjustable.

Furthermore Wolturnus is producing Sport Wheelchairs. They sell custom made racing, basket, rugby, tennis, dance and e-hockey wheelchairs. This is where they get their inspiration for the fixed frame wheelchairs from. During an initial interview the product developer from Wolturnus told us that the company's sport wheelchairs often is seen at Paralympics and the company is using that as an advertisement.

Wolturnus does not have a large market share within electrical wheelchairs because their primary competencies are the manual wheelchair. This is why they expressed an interest in this project being about electrical wheelchairs in order for them to possibly expand their market share.

Project Theme

The master thesis project launches with an initial task of improving a current electrical wheelchair manufactured by Wolturnus A/S. The Project team made a decision of going back to the end user and start from scratch by mapping out the specific needs of the user and then develop an electrical wheelchair based on the research. The timeframe does not allow a total redesign of the wheelchair and the project team will have to limit the area of focus. During the initial research several challenges within existing electrical wheelchairs were found:

- No accessible storage place for personal belongings
- No way to maintain body functions
- Bring dirt from outside into the house
- No electrical wheelchair fulfill the users demands both inside the home and outdoor

As time does not allow working through all the challenges the project team chose to focus on developing a wheelchair which is meeting the needs of the user both indoor and outdoor. The decision was based on the urge to enhance life quality of those in need of an electrical wheelchair and by solving this challenge the project group would be able to provide the users the possibility of outdoor activity.

Experts

In order to start the project, knowledge on the subject is needed and three persons with three different fields of expertise were contacted.
The first expert is Palle Brøndum. Palle is a wheelchair user and has been for 24 years. Palle was interviewed in order to gain an understanding of which challenges wheelchair users face during their daily life. Palle is a manual wheelchair user which is not the target user of this project, but because Palle has been using a wheelchair for so long, his shoulders are worn out and he is considering applying for an electrical wheelchair.
The second expert is Lene Brønbjerg from the visitation unit at Aalborg municipality. She is an occupational therapist working on behalf of the municipality deciding who will receive grants for what. She was interviewed in order to gain knowledge on how the system works and which rules and laws apply when working with electrical wheelchairs.
The third expert was Tina Thellefsen who is a physiotherapist working at PTU (Polio, traffik og ulykkesskadede) rehabilitation center in Aarhus. She provided a crash course in the anatomy of the body, how it works and what makes it not work.

WORKING HYPOTHESIS

The initial objective is to develop a power driven mobility aid that should be used indoor and outdoor. The aim of the project is to make the users suffering from a walking disability more independent in their daily routines. This is done by providing a solution, which makes them able to move outside, and shop in the local store and move around inside their home without shifting mobility aid or being assisted by a family member or a helper assigned from the municipality.

It is assumed that the current solutions are not optimal solutions as the wheelchair created for indoor and outdoor use, are not agile enough to move around in a standard apartment or comfortable to use outside.
The initial assumption is based on a meeting with a user of a manual wheelchair who is considering switching to an electrical wheelchair. He is reluctant to do so because he will have to choose between being able to move around outside or use an electrical wheelchair only for the inside as the combination chair is not agile enough to move around inside his apartment.

The assumption is validated by a ergo therapist from the visitation unit in the municipality of Aalborg. She states in an interview that she does not advice the user to buy/choose a combined wheelchair as it would make the daily routines much harder for the user. In special cases where outside activities is crucial for the user in order to keep their job the municipality would assign a electrical wheelchair for outdoor use. The transition between the chairs is often demanding for the user and they are in need of a person to help them.

Focus:
- **Create which is equally good in indoor and outdoor use**

Context:

- Indoor
- Outdoor

Time of use:

- All waking hours

Buyer:

- Municipality
- End user

Distribution channel:

- Municipality
- Direct contact to the user

End User:

- Current users of electrical wheelchairs

Potential end user:

- Current users of manual wheelchair
- Current users of electrical scooters

EXTERNAL FRAMING

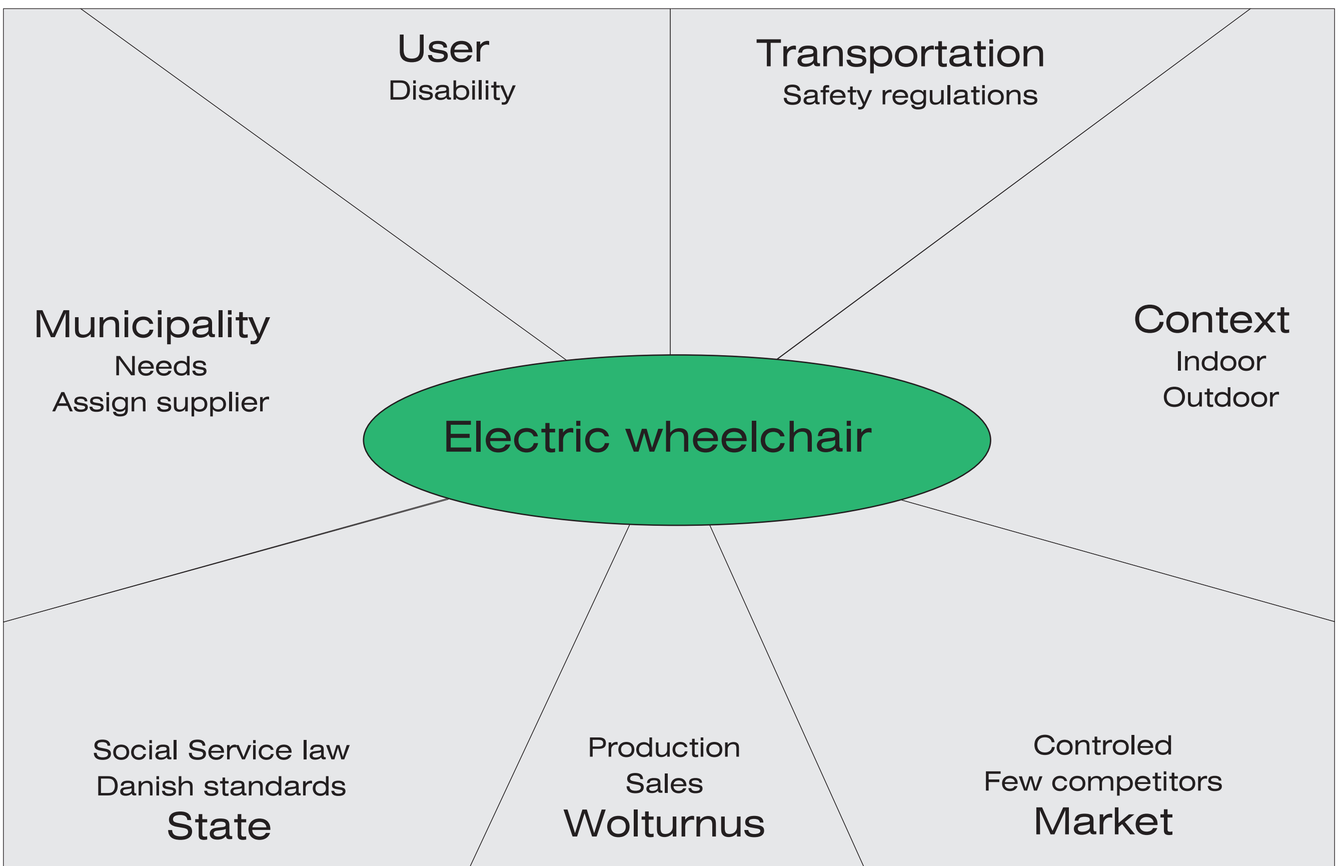
When developing a new electrical wheelchair there are several factors affecting the design, production and business of the chair. Illustration 1 shows the factors influencing the development of a new electrical wheelchair.

User:
The people in need of an electrical wheelchair are suffering for some kind of walking disability and are unable the use a manual chair. The disability can be caused by different things such as an accident or and congenital diagnose. The persons in need of an electrical wheelchair have very different demands to the chair and the project will be focusing on identifying the various needs of users.

Context:
In order to develop a power driven wheelchair for use inside the home and outside, several contexts have to be taken into consideration. The context can be divided up into two main categories:

- Indoor Context: Inside the home the wheelchair, has to be small and agile in order to move around.
- Outdoor Context: The wheelchair should be able to climb minor obstacles <10cm as most of the current wheelchairs are able to. It have to be stable when driving in uneven terrain. The user should be able to drive short distances in a comfortable speed.

Transportation:
The user of the wheelchair is in need of being transported in a car or drive the car by themselves. The chair has to be crash tested in order to be legal for transportation (DS/ISO 7176-19/ DS/ISO 10542-2:2001/ DS/ISO 10542-3:2005) [SOS]

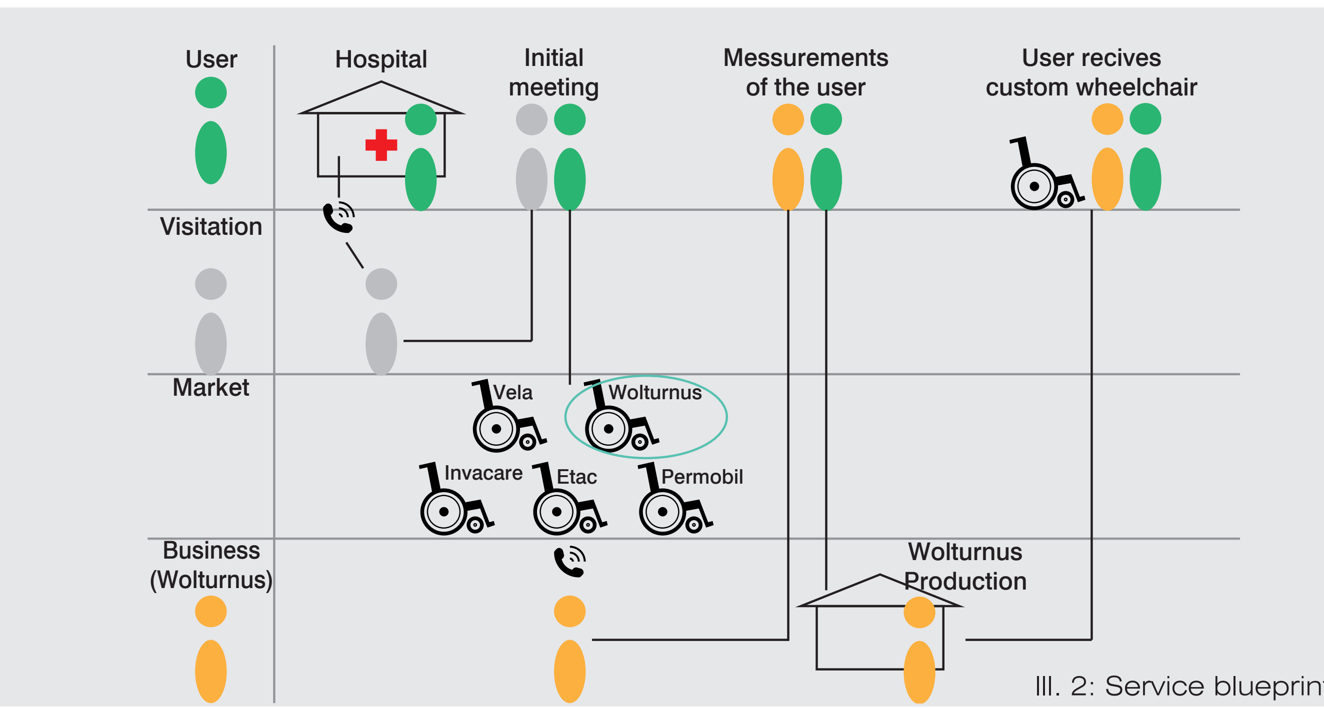


Ill. 1: External framing

Municipality:
The municipalities are responsible for providing permanent disability aids for the citizens within their area. The application process of a mobility aid was clarified during an interview with Lene Brønbjerg from the visitation unit in Aalborg.
When a person is in need of a permanent disability aid, such as a wheelchair, manual or power driven, the person contacts the local municipality and they provide a special educated caseworker who clarify the needs of the person in close corporation with the applicant. When the needs are clarified, the caseworker suggest a specific model of a wheelchair from a supplier. The users have the rights to choose the wheelchair of their own wishes, in cases where the chair is more expensive than the one the caseworker suggests, the user would have to pay the difference. In most cases according to the caseworker from the municipality, the user chooses the product the caseworker sees fit. The choice made of the caseworker is based on several criteria's beside the functional criterias based on the users', these are listed on the next page.
When the supplier is chosen the caseworker arrange a meeting with the consultant from the supplier and the user in order to get the right measurements for manufacturing of the chair. The consultant will deliver the chair then finished and will make small adjustments if needed.

Wolturnus:
At the beginning of the project, a collaboration with the wheelchair manufacturer was initiated in order to gain insights into production and marked details. The collaboration will be running in the project period with frequent meetings. At the initial meeting they put up a few criteria. It is expected that the design proposals will lead to more demands.

State:
The State is representing two instances:
- The social service law, which puts up several rules for the services the municipalities are obligated to provide to their citizens. The Social service law states that the municipality is to provide permanent disability aids including electrical wheelchairs [SOL]
- The board of social services has made a set on minimum specifications the electrical wheelchair has to fulfil in order to be sold on the Danish market [SOS]



Ill. 2: Service blueprint

Sum Up

USER:
There are various reasons for being in need of an electrical wheelchair. The needs of the users are highly independent, which is why they have to be thoroughly investigated to discover possible patterns.

CONTEXT:
The current electrical wheelchairs varies greatly in their ability to climb obstacles. Many of them are able to climb 6-7 cm, meanwhile a few are able to climb 11 cm. Further studies will clarify the needs of climbing an even higher obstacles.

TRANSPORTATION:
Regulations regarding transportation will not be of further focus within this project.

MUNICIPALITY:
The municipality controls which wheelchairs should be offered to the user based on:

- Distance between supplier and user.
- Previous experience.
- Easy replacement of spare parts.
- Quick service.

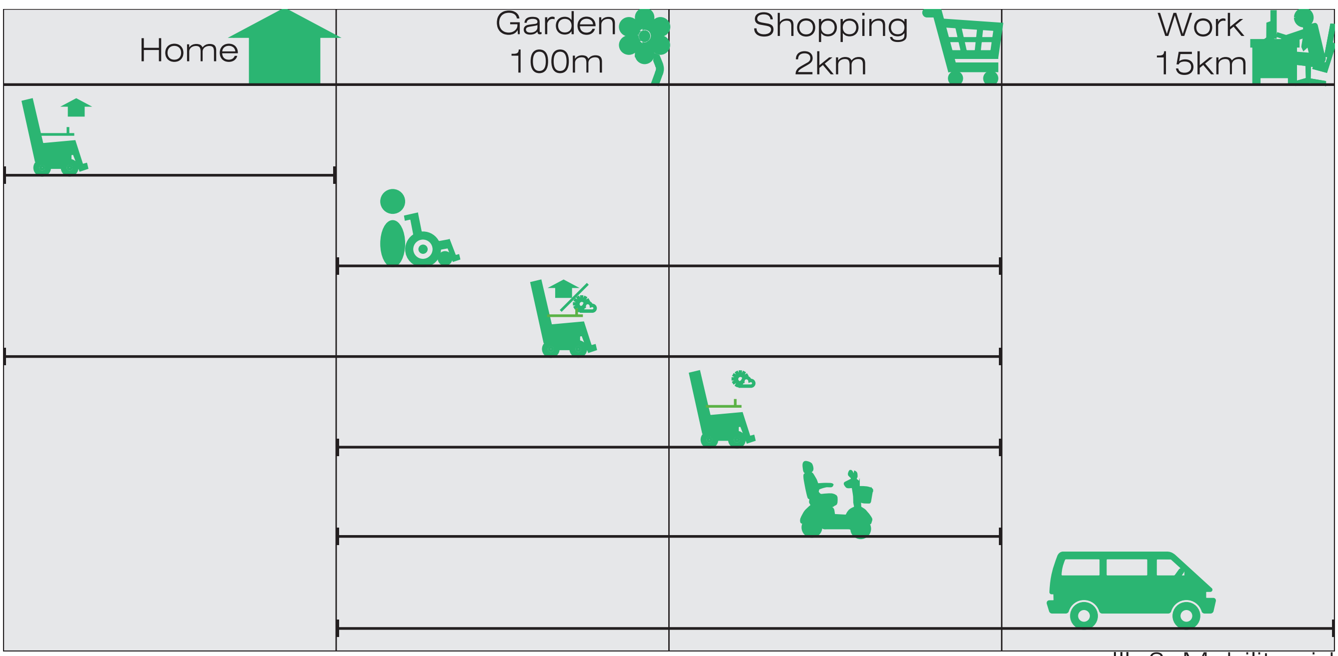
WOLTURNUS:
Wolturnus aims to develop a competitive electrical wheelchair, as their current wheelchair are not selling.

STATE:
The State provides the minimum requirements for an electrical wheelchair. The requirements are met by current suppliers. The requirements shows which are the crucial parts within the construction of the electrical wheelchair. The minimum requirements are as following [SOS]:

- Maximum velocity: 15 km/h.
- Maximum turning radius: 1000mm for electrical wheelchairs made for indoor use .
- Maximum turning radius: 1400mm for electrical wheelchairs made for outdoor use.
- Minimum driving distance per charge 25km.
- Minimum height of climb: 50mm.

LINE UP

People in need of an electrical wheelchair suffers from a variety of disabilities such as congenital diseases to disabilities as a consequence of an accident. In Denmark 90 000 people suffer from a walking disabilities and are in need of some kind of mobility aid [SOH]. There are no recodes covering categorisations of the specific disabilities, the number covers all people in need of a walking cane or an electric wheelchair.
Records from 2006 show that there is a need of 360 new electrical wheelchairs a year. Compared with the need of 30.520 manual wheelchairs it might not seem like much even if it is taken into consideration that the manual wheelchair is half the price of an electrical wheelchair[SOH].
The project has an initial focus on the use of an electrical wheelchair inside and outside. As stated in the working hypothesis the use of the same power driven wheelchair inside and outside is connected with several obstacles, such as limited room for maneuvering or driving on uneven terrain. As illustration 3 shows there are mobility aids providing the transportation of several distances, but as every shift from one mobility aid to another is extremely demanding or painful for a person suffering from a disability and it is hard work for family members and helper, it is important to eliminate all unnecessary shifts in helping aids. The diagram show only one mobility aid that provides the opportunity to go outside without changing helping aid.



Ill. 3: Mobility aid

COMBI CHAIR

Most suppliers have made a range of electrical wheelchairs, which is called "combi chairs". Currently the way of developing an electrical wheelchair for combined indoor and outdoor is to merge the technical specifications of an outdoor chair and an indoor chair. This result in a chair placed in a grey zone, it is not as agile as an indoor chair and it is not as stable outside as an outdoor wheelchair. The indoor functionality of the chair is of highest priority according to the munitipality, as they are obligated to provide solutions for the user in their most important routines, such as moving around inside, go to the toilet etc. In the perspective of the municipality they are not obligated to pay for the user being able to go to the local store or visit an amusement park with the family.
This results in lack of independence for the user of the electrical wheelchairs and this is added to the work of the helper or family member.
In order to determine the wheelchairs indoor and outdoor abilities some technical specifications of importance are shown in illustration 4 (the following specifications are the general data from the most popular suppliers see APP 1)

	INDOOR	COMBI	OUTDOOR
TURNING RADIUS	600mm	600mm	1680mm
OBSTACLE HEIGHT	600mm	700mm	110mm
MAX. SPEED	8 km/h	10 km/h	15 km/h
WIDTH	580mm	600mm	720mm
SEAT HEIGHT	540mm	460mm	530mm

Ill. 4: Specifications of combi chair

REFLECTION

From the listed technical specifications it does not, as initially assumed, seem like there are a direct connection between a small turning radius and low max. speed of the wheelchair as the "combi chair" almost have the same max. speed as the outdoor chair. There might by several things explaining the difference in the turning radius, it might be the production cost of the product, which will be looked into later. The optimal specifications for a new electrical wheelchair are highlighted in the diagram.

PROGRAM I

The knowledge gathered during the initial research are condensed into pointers like the ones stated in the working hypothesis. The pointers are not condensed into specific demands, they are however describing the direction of the project and will continuously be reviewed during the project. New findings will be written with green text font.

The initial challenge of the project is to create a competitive electrical wheelchair. The electrical wheelchair will primarily be distributed through the existing channel, the municipality. As the private sector are growing there might be an opportunity to sell and distribute the wheelchairs directly to the user. The investigation of the abilities of competing wheelchairs showed that they were specialised in either indoor or outdoor use. There have been made failed attempts to produce combined wheelchairs, which meets the demands indoor as well as outdoor, while still being capable of competeing with the specialised product ranges.

The aim of the project is to create an electrical wheelchair desirable to users of manual wheelchairs by providing them with an electrical wheelchair equally agile as the manual wheelchair. Furthermore it could provide users of electrical scooters with a stable alternative that matches the speed and are able to climb obstacles higher than 6 cm.

Market

Buyer:
- Municipality
- End user

Distribution channel:
- Municipality
- Direct contact to the user

Competition:
- Big difference between wheelchairs made for indoor and specialised outdoor wheelchairs

User

End User:
- Current users of electrical wheelchairs

Potential end user:
- Current users of manual wheelchair
- Current users of electrical scooters

Time of use:
- All waking hours

Function

Context:
- The user may not switch seat between when going outside.

Context:
- Indoor
- Outdoor

Technical demands:
- Turning radius: 400mm
- Obstacle height: 110mm
- Speed: 15 Km/h
- Width: 580 mm
- Seat Height: 460 mm

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During the following chapter key competitors and market forces will be clarified. Furthermore the current need of the users to be condensed into specific demands. The result of the chapter is that the experience while using the wheelchair, have a larger impact on the behaviour of the user, than initially assumed.

PROJECT FRAMING

MARKET FORCES

The market of electrical wheelchairs is a niche market of highly customized products. The specific customer segment is divided up into two parts: The end-user and the municipality. The end-user is a person who suffer from a walking disability and is unable to operate a manual wheelchair. The municipality has the function of gatekeeper to the market.
The market is highly controlled without significant price competition as the municipalities' grants founding to electrical wheelchairs within the same price range (85.000 – 120.000 DKK). Furthermore the competition between companies is limited by the municipalities' priority of local suppliers. As a result of these forces, electrical wheelchair suppliers have a limited amount of customers who are the municipalities placed in the area of the supplier. There is no direct competition from other suppliers or price competition.
In each area of a large municipality there are around two or three suppliers. In special circumstances the municipality would order an electrical wheelchair from a supplier placed far away from the municipality if the wheelchair have some specific specification which the local suppliers are unable to fulfill. The companies seem to specialise their product to fulfill a specific criteria such as low seating hight or small turning radius.
The most popular brands are listed to the right, these are referred to by the municipality of Aalborg, a rehabilitation centre in Aarhus and several users. The comments listed to the right are information obtained during interviews. This list is furthermore an overview of the key competitors of Wolturnus A/S.
The most popular suppliers all fulfill common criteria set by the ergotherapists.

Invacare:
Invacare is a popular solution for combined or outdoor use.

Roltec:
Roltec is known for their light and narrow products.

Permobil:
Permobil is popular because of their modular product architecture

Vela:
Is the most bought electrical wheelchair in North Jytland, due to the location and criteria

COMPETITION

In the previous paragraph the most popular suppliers were listed. The objective of this chapter is to clarify the direct competing products to a new chair made for combined indoor and outdoor use. Firstly one chair from each supplier with the best technical specification for combined use will be presented and then compared. Secondly a reflection of the technical specification in relation to the sales process will be made in order to clarify expected production price of the electrical wheelchair developed throughout this project.

The listed competitors are given points for the best technical specifications (APP 1) in order to find the best chair. It should be kept in mind that the specification does not entirely determine quality of the product, this is highly subjective and will vary from person to person. Another thing to keep in mind is during ranking of the products each specification is of equal importance and some specification might be of higher priority than other for some users.

Ill. 5: Competition

Permobil:
Turningradius:715mm
Obstacleheight:60mm
Max. Speed: 8 km/h
Seat Height: 405mm
Width: 675mm
Weight: 181Kg

Roltec:
Turningradius:600mm
Obstacleheight:70mm
Max. Speed: 14 km/h
Seat Height: 460
Width: 650mm
Weight: 130 Kg

Invacare:
Turningradius:550mm
Obstacleheight:75mm
Max. Speed: 12 km/h
Seat Height:420mm
Width: 650mm
Weight: 160Kg

Vela:
Turningradius:580mm
Obstacleheight:60mm
Max. Speed: 10km/h
Seat Height: 540mm
Width: 660mm
Weight: 137Kg

Ill. 5: Competitors

RED OCEAN

As mentioned earlier Wolturnus is producing wheelchairs primarily for the Danish market. The wheelchair industry is characterised according to [Porter, 1998] as a mature market, due to the regulated market, where competitors have minimised competition, by specialising the products. The natural course of action for a company working within a mature market segment is to differentiate themselves from other companies through price, product, marketing, service or distribution [Linneman and Stanton, 1991]. Especially price, product and service is of current interest for Wolturnus. The market in which Wolturnus are operating could also be defined as a red ocean as seen to the top right

The ideal objective for the master thesis would be to introduce a product, which would move Wolturnus into Blue Ocean. This provide a set of objectives, which have to be fulfilled in order to implement a product into Blue Ocean.

RED OCEAN

- Compete in existing market space.
- Focus on beating current competition.
- Exploit existing demands.
- Make the value-cost trade-off.
- Align the whole system of a firm's activities with its strategic choice of differentiation or low cost.

BLUE OCEAN

- Create an uncontested market space.
- Make competition irrelevant.
- Create and capture new demands.
- Break the value-cost trade-off.
- Align the whole system of a firm's activities with its strategic choice of differentiation and low cost.

[Kim and Mauborgne, 2005]

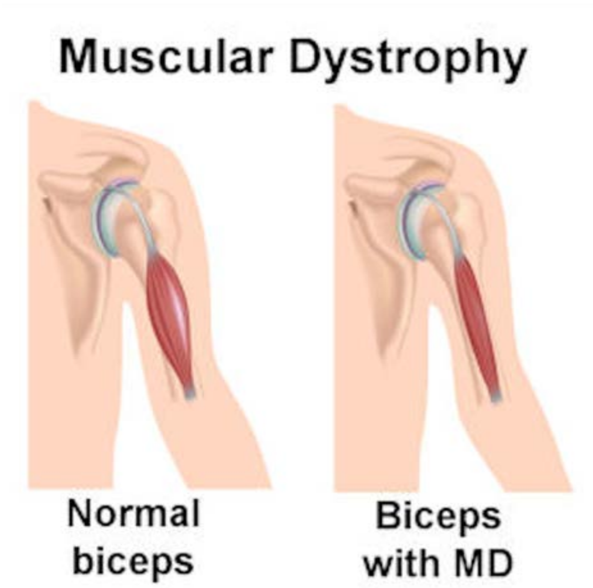
REFLECTION

As the master thesis is based on a product placed within the red ocean a specific set of demands were stated above in order to move the product into a blue ocean. This might create some challenges as the product is developed in order to satisfy a niche market. The first objective, the creation of an uncontested marked space would be challenging due to the specific market segment. The blue ocean strategy is defined by the creation of a new marked, which could prove to be impossible as the helping aids to walking disabled are highly developed.

WHO IS THE USER?

To identify the users an initial meeting was conducted with Tina, a physiotherapist from PTU's rehabilitation centre (polio trafik of ulykkesskadedes rehabiliteringscenter). This was done in order to gain a general understanding of the body, how it works and how the nerves link it together.
There are more types of paralysis: Impaired muscular function, partial paralysis and spasticity. Impaired muscular function is caused by illnesses as polio or muscular dystrophy this type of paralysis can cause nuisances as pain in the shoulder because of the lax arm pulling the tendons. This also means that their joints easily can be dislocated because the muscles are not helping holding the joint together.

Partial paralysis can occur when a person sustain an injury to the spinal cord but the spinal cord is not severed completely. Partial paralysis can cause a user to loose function in his arms but maintained control over his legs.
Spasticity is involuntarily tension of muscles, this often goes hand in hand with paralysis. Spasticity can cause contractures which then stiffen the joints because they are not used. Furthermore, spasms can occur at any time, which can cause the wheelchair user to fall out of their wheelchair. Spasticity is what "normal" people experience as cramps. The difference is that "normal" people can tell the counteracting muscle to react and thereby prevent the affected limb from twitching, paralysed people cannot.



Ill. 7: Muscular dystrophy


Ill. 8: Spine


Ill. 9: Spasm

NEW DEMAND

- Modular product architecture

USER INTERVIEWS

To uncover the requirements for an electric wheelchair, six different users with different disabilities was interviewed. The interviewed users have an active lifestyle where they push themselfs to the extent of their capabilities. They are involved in political work, flex jobs and walking their dogs several times a day. One of the six interviewed is shown below, the rest can be seen in APP 2. The outcome of the interviews were, what set up the limitations for the persons, were not their disabilities, but the wheelchair. Finally the paragraph will define the requirements of the wheelchair, all the interviewed persons has in common.

Bodil

Bodil suffers from muscular dystrophy. She is still able to walk but not for long and not on uneven surfaces because her balance is not great. Bodil uses an electrical wheelchair outside, when walking the dog and getting around the farm. Furthermore she does a lot of political and organisational work, Bodil is also a board member of BPA Nord which is a society for people in need of help from the municipality, she has help 8,5 hours a day.

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- Terrain
- Climb curbs
- Getting around at meetings
- The wheelchair is to slow to keep up with a bicycle
- The helper have to carry everything when they are out shopping

Ill. 10: User scenario

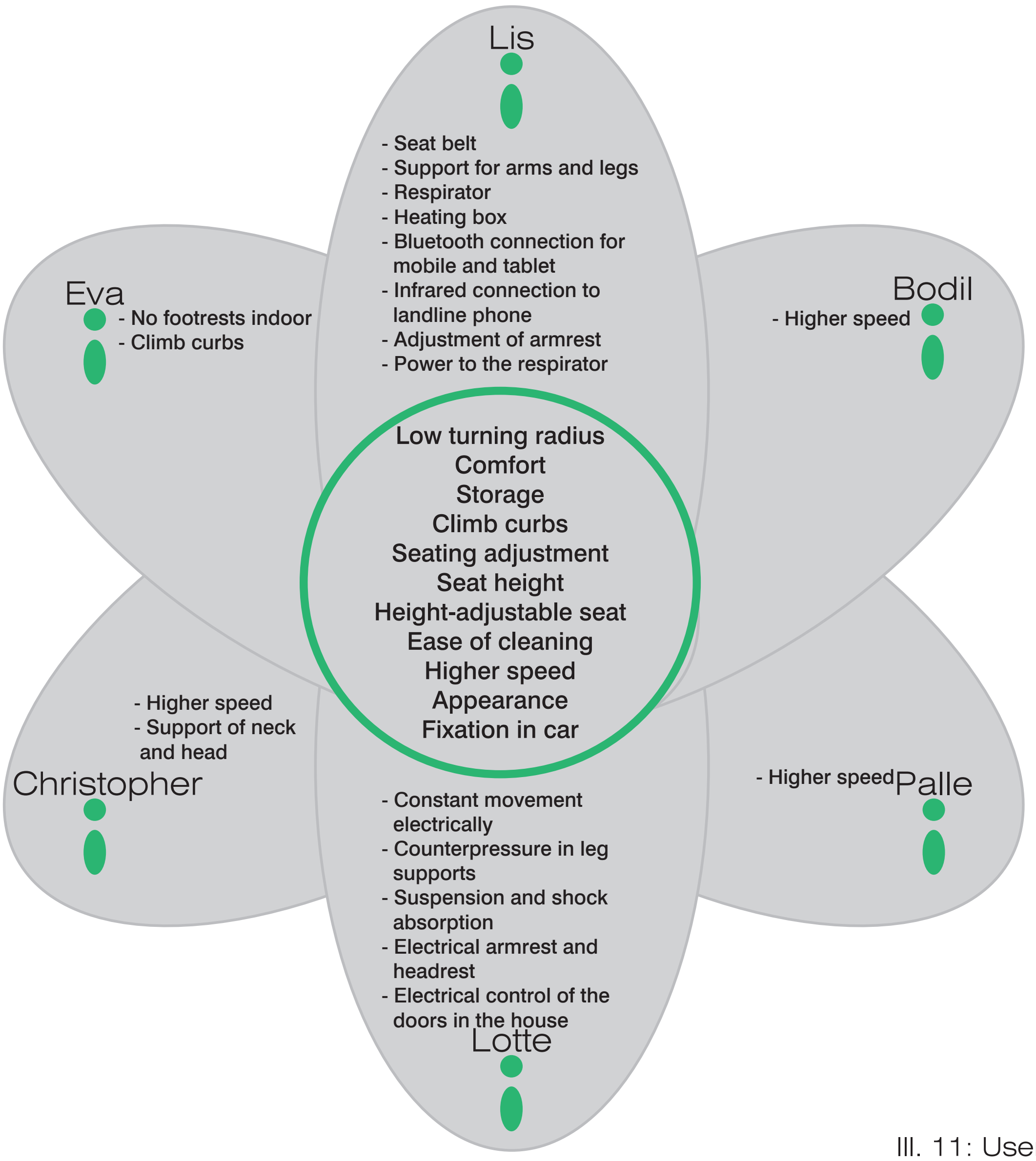
Challenges

The scenarios from the users everyday life illustrates the challenges they meet. These challenges along with others collected through interviews with the users are shown in illustration 11. The challenges all persons have in common are showed in the middle of the illustration. Most of the challenges refers directly back to the construction of the electric wheelchair.
During the interviews the users claimed that they did not care about the looks of their electrical wheelchair, but when asking into their daily life they would say:

"I do not care how it looks as long as it is black"
– Christopher

"I know that this neck rest makes it look like a monster, but I need it"
– Lotte

The aesthetic might not be their first priority, but they have very clear opinions of how the wheelchair should look or not look like. This should be further elaborated.



Ill. 11: User scenario

PRIORITY

In the previous paragraph a number of challenges were stated. In order to develop a product benefitting most users the scope of the project should include challenges common for all the interviewed users. The challenges are prioritised in order to limit the extent of the project, this is based on several parameters:

No existing solutions: There are already solutions solving these challenges

Daily impact: The impact of the solution, will this enhance the quality of life

Gut feeling: Special interests and gut feeling of project team

1 ST. Low turning radius is the first priority as this will have a great impact on the user's movement in stores and at home.

2 ND. The ability to climb curbs will provide the user's with freedom to move around outside without using energy on planning their route according to the placement of the ramps. Especially in smaller cities the ramps are placed up to a kilometre between each other according the users.

3ND. Being comfortable in the chair is will enhance the life quality of the person using the wheelchair.

The chosen challenges all refers to the construction of the wheelchair. Although existing manufactures are working on the same challenges, it is chosen based on the judgement that solving these issues will enhance the quality of life the most. This choice is based on the gut feeling of the project group as existing products are complicated in terms of mechanic solutions. Most new abilities are built on an existing non-modular platform which results in complicated solutions to a simple problem. An example is the ability to climb higher obstacles, by adding another set of wheels which compromises the turning radius.

FOCUS

- Low turning radius
- Ability to climb curbs
- Comfort

CONTEXT

The electrical wheelchair developed for combined use have to work in two very different contexts which is often contradicting in relation to the technical requirements. In order to clarify the basic requirements and challenges of an electrical wheelchair, the following section will represent experiences from the user during the interviews and the project group's own experiences.

Indoor:
The interviewed users expressed that they faced the biggest challenges outside their homes. It could be in stores where it is often impossible to move outside the "main paths" because they might not be able to turn around. It is impossible for the user to look behind them, it is therefore very uncomfortable to drive backwards, the user avoids this uncomfortable situation at home by memorising the position of all their furnitures. Most of the users live an active life of political work or flex jobs but when outside the home they live in a constant fear of hitting someone or something as the heavy chair are able to severely injure a person or the user in the chair. Especially when visiting people who are not using an electrical wheelchair they have trouble moving around without hitting furniture.

Field study:
The member of the group who were driving inside the store were very uncomfortable, due to low height of the chair, other people who are out shopping are not noticing the person before it is almost too late as they are looking up in order to find the products they are looking for. The fear of hitting someone or something was very demanding as you had to navigate around the store from a child's height be constant aware of not hitting anything, predict the movements of the people surrounding you and do your shopping all at the same time.

Ill. 12: Field study clothing store

Ill. 13: Field study apartment

Ill. 14: Field study store

Outdoor:
The amount of time users spends outside varies a lot, some have dogs they love to take out for a walk, others is so much in pain that any bump in the road will be very painfulll. They all have some activities outside such as going from the parking lot into a building or going to an amusement park with their families. Even in short timed outdoor activities they will meet challenges like curbs, short and steep ramps, uneven terrain and holes in the road. Most indoor and combined chairs do not have any suspension, which means the user in the wheelchair will have to compensate for any bump in road. In order to compensate for the bumps in the road the users has to use their abs to stabilise their body, an impossible task for some users since they do not have control of their abdominal muscles which means that they are in risk of falling of the chair. Every time the user faces an edge on more than a few centimetres the wheelchair will have to approach it straight on to avoid the risk of tipping.

Field study:
The experience from the project group verified the challenges stated by the users. When you are not used to driving an electrical wheelchair you start out by looking upwards in order to navigated to your desired destination. The person do not notice the ground, but after the first time you meet a bump and faces the feeling of falling out of the chair or the feeling of the chair almost tipping over are you only looking down. The placement of the ramps to the sidewalk were placed far from each other, which forced the users to dive on in the side of the road which makes you feel very vulnerable.

Ill. 15: Field study access

Ill. 16: Field study slope

Ill. 17: Field study obstacle

Sum Up

During interviews and field studies in the two different contexts, a list of challenges were conducted. The challenges shown below are divided up into two categories, the wheelchair and the experience, according to the origin of the problem. The “Experience” category will cover emotional and physical challenges, where the “Wheelchair” is describing specific scenarios.

EXPERIENCE

- Risk of falling out.
- Fear of hitting someone or something.
- Cognitive demanding.
- Focus on the ground.
- User can’t look back.
- Physical demanding.

REFLECTION

The interviews and field studies showed that the use of the current wheelchairs lead to several challenges regarding the experience when using the wheelchair. These states of minds will have to be clarified, in order to define a direction of the experience when driving the wheelchair.

WHEELCHAIR

- Ramps placed far from each other.
- No room for turning.
- Takes up room.
- Pain (No suspension).
- Obstacles.
- Risk of tipping when approaching an obstacle oblique.
- Not noticed by people passing by.

REFLECTION

The challenges according to the wheelchair refers directly back to its construction. The challenges are elaborated during investigations of the contexts the chair will have to function within and is condensed into specific demands.

Obstacle height:
Most curbs in Aalborg are 6-8 cm, but in newer parts of the city the height of the curbs is only 3-4 cm. When the project group moved 1 km outside the center of the Aalborg in a residential area the curbs were 13 cm high which no electrical on the current market are able to climb. As the study were conducted in Aalborg it will have to be taken into consideration that the roads are frequently renovated and the curbs lowered. The user should be able to move around in residential areas, the specification is therefore determined by the highest curb and with a safety margin in case obstacles heigher than those encoutered by the project group.

Terrain:
The focus of the project is not to create an off-road wheelchair but one who enables the user of an electrical wheelchair to move around freely within cities and parks.

Ill. 18: Field study obstacle


Ill. 20: Field study obstacle

Ill. 19: Field study obstacle


Ill. 21: Field study obstacle

DEMANDS

During further investigation and data collected from the initial field studies specific demands are clarified. The experience of feeling comfortable comes down to whether the person in the chair feels safe. The feeling of safety will be investigated further. The demands for the construction is shown below, where especially the obstacle is much higher than current wheelchairs are able to climb. The risk of not being seen will delimitated, as this highly conflict with the demands of the seat height being as low as possible.

NEW DEMAND: EXPERIENCE

- Feeling safe.

NEW DEMAND: WHEELCHAIR

- Turning radius: max. 50cm in order to turn around in stores
- Able to drive on beaten tracks.
- Obstacle height: 15cm
- Suspensions minimising shocks from the ground and obstacles.
- Max. width of 60 cm.

REFLECTION

The user who are used to moving around in an electrical wheelchair will unconsciously navigate through challenges but most of them cannot be avoided, even cobbles are uncomfortable to drive on. The experience of using an electrical wheelchair are connected to a lot of coping strategies and the person have to pay attention to a lot of things besides just moving around. Every bump and obstacle makes the chair unstable and the user is afraid it might tip. It is mentally and physically exhausting to use the current wheelchairs for combined use, outside.

PROBLEM STATEMENT

How to develop:

A combi wheelchair which is able climb obstacles of 15cm and have a turning radius of maximum 50 cm, while the person in the wheelchair are feeling safe.

SCOPE

In order to limit the extend of the project was all its objectives listed and prioritised, as a consequence the result of the project will be a part of either an existing solution or the foundation of a new one. The connection between the existing solutions and the result of this project will not be a high priority but solved on a principal level. The list will reflect the level of detail with number one as the most detailed part.

1 ST PRIORTY

Develop an electric wheelchair, which has a maximum turning radius of 50 cm and climb obstacles of 15 cm. The improvement of these parameters will have a great impact on the independence of the person using the wheelchair.

2 ND PRIORTY

The experience of feeling safe is crucial for the user in order to use the new abilities of the wheelchair.

3 RD PRIORTY

The aesthetic value of the chair do also have an impact of the use of the chair.

Out of scope

The project will not be including the ergonomics of the seating module, this is specially customized cushions provided by sub suppliers. Furthermore, there will not be developed a new control unit or interface for the solution in this project.

CONSTRUCTION

EXPERIENCE

APPEARANCE

USE VISION

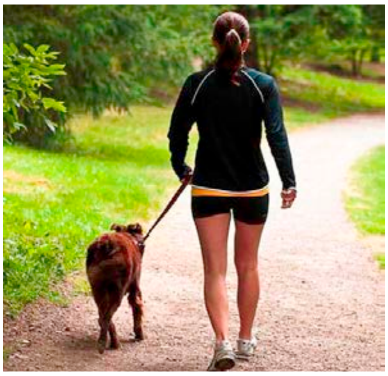
The electric wheelchair is developed for persons who are living an active lifestyle, with the need of a wheelchair that not only are fulfilling requirements of indoor use, but are in need of transportation outdoor. The person dependent on an electric wheelchair spends all waking hours in the chair, this means the chair should be able to fit into a wide variety of daily routines, as illustrated to the right. The interaction with the chair can be divided into two parts according to the role of the wheelchair. The wheelchair will have to function as the legs of the person, seen as an integrated part of the body not instantly noticed by other persons, agile and easy to manoeuver. When going outside the wheelchair becomes a safe personal transportation device. It should be able to transport the person over smaller distances in the same manner as a bicycle. The objective is to incorporate both roles in the wheelchair.

Part of the body

Indoor activity

Grocery shopping

Mobility aid



Outdoor activity

Transportation

Ill. 22: Interaction

PROGRAM II

During project framing the focus of the project have been furhter elaborated to focus on the users living an active life, which requires a wheelchair equally capable of driving in narrow places and function as transportation device outside.

Market
During market analysis it was clarified that the market is lacking a combined wheelchair which is able to fulfil the requirements for both indoor and outdoor use. The municipalities normally grants 85.000 – 120.000 DKK to users in need of an electrical wheelchair every 5. year. The production price should therefore not exceed 60.000 DKK. The project will not be focusing on creating a new distribution channel.

User
As previous stated the need of the users is highly individual, the project will therefore develop a basic platform, which users with no cognitive disability and full function in one arm and hand are able to use. The timeframe does not allow devlopment of special equipment or product architecture.
The experience when using the wheelchair is crucial, in order for the user to exploit the full potential of the wheelchair. If the person in the wheelchair is not feeling safe, he or she would keep avoiding going outside.

Focus

Provide a mobility aid for the active users, which require minimal turning radius and safe transportation outside.

Market

Buyer:
- Municipality.
- End user.

Distribution channel:
- Municipality.
- ~~Direct contact to the user~~

Competition:
- Gap in market, no current wheelchair is able to fulfil both indoor and outdoor requirements.

Production price:
- Max. 60.000 DKK.

User

End User:
- Users without cognitive disabilities and with function in one arm and hand.

Potential end user:
- Current users of manual wheelchair.
- Current users of electrical scooters.

Time of use:
- All waking hours.

Experience:
- Feeling of safety.

Function

- The user may not switch seat when going outside.
- ~~Modular product architecture~~

Context:
- Indoor: Narrow spaces.
- Outdoor: Obstacles and able to drive on beaten tracks.

DEMANDS

The construction of the electrical wheelchair should be as simple as possible. As previous mentioned the existing wheelchairs are complex mechanic solutions based on years of development in technologies without evaluating the previous solutions, as a consequence the product platform is complex and the implementation of new technologies or product solutions has become complicated. A secondary aim of this project will be to provide a reworked construction with a modular product platform. The feeling the user should have, is previously defined , but it should be further elaborated in order to set specific demands. Feeling and experience is not measurable and will therefore be placed as "nice to have".

NEED TO HAVE

Construction:
- Suspension: chock absorbing
- Obstacle height: 15cm
- Width: 60 cm
- Seat height: 45 cm
- Turning radius: 50 cm

Components:
- Battery capacity 25km
- Speed: 15 km/h
- Tilt in seat and backrest

NICE TO HAVE

Components:
- Electrical adjustments in: Back-, neck-, arm-, leg-rest

Experience:
- Feeling of safety

2

The first ideation session will be conducted after an analysis of the dilemmas current wheelchair manufactures are facing. The results of experiments, conducted regarding the experience of safety, are that the person in the chair should change position in the chair when driving outside.

IDEATION I

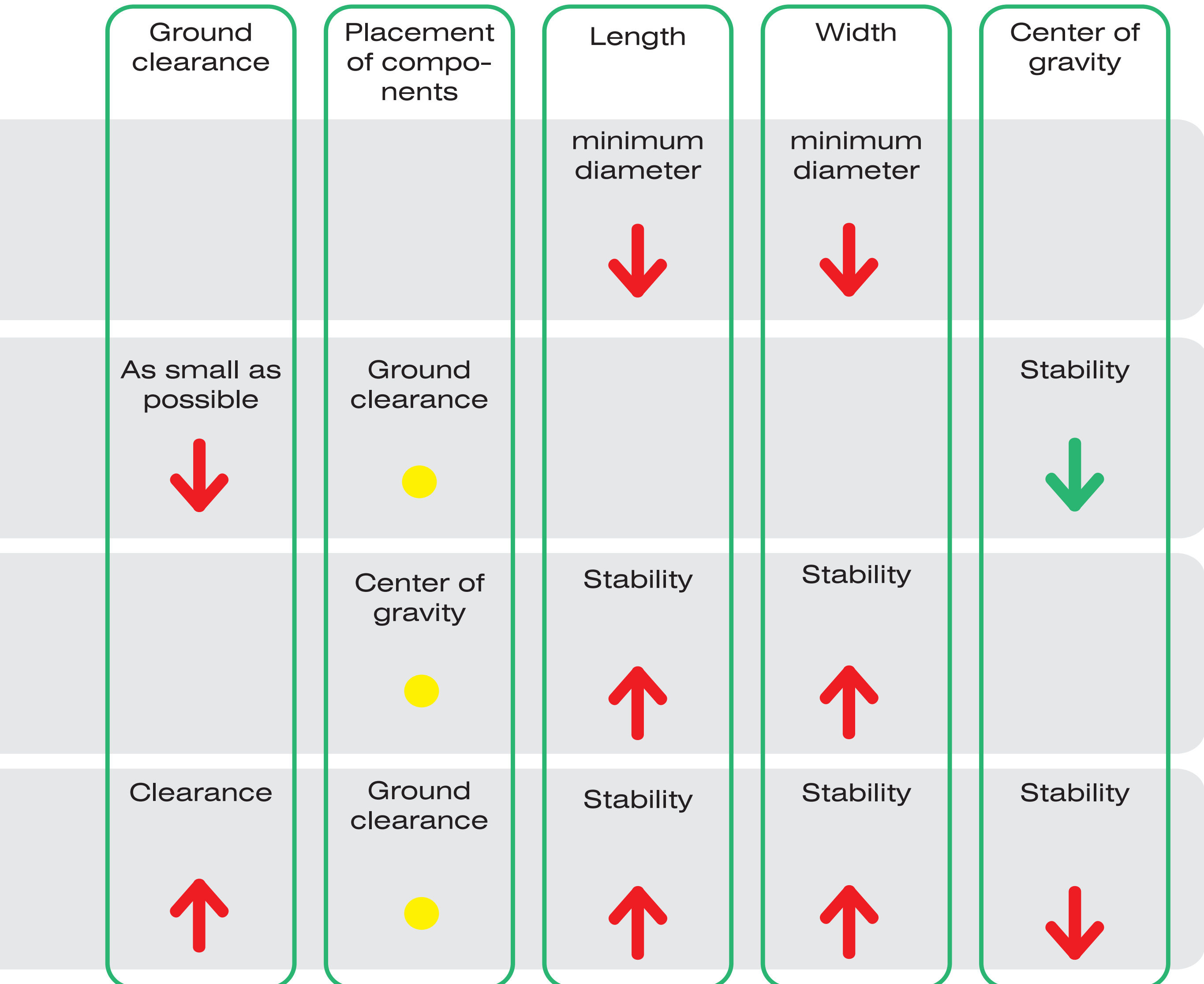
BOUNDARIES

There are four central parameters which describes the wheelchairs ability to manoeuvre in the two very different contexts. The parameters are listed in the vertical part of the matrix below and in the horizontal row, technical parameters which are directly influencing the abilities of the wheelchair. Several of the technical parameters would be directly contradicting in order to fulfill the four abilities, these are marked with a red color. The yellow color marks are parameters which might be an issue. In all cases except from one, the technical parameter is contradicting itself, an example could be the ground clearance of the electrical wheelchair, this should be as high as possible in order secure the wheelchair's ability to climb obstacles but the seat height should be as low as possible. In the case of the wheelchair's ability to climb obstacles the ground clearance and centre of gravity clashes, with a low centre of gravity the wheelchair are stable, but as mentioned before the wheelchair

↑ As high as possible ↓ As low as possible ● Be aware of

	Center of turning cicle	Capacity of motor/ battery	Size of wheels	Numbers of wheels
Turning Radius	Turning cicle ●		Size of wheelchair ↓	
Seat Height				
Speed		Capacity ↑	Distance per revolution ↑	
Obstacle Height		Torque ↑	2/3 heigher than obstacle 450 mm	Stability ●

should have some ground clearance, in order to avoid the obstacle hitting the bottom part of the wheelchair.
In all cases where contradicting parameters occurs, is between the abilities needed for driving indoor and abilities needed for outdoor activities. A way to solving this challenge, colud be trying to work around the product being the exact same in both situations. It might be necessary to prioritise the four abilities and elaborate the parameters needed in order to fulfil the demand of the wheelchair being able to climb an obstacle height of 150mm. The matrix was made in order to clarify possible dilemmas the project might face in the future.



Ill. 23: Bounderies

IDEATION

During the priority of the project, it was decided to focus the bottom part of the wheelchair as a way of limiting the extent of the project. The first ideation will function as an initial workshop in order to visualise ideas generated during the research and to generate more ideas with a quick sketching session. The quick sketching session lead to a large amount of principals, more or less realistic. The solutions with the most potential were evaluated from the set of criteria listed below. The three most promising solutions are showed in the report.

Technology: How mature is the technology.

Construction: The construction should be as simple as possible

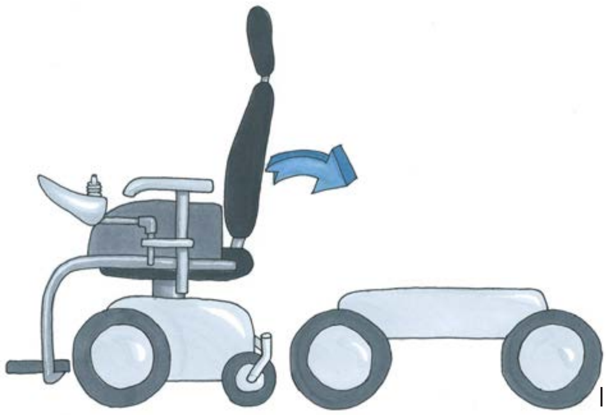
Obstacle height: Ability to climb obstacles of 150mm

Turning radius: The optimal solution is the wheelchair turning around its own axis.

Gut feeling: A principal, with special potential.

Ill. 24: Quick sketching

Principal # 1



Ill. 25: Principal 1

There are no new technical solution in the product, which might lower the cost of wheelchair.

Complex construction as the chair has to be moved safely from one bottom part to the other and all electric connections as well, but it is not impossible to solve.

Solved by specialised bottom for outdoor.

Solved by specialised bottom for outdoor.

There would be a problem with logistic, as the user would have to somehow bring the other part of the wheelchair if he or she has to go inside, when for instance visiting friends.

Principal # 2

Ill. 26: Principal 2

The solution is based on gyro technology, which is seen in Segways. The price of the technology is relatively low, it is used in Lego mindstorm.

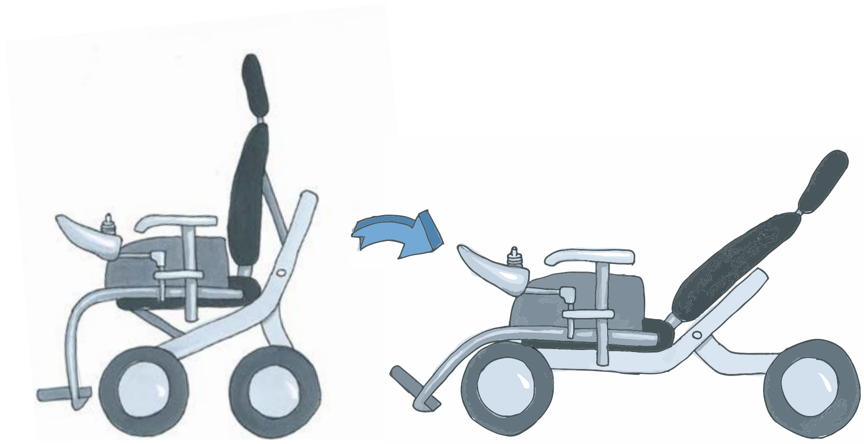
The crucial part in the constriction is the centre of gravity and control of the "ball".

There might be an issue with the stability climbing an obstacle, but a soft surface on the ball would provide grip, it will not be an issue climbing an obstacle.

Minimal turning radius.

The "Ball" would have some problems when the users want to lean back. The project group does not see any potential in the solution.

Principal # 3



Ill. 26: Principal 3

No new technologies .

Movement in a construction is always challenging, but it could be done in a fairly simple construction

By using wheels on at least 450 mm the wheelchair is able to climb obstacles on 150 mm

By placing the two sets of wheels close to each other, is it possible to minimise turning radius.

The solution has potential in the radical change between the contexts and the motion. It can be used in order to change the position of the user, when driving for a longer distance.

EVALUATION

The aim of the ideation workshop was to create solutions that were able to work around the issues of indoor and outdoor specialisation. Choosing a solution, which radically change in order to fit into the different contexts the team would be able to work with two different scenarios of use in one product.

NEW WISH

- The chair should change appearance when driving outside

SAFETY

During the interviews with the different users the word "comfort" was used several times in each interview and the word safety has a different meaning for a person in a wheelchair than a walking person. The outcome of the interviews was that by saying comfort the users meant safety. A person without the ability to walk, relies 100 % on the safety of the wheelchair. They are not able to get out of it, in case of emergencies. The term being safe covers a lot of aspects, this project will be focusing on the experience while moving around both indoor and outdoor.
The users will try to avoid driving new places, because they do not know if their wheelchair is able to climb the obstacles, they have no trust in the wheelchair. The interviews lead to three parameters describing the term safety.

Stability: Bumping around on cobbles or climbing an obstacle when it feels like the wheelchair is going to tip over is very uncomfortable even for persons with the ability to walk. The wheelchair is not going to tip over, when climbing obstacles within cities, but when the body is tipping away from the chair, the users feel unsafe. Most wheelchairs do not have any suspension, as a result the person within the wheelchair has to avoid any uneven surfaces.

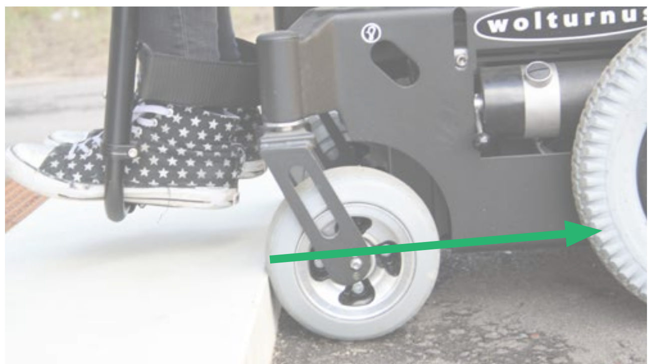
Risk of falling out: Persons using a wheelchair are terrified of falling out of the chair. If the chair hits something and suddenly stops or it tips too much, the user is in risk of falling. The interviewed users avoid safety belts as it compromises safety and their seating position.

The position of the body: As a coping strategy the users tilt their seats while going over an obstacle in order to be positioned back in the chair and thereby change the centre of gravity. The current chairs are not build for a change in gravity and a safety mechanism limit the speed of the chair to 3 km/h even if tilted a bit, which is fine when climbing an obstacle. The interviewed users would like to use the position while driving outside, but for now they can't.

Stability

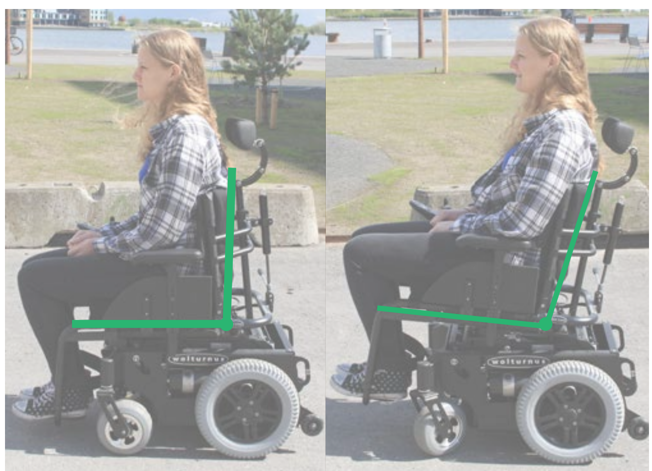
Ill. 27: Stability

Risk of falling out



Ill. 28: Stop

Position



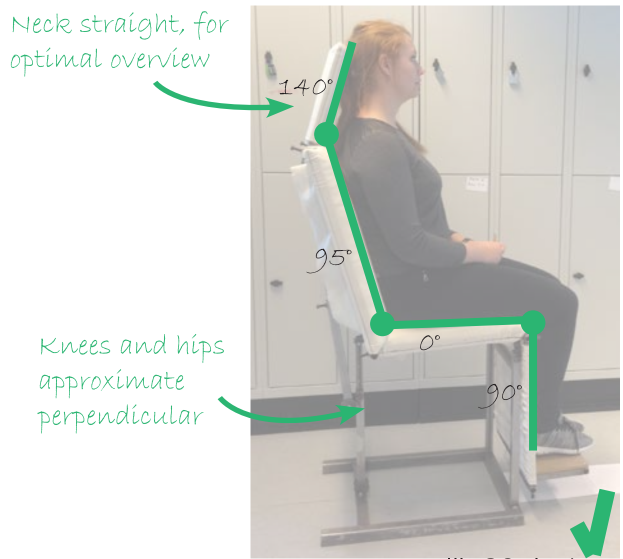
Ill. 29: Position

BODY POSITION

In order to implement the positioning of the body currently used as a coping strategy, is it important to know how the user should be sitting in the different contexts. The aim is to define exact positions in which the user is most safe. The user should be able to change position as the position will change after body proportions, this will be a default setting programmed into the wheelchair. The positions should fit into specific requirements in each contexts:

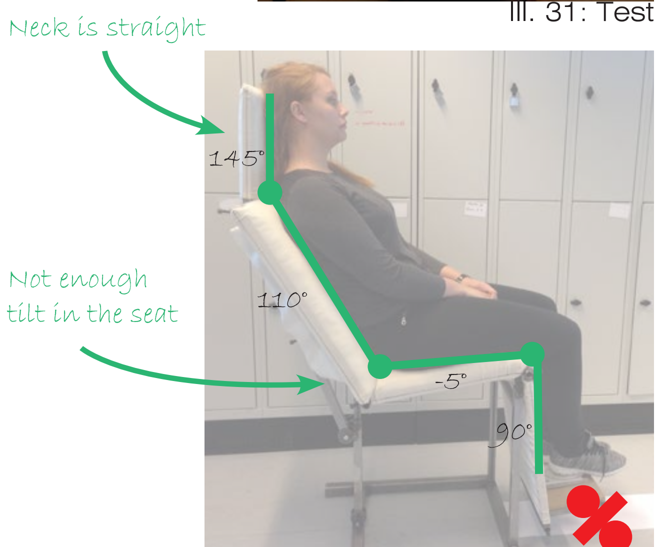
Indoor:
The user should be able to navigate in narrow spaces and have as much overview as possible. An upright position with an angle on 90 degrees which is used today and is tested to be the best. This is tested in an electrical wheelchair in a clothing store and backed up by the user group.

Outdoor:
The feeling of being safe while driving outside is affected by several parameters. Compared to an indoor environment there are more factors influencing on the electrical wheelchair outside, such as other persons, the progression of the road, obstacles and uneven terrain. In order to limit these factors the test was conducted on an even straight path with very little traffic of pedestrians, bicycles or cars. This way the test person would be able to concentrate on the experience of the position of the body and the test object could be constructed without any suspension. As the electrical wheelchair should enhance the outdoor activities and thereby be able to transport the users for longer distances, the wheelchair should have a max. speed of 15 km/h which is the maximum speed before the wheelchair becomes a vehicle [SOS]. The test was divided up into two parts.



Ill. 30: Indoor

Ill. 31: Test



Ill. 32: Seat position 1

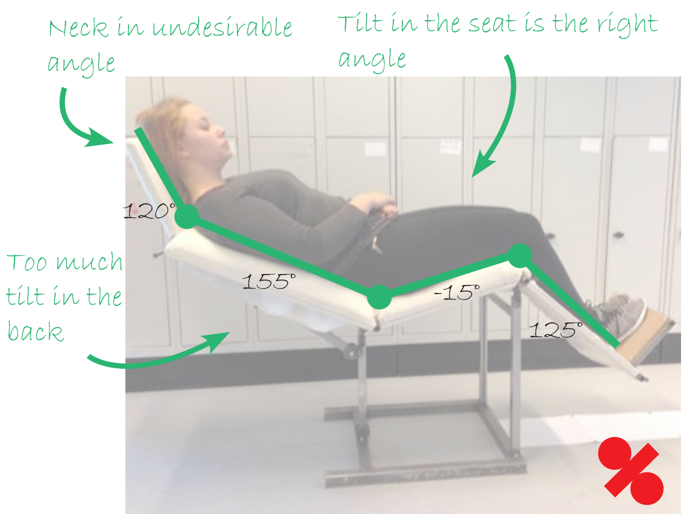
Part 1: Line of sight.
When traveling over longer distances in a higher speed, the line of sight should be moved up wards to the horizon, but it is a balance between looking upwards and being able the see things in front of the wheelchair. The "chair" was set in different positions and measured how close to the "chair" the test person were able to see. See APP 3 for data.

Part 2: Dynamic test.
The "chair" was tested at a speed of approximate 15 km/h in different settings, in order to find the right placement of the center of gravity.
The two settings from the tests were compared and turned out to be close to each other, this was expected, as the line of sight has an impact on the experience of driving outdoors. The test showed that a tilt of a few degrees has big impact on the experience.

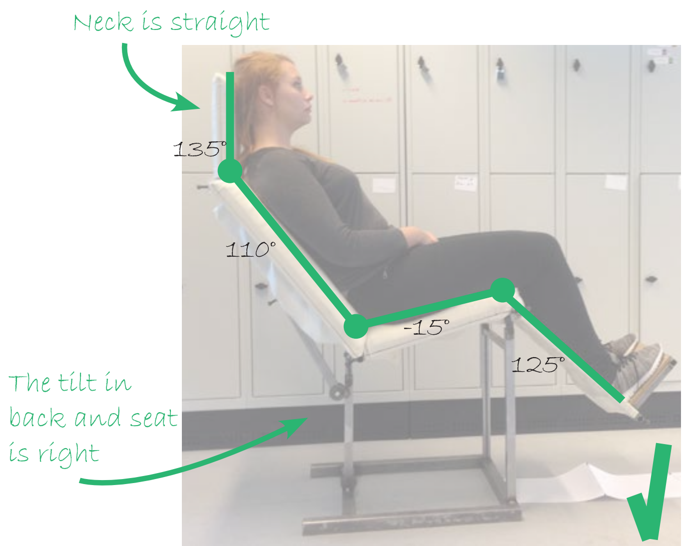
Reflection
The method of testing the position of the body in two different environments were done in order to separate as many influencing parameters as possible. Especially when testing an experience in a dynamic situation, the test will be affected by several parameters, such as the construction, centre of gravity and the surface the "chair" is driving on. The test showed a consistency between the test indoor and the dynamic test. The position of the body had a great impact on the experience of feeling safe and by changing body position the chair felt more stable. The outcome of the test is exact angles, but the exact body position will differ from person to person and should therefore be customizable

NEW WISH

- The chair should tilt the back rest and tilt the seat when driving outside.



Ill. 33: Seat position 2



Ill. 34: Seat position 3


Ill. 35: Dynamic test

STABILITY

The experience of stability will be investigated in two scenarios: The experience, when driving on uneven terrain like cobbles and while driving at a speed of 15 km/h. The aim of these tests is to clarify the connections between the length and width between the wheels. The test showed that the right proportions between the length and the width would improve the stability of the wheelchair, but the positioning of the body had larger impact of the experience of safety.

Scenario 1: driving on cobbles.

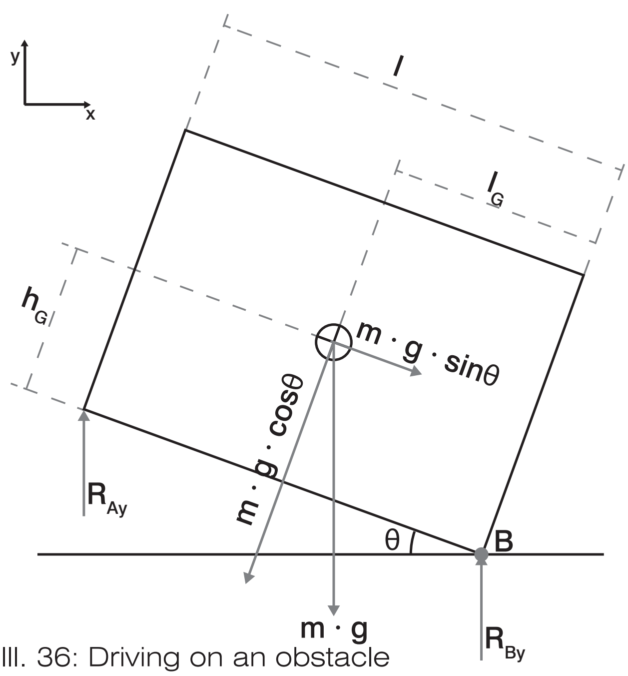
Is often very painful and demanding for a person using an electrical wheelchair and they are constantly afraid of falling out. The wheelchair is complicated to control as the movements of the chair makes it hard to move the joystick steadily. The shocks from the ground can be absorbed by suspension seen in cars or mountain bikes.

Scenario 2: Driving at a speed of 15 km/h.

There are several forces that should be taken into consideration while driving at any speed. If the wheelchair is breaking or speeds up the forces affecting the wheelchair will be placed in the length of the wheelchair. Like in cars the length between shafts (and centre of gravity) will directly affect the stability of the wheelchair. When a wheelchair or car are turning or driving on a curb with one set of wheels the forces will be placed on the side of the object, see APP 4 for moment formula. This is why fast cars are low and long. Existing wheelchair are not in risk of tipping over when using them according to the user manual. But the persons in the wheelchair do not feel safe.

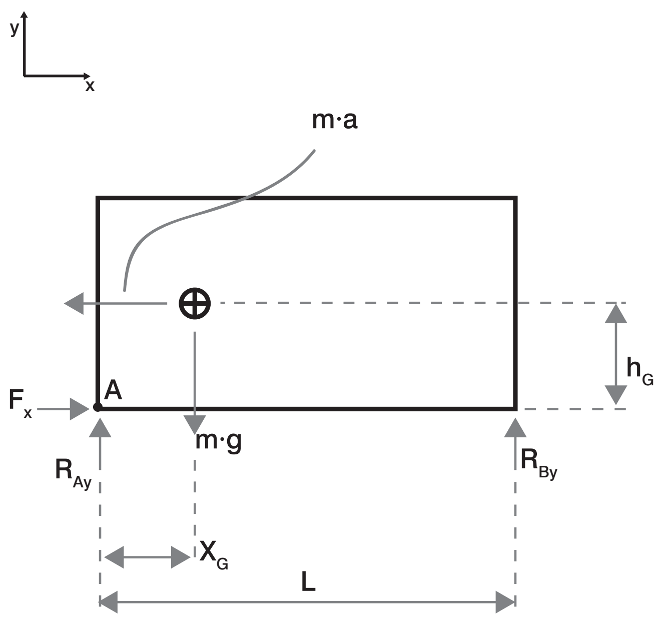
When is the test person able to feel a change in the stability?

Driving on an obstacle



Ill. 36: Driving on an obstacle

When breaking



Ill. 37: When breaking

Experiment:
The "chair" from the test of body positions was modified, in order to be able to change the dimensions between the wheels. The wheelchair is going to be developed with four wheels, as this will make it stable when climbing obstacles. In order to attempt to simulate the real the centre of gravity, the height of the seat on the test "chair" was set at the required height. The position used is the same as the position determinded from previous investigation in order to simulate a real experience. The stability while driving on uneven terrain was tested by driving over a small obstacle of 3 cm. There was some uncertainties during the test, the wheels was smaller than the required 450 mm and in order to experience a speed of 15 km/h the chair was pushed and the force was applied on the top of the backrest and not at the wheels. The length and width were tested in different combinations see APP 5.

Result:
The test were conducted with two different test persons, both of them only felt a very little change in stability when changing the dimensions between wheels. When driving with the rear or front wheel set wider than the other set of wheels, the test person felt an enhanced stability. See illustration to right.

Conclusion:
The result of the test showed surprisingly small difference in the experience. When driving with one set of wheels wider than the other set, the experience of stability were enhanced. The conclusion of the test is that the length and width after a certain point, do not affect the experience of stability in any noticeable extent. The position of the body have a much larger impact on the feeling of being safe within the chair.

Reflection
The method used for testing the experience is extremely simplified, without suspension or a realistic construction. The test were conducted in accelerating and decelerating motion, the test person did not test a steady speed, which would give a more realistic experience. The "chair" used for testing had limitation regarding placement of the wheels. It was not possible to test lengths and width between 60-94 cm and 66-96. During the experiment the test person felt no change in stability then reaching a length of 100 cm and with the limitations of the construction, it is not possible to determine the exact dimension for a stable wheelchair. The test indicates that the proportions between length and width determines the stability of the chair. As the wheelchair can not be wider than 60 cm was the test winner scaled down to accommodate this.

NEW DEMAND

- Construction: consists of 4 wheels

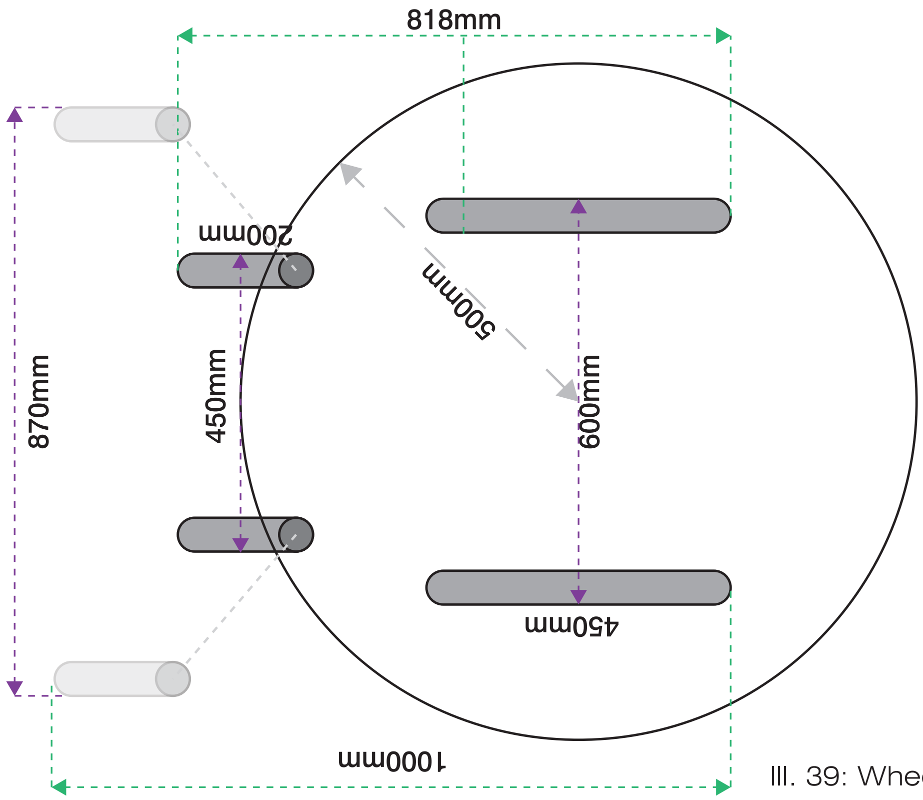
Ill. 38: Wheel test

SUM UP

By developing a wheelchair, which is able to change dimensions, the chair will be able to maintain a small turning radius, but stable when driving outside, by enhancing length and width of the wheelchair.
The test of stability provided the length and width while driving outdoor. The set of wheels which is going to unfold when driving outside have to be placed closer to the driving wheels while driving inside. The dimensions are determined by the turning radius, illustrated to the below. As shown on the illustration the supporting wheels, the ones that are unfolding, have to have a smaller width than 600mm, in order to meet the requirement of a turning radius of 500 mm. The supporting wheels will have to unfold in two directions.
As stated before the size of the wheels have to be 450mm in order to climb an obstacle of 150mm, but if the wheelchair should meet the requirement of the turning radius, the supporting wheel has to be 200 mm.It is not possible to place two sets of 450mm close enough to fulfil the required turning radius. It is assumed that by placing the driving wheels in the front, they will be able to drag the smaller wheel over the obstacle.

DILEMMA

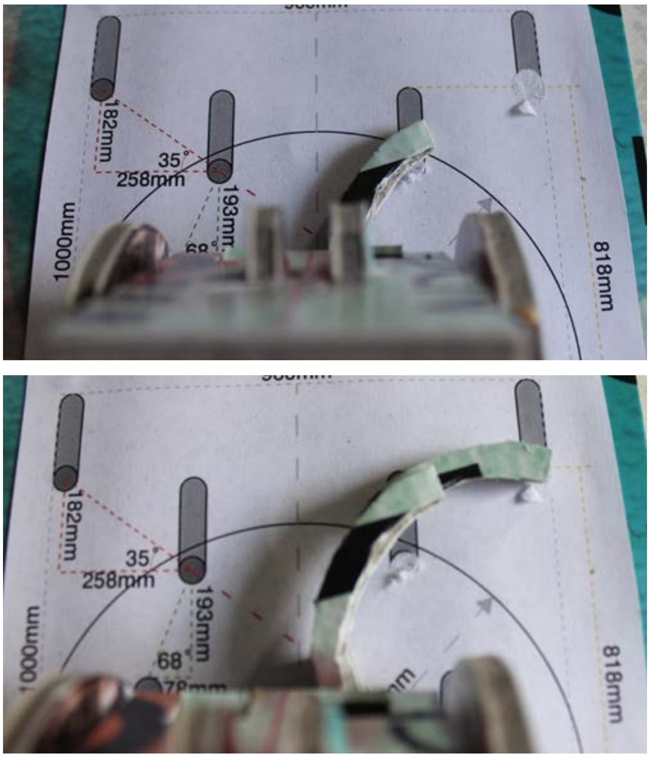
Can't fulfill turning radius with 4 450 mm wheels



Ill. 39: Wheel dimension

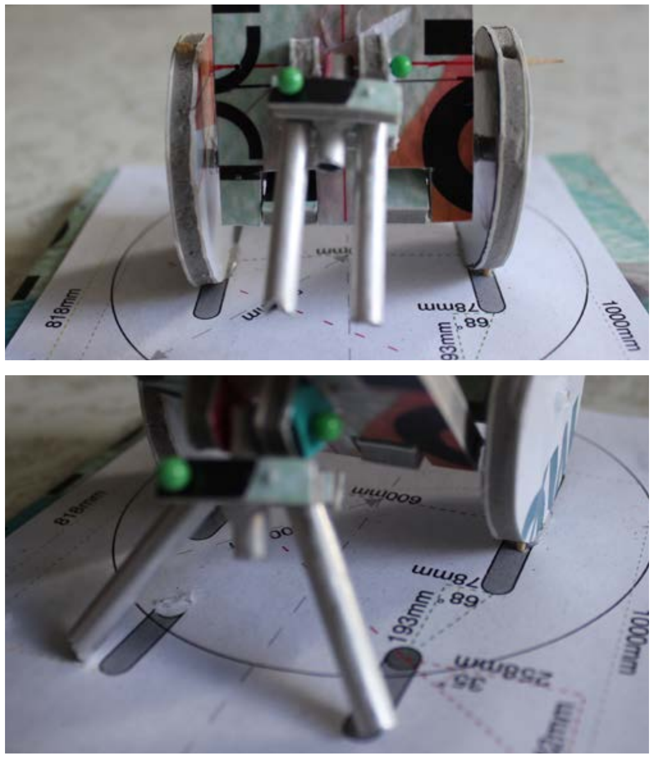
TECHNICAL PRINCIPALS

Curved telescope



Ill. 40: Curved telescope

V-Shape



Ill. 41: V-Shape

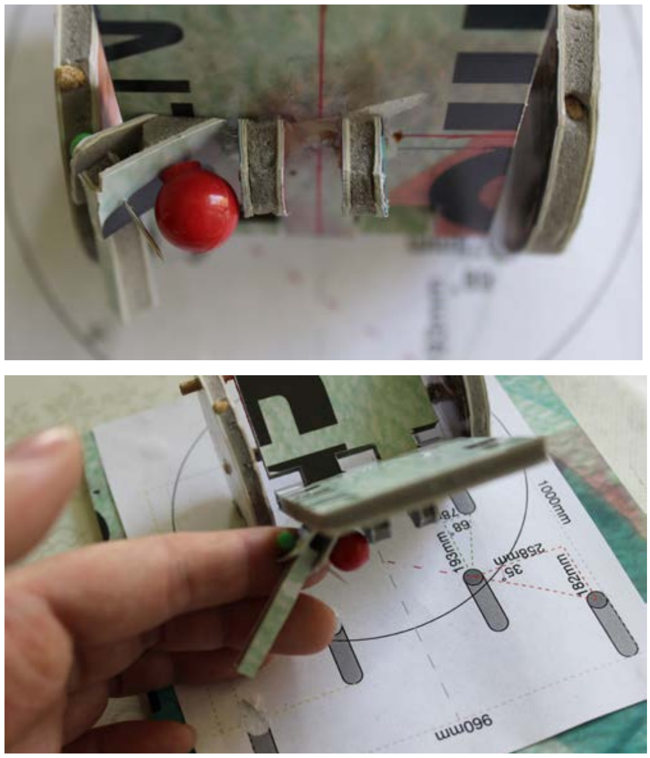
With the right curvature on the telescope it would be able to expand the rear wheels in both directions. A solution involving a telescope could be a way to solve the movement of the rear wheel, but the motion of the chair unfolding and leaning back the user is lost.

The rear wheels are mounted to the backrest. When expanding, the arm is rotated in the joint mounted on the backrest and a threaded rod is turned, rotating the arms into the right angle.
The solution includes the unfolding motion through a programmed motion in the threaded rod. The solution has a lot of force kept in a small area which might lead to a bulky construction.

Angle

Kickstand

Ill. 42:Angle



Ill. 43: Kickstand

The rear wheels are mounted to the backrest and when leaning back, the backrest and joint placed in an angel will rotate to the right width.
This includes the unfolding motion, but the lower part of the rod rotates as well. In order to avoid rotation of the rear wheel another joint with a counter rotation, has to be implemented.

The solution is inspired by a kickstand seen on bicycles. A rotation in one joint expands the wheels in both directions.
By mounting the solution on the backrest are the solution is able to maintain the desired motion and the expansion in both directions will be done by one joint.

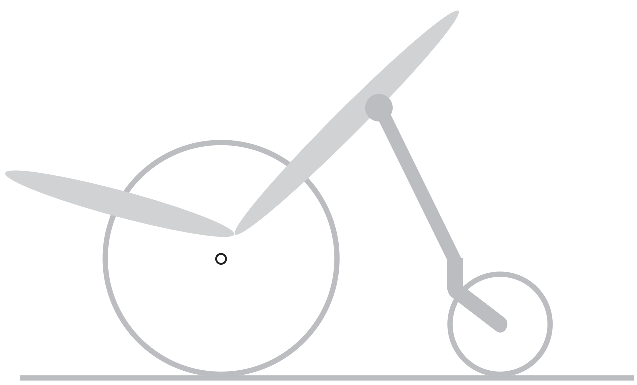
EVALUATION

The expansion in both width and length proved to be troublesome, as most solutions required several joints. As the aim of the project is to create a simple construction without unnecessary weaknesses, only two of the solutions showed potential, the telescope and the kickstand. The telescope seems like the most feasible solution, by handling minimum force and being a proven technology, but it does not have an "authentic" motion. The motion could be simulated by programming the backrest to lean back when expanding the rear wheels.

The chosen solutions are complicated and they still clash with the goal of creating the "clean" and simple electric wheelchair. By implementing another type of suspension than the traditional "car suspension", the suspension are able to keep the person in the wheelchair in the same position when driving on uneven surfaces and slopes, the wheelchair maintains the experience of safety. Suspension made for this purpose already exists in special vehicles called "Buggies".
With the implementation of the suspension, the rear wheels only has to expand in one direction which means the telescope could be a standard component and the kickstand is replaced by a rotating joint.

Ill. 44: Suspension

Ill. 45: Telescope



Ill. 46: Rotating joint

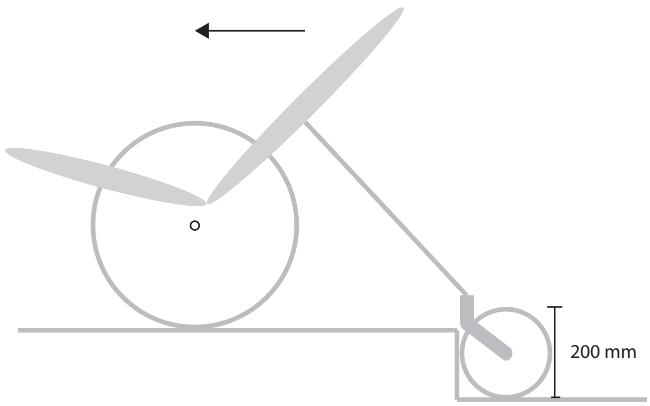
! NEW DEMAND

- Construction Telescope or roa-tiong joint

OBSTACLE TEST

In order to validate the assumption of the wheelchair being able to drag the rear wheel over an obstacle of 150mm the following experiment were conducted:
A set of 200mm wheels placed in a distance of 870mm was mounted on a rod, and dragged in the angle consistent to the height of the attachment on the back of the chair. The same test was conducted with the force applied in the height similar to the attachment of the telescope.
The person had no problem dragging the wheels over the obstacle when the rear wheels were mounted on the backrest, the force used to drag the wheel would not be an issue for the motor.
The person was not able to drag the rear wheels onto the obstacle, in the same height as the telescope.

The rotating joint is the only feasible solution, with the requirement of the wheelchair being able the climb obstacles on 150mm



Ill. 47: Obstacle illustration

NEW DEMAND

New dimensions of the wheels:
Driving wheels: 450 mm
Support wheels: 200mm
Construction: Roating joint

Ill. 48: Obstacle test

DEMANDS

During this chapter a direction of construction was set. The direction leads towards a new set of demands, which are written with green text. The experience of safety was defined by three parameters, which was condensed into the change in dimensions. The change in diemensions was made in order to enhance stability when driving outside. To avoid the experience of falling out of the chair, the wheelchair will automaticly adjust the body position of the user. During the early stages of the construction, the project were facing a dilemma, as the 450mm wheels cannot be placed closed enough to fulfil the turning radius of 500mm. Thus resulting in the driving wheels need to drag the support wheels over the obstacle. To accomplish this the rear wheels will have to be attached to the backrest in order to lift the wheels upwards. The telescope is no longer an option that can be used for enhancing the length and width of the rear wheels.

NEED TO HAVE

Construction:
- Suspension: chock absorbing.
- Obstacle height: 15cm.
- Width: 60 cm.
- Seat height: 45 cm.
- Turning radius: 50 cm.
- Driving wheels: 450 mm.
- Support wheels: 200mm.
- ~~Telescope~~
- Unfold: Roating joint.

Components:
- Battery capacity 25km.
- Speed: 15 km/h.
- Tilt in seat and backrest.

NICE TO HAVE

Construction:
- The chair should change appearance when driving outside.

Components:
- Electrical adjustments in: Back-, neck-, arm- and legrest.

Experience:
- Feeling of safety: Stability, position, risk of falling out.
- The chair should lean back the back rest and tilt the seat when driving outside.

3

Ideation number two will be presenting the work of the aesthetic direction of the product. The chapter will furthermore be presenting a reframe of the project. The current construction would not be able to fulfil the demands set for the project.

IDEATION II

IDENTITY

The objective of the following section is to put up a set of ”design rules”, which will be used to develop and evaluate concepts. Firstly the research will be an interview with two of the previous presented users in order to determine the relationship between the user and the wheelchair. The important thing during the interviews is to challenge the minds of the users to see beyond the wheelchair they are currently using. The interviewed users find it difficult being critical to the wheelchair they are so highly dependent on. By challenging the users to imagine their relationship to a wheelchair they will purchase in the future and keep the conversation on an abstract level, with as few connections to their current wheelchair as possible, the users were able to challenge their relationship to an electrical wheelchair.

The initial approach of the interview is to present five different categories:

- Car
- Shoes
- Bicycle
- Chair
- Clothes

The users pick the one of the five categories which represent their relationship to the electrical wheelchair in the best way. Five very different pictures will now be presented to the user, who picks the most attractive product. This will be the groundwork for an open discussion about shapes and styles.

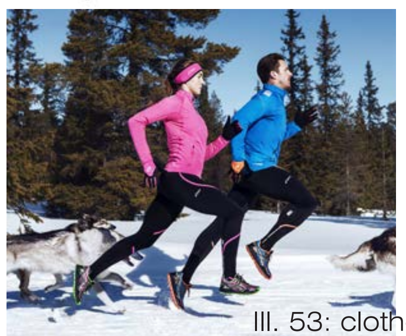
Both the interviewed do not acknowledge the wheelchair as a helping aid, it is an extended part of the body enabling them to do the same things as walking persons. It is extremely important that other people see the person in the wheelchair before the wheelchair. In the ideal situation other people would not notice the wheelchair at all. Both of the users are putting a lot of energy into compensating for the dominant looking wheelchair, by dressing in clothes in flashing colors. A wheelchair should be a part of the user, like clothes you wears on the body, but it should not follow fashion trends. “It’s like the blazer, it never goes out of fashion and you are able to combine it with the latest trend”. - Bodil

Ill. 49: Car, practical

Ill. 50: Shoe, practical

Ill. 51: Bicycle, classy

Ill. 52: Chair, luxury



Ill. 53: clothes, sporty

In outdoor use, the person should still be seen before the wheelchair, but it turns into a transportation device even though the distance is only from the parking lot into the building or to the next pedestrian crossing. The transformation between indoor and outdoor use should be safe but fast, the user does not want to wait for the transformation. The final product has to go through a double transformation:

Technical: A safe transformation from a compact wheelchair with a low turning radius to a stable transportation device.

Identity: Invisible part of the user to a safe transportation device which does not steal attention from the user.


Ill. 54: Classy

Ill. 55: Luxury


Ill. 56: Practical


Ill. 57: Sporty

REFLECTION

During the interviews it became clear that the users are using a lot of energy on highlighting themselves from the wheelchair. During the discussion the users referred to manual wheelchairs, which they saw as less dominant in expression. The outcome of the investigation is that the electrical wheelchair has to be invisible. This is not possible, but it should be further elaborated what makes products look less dominant. The whish for an "invisible" product creates a tension between the wheelchair being a helping aid with easy understandable functions and being a product not noticed by people. The cards used during the interveiws, did not provide an aesthetic direction. They were meant as a conversation starter, by providing the interviewed users which reference points. The users will not be able to contribute further in the development of the aesthetic value of the wheelchair, as they are bound to a strict impression of that electrical wheelchairs just have to look the way they do.

DILEMMA

Safety: Invisible vs. safe and protecting

INVISIBLE DESIGN

”Good design, when it’s done well, becomes invisible” – Jared Spool

In the previous chapter it was stated that the optimal design of an electrical wheelchair was one you did not notice, but how do you make an electrical wheelchair invisible?

Hearing aids

The design of invisible products is not an unknown art within design and especially practiced within healthcare and helping aid. People have a natural fear of standing out from a crowd and wishing to be noticed for their person and not their disability, regardless of the nature of their disability. The industry of hearing aids have put large amount of money into making hearing aids disappear. The development of the hearing aids happens as the technology evolves and the suppliers are able to make smaller devices, but they are also using strategies in order to make the device attract less attention.

Visible

Color resemble skin tone

Ill. 58: Colour

Follow the shape of the ear

Ill. 59: Shape

Hide behind the ear

Ill. 60: Behind ear

Hide in the ear

Ill. 61: In ear

Invisible

Manual wheelchair

The focus of making manual wheelchairs disappear, unlike the hearing aid, they are not (yet) attached to the body of the walking disabled. A number of parameters are hard to work around when designing a wheelchair. The fact that the user has to be sitting and therefore is lower than standing people and the fact that their legs are wheels. Some of the strategies used when designing hearing aids are also being practiced within the design of manual wheelchairs, such as mimicking shapes from the body and cut down on construction, in this case the frame of the wheelchair.

Visible

Visible joints

Ill. 62: Joints

Minimise construction

Ill. 63: construction

Invisible

If you can't hide it, highlight it

A way of coping with helping aid the person cannot hide is to make a statement of it, a personal trademark.
Another example is the walking cane, with simple means a designer is able to make a walking cane a luxury product.

Ill. 64: Hearing aid

Ill. 65: Wheelchair

Ill. 66: Walking cane

Ill. 67: New walking cane

REFLECTION

An electrical wheelchair is a combination of previous analysed examples. The electrical wheelchair is highly comparable to the manual wheelchair, but the design and construction of the electrical wheelchair is limited by the development of technical parts such as dimensions of the batteries and motors. When developing the electrical wheelchair it should be taken into account that the progression of the mentioned parts are happening fast. It is not unrealistic to assume, based on previous development of batteries the size would be the half in 3-5 years.

! NEW DEMAND

Seating unit does not change in shape or seize

SUM UP

The electrical wheelchair has two different identities, it has to be "invisible" inside and be a safe transportation device while driving outside. It is a possibility to further enhance the transformation of identity by increasing the size of the seating unit. This is not a desirable solution as motion attracts attention and the first priority of the users, was to attract as little attention as possible, even outside. The transformation should only be done by expanding the length of the wheelchair and tilt the user back.

The strategies used in the design of the investigated product categories are condensed to a set of design rules which will be used in the further development of the project:

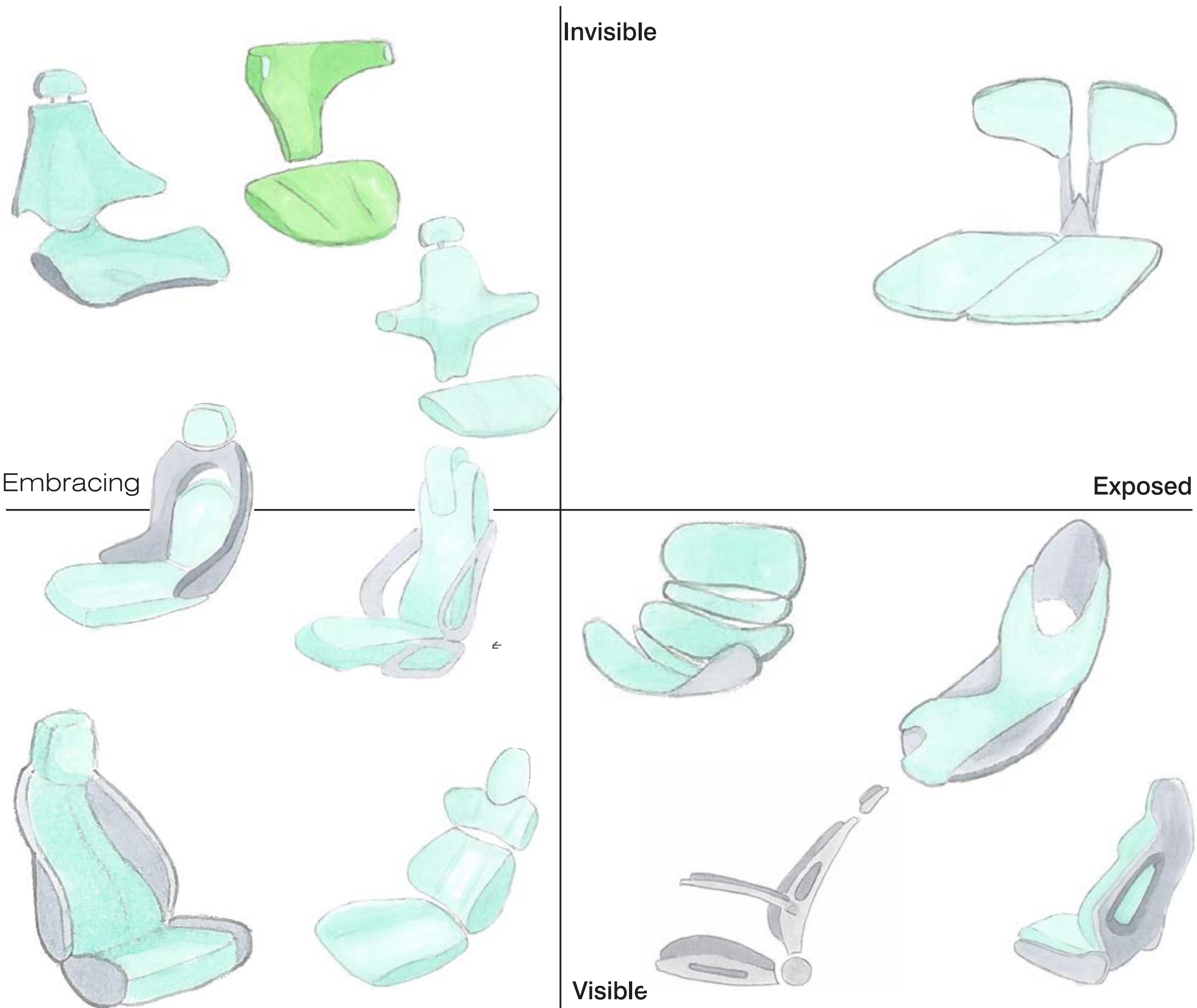
- Minimise visible construction
- Minimise dimensions
- Avoid visible joints and adjustments
- Mimic the shape of the body
- Use flashy colors only when highlighting desired details.

IDEATION

The safety is mainly provided by the positioning of the user, in order to minimise the experience of falling out of the chair and to lower the centre of gravity. It was decided to keep the number of moving part on a minimum in order to reach the right balance between an outdoor safe transportation device and a mobility aid not noticed by other people. A way of enhancing the feeling of safety,is to further avoid the user's experience of being able to fall out of the wheelchair. This is done by creating an embracing seating unit, which supports the body. The aim of the ideation is the creation a solution map with degrees of invisibility and embracing shapes, by visualising solutions it is possible to find the seat matching both contexts.

DILEMMA

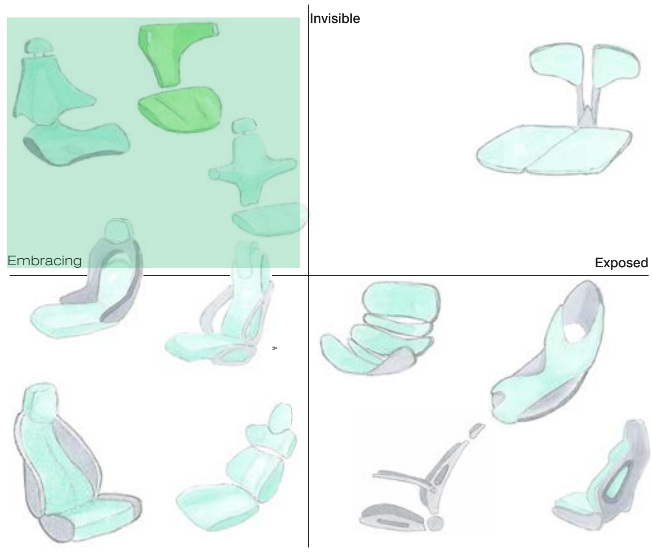
Embracing seat unit vs. visibility



Ill. 68: Seat module

EVALUATION

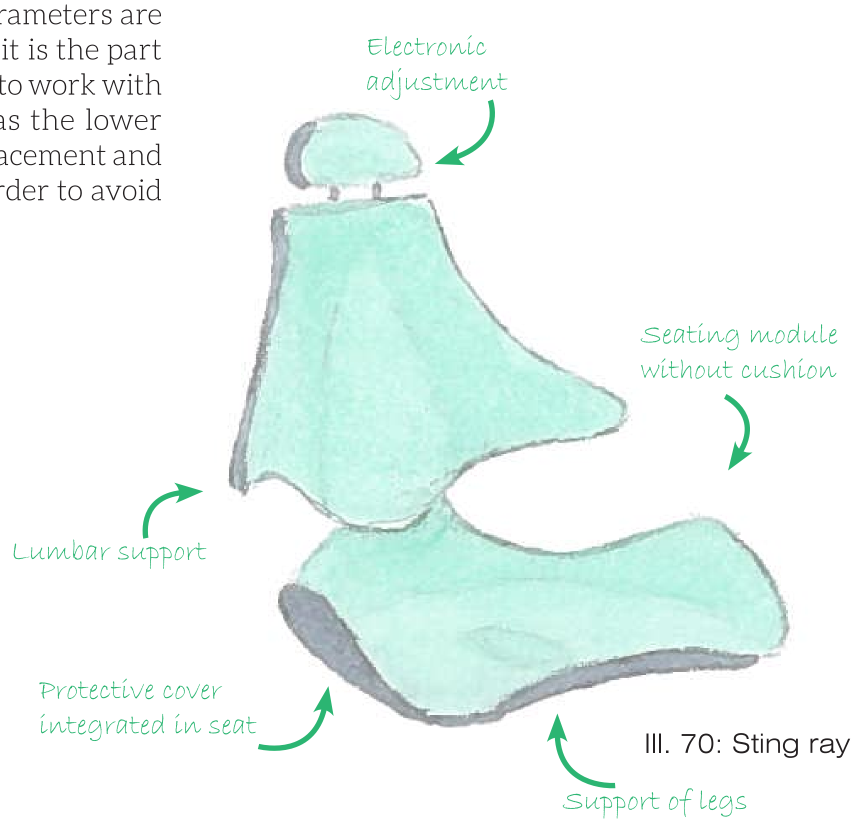
The ideal balance between the invisible and embracing seat will be placed in the upper left corner of the solution map. The project group saw potential in the sting ray shaped seating unit and this shape will be developed further in physical models in order to make it fit the proportions of the human body. Furthermore there should be implemented armrests matching the expression of the seat and the back rets.



Ill. 69: Focus

Reflection

Working with the aesthetic of the wheelchair is divided into tracks, in order to avoid delays in the development of the product. As the aesthetics of lower part of the wheelchair are restricted by the size, shape and placement of components, this track is paused until the previous parameters are decided. The shape of the seating unit is the part of the wheelchair where it is possible to work with the aesthetic expression the most as the lower construction are bound by specific placement and has the be placed within a shell in order to avoid dirt in the components.

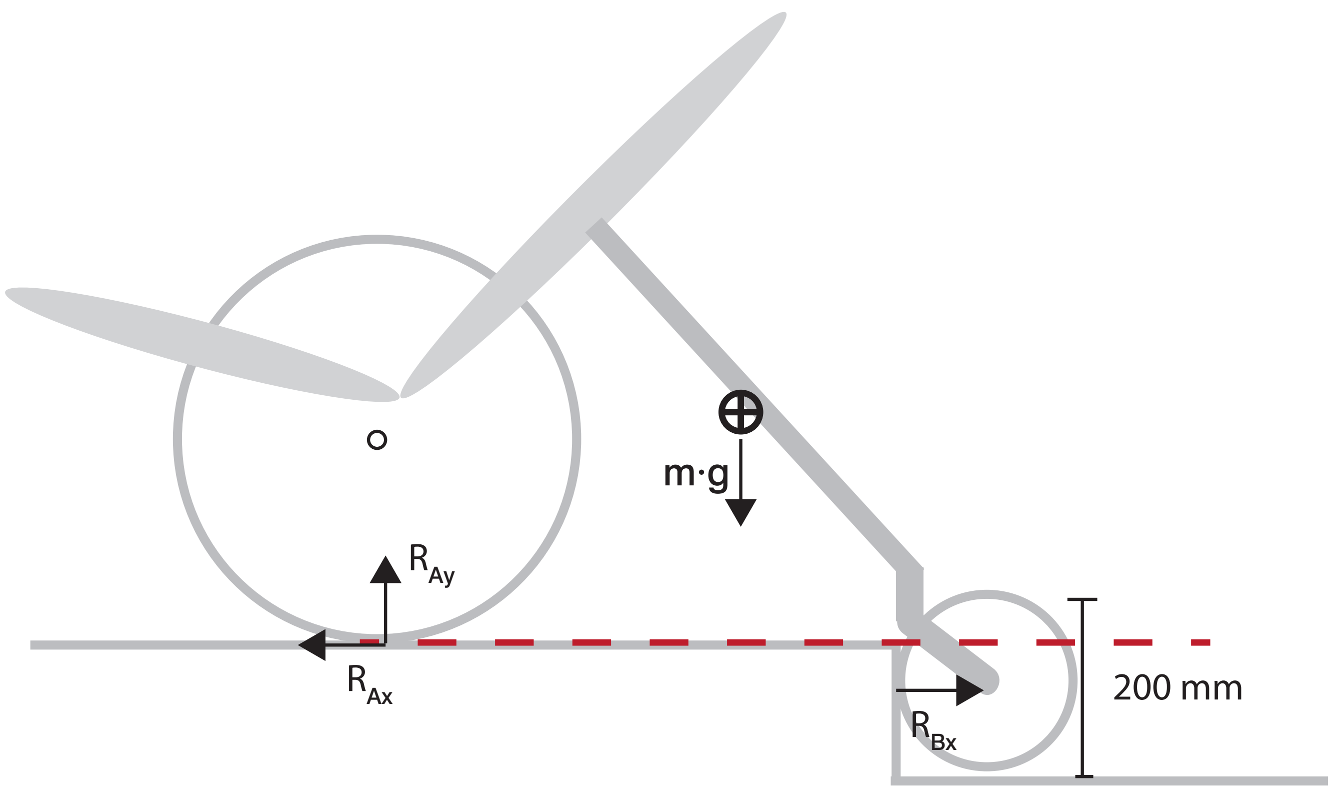


Ill. 70: Sting ray

THEORETICAL OBSTACLE TEST

In order to validate the practical test of 200mm wheels being able to be dragged over an obstacle of 15 mm the team made a diagram showing the forces influencing on the wheelchair. The assumption of a force dragging the wheel in an upwards direction proved to be wrong as the force is delivered by forward motion of the driving wheels. As the torque is at its highest when the centre of the wheel is in the exact height of the obstacle (150mm), the centre of the wheel has to be higher than the obstacle in order to be able to be dragged onto it. This means the rear wheels have to be at least 310 mm high. Wheels of this seize are not able to be placed close enough to the driving wheels, which results in a bigger turning radius than 500mm.

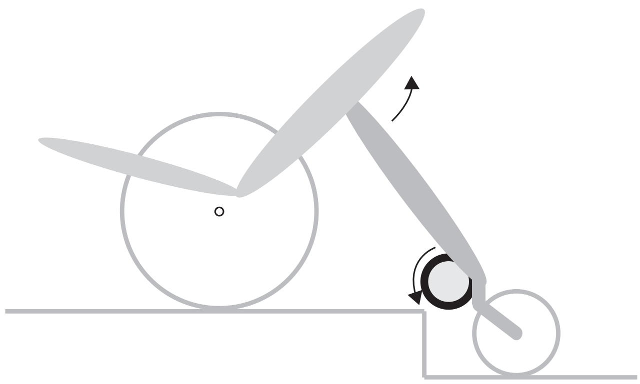
The solution of the problem would be to find a way of lifting the 200mm wheel 11 cm from the ground.



Ill. 71: Obstacle test

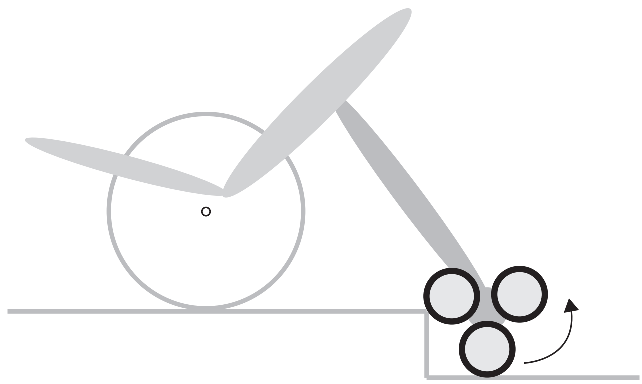
TECHNICAL SOLUTIONS

Wheel



Ill. 72: Wheel

Three Wheels

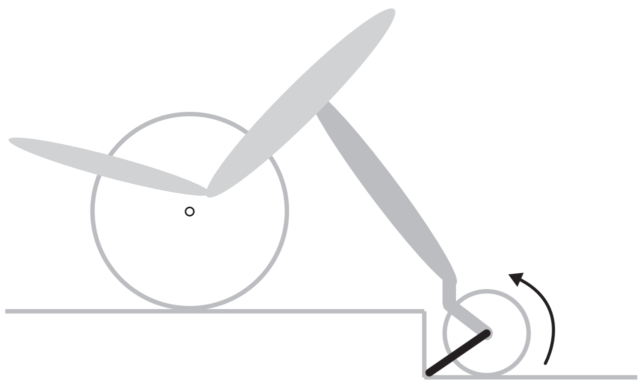


Ill. 73: Three wheel

In order to raise the rear wheels onto the obstacle one or more smaller wheels could be mounted close to the main wheel. When approaching an obstacle the smaller wheel, which is placed higher will meet the obstacle first and lift main wheel to a height of 160mm and the wheels can be dragged over the obstacle. It is a technological simple solution, but it takes up a lot of room. This will have an impact on the desired simple aesthetic expression of the construction, the additional wheel could be incorporated in the aesthetic solution of the wheelchair. The secondary wheel should have a curtain seize dependent on where the wheel should be mounted and no matter seize and placement, this will conflict the construction when the chair is driving inside.

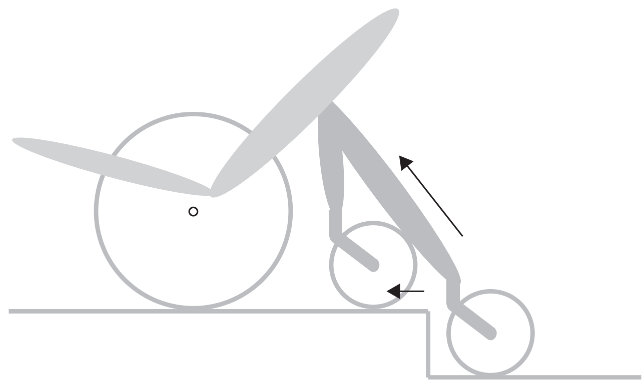
When approaching the obstacle the lower wheel will be stopped by the obstacle and a set of three wheels will rotate. The construction should at least have a diameter of 250mm. The is a chunky solution, which will be hard to work with in terms of aesthetic.

“Stick”



Ill. 74: Stick

Walk



Ill. 75: Walk

By mounting a “stick” by the wheel, the stick will meet resistance from the obstacle and rotate. The wheel will be lifted the 60mm required. This solution is undesirable, as the wheelchair will meet obstacles in varying heights. When meeting an obstacle lower than 6 cm the wheels will drop in free fall.

A technologic demanding solution where each wheel will be lifted onto the obstacle individually, by a telescope that shortens the length of the arm and a joint rotates the wheel mounted on the arm. One of the wheels will be stabilizing while the other one is in motion. The solution requires a lot of censors and programming and the time spent on climbing an obstacle is significant prolonged. This is not a desirable solution.

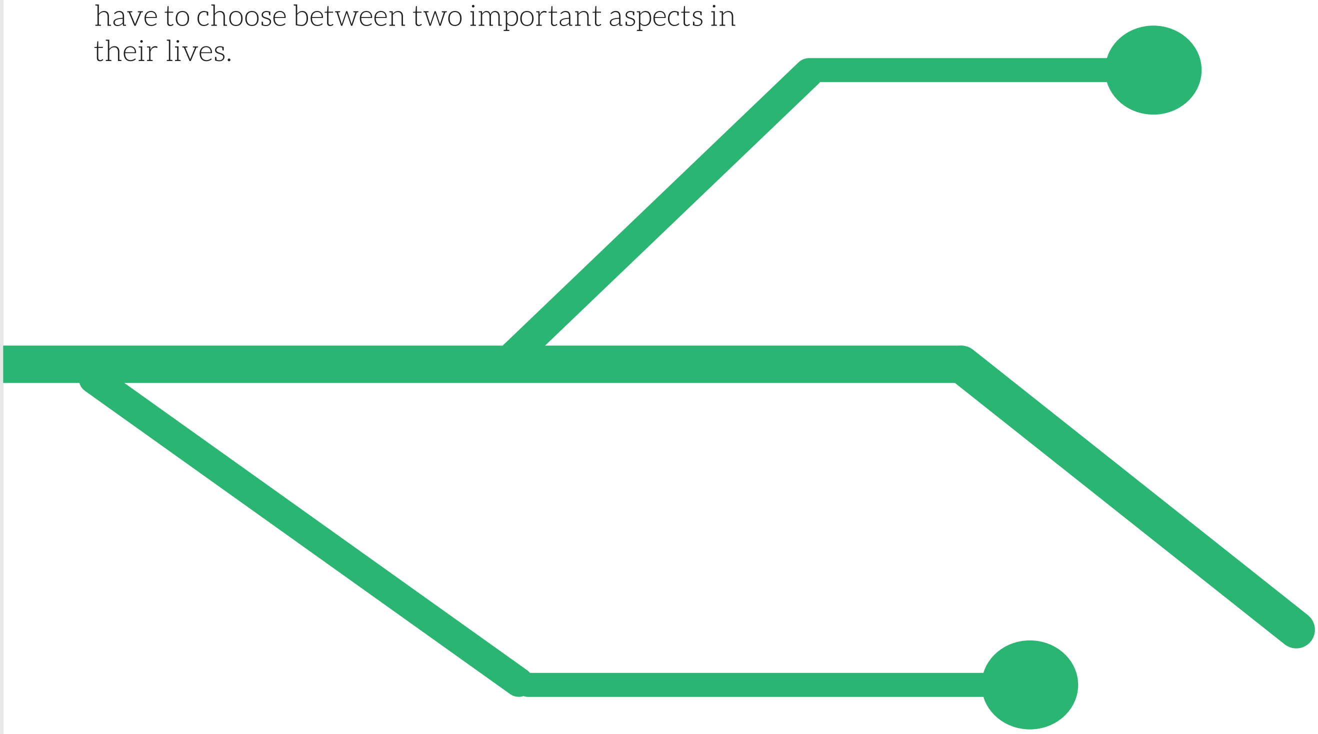
PROJECT DIRECTION

None of the previous solutions proved to be desirable, they were all complex and separated solutions added to the original construction. They were all able to solve the challenge of climbing the obstacle, but the wheelchair do not fulfill the wish of developing a simple construction. The secondary goal of this project is to challenge the construction of existing wheelchairs, which is characterized by implementing separately constructed solutions without integration of the original construction. By choosing a solution hard to incorporate into the original construction, the project will have to give up that wish.

A second solution would be to assume that it will be impossible to develop a wheelchair capable of turning around within one meter and climb an obstacle of 15cm. The demands of the ability to climb an obstacle could be lowered to a competing height of 9cm and settle with the simple “clean” solution, which is already an improvement, compared to existing wheelchairs. By doing this the project,will not improve the user’s situation, they would still have to choose between two important aspects in their lives.

The third solution would be to step back in the process of the project and try to come up with a new solution capable of fulfilling both requirements. By doing this the project would be significant delayed and there would be no guarantee of finding a more feasible solution than the current one. Furthermore the project team had to take into consideration that they might not reach the preferred level of detail of the solution.

When working with development of new products the design process might lead to dead ends, where a decision of accepting the current solution to be the right one and make the compromise or go back and explore another direction, which might lead to the exact same conclusion. The desire of enhancing life quality and challenge the current competitors was defined from the launch of the project, therefore the team chose to step back in design process.



4

This chapter will present the final concept of the electrical wheelchair through scenarios, placement of components and mock up models

IDEATION III

NEW TECHNOLOGY

The wheelchair being able to lift its rear wheels onto the obstacle, from the last ideation generated the idea of implementing gyroscopes The most challenging part of the solution would be to balance the chair while lifting the wheels, by implementing a gyroscope, the wheelchair would be able to balance itself and both of the wheels could be lifted at the same time. There are different kinds of gyro technologies, which have matured enough to be a feasible solution in terms of price. By gyro stabilising the wheelchair, it will no longer be necessary to drive on four wheel indoor, which is radically minimising turning radius, as the wheelchair is able to turn around its own axis.

The gyro technology was invented in 1743 as a spinning top used to locate the horizon on ships in foggy weather. Two types of gyroscopes have potential regarding implementation the construction of an electrical wheelchair[GYR]

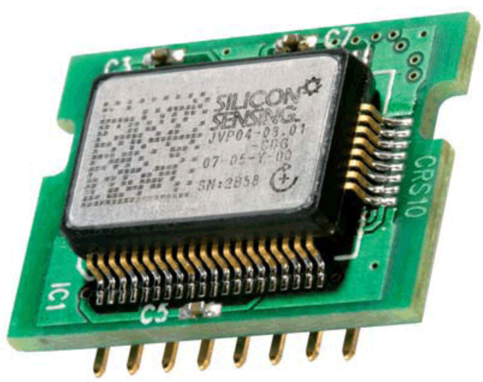
A mechanical gyroscope consists of a flywheel around a spin axis, this flywheel will rotate and counter external torque and keep the wheelchair in an upright position [GYR]. This technology is used in a vehicle developed by Lit motors APP 6 illustrates the function of the mechanical gyroscopes. The gyroscope should only run while driving indoor and climbing obstacles.

A gyro sensor is only able to measure angular movement of the wheelchair. It is based on the same principal of rotation, but in much smaller scale. It does not have to be a flywheel rotating but a vibrating silicon plate will be enough to detect a change in direction [MEM].

Selection:
The mechanical gyro is able to stabilise the wheelchair, but a mechanical gyro is heavy, expensive and takes up a lot of room. The stabilisation with gyro will as mentioned only be used when driving indoors and climbing obstacles. w motion and the safety while using the method of stabilising should be elaborated.

Ill. 76: Ibot 4000

Ill. 77: Genny mobility



Ill. 78: Gyro sensor

DEMANDS

The decision of solving the challenge of overcomming the set height of an obstacle have caused delays in all tracks of the project. The integration of the seating unit and overall aesthetic value cannot be developed before the final construction is complete. The new technology do not radically change the components or the construction, other than the implementation of the gyro sensors. When raising the rear wheels, while driving inside, the front wheel does not have a limitation in size anymore. In order to create an expression similar to the typical manual wheelchair, the driving wheels will now be 600 mm high. During the last session of ideation a set of design rules were defined in order to develop a wheelchair, not noticed by other persons. The rules will still be used when evaluating the expression of the wheelchair. The wheelchair will still create some attention as it does not look like the current electrical wheelchairs.

NEED TO HAVE

Construction:

- Suspension: chock absorbing.
- Obstacle height: 15cm.
- Width: 60 cm.
- Seat height: 45 cm.
- Turning radius: 50 cm.
- Driving wheels: 600 mm.
- Support wheels: 200mm.
- Unfold: Roating joint.
- Seating unit do not change in shape or size.

Components:

- Battery capacity 25 km.
- Speed: 15 km/h.
- Tilt in seat and backrest.
- Gyro sensors.

NICE TO HAVE

Construction:

- The chair should change appearance when driving outside.

Components:

- Electrical adjustments in: Back-, neck-, arm- and legrest.

Experience:

- Feeling of safety: Stability, position, risk of falling out.
- The chair should lean back the back rest and tilt the seat when driving outside.

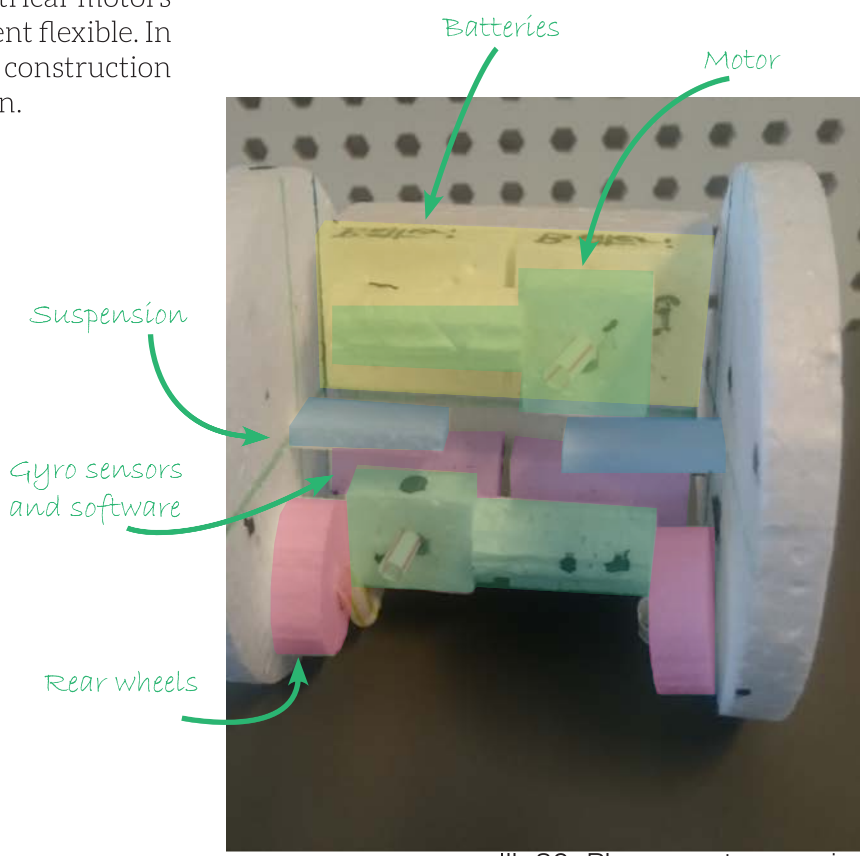
Aesthetics:

- Minimise visible construction.
- Minimise dimensions.
- Avoid visible joints and adjustments.
- Mimic the shape of the body.
- Use flashy colors only when highlighting desired details.

PLACEMENT OF COMPONENTS

The components used for electric wheelchair do not differ much from existing chairs. The implementation of the gyro will be done through a set of small gyro sensors connected to a computer. The large components have a direct impact on the shape and aesthetic expression of the wheelchair. The components should be placed in the most space efficient way under the seat, in order to hide them and to keep the centre of gravity in the centre of the chair. The placement of the seat should match the person's centre of gravity the sum should be placed in the centre of the chair. The largest components of the chair are the batteries and the motors, minor components, such as the computer which connects the joystick to seat adjustments and wheels, can be placed where space allows it. The components are placed as shown in the diagram to the right. The components are able to fit right under the seat including the suspension which are attached in the centre of the wheels. The motors cannot be attached directly onto the wheel because of the suspension, instead a gimbal will transmit the rotating motion from the motor to the wheels. The batteries are connected to the electrical motors with cords, which makes the placement flexible. In order to evaluate the placement, the construction should be made in a mock up version.

Ill. 79: Placement of components



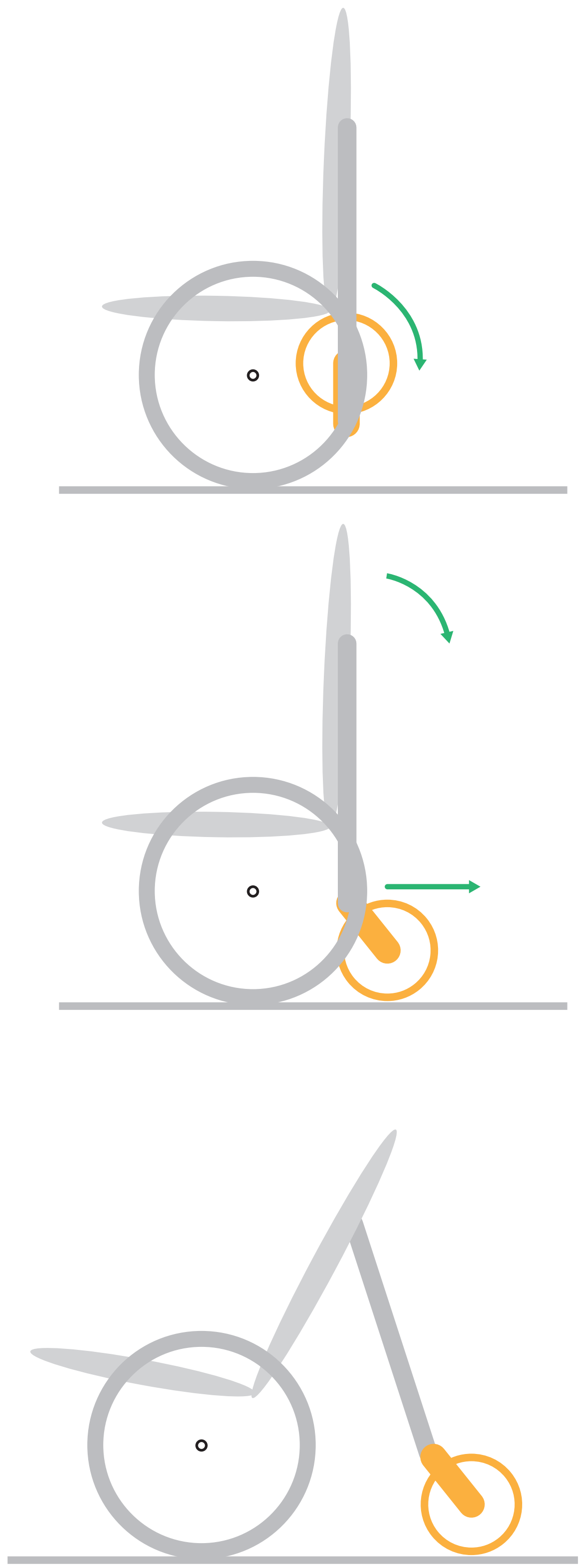
Ill. 80: Placement overveiw

UNFOLDING

While driving indoor the rear wheels should be hidden, the optimal placement of the wheels will be under the seat of the wheelchair. In order to synchronise the motions of the user being leaned back and the unfolding of the rear wheels, the wheels are mounted on the backrest. The arm is mounted to a rotation joint that will expand the length of the wheelchair, the arm will furthermore have a joint above the wheel in order to be able to place the wheel under the seat. When unfolding the lower joint rotate until the wheel has contact with the ground, then the gyro will turn off. The upper and lower joint will now rotate. The upper, in order to expand the length and the lower in order to expand the length of the arm.

Reflection

The way of unfolding the chair has a complex choreography by adding the joint above the wheels and the joint makes the construction of the rear wheels look like they are about to break. Each wheel is mounted individually on the backrest, this might cause some stability issues, relating to forces applied on the side of the rod. It could be solved be connecting the two unfolding arm, this will result in a more heavy looking construction.

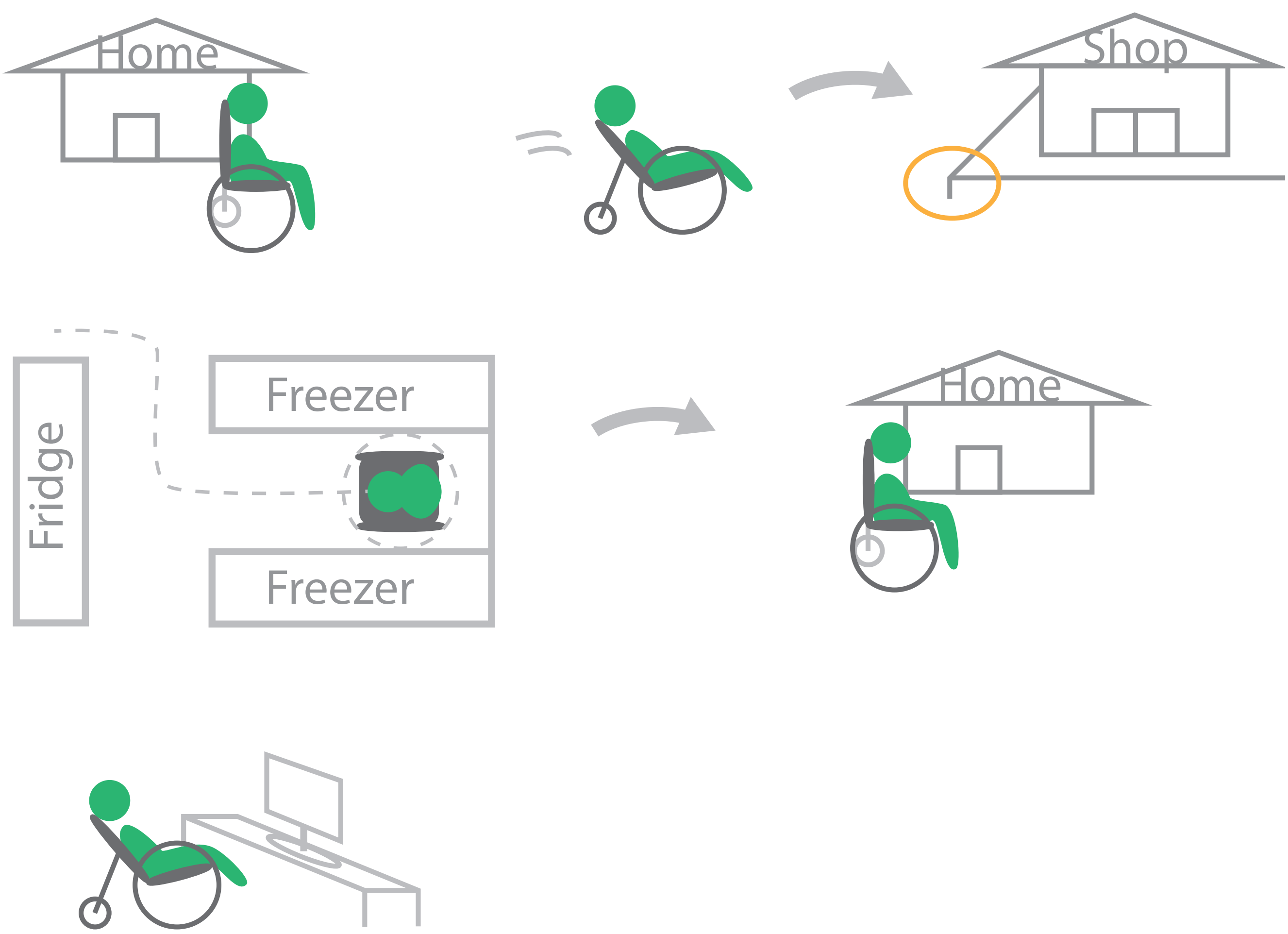


Ill. 81: Unfold

SCENARIOS

As stated before, the gyro will only be turned on while driving indoors and climbing obstacles in order the keep the power consumption as low as possible. In order of safety the wheelchair have a speed limit of 5 km/h when driving inside, it is the same speed as most electrical wheelchairs today. The joystick should be more sensitive when driving inside than outside and by dividing the use of the chair up into an outdoor and indoor setting the sensitivity of the joystick will automatically adapt with the change in speed limit.

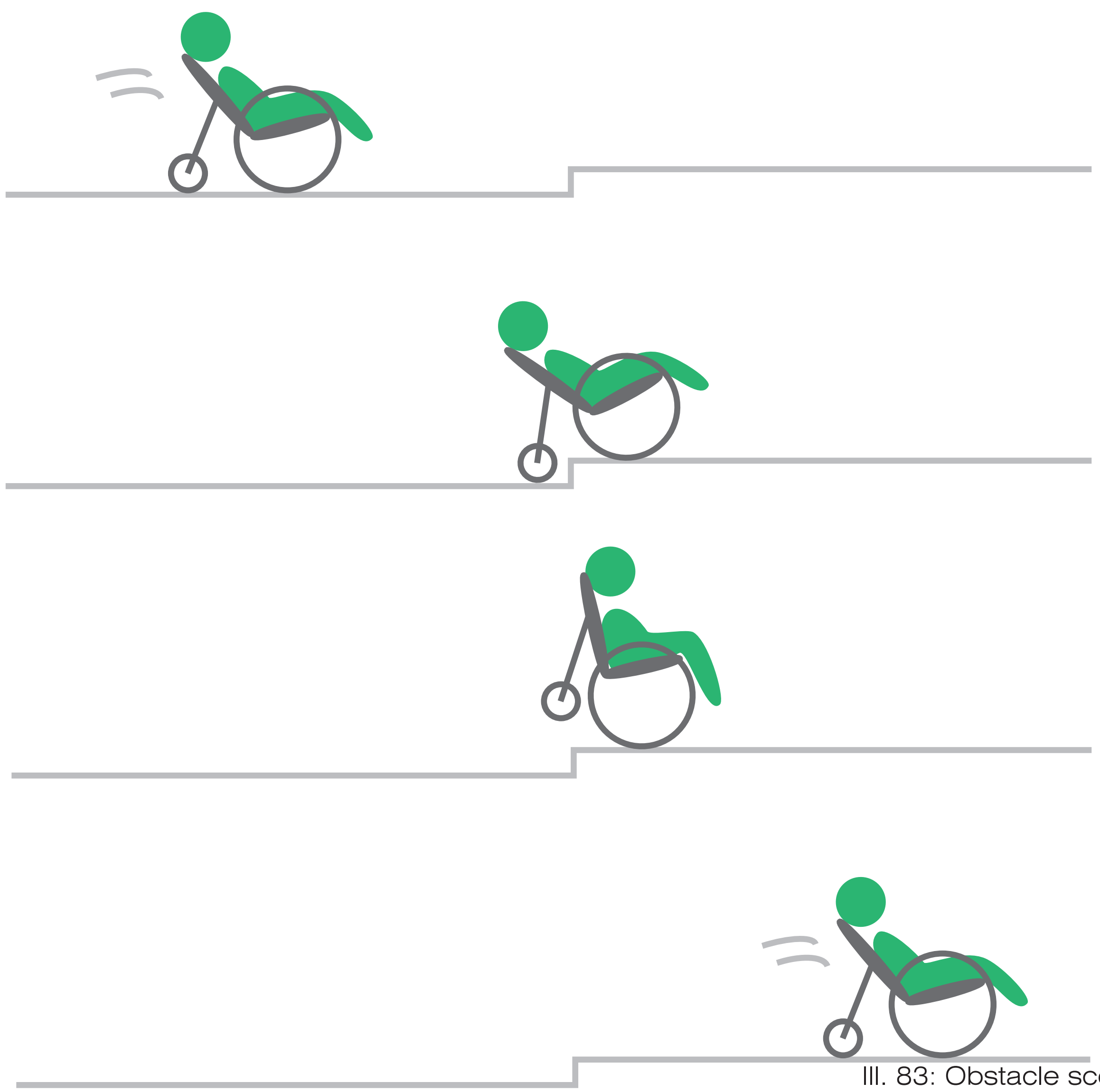
When going out for grocery shopping Dave drives outside, the wheelchair will unfold the wheels and the chair is now able to drive with a speed of 15 km/h. When going into the store the gyro will turn on and Dave raises the rear wheels, the wheelchair will progress on two wheels, with a turning radius on 300mm he will be able to manoeuvre in the narrow paths in stores.
When Dave is done with the shopping he unfolds the chair outside the store and drives home. When going inside the chair goes back onto two wheels until Dave stands still for more than 10 sec or he turns on a sleeping mode. By doing this the chair will unfold its rear legs, the chair will not take up more room than existing electrical wheelchairs, in this mode. The sleeping mode should also be used when moving in and out of the chair.



Ill. 82: Scenario

OBSTACLE

When approaching an obstacle, the front wheels will climb the obstacle and the gyroscope will detect if the curb is too high for the rear wheels to climb. When the obstacle is too hight, the chair will stop with the front wheel on the curb, turn on the gyroscope and raise the rear wheels. The chair drives forward and the rear wheels are being lowered into the previous position.



Ill. 83: Obstacle scenario

Reflection

The time of the transformation has crucial impact on the experience of driving the wheelchair. The person within, the wheelchair should not wait too long for the transformation to be happening. In order to find a time frame of transformation, existing adjustments were used as reference. Raising the seat height to its highest took 20 sec in the chair by Wolturnus A/S, this is the maximum amount of time the user should wait for the transformation, as 20 sec. feels like a long time when a persons is waiting. The transformation should not be too fast either as this would be very uncomfortable.

The scenario of climbing curbs is very complex and time consuming as this climb will be within the same timeframe as the transformation. The scenario should be reworked.

Ill. 84: Time test

MOCK UP 1

In order to evaluate the placement of the components and work with the aesthetic of the seating unit a mock up model was made of the chair. The model gives an impression of proportion which is not possible to capture in scaled models, sketches or 3D models. The components were not noticed from a standing position, but the suspension was visible. One of the criterias when trying to hide a product was to avoid visible construction or technical components. The suspension would be less visible with a person in the chair.
The "sting ray" sketch showed a lot of potentials when evaluated, but it did not support the proportions of a body. The backrest should as a minimum support the shoulder blades as back support is needed when the users are leaned back. The first mock-up of the backrest was inspired by the curves of the "sting ray" but matching the proportions of the body. The seat fitted the right proportion without the separation of the legs, in order to keep this the structure of the seat, it will have be produced specific for every user.
The construction of the rear wheels seems too fragile including the size of the wheels. The construction should be reworked.
The curvature in the back of the seat leaves the construction and components visible the seat should meet the backrest in the back of the seat.
The backrest supports the back in the right way, but it have lost the overall shape of the "sting ray". It should be reworked in order to get closer to the concept from the drawing.


Ill. 85: Unfolded


Ill. 86: Balance


Ill. 87: Components

MOCK UP 2

The seat is corrected, but by leaving out the curvature in the back it lis still missing the "sting ray" touch. The curvature of the sides is not satisfying yet, this will be corrected when CAD modelling. The overall dimensions are right of the seat and the backrest, the curvature of the seat and backrest have the right height. The detailing of the curvatures will be done in 3D.

In order to investigate the right proportions between front and back wheels were made and set in the position of the unfolded length. As the construction of the unfolding arms was not reworked the evaluation was only based on the proportions. The chosen wheel seize of 350 mm was based the impression that 200mm wheels being too small compared to the driving wheels and wheels of 400mm being too large. By choosing a wheel seize of 350mm the wheelchair will now be able to climb obstacles of 150mm without raising the rear wheels. The seize of the rear wheels will not be an issue as long as they do not touch the ground, when driving on two wheels inside. The larger wheels will be more visible, but by making this compromise, the wheelchair does not change the current behaviour of the user when approaching an obstacle.

The current suspension does not make it possible to place the rear wheel of this size under the seat.

Ill. 88: Components

Ill. 89: Components

Ill. 90: Components

NEW DEMAND !

Support wheels: 350mm

5

The following chapter will present the final construction and specify the suspension. The scenarios specific for the functionality of the gyro senses will be illustrated through flowcharts. Finally the chapter will present the final aesthetics and business case.

DETAILING

SAFETY

The project is worked around the success criteria that the user within the chair, is feeling safe. When driving outside the user does no longer have to approach an obstacle directly, the suspension will provide a safe and stable climb of any obstacle within 150mm height. By implementing a solution where two different sets of gyroscopes are balancing the chair on 2 wheels, when driving indoors, the user will have to rely on safety incorporated in the chair. A chair driving on two wheels does not necessarily look safe, specific scenarios is crucial in order for the user to feel safe when driving in a wheelchair on two wheels.

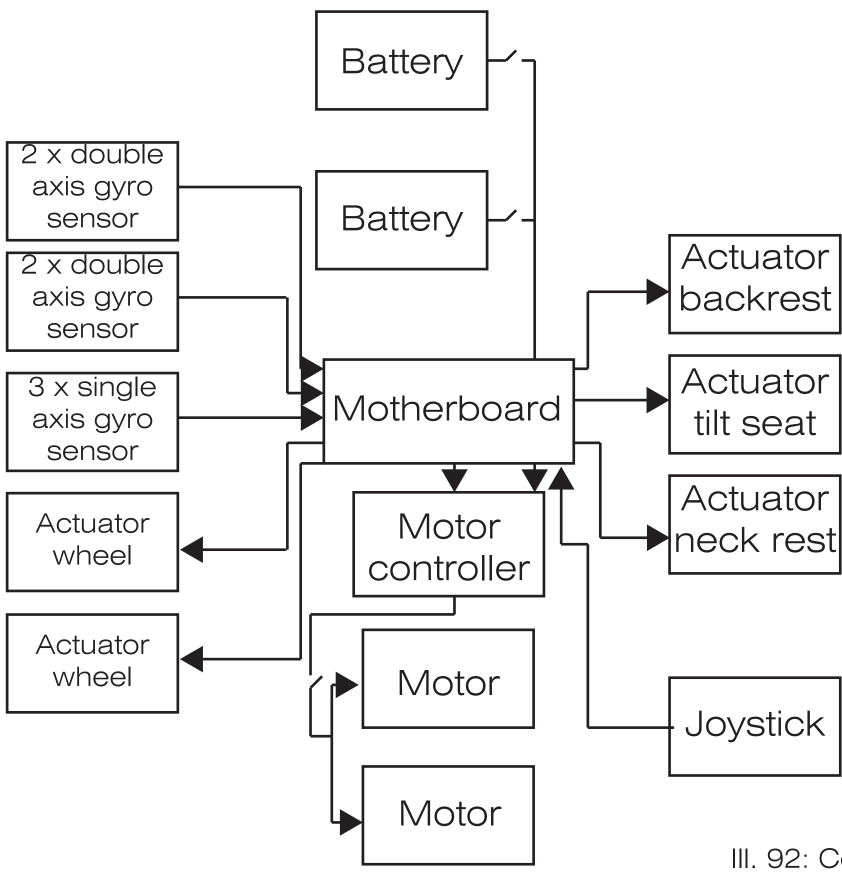
- Sensor breakdown: The chair should still be functioning
- Getting in and out of the wheelchair: The wheelchair must be stable.
- The user in the chair suddenly lean forward: No risk of the wheelchair tipping
- Standing still on two wheel: When standing on two wheels, the wheelchair should not drive back and forth in order to keep balance.
- Safe transformation: A new way of unfolding the chair, as the previous was not as fluent as wished for.

Ill. 91: From bed

COMPONENTS

In order to understand which safety measures are implemented in the system of the electrical wheelchair, an overview of the components were made. A technical system like this can be made in different ways according to the chosen components. The following section will briefly describe the main components needed in a self-balancing wheelchair. To keep the production price as low as possible the components within the electrical wheelchair should be standard components. Several suppliers specialise in selling the control unit, the joystick and the main computer in sets. These sets would be able to control the different actuators for seat adjustments and unfolding of the rear wheels. Most control processors are able to translate the feedback from the gyro sensors, this is done in microchips in Lego mind storm and in Arduino boards. Standard computers manufactured by companies specialised in selling control units for electrical wheelchairs, might not be built to revise feedback from gyro scopes. By purchasing a microprocessor to transform the feedback from the sensors would enable the computer to translate the feedback into action.

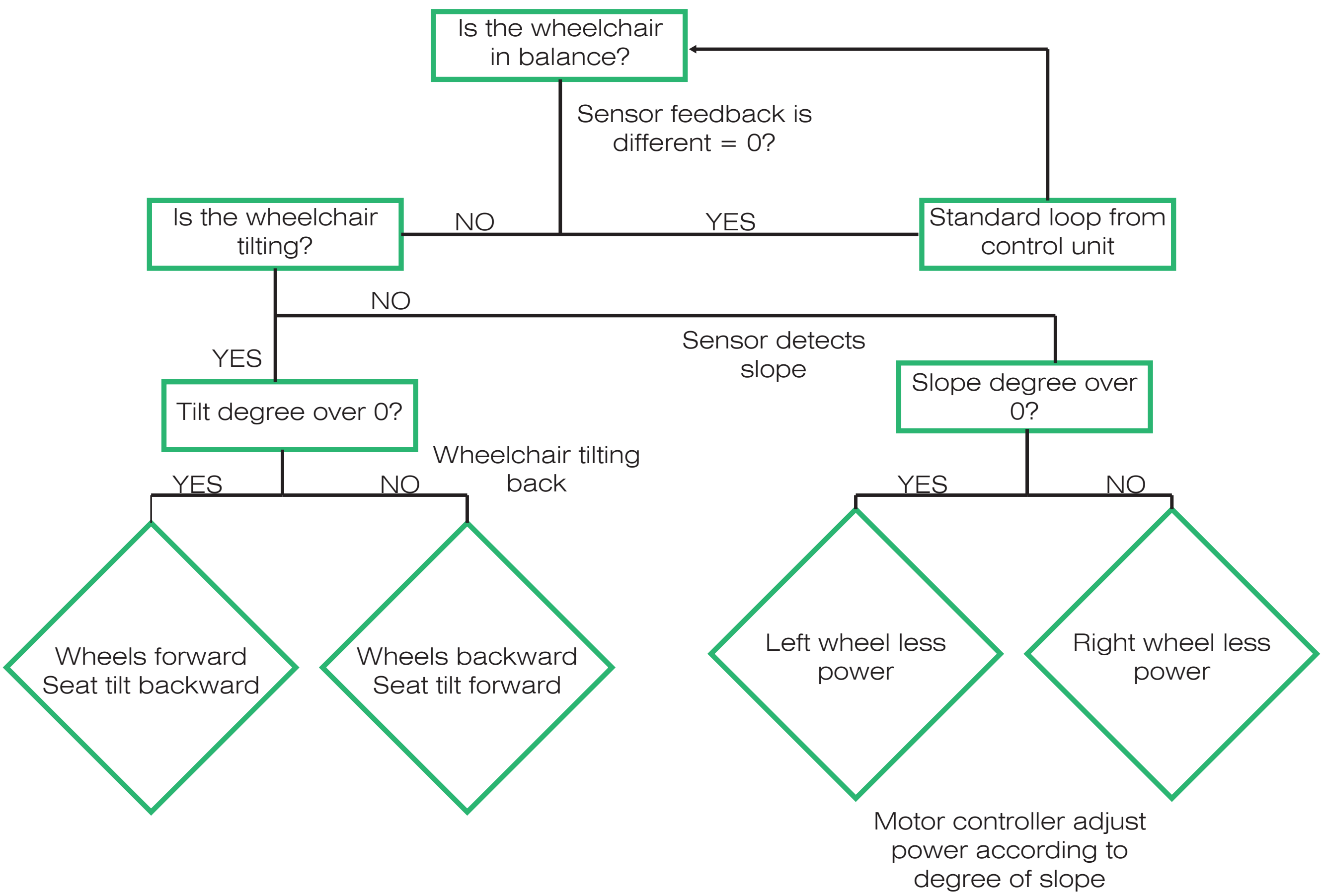
- Motherboard (with double redundancy)
- Motor controller
- Motor
- Actuator on backrest
- Actuator on tilt of seat
- Actuator on neck rest
- 2x Actuator on rear wheels
- Battery
- 3x one axis pitch gyro sensor
- 2 x two axis roll and yaw gyro sensor
- Weight sensor
- Joystick



Ill. 92: Component overview

Software

The software is embedded in the main control unit and might change depending type and if it is chosen to implement more than one controller the software will have to be compatible. A self-balancing system need calibration, in order to find the precise centre of gravity. Especially the combination of a self-balancing system and suspension which are changing the movements of wheelchair, will need extensive calibration in various scenarios. The calibration is done by running the software through an external computer, which is calculating the centre of gravity and calibrating the gyroscopes according to that. The precision of the software detriments how well the electrical wheelchair is going to balance, if the software is not calibrated right, sensors or software is not precise enough the wheelchair will be "hunting" for balance (driving back and forth). The technology has matured enough to avoid this from happening. The illustration is an example of how a flow in the programme would look like.

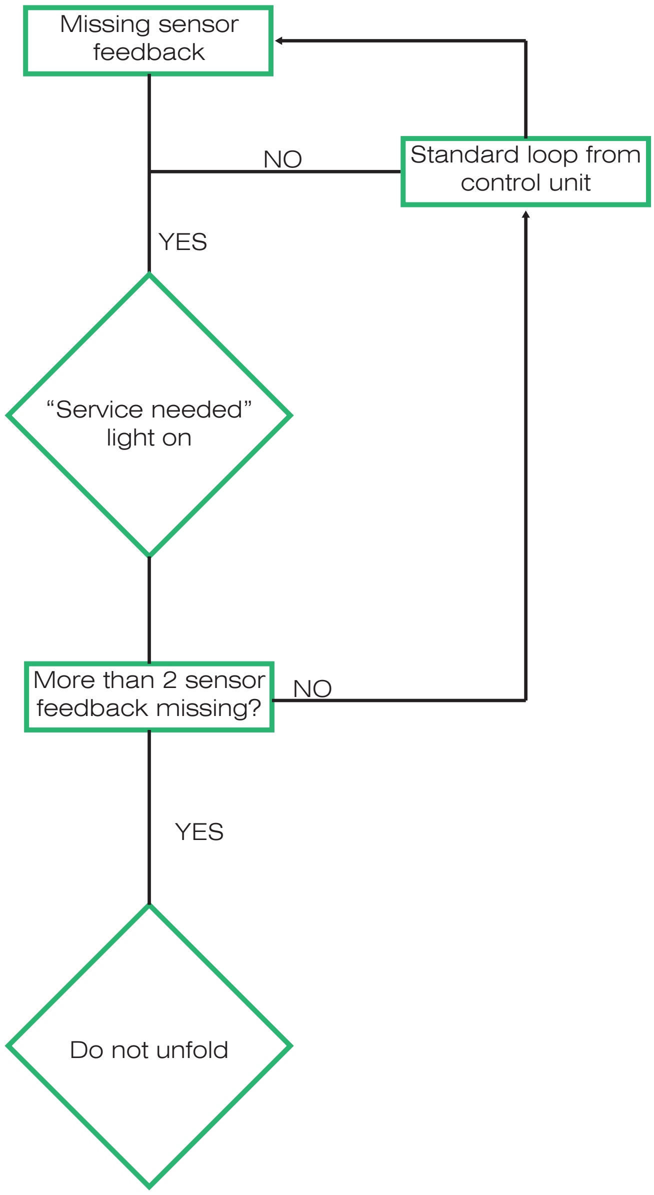


Ill. 93: Standard programme

Gyro sensors

Then driving indoors the user has to rely on the technology of the gyro, in order to prevent accidents from happening the software and the gyro censors should be developed with a certain redundancy, meaning if a sensor breaks down, the chair would still be able to maintain balance and safely, unfold the rear wheels and call for service. Like the Segways, the electric wheelchair should be able to sense angular motion when leaning forward and backwards (pitch axis) in order to prevent the chair from tilting. Furthermore the electrical wheelchair should be able to sense when it is driving on a slope (roll and yaw axes) in order to match the velocity of the wheels to the slope. The most important set of sensors, are the ones preventing the wheelchair from tilting, when driving on two wheels. On the Segway they have triple redundancy in this set of sensors, in order to minimise the risk as much as possible. The wheelchair will also be provided with triple redundancy. The roll and yaw sensors will have a double redundancy as this are not curial for the safety of the user.

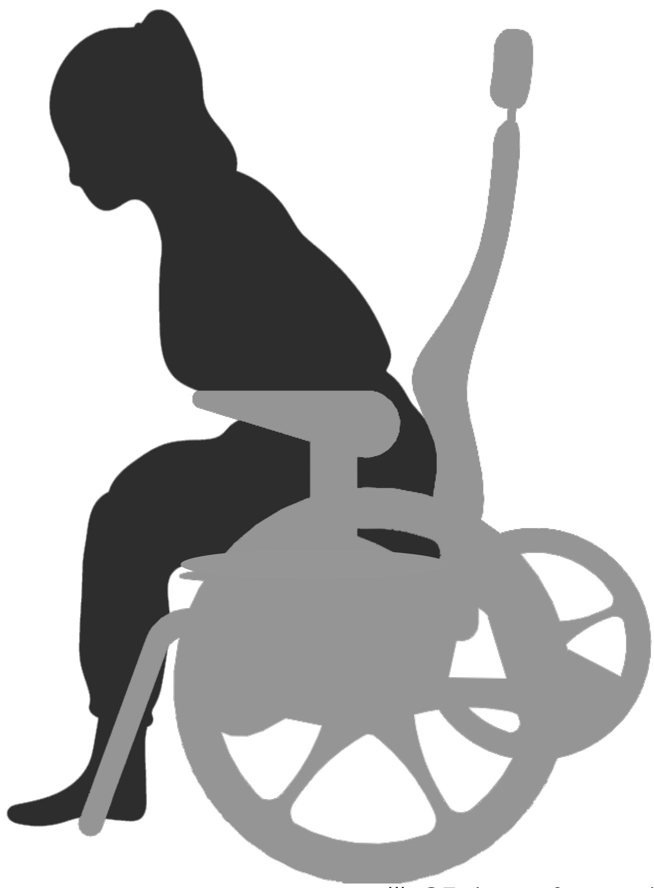
Purchase
Manufactures like Silicon Sensing are selling gyro sensors made for Segways, self-balancing wheelchairs, automotive safety ect. The inventor of these sensors is also the designer of the previous showed iBot4000, which is able to keep the wheelchair in balance with a higher centre of gravity than in this proposal. With a higher centre the wheelchair is easier to balance, this means the software has to be very precise in order to remain balance [POC].



Ill. 94: Sensor break down

Extreme situation

As shown previously the wheelchair will keep balance, by driving back and forth and changing the centre of gravity of the user by tilting the seat. The wheelchair is able the stand still without "hunting" and in normal use the chair does not correct more than the distance of the person's motion. The wheelchair will be able to hold the person still while accelerating and decelerating. In extreme situations when the wheelchair is being pushed or the person within the chair get hit by a muscle spasm and leans forward, is it important that the chair does not tip over. Furthermore the chair should avoid moving too much forward or backwards out of risk of hitting something. According to reviews of the Ibot 4000 the chair does not move more than a walkng person would do, if he or she are being pushed [POR].
If a user is driving forward and suddenly throws himself forward, the software detects the weight being pushed to the limit of what the chair can recover from within centimeters. The software will overwrite the commands from the joystick, tilt seat, correct with the wheels until the chair is in balance and go into sleep mode, in order to wait for the user to recover from the spasm.



Ill. 95: Lean forward

Motor

To drive the wheelchair two electrical motors are needed, one for each of the driving wheels. The size of these motors are determined by calculating the necessary effect, torque and revolutions per minute of the motor. For the wheelchair to be able to climb the 15 cm obstacle the motor must deliver 120 Nm of torque at the wheels which means 12 Nm from the motor when including the gearing. The motor needs to deliver 400W effect for the wheelchair to go 15 km/h up a small slope and it needs to deliver 1500 rpm. see appendix 7

Battery

A motor with the mentioned specifications requires 24V DC power. The batteries used are two 12V li-ion batteries which delivers 24V when connected in series. These batteries are chosen because they take up less space than the ones used in existing wheelchairs. They are more expensive, than batteries currently used by Wolturnus, but the price on batteries are going down, due to the rapid development.
Two Swedish scientist states in an article published in Marts 2015, that the price on lithium-ion-batteries will drop to 100 dollars pr. kWh from current 400 dollars pr. kWh, within five years [ING]. The rapid development in battieres means that the capacity and therefore the distance the chair can travel will increase drastically over the next few years.

Actuator

Besides the two driving motors the wheelchair needs six actuators. Three controlling the unfolding of the back wheels, one for the back rest, one for the neck rest and one for steering the back wheels when unfolded.

Weight sensor

For safety measures the wheelchair should be able to detect when a person is sitting in the chair, in order to avoid turning it on balance mode when no one is in the chair. It is a simple sensor which can be purchased as an analogue sensor based on a switch or an electronic weight sensor. The sensor would be able to detect the exact weight the user, which is useful in order to detect weight limit.

Joystik

Redesign of the joystick was not a focus in the project and will therefore be the same joystick as Wolturnus A/S is currently using. The joystick should undergo some changes as new functions are added to the control unit.

MODES

As mentioned, the control of the electrical wheelchair is not within the scope of the project, but when radically changing the design and construction of a product, then there should be some reflection about the implementation of the new functions into the existing control unit. Today the users is able to control the speed limit by adjusting a bar on the joystick (see picture to the right), the bar also controls the sensibility of the joystick. When driving inside the user has a more sensitive joystick in order to drive in narrow spaces. When driving outside the joystick in less sensible, it is the same principle in cars when a person drives faster, the less sensible the steering wheel becomes, in order to avoid the car from driving off the road with a small motion of the steering wheel. The user controls the speed limit of the wheelchair according to the context they are driving in.

The electrical wheelchair is divided into three modes, which are used in three different situations. The implementation of the additional functions, could be inspired of the current action of the user by implementing the buttons for each mode or use the bar by dividing it up into three.

Ill. 96: Joystick

Sleeping mode:
The rear wheels are unfolded and the gyros are turned off in order to save power. This mode is used while the user is resting and not moving around. The chair will automatically unfold the rear wheel and go into sleeping mode when the chair haven't been moving for more than 10 seconds or the user sets the chair in sleeping mode. The function should always be used when the user is shifting into or out of the chair in order to have maximal stability in the chair.

Balance mode:
Is used indoors or in narrow spaces, the chair has a speed limit of 5 km/h. When going into balance mode the chair balances and folds within 5 seconds.

Travel mode:
When going outdoors, travel mode is set, the chair will unfold and lean the user back, for a more embracing position. The wheelchair has a max speed of 15km/h and the sensitivity of the joystick is decreased.

TRANSFORMATION

Earlier in the process the transformation between balance and travelmode happened when the wheelchair was stationary. The transformation was very robotic looking (moving in steps), which meant that the chair was attracting undesired attention and that the transformation time could be reduces by doing serveral transformations steps simultaneously.
When the wheelchair is put into travel mode it does not unfold on the spot. Instead the user can drive ahead and when the wheelchair reaches a velocity of 5 km/h it will automatically put down the back wheels and put the wheelchair in a laid back position. The wheelchair folds back into an upright position when the user selects balance mode.
I was possible In sleep mode it would also be a possibility to drive the back wheels in to the point just before they lift of the ground in that way the seat would move to the right position automatically. The back wheels need to be in travel postion when in sleep mode because the footprint of the wheelchair would be too small, which is not desirable since it would compromise the stability of the chair.

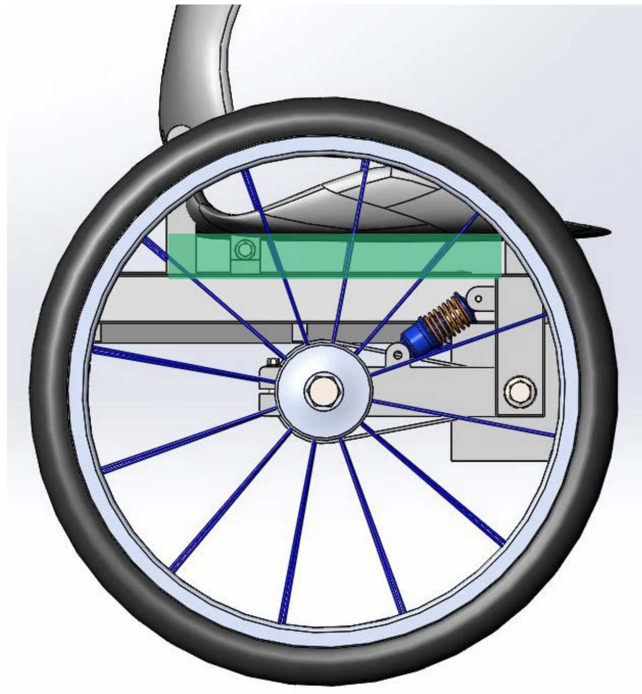
Ill. 97: Joystick

CONSTRUCTION

The wheelchair consists of four main parts:

- Seat module.
- Chassis.
- Suspension.
- Suspension of the rear wheels.

The following section will briefly describe the seating module, the fixation on the chassis, the mounting of motor parts and the suspension. The suspension has undergone some changes in order the fit the new wheels under the seat. This will further be elaborated during the following section.



Ill. 98 Tilt and elevation

Seat module

The seat module will be constructed of two carbon fiber shells on which the specially made cushions are mounted. The first ideation of the seat suggested a shape which follows the curvature of the body and supports the lumbar area. The seat had support for the positioning of the legs. In order to create a functional seating unit it has to be specially made to the compliment the particular body shape of every single person, which would be very costly. Therefore were the curvature straightened out and the support between the legs were removed. The compromise resulted in that the seat unit lost the very curvy expression similar to a sting ray. The seat unit is mounted on the chassis as shown on the pictures. The current version do not have tilt or elevation in the seat module, since this is a standard component which is easily installed under the seat as shown with green on the illustraion to the right.

Ill. 99 seat module

Chassis

The chassis consists of a frame in which the batteries and software are mounted. The frame is made in aluminium profiles in order to protect the components and to mount the motor and suspension on the frame.

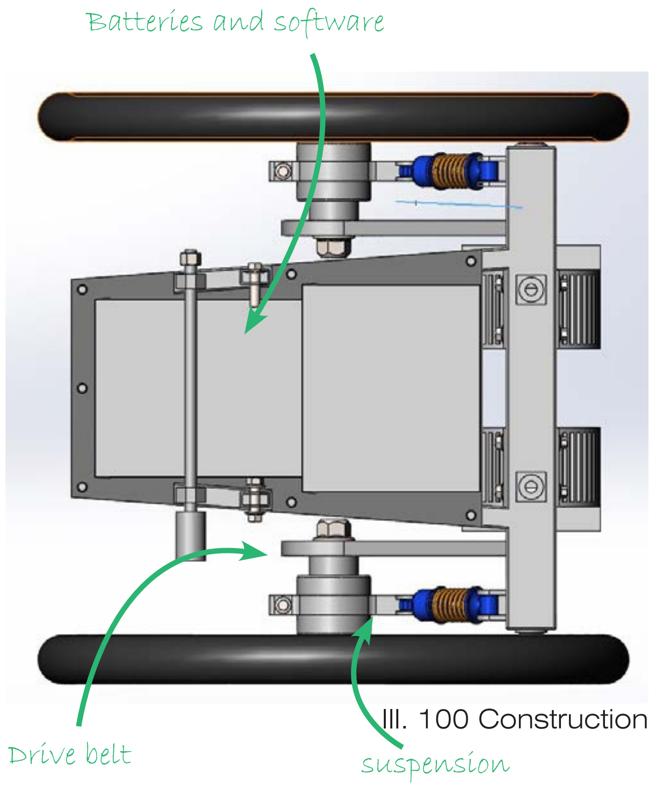
Suspension

As stated during the mock up session 2, the larger dimensions of the wheels means that the wheels cannot be placed under the seat. The problem can be solved in two different manners:

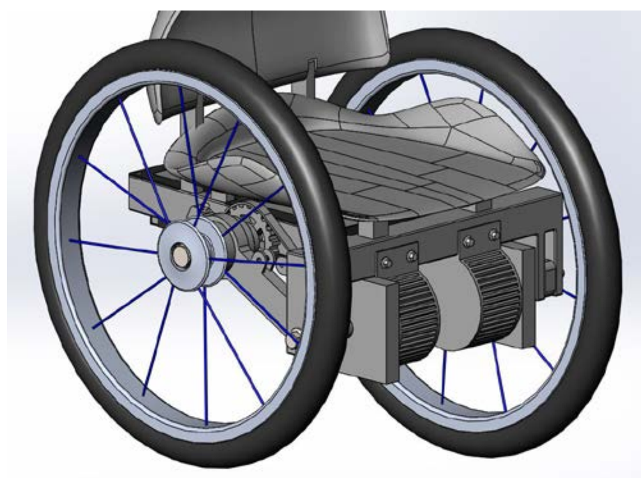
- Place the wheels in another position when folded.
- Find a suspension that takes up less room under the seat and thereby making room for the wheels.

The initial wish was to hide the wheels as much as possible, which lead to the initial dimensions of the rear wheels on 200mm. A compromise were made, in order to climb curbs fluently without the "robotic" climb. The wheels were placed underneath the seat in order to easily incorporate the wheels in the overal apperance of the chair.
The optimal solution for a suspension is one placed as close to the wheels as possible in order to avoid an arm to take up space across the bottom of the wheelchair. The implementation of a suspension, which is moving from the front to the center of the driving wheels of the chair, would be a solution.

By mounting an arm as showed in the illustration to the right, the wheel would move in the same manner as the "buggy" suspension. The suspension is mounted on the centre of the wheel. The motor is placed towards the front while the fixation is placed in the front of the centre of the wheel, in order the match the force from the obstacle.
The motor is placed in front of the centre and not in the rear, in order to avoid lifting it, when driving over an obstacle. The wheel is driven by a belt with the fixation on the wheel working as a gear.



Ill. 100 Construction


Ill. 101 Suspension

Rear suspension

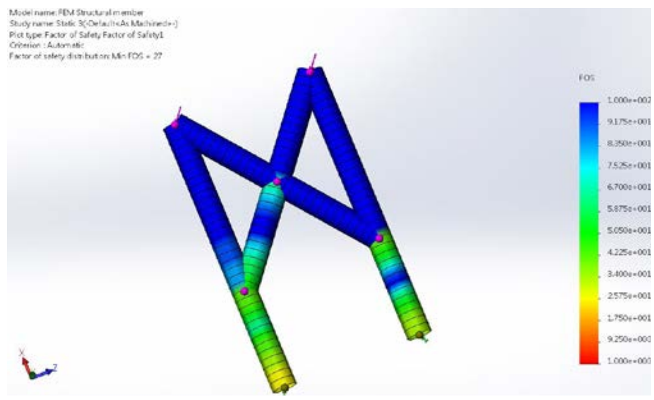
When the rear wheels was enlarged they has to be placed further in under the seat in order to hide the wheels as much as possible. The previous construction had issues in terms of strengths when forces was applied sideway on the construction. During the unfolding of the rear wheels the joint above the wheels make the arm look weak and fragilie. Some rework was required in order to achive an overall stronger construction. The rotating arm could no longer be placed in the given height in order since the wheels had to be placed more in front under the seat. The rear wheels are now mounted in two places in order to secure the strength of the construction and to be able to move the wheels into the right position. The individually attached wheels would still be unstable when turning or driving on a slope. By joining the wheels into one connected construction, with diagonal reinforcement, the construction is optimised for absorbing forces applied sideways on the rear suspension. The construction will be more visible, but it will also add some trust in the chair, as it will look more robust. The rear wheel will be turning by a steering arm rotated by an actuator (see illustration to the right).

In order to evaluate the construction a Finite Element Analysis was done. The construction was tested in a scenario, where the wheelchair was approaching an obstacle in an oblique angle with an applied force of 200Nm. The construction will absorb the torque as a result of the different height of the wheels.

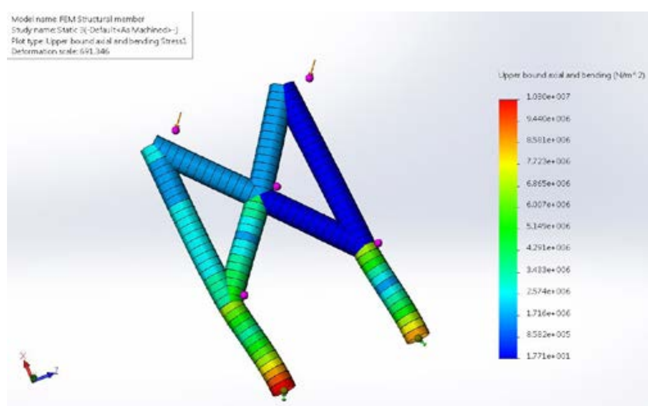
The material used in the construction is tube profiles made of 25x2 mm 6061-T6 aluminium alloy, which is most commonly used, due to the good machinability [OMT].

The result showed a factor of safety of 27, as a rule of thumb the factor of safety should always be above 1.5-3. This means that the construction could be made of thinner profiles in order to save material, but this is not chosen as the construction should look stable.

Ill. 102 Rear suspension



Ill. 103 Factor of safety



Ill. 104 Deformation

PRODUCTION

Ill. 105 Exploded view

Part name	Material	Production method	Price (DKK)	Quantity
Headrest	-	-	300,00	1
Back cushion	-	-	1.000,00	1
Backrest	Carbon fibre	Vacuum infusion process	1.700,00	1
Seat cushion	-	-	1.000,00	1
Armrest	-	-	125,00	2
Seat	Carbon fibre	Vacuum infusion process	1.200,00	1
Battery	-	-	1.800,00	2
Clip	ABS	-		7
Battery holder	ABS	Thermoforming	112,00	1
Body 1.1	ABS	Thermoforming	150,00	1
Actuator	-	-	75,00	6
Rear fork top	Aluminium	Processing of tubes	190,00	1
Body 2	ABS	Thermoforming	90,00	1
Steering arm	Aluminium	Processing	35,00	1
Rear suspension	Aluminium	Processing of tubes	227,00	1
Rear control arm	Aluminium	Sand casting	13,00	2
Rear fork bottom	Aluminium	Processing of tubes	75,50	2
Rear wheel	-	-	400,00	2
Rear wheel axle	-	-		
Chassis	Aluminium	Processing of tubes	605,00	1

Chassis	Aluminium	Processing of tubes	605,00	1
Footrest	Aluminium	Processing of tubes	227,00	1
Motor	-	-	1.250,00	2
Body 1.2	ABS	Thermoforming	53,00	2
Shock absorber	-	-	1.200,00	2
Front suspension	-	-		
Front wheel	-	-	600,00	2
Front wheel axle	-	-		
Electrical components	-	-	1.500,00	1
Joystick	-	-	1.000,00	1

Most of the components are standard and available from sub suppliers see the table above for the prices. The components that needs to be specially made are components used for the chassis, the bodywork and the seat.
The seat is made from carbon fiber in order to get strong thin sheets. The production method used for the seat and backrest is the Vacuum Infusion Process. This process is often used for propellers and marine components.
The bodywork is thermoformed ABS plastic. It could have been made of carbon fibre as well, but due to the price difference between the two types of materials was it is chosen to keep components exposed for lesser amount of stress in ABS plastic. ABS plastic is a tough and rigid material used in many contexts, furthermore is it cheap and easy to process. Thermoforming is a cheap process for moulding plastic due to the low cost of the mold. This makes the production method suitable for both prototyping as well as large scale production.
The chassis is welded together from extruded aluminiumtubes, except for the rear control arm, which is sand casted because of its high complexity in shape.

AESTHETIC

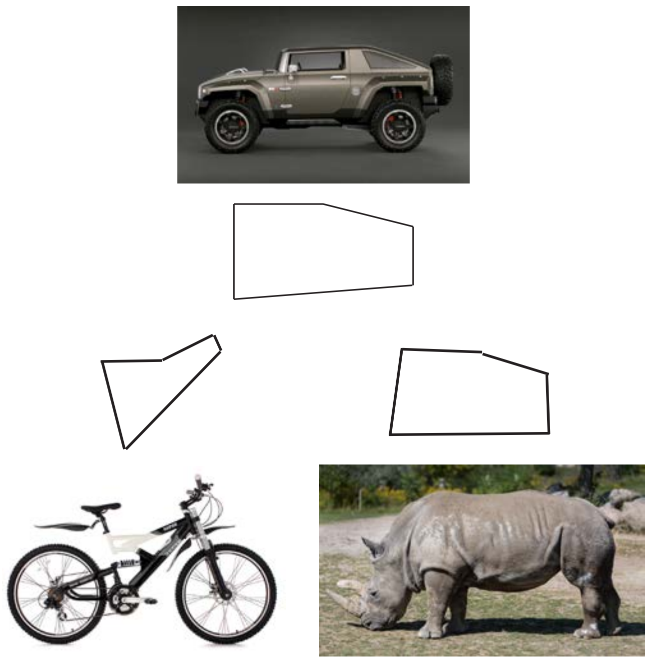
The objective of the detailing of the aesthetics is to create a connection between the curvature in the seat unit and the geometric construction and components. During the project the demand of an electrical wheelchair, not noticed by other persons were clarified. Previous analysis and ideation suggested a direction of a curved shaping of the seat unit. By making the seat as less noticeable as possible, the user will be made more visible in the chair. The aim is to find the right balance between the wheelchair being invisible and enhancing the experience of safety. These analyses were based on hiding undesirable expression. The developed wheelchair should express mobility and activity, without the expression taking away focus from the person in the chair.
In order to determine the guideline for an overall identity of the wheelchair, 3 different identities (see APPP 6 for full size) were defined from three different products. These guideline will be used when evaluating the final aesthetic of the wheelchair.

The first identity is the heavy and robust expression of strength and stability. This identity would fit for a wheelchair made for off roads.

The second identity is more feminine and urban, it is practical when moving in narrow spaces.

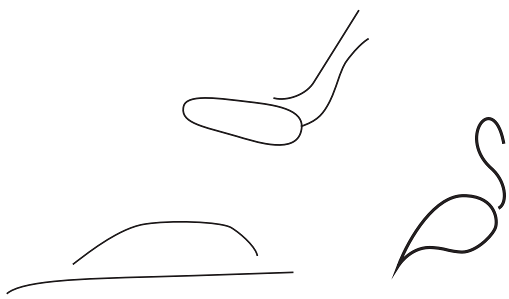
The third identity is fast and athletic, the identity is explosive and fast looking.

Robust



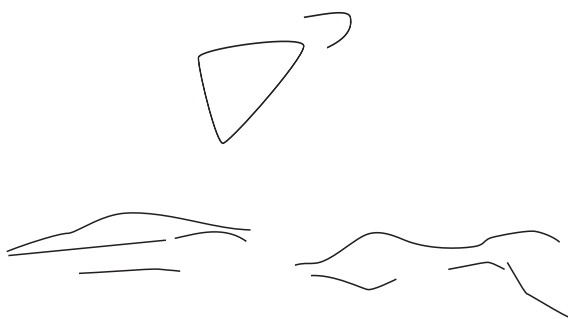
Ill. 106 Robust identity

Soft



Ill. 107 Soft identity

Fast



Ill. 108 Fast identity

The aim is the incorporate an identity that looks like a transportation device, but it should also function in an indoor context. The identity should be a combination between the sporty aerodynamic curves and soft lines from to add a softer touch to the identity.

Some components in the construction have to be covered in order to prevent dirt from entering the mechanical system while also containing the lubricates. This is the reason for the cover around the drive belts and the steering of the rear wheels. The covers will have to be integrated into the overall aesthetic.

The challenge of the developed wheelchair is to simplify the dominant expression of the construction parts. Especially the arms unfolding the rear wheels have a very industrial look. As mentioned before, the aim is for the users to feel as if the chair is a extension of their body instead of it being a clumpsy necessity. Existing wheelchair aim at being as neutral in their statement as possible, which results in a box placed under the seat of the user which places the components as space efficient as possible. By working with the contrasts between covering some parts of the construction up and leaving some of it exposed, the construction will avoid being covered up in a box. Motor bikes are using the same method to create or enhance desired lines and highlight important construction. The challenge is to find the new balance between the invisibility and automotive looking wheelchair. The designs of motor bikes is not equally attractive on all persons, the design will therefore be evaluated in relation to the three different identities.

The aim is to use the contrast between the soft lines on the covers to create a connection to the seat unit, but still maintain some of the aerodynamic curves to express the mobility and speed of the wheelchair. The ideation was done through sketches and finalised in 3D, it has however not been tested in the right scale. This will be done later while making the final expression of the electrical wheelchair.

Ill. 109 Motorbike

Ill. 110 Final Product

BUSINESS

As stated during the framing of the project are the needs of the users highly individual so in order the keep production price low, a modular product architecture is prefered. In the following chapter will possible buyers be evaluated together with a reflection of the market potential and competition. The developed wheelchair is made for persons with an active lifestyle, for instance persons who love to take the dog for a walk or are doing in places otherwise unavailable to ordinary wheelchairs.

The implementation of suspension and enhancing of the travel speed of the wheelchair have provided the user with a better feeling of independence as they do no longer require aid or specially chosen routes when outside. Considering the requirement for further development and the high cost of the equipment used for production would make the project difficult to finance for a start-up business. The most feasible way to make an earning of this product proposal would be to sell it to a well-established firm and make a royalty agreement.

Customer segment

Primary – People who live an active life style, without the ability to walk or use a manual wheelchair.
Secondary – People with some ability to walk but have to use a scooter or manual wheelchair during longer walks or outdoor activities.

Value proposition

Enhancing the independence and freedom for persons suffering from a walking disablity, who have a wish of living an active life style.

Channels

The municipalities in Denmark

Customer relationship

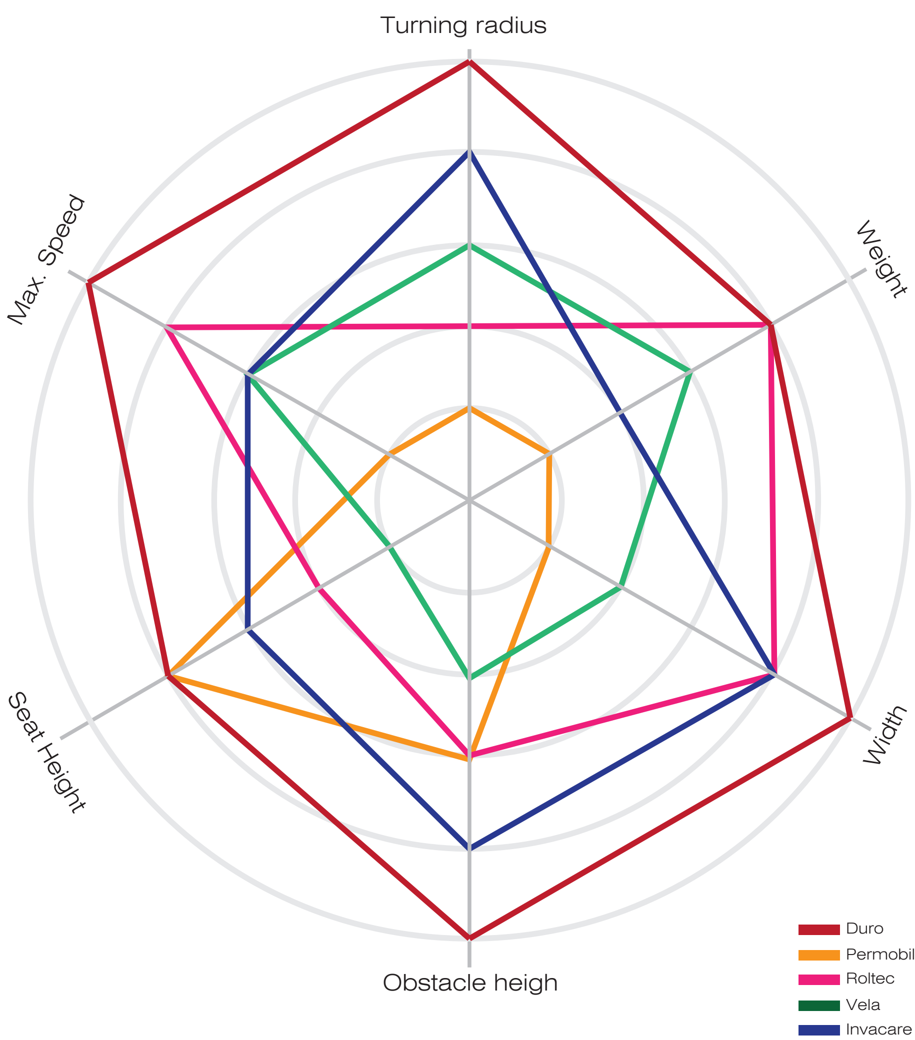
Service, contacted by the user or an ergo therapist

Market

The danish market of helping aids have been challenged by the cheaper products produced in Asia. The market is furthermore highly controlled by the municipalities who are granted between 85.000 – 120.000 DKK for an electrical wheelchair, which minimises competition of price and innovation between the wheelchair manufacturers. The amount of electric wheelchair sold in Denmark per year is around 800 units and approximate the same relative amount in Norway, based on population, according to sales director Rene B. Jørgensen from Vela. Vela is one of the biggest manufacturers within electric wheelchairs in Denmark. Wolturnus is in the process of expanding to the German market and by introducing Duro, the product will open up to a lot of potential customers. The private sector has expanded worldwide the previous years, which will have an impact on welfare in the future. More and more people will have private insurances to pay for mobility aids. The user of the wheelchair would therefore be able to make their choices impendently of the municipalities. This will affect helping aid manufactures as they can no longer rely on the municipalities to sell their products which will result in competition of price and will lead to an enhancing of service. In the Netherlands the user in need of a helping aid gets financial support partly from the state and partly from private insurances. The private sector in the Netherlands is providing the services of finding and delivering the right helping aid to the applicant, which might well be the future in Denmark as well, in order to cut down in the public sector.

Competitors

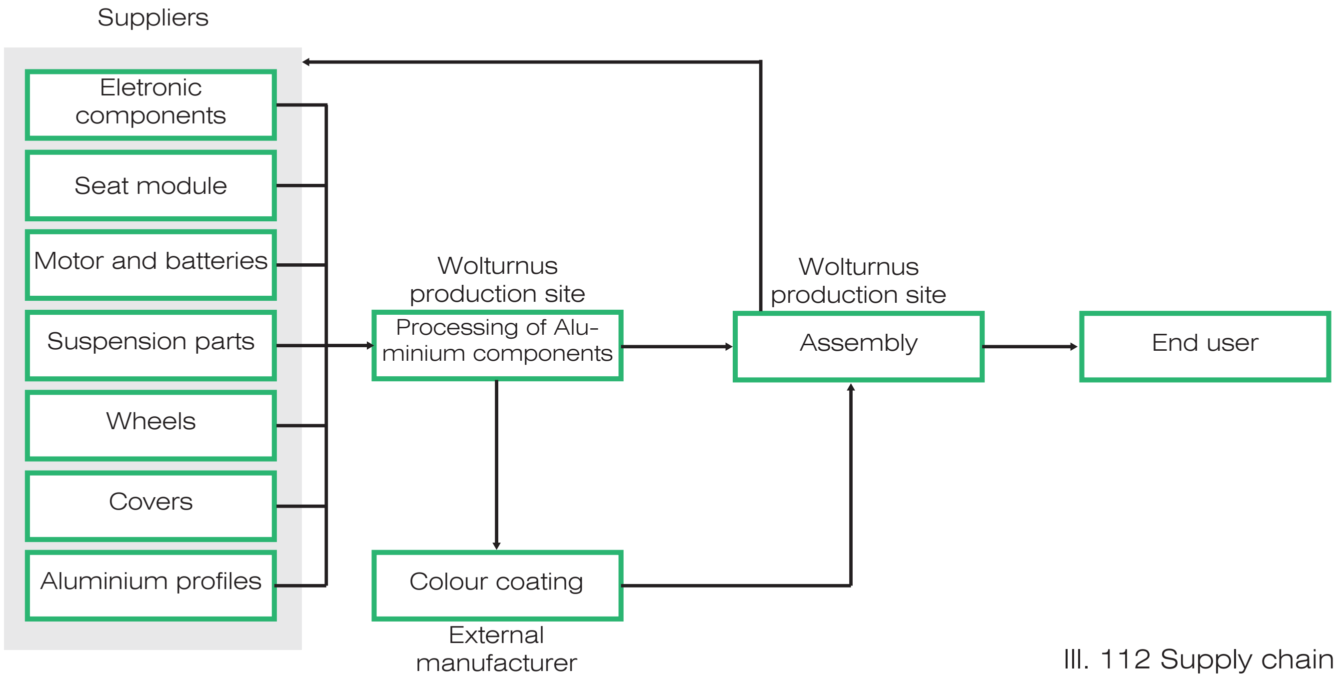
The aim of the project was to develop an electric wheelchair that was able to fulfil the requirements from persons living an active life, since no current wheelchair on the marked was able to proppерly do so. The developed wheelchair is able to fulfill the demands described during the project which means it is able to compete against current electrical wheelchairs. During the lastest years new technology has been developed within personal transportation and have impacted the design of the wheelchair. The Segway was a start of various possibilities of implementation of the self-balancing technology. The self-balancing technology made it possible to develop a wheelchair fulfilling demands other wheelchair manufacturers in Denmark have not been able to so far. The global market has been introduced to gyro based wheelchairs, such as the Ibot 4000, though it is no longer in production, and the Genny wheelchair which is currently being introduced to the Danish market. When implementing a technology that has matured rapidly, a future manufacturer would have to move fast in order the keep the distance from the competitors. The Genny wheelchair can only be used by persons with control of their abdominal muscles, as it is being controlled by the weight of the driver. Duro can however be used by any person with motion in their fingers. Duro have access to a bigger amount of potential customers. The investigation shows that it currently has no competitors on the international market, that have introduced gyro stabilisation without balanceing control.



Ill. 111 Competition

Supply chain

As most manufacturers have a main production of products similar electrical wheelchairs, means that they are able to cut down on expense of the production line. A supply chain made for Duro will therefor vary a lot according to the manufacturer. The following supply chain is based on the assumption that Wolturnus will be producing the wheelchair. Wolturnus is highly specialised in the construction of customised wheelchairs in aluminium profiles. Their production setup is based on manual work and they are not capable of preforming advanced processing methods. In order to avoid expenses for processing equipment only used to manufacture Duro, Wolturnus will only be processing the aluminium parts themselves and assemble standard components purchased from external suppliers.



Ill. 112 Supply chain

Retail price

When creating a business plan it is recommended to to a break even analysis. The result of the analysis will provide the required number of sold wheelchairs in order to make a profit. I order to calculate the break even, four types of information is required [INC].

Fixed cost: covers rent, and administrative expenses. It will not be a focus within this break even analysis as the business case is based on an existing production setup, which expenses are already covered for. A royalty agreement of 3% is added to the fixed cost.

Production price: The production price is a sum of the cost of each material and component needed. The prices of the material were estimated based on prices found online. Online prices are higher than the actual price would be from a sub-supplier as the manufacturer will be able to make agreements, when buying a large quantity. The estimated prices are in general set high as a safety margin in case of uncertainties. The total cost of producing Duro is set to 22.000 DKK.

Variable cost: Is expenses used for maintaince of production lines.

An initial investment is needed in order to pay for the further development and startup of the production of Duro. The investment needed is set for 2.560.000 DKK. The estimation of the investment is based on the salary of two engineers in a year, research, founds and the production cost of the 25 first wheelchairs.

As the municipality is granting between 85.000-120.000 DKK, the price of electrical wheelchair is placed in the same price range. Setting the price of Duro to 88.000 DKK without special equipment gives results in a mark up factor of 4.

In order to make profit of Duro it has to sell:

$$\frac{2.560.00}{85.360} = 30 \text{ units}$$

The number of units sold when breaking even is higher than 25 unit which is what the investment is covering, this results in added operational cost. In order to find the new break even following equation were made:

$$\frac{2.560.00+(x\cdot 22.000)}{85.360} = 25+x$$

$$X=6.7$$

The balance will break when 32 units is sold.

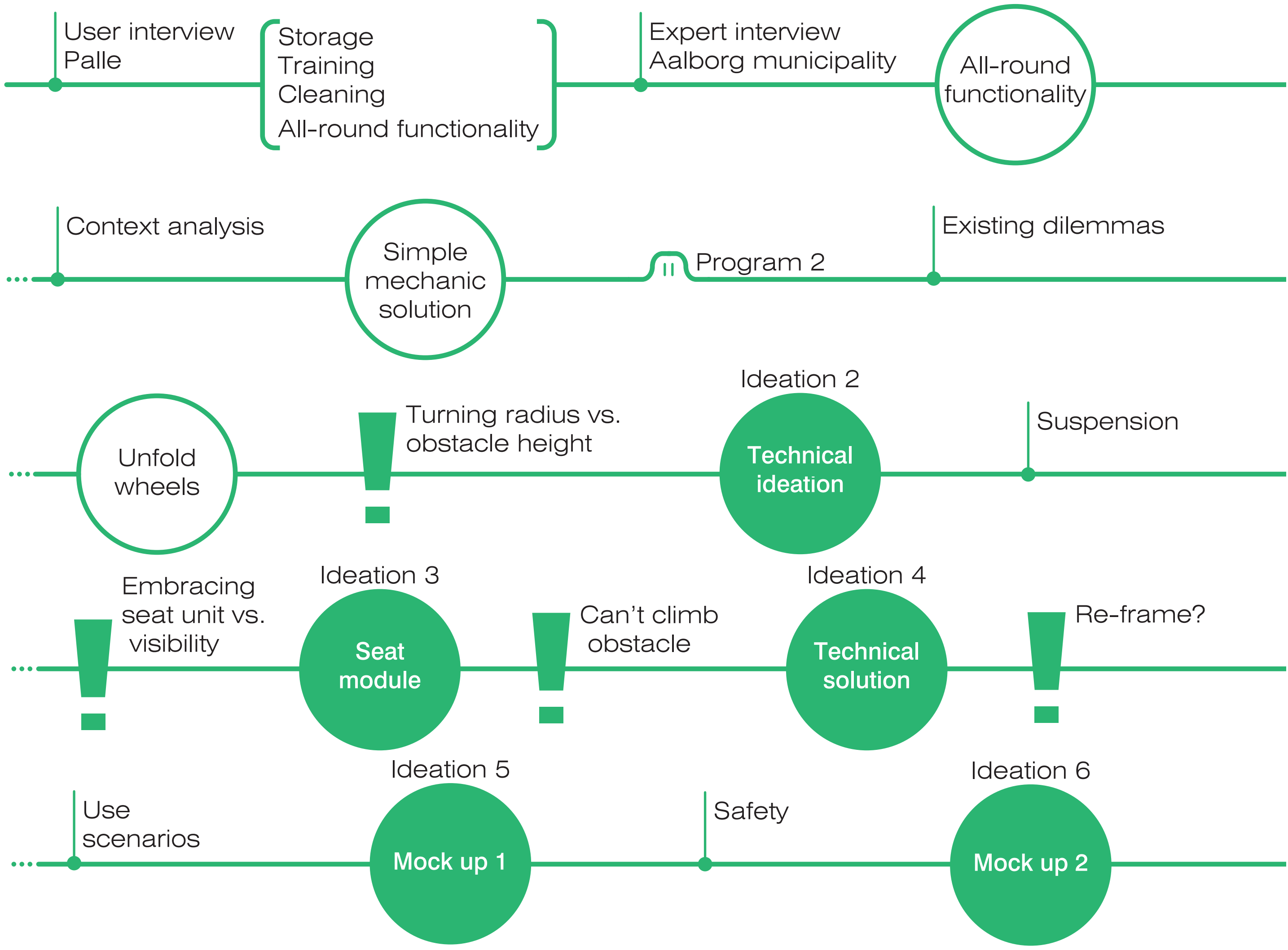
As the market need is 800 wheelchairs a year it is not unrealistic to assume the Wolturnus would be able to sell 50 wheelchairs within the first year after the launch of Duro. The amount of sold wheelchairs is expected to be increased to 100 wheelchairs a year after the initial year, which will mean a market share of 12,5 %. There are some uncertainties in the result of the break even analysis, as the investment is only a rough estimate. Realistically it will not be possible to exclude the fixed costs as the enhanced production will require more tools and administrative expenses.

The last chapter will present the final reflections of the framing process and product. The chapter will be showing a process overview and a conclusion of the project

6

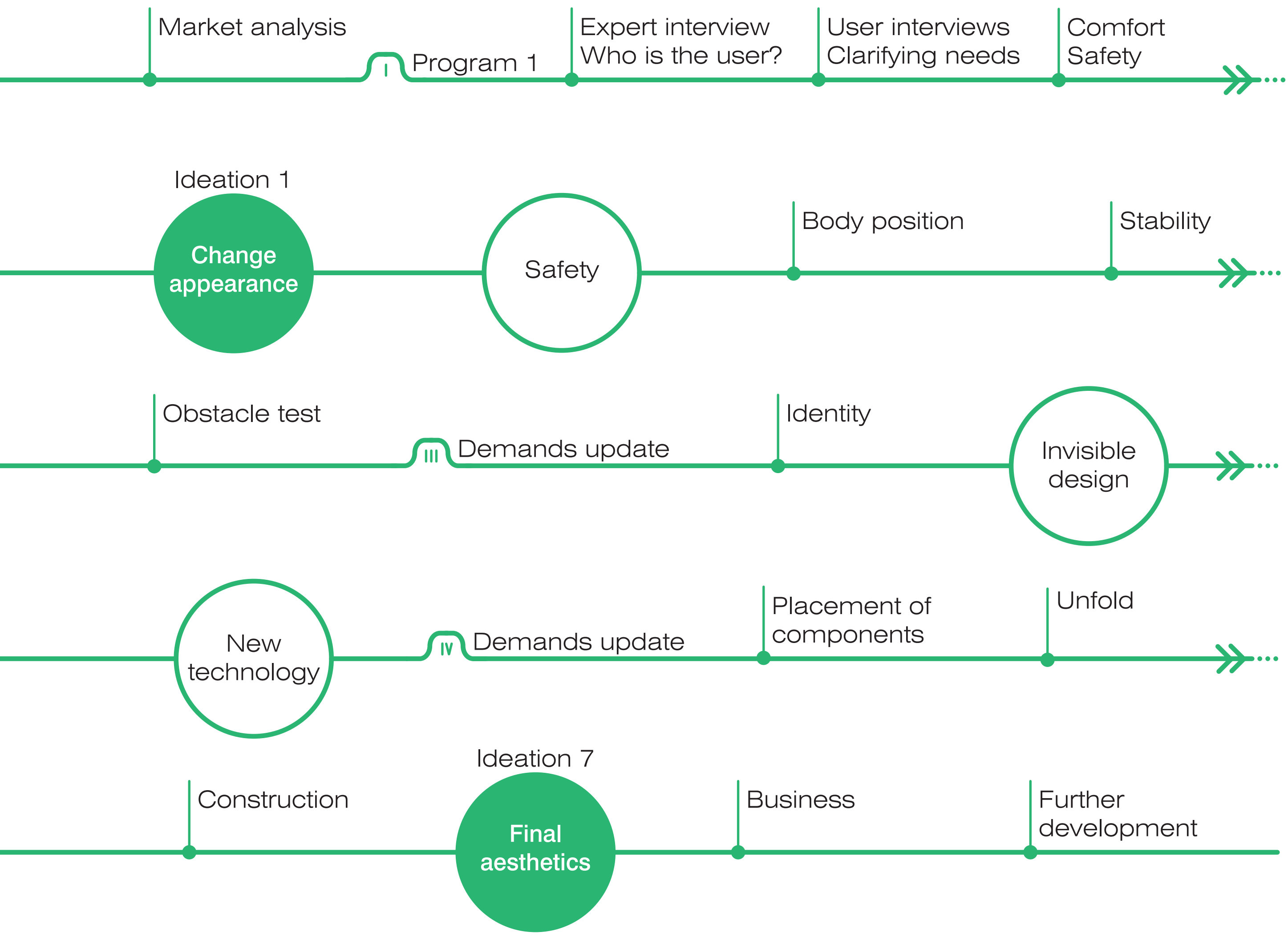
PROJECT CLOSING

REFLECTION



Frame

During the project framing was the scope set to be on the construction of the electrical wheelchair. As initially investigating suggested the construction was the reason why persons with a walking disability, were forced to choose the ability to manoeuvre indoor over the ability to drive comfortably around outside. Limiting a project to a part of a product, highly dependent on the entire construction, is a challenge. By developing a sup-system, the project group should still take into consideration, how the solution would be integrated into the current wheelchair. This was solved by dividing the scope into three parts, according to level of detail, although second level was expanded more than initially expected, as it turned out, the experience of the user had a great impact on the final solution. Current wheelchairs are safe in use, but the persons in the chair does not necessarily feel safe. By acknowledging the need to clarify how to make the user feel safe, the project group expanded the scope further as this knowledge not only would benefit this project, but would also enhance the quality of current products as well.



Ill. 113 Process overview

Process

An electrical wheelchair has to function in very different situations. In order to set the demands for an electrical wheelchair, all situations have to be clarified. The process of developing a mobility aid includes testing of experience and evaluation of the progress of the project. The main challenges of this project is to evaluate and develop a product, which success is depending entirely on the user's experience in dynamic situations. Testing and communicating ideas in dynamic situations are dependent on a high number of variables, it was not possible to test the concepts in the right contexts and combinations, since it would make the project exceed the time frame. As a consequence the project risks a degree of assumptions without any argumentation for the choices made.
The scope of the project was set to challenge the current way of constructing electrical wheelchairs. As stated previously the construction of electrical becomes more complex as demands for climbing higher obstacles are set. During the project the dilemmas current wheelchair manufactures face was clarified and especially the clash between the ability to climb obstacles ant maintaining a

small turning radius kept delaying the project. The team were focusing on solving the challenges by simplifying the construction of the wheelchair. As it turned out, an all mechanic solution, was not possible, if it had been would wheelchair manufactures properly have found it. Collecting the experience by the project group them selves, made them able to use the experience to implement technologies not yet used by Danish wheelchair manufactures. Thus making a product addressing a larger segments of users, than current wheelchairs based on gyro technology. Wolturnus A/S stated their wish for a wheelchair that were able to compete in the current marked, they do however not have a wish for pushing new technology to the market. The team could have chosen to stop pushing for a solution when they discoved, that it is impossible to create an electrical wheelchair able to climb an obstacle of 150 mm and turn around within 1000mm, with at least four wheels on the ground. The team could have delivered a detailed rework of the mechanical solution to Wolturnus and thereby provided them with a product able to compete on the current marked. Instead the project team chose to look for potential in newly matured technologies and creating a new design proposal by implementing gyro scopes in the electrical wheelchair.

The choice delayed the process and were complicated further by the lack of experience in implementing the technology into mobility aids, made for people without control of their abdominal muscles. As a consequence the level of detail were not as thorough as initial desired. The project team were aware of this risk when they chose to continue searching for a solution, that would provide freedom and independence to persons who currently are limited in their way of living.

Product

The newly developed electrical wheelchair will be introduced into a highly occupied market, otherwise known as a red ocean. The market is challenged by cheaper products produced in Asia and other international companies expanding into the Danish marked through Danish retailers. Despite of the challenge from international companies, the local wheelchair manufactures are inefficient due to the control of the municipalities prioritising local manufactures and buying the same chairs they have done the last 10 years while granting the same financial aid. This results in a non-competitive environment without any motivation for innovation and progress, with electrical wheelchairs fulfilling the minimum requirement in order to produce chairs at the lowest cost and sell to the highest price, without any concern of the end users and their quality of life. By developing a wheelchair within the price frame set by the municipalities and with far better specifications Duro would be able compete against current competitors, including the ones which implement gyros, as they are only useable for a very specific user segment. The competitor closest to Duro is the Ibot 4000 which is no longer being produced. In order to launch this wheelchair a manufacturer would benefit from a collaboration with the manufacturer of the Segway or other companies working with the gyro technology since the low centre of gravity might cause some complications in terms of self-balancing. It is also be possible that companies with experience in self-balancing systems would show interest in launching electrical wheelchairs. The development of Duro is not completed, as mentioned the product needs testing in order to ensure the experience of safety. It has not been possible to construct models which integrated self-balancing systems and therefore impossible to evaluate the experience in dynamic situations. Due to the delay in the process does Duro lack some details, such as independent tilt in the seat and elevation in the seat module. Furthermore is the full integration of the aesthetics not completed. Especially armrest and the construction of the rear wheels do not have the desired expression.

CONCLUSION

The objective of the project was to provide an option for persons who have a desire to live an active life despite their walking disability. The secondary aim was to challenge current wheelchair manufacturers' way of construction electrical wheelchairs by simplifying the construction as much as possible and still meet the requirements from the users. The project has given a deep insight into the dilemmas between the ability to climb obstacles and provide a small turning radius, which the wheelchair manufactures are facing when constructing a new wheelchair. The process has created an understanding of why a chair is specialised in indoor or outdoor use and the combined wheelchairs are not able to fulfil the requirements of the users. The process has clarified the significance of the user's experience of safety since users are avoiding unnecessary activity when being afraid. Inspired by coping strategies of the users the chair will change the position of the user and enhance the feeling of being embraced and safe while driving outside.
The product will require further testing through complex prototypes in order to evaluate the final product, in terms of experience, aesthetics and strength of construction and safety.

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APPENDIX LIST

APP1: Data specification from popular suppliers.

APP2: User interviews

APP3: Body position

APP4: Free body diagram and moment formulas

APP 5: Stability test

APP 6: Lit motors stability video

APP 7: Identity

APP 8: Motor calculation

ILLUSTRATION LIST

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Department of Architecture, Design and Media technology

Duro Balance

MASTER THESIS
PRODUCT REPORT

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MSc04 - 06
Industrial Design
Aalborg University
Spring 2015

Ill. 1: Hero shot

ABSTRACT

Duro seeks to prevent the users from having to choose between specialised wheelchairs, because it is optimised for both indoor and outdoor use. This is possible using a new technology, enabling Duro to drive on only two wheels inside making it easy for the user to manoeuvre. Duro unfolds outside and drives on four wheels, making it more stable when driving faster.

HELENE HØYER JENSEN

JULIE GILTOFT JENSEN

CONTENTS

NAME

Ill. 2: Name collage

NEED

In todays Denmark wheelchair users get funding from the municipalities. This means that the municipalities evaluate how much help the user needs. The result is that the users are forced to choose between a wheelchair that is optimised for either indoor or outdoor use. Often the wheelchair specialised for indoor use is chosen, because they need to be able to get around inside their homes. This makes them unable to do things like walk the dog because they cannot drive over the curbs and obstacles they meet outside.

If the user choose a wheelchair optimised for outdoor use, they have to arrange their furniture carefully in order to move around inside their homes. The wheelchairs for outdoor use have a large turning circle making them hard to manoeuvre.

DURO

Ill. 3: Duro

Duro seeks to prevent the users from having to choose between specialised wheelchairs, because it is optimised for both indoor and outdoor use. This is possible using a new technology, enabling Duro to drive on only two wheels inside making it easy for the user to manoeuvre. Duro unfolds outside and drives on four wheels, making it more stable when driving faster.

SCENARIOS

ENTRY AND EXIT OF THE CHAIR

When the user is moving into or out from Duro it is set into sleep mode. In sleep mode Duro is unfolded and stabilised on all four wheels. The low construction of Duro places the seat lower than the bed making it easier for the user to move down into the chair.
Furthermore while in sleep mode Duro will not move if the joystick is accidentally pushed.

Ill. 4: Entry/exit scenario

Ill. 5: Inside scenario

GETTING AROUND INSIDE

When Duro is driving indoors it is put into balance mode. This mode limits the speed of Duro to 5 km/h. When Duro is in balance mode and the user does not touch the joystick for 10 seconds Duro automatically goes into sleep mode and unfoldes in order to save power.

Due to the gyro stabilisation of Duro it is able to drive on only two wheels enabling it to turn around itself in tight spaces. This makes it easier to manoeuvre for example around the dining table.

The centre of gravity for Duro is located directly over the centre of the front wheels making it easy for Duro to keep the balance without moving.


HEDEGAARD

Ill. 6: Transformation scenario

TRANSFORMATION

Traveling outdoors Duro is put in travel mode enabling it to go 15 km/h when unfolded. Duro does not unfold the moment it is put in travel mode, it waits for the user to reach 5km/h then unfoldes while driving. When Duro is unfolded it does not fold back in, before balance mode is chosen.

The 15km/h speed enables the user to accompany friends or family cycling.

Furthermore the speed expands the travel radius for the user enabling them to go to the local store without having to use the car.

CLIMBING THE CURB

Duro is able to drive over a 15 cm curb. This gives the users freedom in their everyday life, preventing them form having to search for ramps when traveling in the city. This also enables the users to go over doorsteps making it easier for them to visit friends and family.

The suspension makes the travel smooth providing the feeling safety for the uses. The seat stays stable and horizontal even if the user drives over an edge on an angle.

Ill. 7: Curb scenario

RISK SCENARIOS

“I have tried many time
that a spasm in my leg have forced me
backwards so violently that my wheelchair is
overthrown backwards, leaving me on the floor”

- Palle, Manual wheelchair user

Ill. 8: Palle, manual wheelchair user

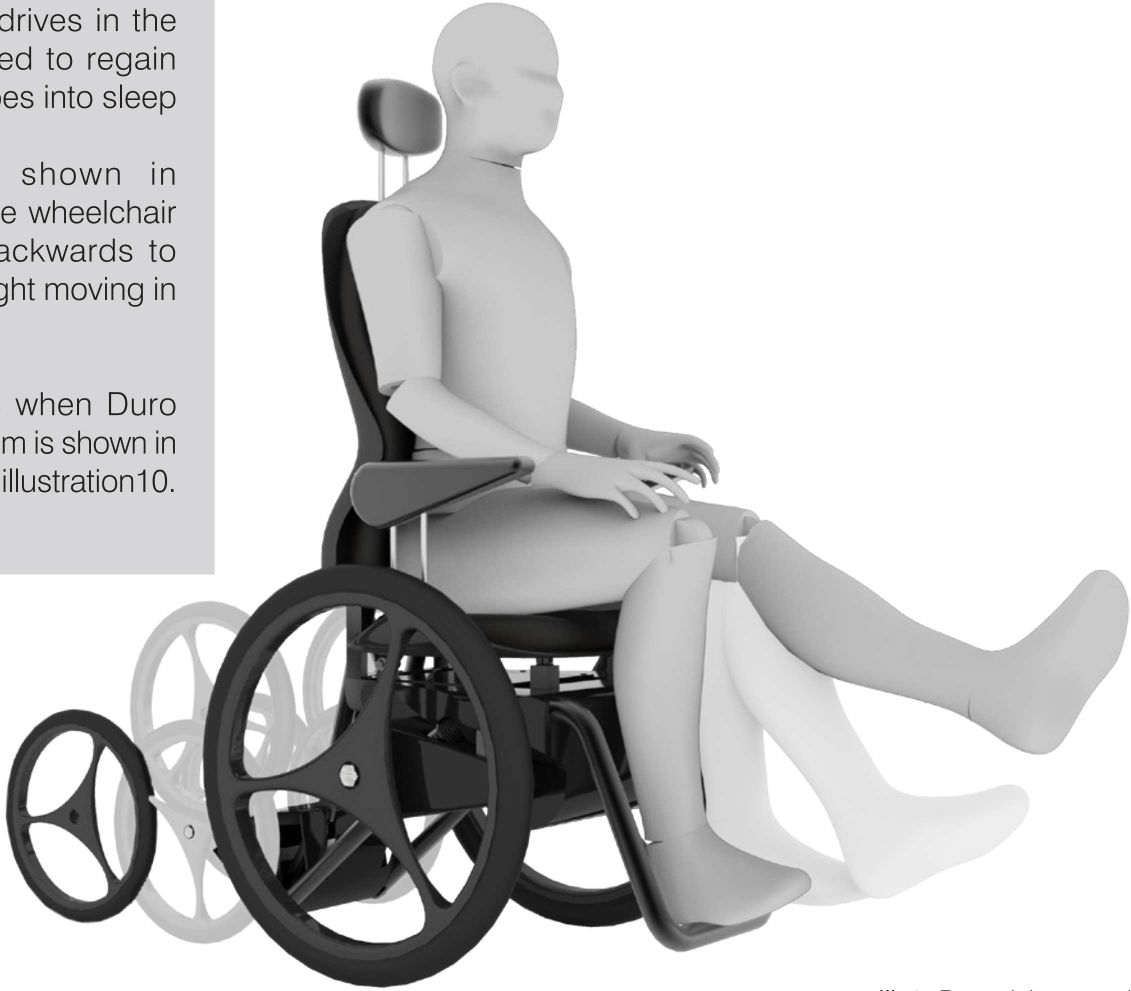
SPASMS AND BALANCE?

When paralysed it is normal to get muscle spasms quite often. A spasm is basically a cramp except a paralysed person does not have a working nervous system telling the counteracting muscle to tighten in order not to suddenly stretch or bend a limb.
This can result in sudden violent movement from the user making them change the centre of mass bringing Duro out of balance.

PRODUKT NAVNS REAKTION

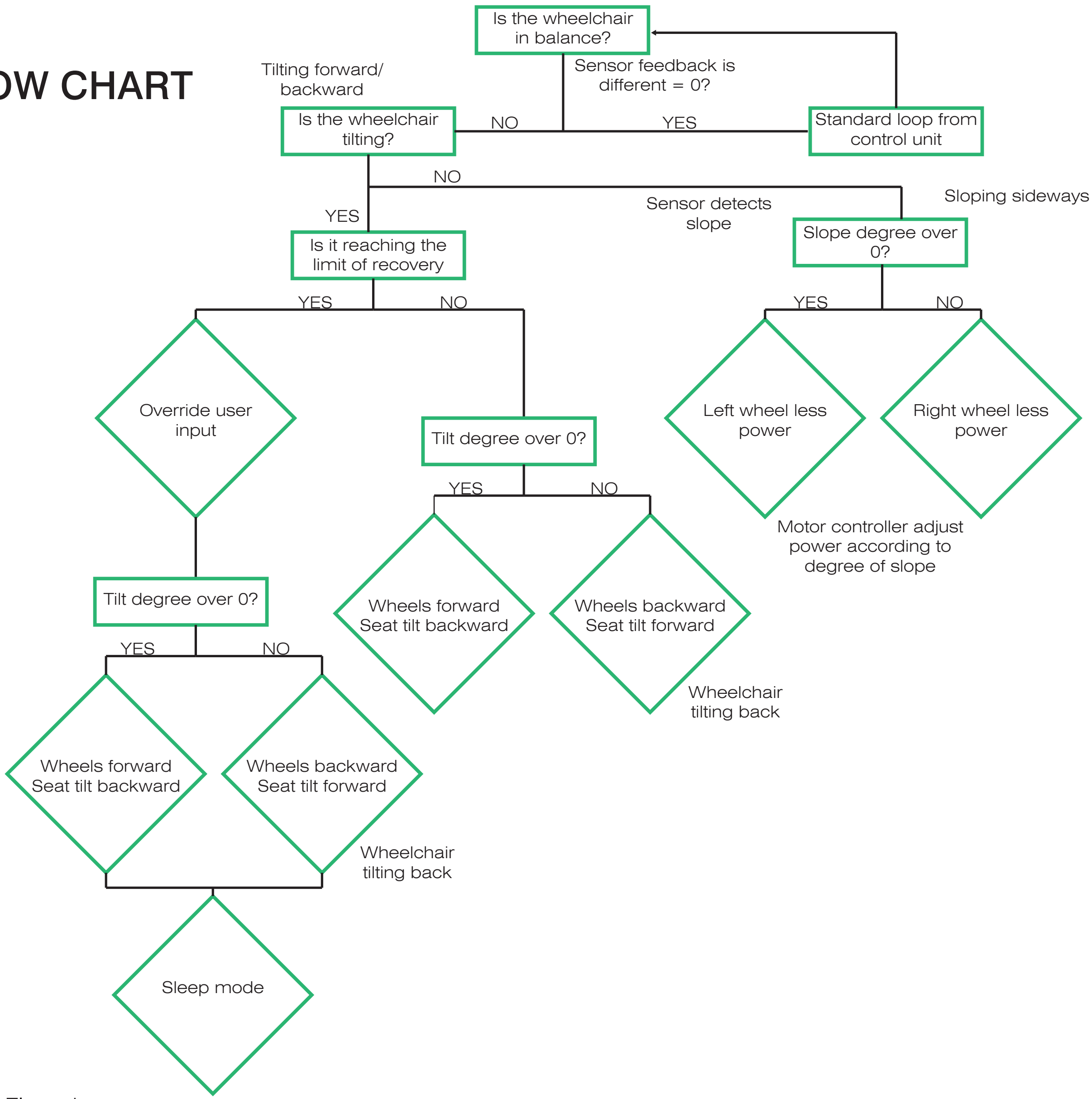
When Duro detects a spasm from a user it drives in the direction needed to regain balance and goes into sleep mode.
In the case shown in illustration 9, the wheelchair would drive backwards to "catch" the weight moving in that direction.

What happens when Duro detects the spasm is shown in the flow chart in illustration10.



Ill. 9: Duro risk scenario

FLOW CHART



Ill. 10: Flow chart

EXPLODED VIEW

Ill. 11: Exploded View

BILL OF MATERIALS

Item no.	Part name	Quantity
1	Headrest	1
2	Back cushion	1
3	Backrest	1
4	Seat cushion	1
5	Armrest	2
6	Seat	1
7	Battery	2
8	Clip	7
9	Battery holder	1
10	Body 1.1	1
11	Actuator	6
12	Rear fork top	1
13	Body 2	1
14	Steering arm	1
15	Rear suspension	1
16	Rear control arm	2
17	Rear fork bottom	2

Item no.	Part name	Quantity
18	Rear wheel	2
19	Rear wheel axle	
20	Chassis	1
21	Footrest	1
22	Motor	2
23	Body 1.2	2
24	Shock absorber	2
25	Front suspension	
26	Front wheel	2
27	Front wheel axle	
28	Electrical components	1
29	Joystick	1

DETAILS

THE UNFOLDING

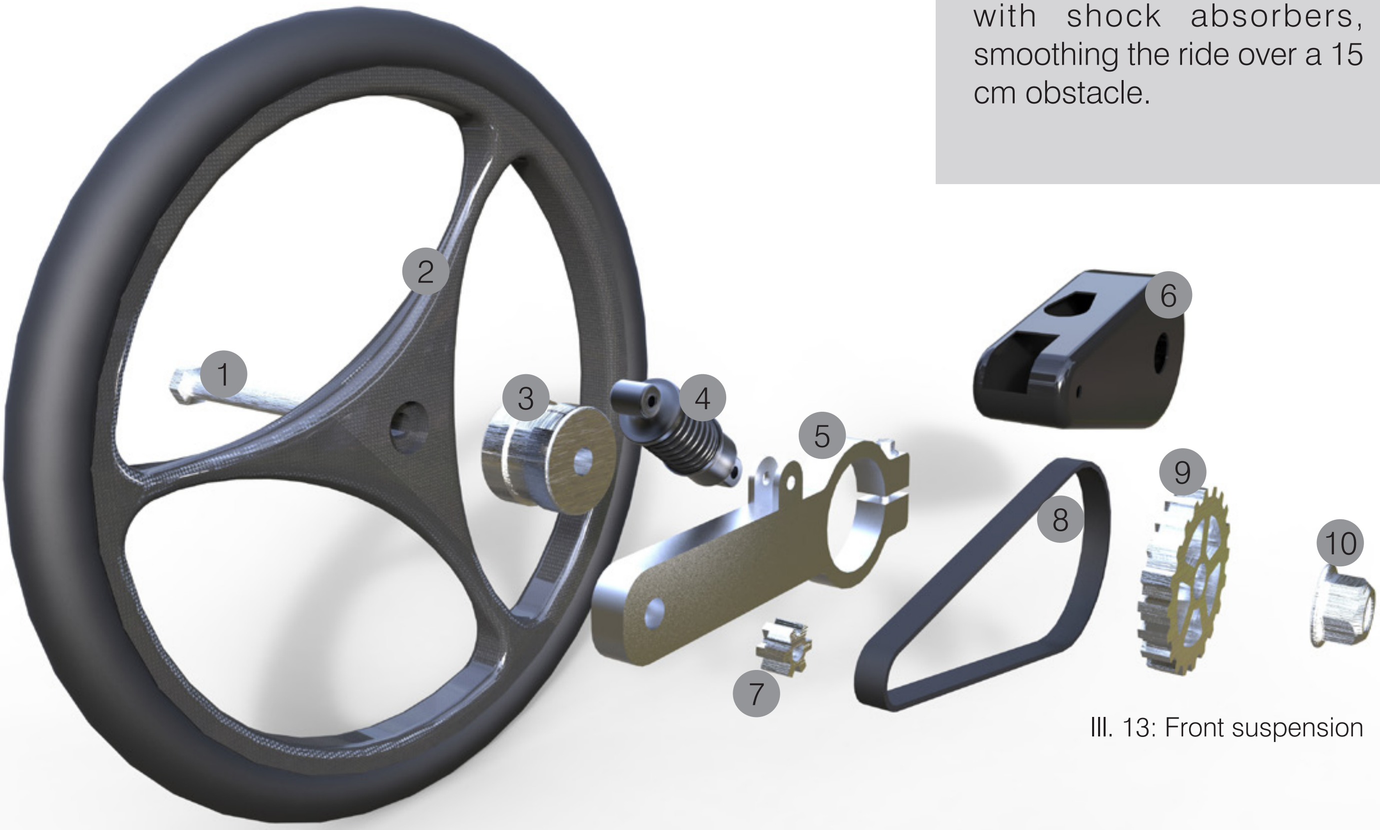
Earlier in the report it was shown that the wheelchair unfolded when driving outside. In that situation an actuator in the end of each fork rotates the forks. This forces the back wheel suspension outwards and down in a counterclockwise motion.

Ill. 12: The unfolding

1	Front wheel axle
2	Front wheel
3	Front wheel bearing
4	Shock absorber
5	Swingarm
6	Body 3
7	Belt drive gear small
8	Belt
9	Belt drive gear large
10	axle nut

FRONT SUSPENSION

The front suspension consists of the parts shown in the illustration. A belt drive connects the motor to the wheels providing the required gearing in order to climb obstacles. The front wheel suspension is constructed with shock absorbers, smoothing the ride over a 15 cm obstacle.

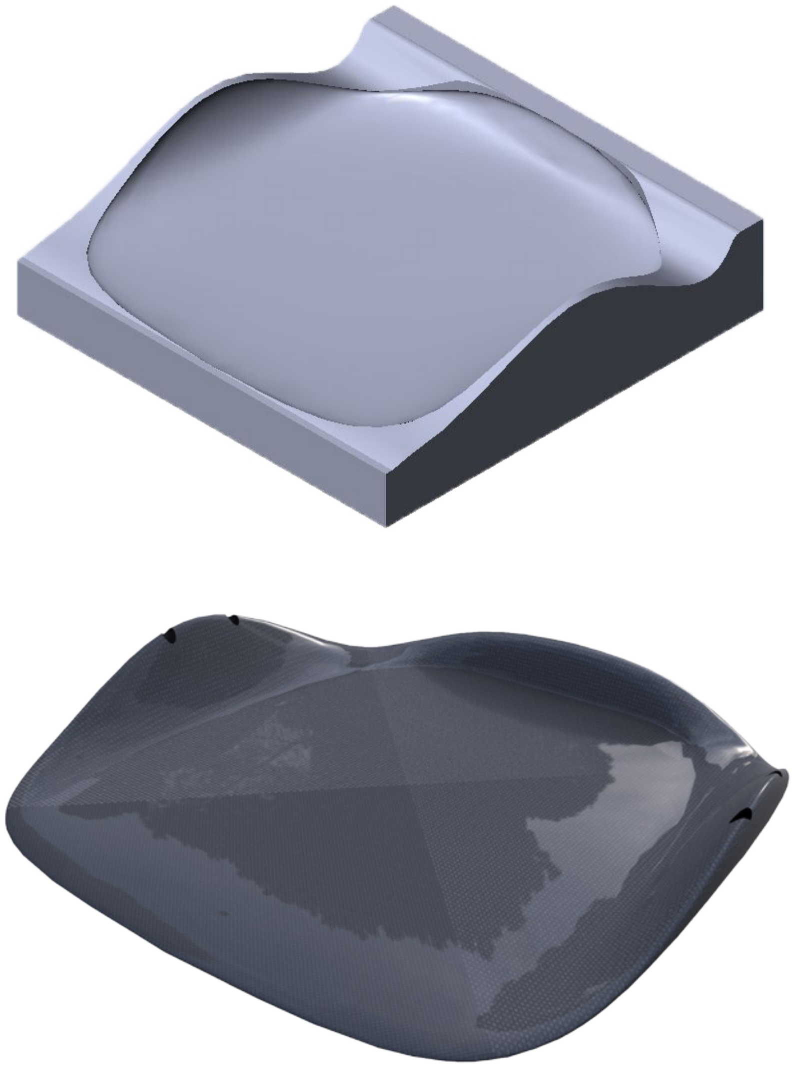


Ill. 13: Front suspension

PRODUCTION

SEAT

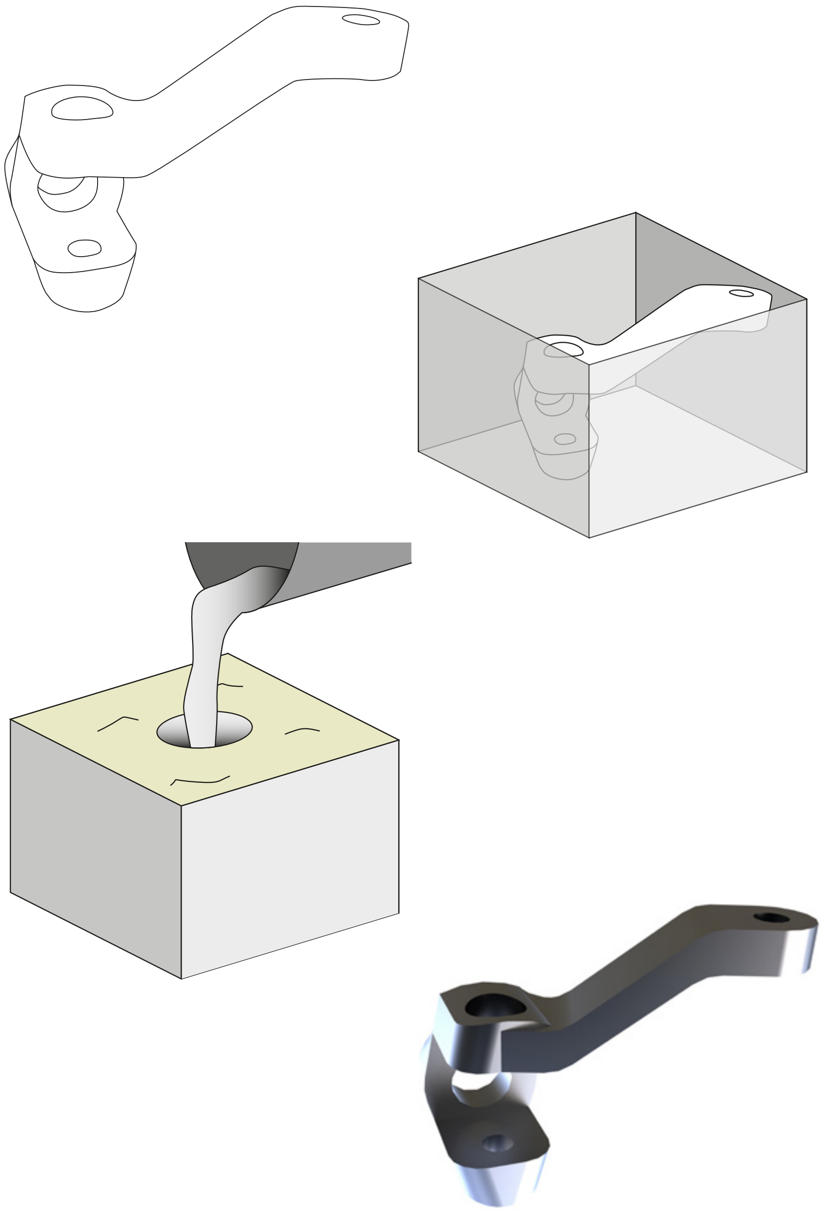
The seat for Duro is made from Carbon fibre to get a strong but thin shell. The production method used is Vacuum Infusion Process which is often used for propellers and marine components. The process is as the name indicate a vacuum process where carbon fibres are laid over a mould and the epoxy resin is brushed or sprayed into it.The mould is covered and sealed after which the air is pumped out which forces the materials into the mould and the resin thoroughly into the fibres creating the strength of the final product.
[Lefteri, 2013]



Ill. 14: Seat production

REAR CONTROL ARM

The rear control arm has a fairly complex shape and needs to be sand casted. Sand casting is a process where the part is made from polystyrene, the part is covered in a sand/clay mixture. In the sand mixture a hole is left for pouring in metal. Furthermore there are risers used for excess metal which fill the mould when the metal stinks while solidifying. When the metal is poured into the mould it burns away the polystyrene and the cavity is filled with metal.
The surface of a sand casted part is very rough, it can be treated afterwards to get a smoother look. [Lefteri, 2013]



Ill. 15: Rear control arm production

BUSINESS

The following section will present the overall specification of the business case directed to the company profile of Wolturnus. Wolturnus is currently expanding into a European marked which has other distribution channels than the Danish marked.

VALUE PROPOSITION

Duro is a mobility aid which provides freedom and independence to people who do not wish to be limited by their walking disability

USER SEGMENT

The mobility aid is specially developed for people living an active lifestyle, who requires a chair optimised for both indoor and outdoor use. Duro can be used of current users of electric wheelchairs and will furthermore provide an alternative to users of electrical scooters.

CHANNELS

The municipality is the main distribution channel in Denmark when providing financed mobility aids to the users. In Germany which Wolturnus is currently expanding to, the mobility aids are sold through specialised stores

AWARENESS

Awareness of the product is crucial when Duro is introduced to the marked. The information should be directed to the different costumer segments, the caseworkers at the municipalities and the end users. The municipalities should be informed of the basic functionality of the product and why this is the best solution to the price. As the caseworkers will be able to find products to a lower prize, it is important to inform the end user of Duro as an alternative providing more freedom and independence than current products. This could be done by promoting Duro in helping aid stores, such as Actium plus in Aalborg, with a consultant offering test drives. Based on the tendency from other countries comparable to Denmark the number of stores specialised in helping aids will grow within years. The growth is a result of an enhancment in private founding of helping aids, which will enhance the number of channels to the end-user.

Ill. 16: ActiumPlus

COMPETITION

The electric wheelchair is launched into an occupied marked with a high number of competing brands. Duro will compete against current wheelchairs as the product developed for the active user. The evaluation of an eletrical wheelchair is based on several parameters, which are shown in the illustration. Duro is able compete against the wheelchairs specialised for either indoor or outdoor use, as it has one of the lowest turning radiuses on the marked and is able to climb higher obstacles than any existing wheelchair.

Duro:
Turning radius: 480mm
Obstacle height: 150mm
Max. Speed: 15km/h
Seat Height: 450mm
Width: 600mm

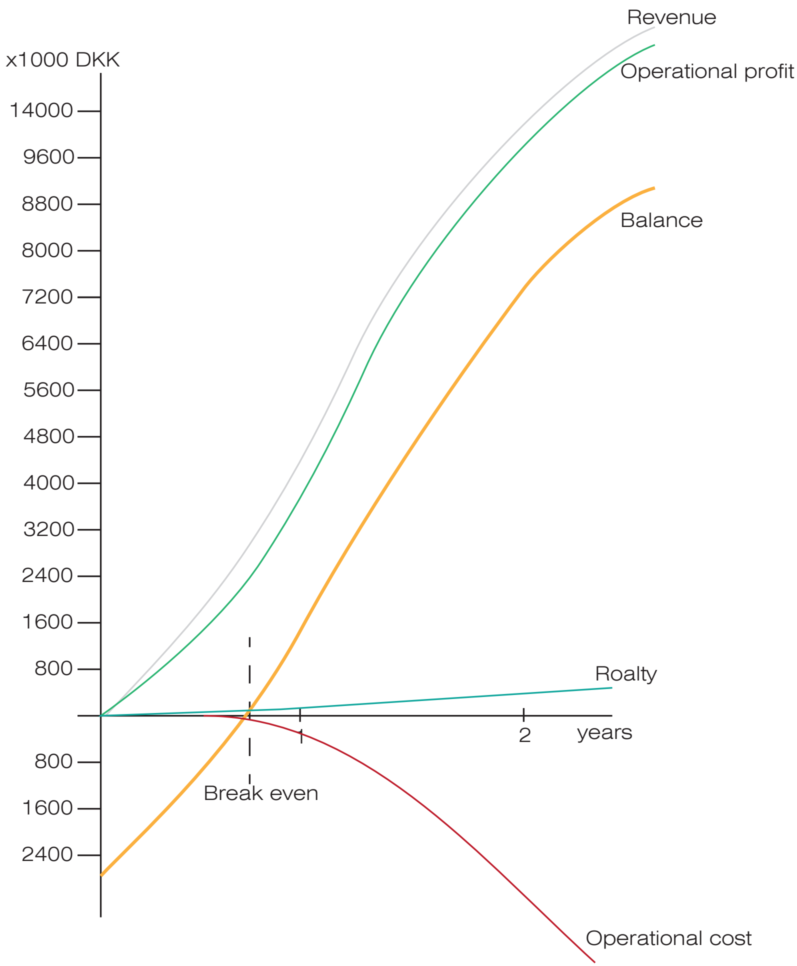
Permobil:
Turning radius: 715mm
Obstacle height: 60mm
Max. Speed: 8 km/h
Seat Height: 405mm
Width: 675mm

Roltec:
Turning radius: 600mm
Obstacle height: 70mm
Max. Speed: 14 km/h
Seat Height: 460
Width: 650mm

Vela:
Turning radius: 580mm
Obstacle height: 60mm
Max. Speed: 10km/h
Seat Height: 540mm
Width: 660mm

Invacare:
Turning radius: 550mm
Obstacle height: 75mm
Max. Speed: 12 km/h
Seat Height:420mm
Width: 650mm

Ill. 17: Competition



Ill. 18: Revenue stream

REVENUE STREAM

Duro is expected to sell 150 units within the first two years, 50 units within the first year and afterwards 100 units a year, this is a market share of 12,5% of the 800 electrical wheelchairs sold every year. The launch of Duro will require an investment of 2.560.000 DKK, but with a mark-up factor of 4 the profit will break even after the sale of 32 wheelchairs. The production price of 22.000 and the investment of 2.560.000DKK arerough estimates based on salary and cost of materials. It would be possible to lower the retail price, in order to attract customers. The revenue stream for the current retail price can be seen in illustration 18.

PRODUCT PLATFORM

The proposal presented is the basic platform of the product architecture. The wheelchair is very customisable in order to meet the specific requirement of the particular user. The proposal does not include a specification of the design of arm- neck- and leg rest, these will be developed in different modifications in order for the user to choose the equipment of own preference.

In order to launch the product, the client is able to choose to launch Duro with existing equipment or to redesign the entire product architecture. The manufacturer is able to control the production costs of the wheelchair by varying the complexity of the product architecture. The product architecture is divided into three parts: The bottom construction which is the basic platform, equipment such as arm- or neck rest and components from sub-suppliers, for instance the joystick (see illustration 19)

The client is able to choose different strategies of implementation, the strategy could be to introduce the minimum viable solution to the marked and develop the product architecture when the product makes profit. By doing this the client will minimise the customisation of the product and thereby exclude some users, but the financial risk is higher when launching a full product architecture.

Ill. 19: Product platform

ILLUSTRATIONS

Ill. 1 - 15: Own illustrations

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Ill. 18 - 20: Own illustrations

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Ill. 20: Hero shot 2


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