CRE[ATIVO]^2

Mobility Devices for an Active Lifestyle

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Foreword

Our Luleå-based team included seven graduate engineering students from various educational backgrounds and one exchange student from Duluth, Minnesota taking the final-year course in Mechanical Engineering Design, SIRIUS at the Luleå University of Technology, Luleå, Sweden. The Luleå-based team worked together with four graduate students taking ME310 at Stanford University, Stanford, CA, USA in a distributed team. In our year long project the students have been working towards a common goal, to enhance the wellbeing of a person with a disability, through a project called CRE[ATIVO]^2 through the Design for Wellbeing organization.

The purpose of this document is to illustrate our work process and our discussions so our coaches, people that have been involved in this project and people that are interested in the Design for Wellbeing organization can better understand what we learned throughout the year, what results we achieved, and how we learned to work as a distributed team. We have therefore decided to document our process in detail so you can follow the workflow through the year. After each chapter we created a discussion section, to show what we have learned in each phase, but also so others can read and understand the method used.

We would like to thank everyone who has helped us and supported us throughout the project, those who answered our surveys, provided us with information, assisted us in the prototype building and helped us navigate through tough situations. There are so many people we want to thank we cannot list them all. Many of you are cited throughout this document. Most of all we want to thank our coaches, other teachers and staff at Luleå University of Technology and Stanford University.

Thank you for your support, without you this project would not have been possible.

Executive Summary

Active, winter, leisure time. These three words described the initial assignment for the group that would become the Design for Wellbeing CRE[ATIVO]^2 project team. Our initial target was to create a new product that would improve the quality of life for people with disabilities. Students from Luleå University of Technology, Luleå, Sweden and Stanford University, Palo Alto, California, USA collaborated on this year-long project using a distributed engineering design model.

Throughout the fall the two work teams communicated via teleconference, telephone, e-mail, and MSN messenger. The initial phase of Design Space Exploration included a needfinding survey of disabled people and those who work with the disabled. Other sub-groups benchmarked currently available products and analyzed related technologies.

From this work a list of needs and currently available solutions was created. The groups then agreed on a name CRE[ATIVO]^2 and a mission statement for the project: to develop a safe mobility device that is easy to maneuver on varied terrains and in multiple weather conditions. The device should also improve user access to facilities and transportation, while being easily transportable.

In January the four Stanford students visited Luleå for the first face to face meeting of the work groups. Work began on concept generation and evaluation Initially ideas were grouped into categories such as Quietness, Storage, Terrain, Safety, and Clean/Dry/Cool. No idea was discarded at this point. During the Stanford meetings two key decisions were reached. The first was the decision to build a manual wheelchair. For the second decision the groups ranked the concepts that had been generated and selected the top three categories as traction, comfort, and human interface (cleanliness). Stanford had completed some preliminary work on human interface so they were assigned to continue with that topic. Luleå began work on traction and comfort.

The Luleå team utilized the mission statement to identify and evaluate the various concepts related to traction and comfort. Pugh's method along with group discussion was employed to select the concepts that would be developed. The following concepts were selected:

- The ability to change the wheelchair's centre of gravity while the user is in the chair and without using tools. This will increase comfort and allow the user greater flexibility in interacting with the environment.
- The ability to adjust the camber angle of the wheels while seated and without tools. This will improve traction and manoeuvrability.
- Identify a lightweight composite construction of the frame. If the chair is lighter more features can be added, as a lighter chair is easier to move.
- Clip on/ snap on traction with a lightweight hub design. This will increase traction in the winter and the hub design will be lighter and will keep snow from sticking to it.
- Design an adjustable backseat. This will significantly increase the comfort.

Throughout February and March detailed drawings were created to integrate the concepts into a product design. CAM/CAD and Alias Autostudio were invaluable tools in this process. In late March the Luleå team visited Stanford University. During these meetings the detailed drawings were shared and improvements were made. Stanford also shared its design for cleaning the wheels of the wheelchair.

Once the group returned to Luleå work began on the creation of a physical prototype. The detailed drawings were turned into product specifications, material to construct the prototype was obtained, and wheelchair pieces were manufactured by the work team utilizing various processes. The Stanford group also completed work on their wheel-cleaning device.

In early May the prototype was completed. The only concept that was not included in the prototype was the ability to change the camber angle. This concept was dropped during the detail design phase due to cost and time constraints. On May 13th the product was launched via an oral/video presentation at Luleå University of Technology. The launch included a display of the chair with posters highlighting the project and the team, inclusion of the CRE[ATIVO]^2 project in the SIRIUS brochure, and development of a web site where the prototype could be viewed.

The CRE[ATIVO]^2 team completed the project on time and met the goals outlined in its mission statement.

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Section 1 Team Introduction

During the first two quarters the Design for wellbeing project consisted of eleven students from LTU, nine students from Stanford and nine students from KTH, totalling twenty-nine students. This group performed research and brainstorming to determine the scope of the project. Simultaneously at Stanford another group worked with a project that was linked to Intel corporation. Also at KTH, students worked with a project called Elemental Game. In the beginning of the third quarter all students had the chance to select which project they wanted to work on for the rest of the course. The final Cre[ativo]^2 team consisted of eight students from LTU and four Stanford students.

1.1 Luleå Team

Boel Arlock
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Boel received a B.S in Industrial Design in 2002. Now she is studying complete an MSc in Mechanical engineering and will be finished in May 2005. Boel graduated from Luleå University of Technology in 1996 with a teacher's degree for year 1-7. She worked as a teacher for two and a half years before she started her technical education. She has also worked part time for several years at The House of Technology, a science centre in Luleå.

Kajsa Dymling
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Kajsa is presently a fifth-year student at Luleå University of Technology. She is studying toward her MSc in Mechanical Engineering. During her five years at University she has participated in exchange programs with the Technical University of Denmark and Strathclyde University, Scotland.

Kajsa has worked within the industry, at companies like Scania and Alfa Laval, and as a saleswoman at Stadium, in both Sweden and Denmark.

Jimmy Holmström
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Jimmy previously studied mechanical engineering at Umeå University for three years before starting his final year to become a MSc at Luleå Technical University. He has worked as a forklift operator at Upponor Wirsbo AB and he has manufactured cutters for milling and turning at Seco Tools.

John Kapla
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John will receive his B.S. in Industrial Engineering, Mechanical Engineering and Mathematics in fall of 2004. John is the lone American exchange student on the team. To date, he completed one four-month co-op with Marshfield Door, a door manufacturing company. He designed quality procedures and protocols for a number of systems, along with implementing a number of lean manufacturing processes. He also completed two fifteen-week co-ops with PaR systems, a robotics firm. There he designed a number of actuators and switches for an automated crane system for the transfer of fuel cells in nuclear reactors. This summer John will be heading up the student group in a research project at the Ford Plant in Köln, Germany. The project will deal with virtual PLC's and design for manufacturing.

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Malin is a final year student in Mechanical Engineering at Luleå University of Technology. Construction is her major. This spring, 2004, she will receive her MSc in Mechanical Engineering. During the spring of 2003 Malin was an exchange student at Strathclyde University in Glasgow, Scotland. Malin worked at several different companies during her summer vacations. She has found those experiences very educational.

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Emma is presently a fourth-year student at Luleå University of Technology. She is studying toward her MSc in Mechanical Engineering. During her third year she was an exchange student at Strathclyde University, Scotland. She also worked in Dublin, Ireland for six months and worked at several companies in Luleå including Inexa Profil, Carl Lamm and Sexans taxi.

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Jimmy is currently a fourth year student at Luleå University of Technology. He is studying towards an MSc in Mechanical Engineering, specializing in construction. Last year, Jimmy was an exchange student at Strathclyde University in Glasgow, Scotland, and next year he will broaden his education towards industrial design. During the past five summers he worked for a construction company that makes aluminium products.

Hans Wikström
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Hans received his B.S. in Mechanical Engineering in August 2001. Now Hans is studying his final year at Luleå University of Technology and during 2004 he is earning his MSc in Mechanical Engineering. In 2003 he worked at Hartl Energy Technology KEG, Austria, for 6 months. His task was to construct a conveyor system for pellets.

1.2 Stanford Team

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Karlin received a B.S in Mechanical Engineering from the University of Michigan in April 2003. She is presently a first-year MSME student at Stanford University. Karlin has worked as an intern at both Goodyear Tires and at DaimlerChrysler. As an undergraduate, she also spent time working in the Solid Freeform Fabrication Lab and the Haptics Lab at the University of Michigan.

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Jeremy received degrees in Mechanical Engineering and Math from Tufts University in June, 2002. He is presently a second-year master's student in Mechanical Engineering at Stanford. Jeremy is specializing in dynamics and design. His work experience includes working at Ford Motor Company, Credit Lyonnais (a French bank), and Connex (a transport company part of the Vivendi Environment group) in the UK.

James Parle
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James received a B.S in Mechanical Engineering from the University of Southern California in May, 2003. He is presently a first-year master's student in Mechanical Engineering at Stanford. During his junior year, James had a co-op position at NASA Dryden Flight Research Center. To date, James has completed three co-op tours at Dryden with the first being a seventh month tour, followed by two three-month tours. While co-oping James worked on a variety of aerospace projects including autonomous formation flight of F-18's, the Shaped Sonic Boom Demonstrator, and he designed hardware to support simulation work.

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Brett received a B.S in Mechanical Engineering from Clemson University in 2002. He is presently a first-year master's student in Mechanical Engineering at Stanford. Brett has been an intermittent employee at the National Institute of Standards and Technology (NIST) from 1998-2003. Work at NIST involved prototyping design and testing. He has worked on a wide range of projects during his time at NIST, including MEMS micro-fluids research, tactile display prototypes, and Braille display prototypes.

Section 2 Distributed Engineering

2.1 Distributed engineering team work

Many of the students in Design for Wellbeing worked as part of a global team for the first time during this project. Many different opinions and thoughts have been exchanged throughout this year. There have been some difficulties and disagreements but the key advantage, is that a team consisting of both Stanford and Luleå students will develop a more diverse solution than a team consisting of only students from one university. The more diversity there is within a team, the better the likelihood that the design problem has been viewed from all angles and therefore the result is more applicable with a distributed team. Of course this can only happen if the problems with communication can be overcome and everyone participates.

The Luleå and Stanford teams met each other in person for the first time in late January, the primary reason being to become better acquainted with each other. It is much easier to discuss the project after you get to know the other teammates on a more personal level. It is easier to ask somebody whom you refer to as your friend or colleague for help or input, than somebody that you have only seen briefly in videoconferences. After the Luleå visit it was much easier to talk to the Stanford team mates during videoconferences. You know each other and you are not as nervous about making a fool out of yourself or miss speaking. A meeting visit closer to the beginning of the project would be more advantageous in future projects.

After the visit in Luleå the work was split into three areas: comfort, cleanliness and traction. The Luleå team dealt with comfort and traction while the Stanford team looked into the cleanliness issue. The intention was the team would work on the same product just different areas, but in the end Luleå worked on their wheelchair and Stanford worked with their cleanliness device. Although Luleå and Stanford were involved in each other's projects the teams drifted apart, mainly because it was now possible to work on our "own" project without help from the other team. Granted this developed more on its own than by design but it does prove to be a little misleading when the team describes itself as a fully distributed team.

It is more likely the teams would have continued the distributed model, if both teams' names had been the same and the teams were forced to focus on the same issue. Due to the openness of the project and the fact the teams had different project goals from the start proved to undermine the effort of distributed collaboration. While the teams still worked together to achieve the best products possible, the designs are not very dependent on each other's. The Luleå team had hoped for a more dependant outcome, where everybody was striving for a common goal. However, the teams have used the principles associated with a distributed team and have learned how to collaborate from a distance.

2.2 Globally distributed communication tools

During this project the Luleå team kept in contact with the Stanford team by telephone, e-mail, storm blog and regular videoconferences. The Luleå team also used a project coordinator where meetings were set up, documents and pictures were shared and so on.

Telephone was used to exchange information quickly. Most calls took place when it was difficult to connect through the videoconference system. E-mail was used to send information about meetings or follow-ups after the meetings, such as meeting minutes or more information about an area that had been discussed. Sometimes the project coordinator would have been a better option for communication. For example a number of documents were passed around with e-mail. It would have been easier to keep the documents in order if the documents had been put onto the project coordinator. Why the teams didn't do so was mainly due to the simplicity of e-mail and that e-mail is a more common format for document sharing.

The project coordinator was a big help. Meetings were set up and documents and pictures were shared via the project coordinator. The project plan was also presented on the project coordinator in the form of a Gant chart. There was also a team coordinator, which was imbedded into the project coordinator. The team coordinator had personal team member presentations, personal blog, team blog, web-cam (recording the Luleå team's project room) and the ability to send e-mail and SMS. The most valuable functions were document sharing, setting up meetings and SMS. The SMS was used primarily for emergency messages when fast information needed to be shared. The document sharing system was a necessity to keep all the documents and pictures in order. The project coordinator was great for setting up meetings. When a meeting was arranged an invitation was sent via e-mail to all the participants and they replied on the project coordinator if they could attend or not. It was easy to see who was going to attend and who was not and keep all the meetings in order.

The videoconference system, Confero, was used to hold regular meetings. This technology was sometimes a bit unreliable. It was hard to connect it and sometimes the picture just froze in the middle of a session. As long as the program is working and all reflectors that will be used are up and running everything works fine. All systems have weaknesses, even Confero, but after a while you get used to it, and you learn how to anticipate and solve the problems.

Using a videoconference system has both positive and negative aspects. Mainly it is positive, for example you see the people you are talking to in real life. You can see their body language and gestures in real time. When showing each other prototypes that have been built in each group you actually see the functions and you have the opportunity to ask questions directly in person. It is easier to ask questions eye to eye than via email or through the storm blog. One negative or rather a problem, is that sometimes it is intimidating to talk since the Luleå team is not speaking their native language and the environment in their videoconference room, the Studio, can be seen as very stiff and formal. The Luleå team would have preferred a more relaxed environment, with comfortable chairs and without microphones. When talking into a microphone you have to lean over and it is difficult to comment or interrupt when someone else is talking. A headset for every project member or a microphone in the middle of the table could facilitate this. Despite these minor difficulties, having videoconferences helped the work progress.

Section 3 Selection of Project Direction

The beginning of the first semester was dedicated to finding a project that all in the project group found exciting and challenging. To do so the project group studied design methodology, created networks among the physically challenged communities and narrowed the project down to an actual idea. To be able to narrow the project down the group divided into 3 subgroups. One subgroup focused on gathering needs and requests from physically challenged persons and the people that work with them. The second group worked with benchmarking existing solutions. The final group focused on gathering information about related technology, which perhaps could be used in the final product.

3.1 Design Methodology

To get in terms with the design methodology, which the project group was going to work with, three different definitions of a methodology were studied. “Design For All”, “Inclusive Design” and “Universal Design” all include the same thinking and structure:

- Equitable use
- Flexibility in use
- Simple and intuitive
- Perceivable information
- Tolerance for error
- Low physical effort
- Size and space for approach and use

These “seven commandments” constitutes the main idea of the three “philosophies”. These design methodologies aim to guide designers in creating products that can be used by as many people as possible, irrespective of age and ability.

3.2 Networking

In order to get as much support as possible and to get in contact with the physically challenged communities (i.e. handicapped organizations, physically challenged people, persons that work with the physically disable), the project group visited the institution of health and science in Boden, Sweden. The group also visited a fair with health care equipment in Luleå. At the fair were different types of vehicles, seats, beds and chairs etc displayed. The group had also the opportunity to get in contact with companies that sell and develop aids for psychically challenged people.

3.3 Brainstorming

To narrow the project definition down the team in Luleå held a brainstorming session. The main point with brainstorming is to come up with good and sometimes crazy ideas. First all the people that are going to attend the session are briefed on what the topic is. Then all session members sit down and write up every idea they come up with on a paper. After that the ideas are compiled into different areas. After the ideas are compiled it is time to evaluate them. The evaluation resulted in a large number of different categories. Among these were “smart homes”, “educational toys”, “rehabilitation equipment” and “motorized mobility devices”. From these categories “motorized mobility devices” was chosen.

The group wanted a project name that symbolizes the purpose with the project, which is that physically challenged people should have the chance to live an active and creative life. Creative is creativo and active is activo in Portuguese. When both of these Portuguese words are combined the project name came naturally CRE[ATIVO]^2.

3.4 Guidelines for the CRE[ATIVO]^2 Project

The main goal with the project is to, within the meaning of the keywords *active*, *winter*, *leisure time*, expand on today’s concept of *motorized mobility devices* into a new meaning – aiming for an innovative concept that is not limited in scope by the ways in which, for example, wheelchairs, scooters and Segways are designed and being used today. Aspects of interest include diversity in use, usability (ease of use) and usefulness (value of use). One of the underlying reasons for choosing the keywords above is related to the challenges that people with disabilities face during winters in Luleå, due to the arctic climate that inhibits an active lifestyle during that period. However, the usefulness of such motorized mobility devices are not in any way limited to the arctic scenario. Just consider the mobility requirements involved with going to the beach, hiking in the mountains, shopping at the mall…and the list goes on.

Section 4 Design Space Exploration

This is an information-gathering phase. It is done to get enough background information to be able to design a product that is relevant and innovative. This was done by dividing the group into three subgroups, Needfinding, Benchmarking and Related technology.

The Needfinding group has gathered information about customer needs and opinions by doing surveys, interviews and observations. This is to avoid making a product which the user don't need or want.

The Benchmarking group has looked into already existing products on the market. This is to get inspiration and to avoid making an already existing product. The information was gathered by using the internet, the library, doing field trips etc.

The Related Technology group has done their research on the internet about technology that can inspire to make new and creative solutions.

These three areas will then be combined and analyzed. For example, the identified customer needs can be used to find gaps in the market today. Those gaps can then be filled by combining existing and new solutions into a new product.

4.1 Needfinding

4.1.1 Purpose

To gain the knowledge needed to design and construct a mobility device that satisfies the needs of the user, the user being the disabled and the ones that interact with them. This knowledge can be gained through a number of ways. These needs are found primarily through surveys, interviews and observations.

4.1.2 Ideology

A need is a physiological or psychological requirement for the well being of an organism (Webster's Dictionary 2004). The idea behind needfinding is to find this underlined requirement for the well being of our focus group. In our case the needfinding aspect of our project focuses on the needs, opinions and behaviors of our target group.

4.1.3 Methodology

The method used to gather information about what might be perceived as positive or negative with today's mobility devices were surveys and interviews. The survey targets people with mobility disabilities in all ages resident in Sweden and the northern mid-west in the USA. Also people that work with the disabled within these geographical areas are included in the survey. The Swedish survey was conducted through an online application while the USA survey was email based. Aside from the surveys interview were conducted with prominent members of the medical community in both regions.

4.1.4 Results

Due to the short time frame the survey and interview process was seen as the most viable solution to the needfinding phase. The questionnaire ran for a week and 30 out of the 100 surveys were returned. The responses ranged from parents of disabled people and the disabled to medical staff that works with them. The interviews were conducted based on the survey questions. Three primary questions were asked of the focus group.

The first question asked was, "In regards to society today, what are the problems you face with your mobility device, i.e. climate, access, sports, and leisure etc.?" The majority of the sampling population that have a disability stated that the primary problems they face with society and climate is the difficulty in maneuvering in the winter and general access to facilities. The most prevalent issue with climate is that in the winter they find it too slippery and their mobility device gets too cold to operate. In regards to availability of access many users find it very difficult to find facilities and public transportation that is user friendly for their type of disability. The majority of the sampling population that work with the disabled stated that the primary problems they see with society and climate is maneuvering in winter, mobility device characteristics i.e. weight and size and the expense. The biggest issues with winter were problems with ice and snow accumulation. There were many observations of difficulties with bulkiness or awkwardness of the mobility device. Also they have observed that cost prohibits the user from getting the appropriate device.

The second question asked was, "What are the biggest problems you have with your current mobility devices or the ones you work with? What would you change? What is good about them?" The majority of the sampling population that have a disability stated that the primary problems they face with their mobility device is the device's performance in winter, device characteristics, accessibility, expense and complicated design. The majority of the responses stated this: The conditions of winter i.e. cold, ice, and snow, complicate the operation of the vehicle. The size of the vehicle seems to be a big issue along with its maneuverability. Devices that suit the needs of the user are very costly. The device should be easy and simple to understand. The majority of the sampling population that work with the disabled stated that the primary problems they see with the current mobility devices are the design of the device, design of seat, winter related issues, cost and how to us it. The bulkiness and maneuverability are the biggest issues and are related with size and weight of the device. The current designs of devices are a major source of confusion and misuse.

The final question asked was, "If there were a possibility to have a mobility device developed just for your favorite activity what would that activity be or if you are someone who works with the disabled what unmet need for mobility do you see in your situation?" The majority of the sampling population that has a disability gave the following suggestions for their own personalized mobility device. The suggestions were that they wanted their device to be easier to transport; in particular airplane access, easier to maneuver, adjustable height, more fashion friendly design, and better storage on the vehicle. The majority of the sampling population that works with the disabled found certain unmet needs. These unmet needs were a detachable seat and harness, adjustable device that suits different body sizes, a strong, lightweight, inexpensive, user friendly device, a device that doubles as a wheelchair and as a stander with adjustable height, a device that is easily transportable, and a device that can handle rough terrain but work well in a home.

4.1.5 Conclusion

Based on the results of our surveys and interviews we have formed some conclusions on what the mobility device characteristics should be. The primary concerns were the devices weight, expense and usability coupled with its performance in the winter climate. Along with these concerns was the ability for the device to be easily transported by having it fold or compact itself. The device being design should encompass all of these concerns. Thus it should have perhaps heated handles to cope with the cold winter air, ergonomically correct seat, better wheel traction, and light frame. Some alternate or optional features could include a detachable seat with harness, a wheelchair and stander combo or adjustable height and a fashionably correct design.

Through the needfinding phase the characteristics of the mobility device have been outlined. Even though the needfinding phase has ended we are continuing to keep channels open in case there are new developments or needs found by the users. Thus the outline of the device may change in the future.

4.1.6 Discussion

Timing seemed to be the largest obstacle in the needfinding phase. The time allowed to make an understandable survey a long with getting that survey to the desired audience was very short. If the needfinding phase were to be repeated more time would be spent on researching proper survey guidelines and finding better ways to reach the target group. One book in particular that was found after the completion of the phase was Enkätboken by Jan Trost. Here the book illustrates simply rules to follow when creating a survey.

The survey should contain:

1. one inquiry per question
2. simple easy to understand language
3. access to the survey should be to as many people as possible
4. to some degree of accuracy you should be confident that you have obtained the majority voice of the target population

After reviewing these rules and the survey it was clear that the survey violated some of these basic principles. The questions in the survey had more than one inquiry in them. Of course the survey was trying to get both disabled and professionals that work with them. The Swedish survey was limited to those who had access to computers. This narrowed the population down and thus reduced the number of potential responses. The survey was not sent to enough people to be able to conclude that it was the voice of the majority of the population. While thirty percent of the surveys were returned the sampling base was too small to accurately portray the needs of the population. More time would have resulted in more responses.

4.2 Benchmarking

By definition benchmarking is the action or practice of comparing something to a benchmark; evaluation towards an established standard (Britannica Online 20031113). The purpose of the benchmarking process is to gather information about existing solutions on the market today. This is done to prevent development of already existing products and instead come up with new technical solutions. Also to gain a greater understanding of the needs to satisfied today is reached by increasing the knowledge of current products. The objective is to create a bank of information for the participants in the project which can be a knowledge base for future work.

4.2.1 Course of action

A subgroup was assigned to work with the benchmarking process and the group started this work by analyzing and dividing the problem into smaller fields. The four group members then used different tools to find information. This included using the library, searching the Internet, field trips and contacting staff at health care and handicap organizations. The web-based sources with relevant information that were found have been structured and organized in a specific document to facilitate reviewing. The books used work as an encyclopedia for the group, where specific solutions of construction problems could be looked up. The first three tools comprised of ordinary information retrieval, while the field trips meant practical testing and discussions with the staff concerned.

One of the group members conducted a field trip to the aid centre in Malmö. During this visit, information from one of the staff members that gives guest lectures at Malmö University was collected. The teaching material that Anna Månsson use contains a summary of the most important information about the Swedish aid system in this field, and it also mentions corporations and organizations that concern the care of disabled people. Furthermore the group members were given a booklet about disabled people's interaction with society.

The entire subgroup also conducted a field trip together to the aid centre, Hjälpmedelscentrum, in Boden, as seen in figure 4.1. During this visit a foundation for the understanding of difficulties of developing aids was based. The staff informed about the strict laws and legislations that apply to development of products that are certified as aids. Different solutions of power chairs and scooters were presented. These solutions ranged from both vehicles that are driven by the user and vehicles with controlling mechanisms that make work easier for the user were presented. There were also different adjustments depending on physical abilities of the user.

Figure 4.1

Figure 4.1 *Wheelchair race at Hjälpmedelscentrum in Boden*

A few examples of this is the ‘suck and blow’-steering, extra powerful constructions for heavy users, adjustable seats to reduce the risk of bedsores and rotating seats to make getting in and out of the chair easier.

During the visit, tests of different motorized mobility devices were conducted. The weather conditions did not permit testing in an extreme environment, for example slippery conditions. In spite of this a clear difference in propelling the vehicle outdoors and indoors were noticed. A surface that leans sideways meant that the user had to compensate with moving its body position. This meant a feeling of discomfort and an improper sitting position from an ergonomic perspective. Another observation was the importance of easy-to-understand symbols on the steering controls and that different speeds result in different steering characteristics. This visit led to new ways of thinking and questions concerning the area. That information was to be analyzed more deeply.

4.2.2 Products on the market today

During the analysis a natural subdivision of the discovered material was made. The fields were categorized by the products functions and not by manufacturers. This categorization is power chairs, scooters / four wheeled vehicles (ATV) and other products. For the moment there is no focus on ordinary wheelchairs as the project is focused on motorized mobility devices.

4.2.3 Power chairs

There is a wide range of wheelchairs on the market. The most important properties on these chairs is ergonomic design, running reliability, weight, maneuverability, ease to dismantle and ease to load into another vehicle.

The most common power source for power chairs is different types of batteries. The batteries vary in size, weight, stand by time, running time and charging time. Most chairs have devices for not tipping over in the shape of an extra pair of rear wheels, as seen in figure 4.2. Some chairs have adjustable seats. The user can change position by them self and somewhere the adjustment must be done manually by somebody else.

To assist the user in reaching things some chairs feature an elevation function that helps the user to stand up. The user is then strapped around their waist and legs. A big advantage with this is that the user can manage better also in an environment that is not adapted for disabled persons. One example of such a power chair is the iBOT, as seen in figure 4.3, which is developed at Johnson & Johnson. This features multiple gyros that enables it to stand on

Figure 4.2 *Maneuverable power chair with adjustable seat and device for not tipping over.*

Figure 4.3 *iBOT, by Johnson & Johnson*

Figure 4.2
Figure 4.3

two wheels and let the user get up to the same level as pedestrians. It also features a stair climbing function. It is currently being tested and certified and is expected on the market in a few years. It climbs stairs, gets up on curbs and over thresholds. It will also work on rougher surfaces like for instance sand and will at the same time work indoors as well.

Several corporations manufacture power chairs that are supposed to work well in terrain. These have a large resemblance in appearance. There are however quite a few differences in turning radius, speed, curb climbing, maximum allowable road angle, suspension and so on. Some chairs have specifically designed constructions to enhance road grip as seen in figure 4.4 and to be able to drive without all wheels in contact with the ground. This can be solved by featuring more than four wheels or by driving the wheels independently of each other.

If you need a vehicle with greater opportunities to go off road Permobil has a vehicle that is called Trax, as seen in figure 4.5.

Figure 4.4
Figure 4.5

Figure 4.4 *Mini Crosser Jazzy*

Figure 4.5 *Permobil Trax*

This four-wheeled wheelchair comes in several models both for children and adults. The chair has springs to allow maximum comfort also in rough terrain. The spring is adjustable due to the weight of the user and has also individual suspension on the front wheels.

Trax can be equipped with a manual or an electrical system for turning the seat to make getting in and out of the chair easier. Manual or electrical adjustment of the wheelbase enables the chair to operate in both terrain and tight spaces. It can also be equipped with a roll bar to reduce the cause of injury in the event of a roll over.

Tunbjers has developed an all terrain wheelchair, as seen in figure 4.6, that is called Adventure and the advantage of it is that it can be taken apart to a transportable unit in 30 seconds. The idea is that it should be able to drive in any terrain.

4.2.4 Scooters

For people with lighter form of disabilities a scooter may work as a way of transportation outdoors. There are multiple examples of both three- and four-wheeled scooters. There are different focuses on different models. Some are easy to get into because the handlebar is foldable or because the seat can be turned. Top speeds vary between 7 and 15 km/h. The model Sonic from Miniscooter, as seen in figure 4.7, has an advantage where if you want to be able to transport it in an easy manner it is possible to take it apart. Other manufacturers aim to offer a small covered trailer to transport and store it in. Majority of Scooters come in three wheeled format but there a number of four wheeled versions available.

Figure 4.6
Figure 4.7

Figure 4.6 *A brand new terrain power chair from Tunbjers.*

Figure 4.7 *Mini Crosser Sonic*

4.2.5 Woodstar ATC

The Woodstar all terrain cart is a vehicle, primarily developed for the physically impaired. It differs in that the driver is seated more inside the vehicle rather than on top of, or astride it, as seen in figure 4.8. Woodstar ATC can be customized to make it available and functional for persons with a wide range of different disabilities. It has 570cc engine and a top speed of 100 km/h.

The vehicle is steered by a rod, which is connected to the helmet at one end and to the steering system at the other end. With light head motions the vehicle is steered in the desired direction.

Braking and acceleration is controlled by a “suck and blow”-device. It is a small hose, which you place in your mouth; the car accelerates when blowing into the hose and brakes when sucking. By pressing the tongue to the right the car starts. To change gear you press the tongue to the right and at the same time press the head backwards on a control in the backrest.

4.2.6 ATV All terrain vehicles

There are two main groups of ATVs, sport and utility, as seen in figure 4.9. They are mainly used off road. The landowner’s permission is needed to use it off road. When using it on the roads you have to get a special permission from Länsstyrelsen.

ATVs are often used by persons with disabilities. They can be adapted by installing for example special footrests, and holders for wheelchairs. If the person has less arm strength it may be suitable to choose an ATV with engine brake, power steering and automatic transmission.

Figure 4.8
Figure 4.9

Figure 4.*8 Woodstar all terrain carts*

Figure 4.9 *Top is a Yamaha sport ATV and bottom is a Honda utility ATV*

4.2.7 Adapted cars

There are many companies that have adapted cars for disabled persons. They have a lot of solutions depending on the individual needs. These solutions range from driving mechanisms to vehicle access.

1 Steering

For people who only steer with one arm there is a Steering wheel spinner, as seen in figure 4.10. These devices make it possible to only use one arm and still turn the steering wheel adequately. It comes in different shapes and with different grips.

For people with less arm strength it is possible to install a miniature stirring wheel, as seen in figure 4.11. The original steering wheel is often kept and it is possible to choose which steering wheel to use via a control panel. The miniature steering wheel can be combined with a Steering wheel spinner.

Another solution is to install a foot steering device. This is a round device that looks like a big pedal, as seen in figure 4.12. It is connected to a power steering and is maneuvered by turning the device. The angle of the foot steering device is set after the individual needs.

It is also possible to install a joystick for steering. This solution also controls braking and accelerating. When the joystick is pushed forward it accelerates and backwards it brakes. To make the stirring easier the system is speed adapted. It gives a smother steering when the car accelerates. Joystick suits persons with less move ability as well as less arm and hand strength. Depending on the individual need the joysticks come in different designs.

2 Accelerators and brakes

If the person has less or no motion use of their legs an accelerator

Figure 7.10
Figure 7.11

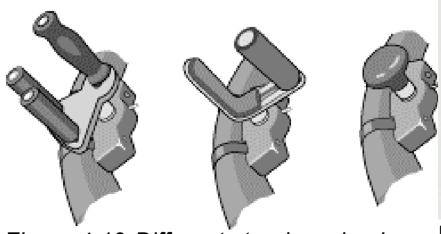

Figure 4.10 *Different steering wheel spinners*

Figure 4.11 *Miniature and original steering wheel with control panel*

Figure 4.12
Figure 4.13

Figure 4.12 *Foot steering device*

Figure 4.13 A*ccelerator ring*

ring can be installed. This device is integrated with the steering wheel and is maneuvered with the lower part of the hand or the thumbs, as seen in figure 4.13. The accelerator ring can be complemented with a mechanical braking stick. When hitting the break the acceleration is adjusted automatically.

Another solution is to install an acceleration/braking stick. There are two types, joystick and lever. The joystick also controls the steering. The lever on the other hand only controls braking and acceleration. The braking system has double electrical security. That means that you can brake even if the motor stops.

3 Wheelchair lifts

There are several products that are supposed to ease the transportation of people in wheelchairs. One example of this is different types of wheelchair lifts. There are lifts that help the passengers get into large automobiles or buses, see figure 4.14. There are also lifts for wheelchairs without passengers that lift the mobility device into the car or onto the roof of the car, see figure 4.15.

Figure 4.14
Figure 4.15

Figure 4.14 *Visualization of a wheel chair lift form U-lift.*

Figure 4.15 *The wheelchair lift, Chairtopper from Autoadapt, which lifts it onto the roof.*

4 Other features for adapted cars

There are a lot of devices or alterations, which makes it easier for people with less motional ability. For example there is special armrests, gearlever grip alterations, seatbelt grip, defrost devices, wide angel mirror. They companies also move dryer lever, directional indicator lever, pedals and electrical functions to suit the individual need.

In some vans it is possible to drive the wheelchair into the car by a lift or a ramp and then locking the chair to the floor. It is also possible to change the suspension of the car seat so it can be turned outwards. This alteration makes it easier for persons getting in and out of cars. Another common alteration is to make the car door open more.

The seat comfort can be altered by installing special seats or controls. There is one neck-rest that can change position electrically just by pressing the head in different directions. Though the seat comfort already is a high priority in cars, it is even more so for adapted cars, because of the risk of bedsores.

4.2.8 Adaptive skiing

To go downhill a number of solutions are available depending on the degree of the handicap. These devices enable people who can't stand up to ski. The mono-ski is a device in which the skier sits in a moulded seat (bucket) mounted to a frame above a single ski, as seen in figure 4.16. It requires good upper body strength and balance.

A bi-skier sits in a moulded fibreglass shell above two specially designed skis, as seen in figure 4.17. This is for individuals who ski in a sitting position. People with significant physical limitations usually prefer the Sit-Ski. To turn the Sit-Ski, a skier can drag

Figure 4.16
Figure 4.17

Figure 4.16 *Mono-ski*

Figure 4.17 *Bi-ski*

Figure 4.18
Figure 4.19

Figure 4.18 *Sit-ski*

Figure 4.19 *Three Track*

very short ski poles in the snow and lean in the desired direction, as seen in figure 4.18. The Three Track skiers have one good leg and two good arms. They are generally individuals who have amputations, post polio or hemiplegia. Three trackers use a full-size ski and outriggers giving them three points of contact on the snow, as seen in figure 4.19.

4.2.9 Other products

Knerten is an electric wheelchair for children. It is designed to manage both games and adventures. It is developed for active children between five and eleven years old (maximum weight of 50kg). Knerten is easy to take apart and also has a joint in the middle, which permits it to keep contact with the road at all times. Scalamobil is a lightweight stair-climbing machine for wheelchairs. It can climb tight and steep stairs. Scalamobil can be adapted for all wheelchairs as well as for different children aids. It can be useful for people who are not dependant of wheelchairs, but who have problems climbing stairs. Any special physical strength for the driver is not required.

Figure 4.20
Figure 4.21

Figure 4.20 *Handicare Knerten*

Figure 4.21 *Scalamobil from Tunbjers*

4.2.10 Laws and legislations in Sweden

To be able to develop a good aid you need to be familiar with the current laws in the country in which you want to launch and sell the product. In Sweden the laws are very extensive since it deals with safety aspects for individuals and the equal right to a decent life for all. The most relevant law for this project is The Health Care act that is described underneath.

1 Hälso- och sjukvårdslagen – Health Care Act

In Sweden there is a basic act, the *Health Care Act*, which is the foundation of all medical care activity.

The purpose of this act is to ensure a good health and equal care for the entire population. The care is to be given with respect to all humans' equal value and for the individual human value. From a disabled point of view this means that the people with the need of aids will have access to those needs.

The responsibility of medical care is divided into both the county council and municipality. These two organizations have three main tasks. These includes informing about devices, investigate current needs and to try out devices. According to the law the aids will compensate difficulties in daily life. The act says which needs that shall be satisfied by the aids:

- Satisfy basic needs: eat, get dressed, and manage hygiene.
- To be able to move.
- To be able to communicate with the surrounding world.
- To function in the home and surrounding environment.
- To be able to orient oneself.
- Manage everyday routines at home.
- Take part in normal leisure and recreation activities.

(Månsson, Anna; 2003)

Aids are supposed to be available for the user to take part in normal leisure time activities. That is such activities that pretty much everybody can participate in. On the other hand aids that are used to conduct specific sport exercises are not included, for instance a wheelchair for wheelchair basketball.

2 Nationell handlingsplan "Från patient till medborgare"

The Swedish government has decided to prioritize three working areas within the handicap politics over the next few years. These are:

- Making sure that handicap activity shall pervade all society sectors.

To create an accessible society.

- To receive people better.

(Anna Månsson, 2003)

The government has decided that by the end of year 2010 all current public areas will be accessible and useable to all, even people with reduced ability to move and orient. It can seem to be an obvious thing but it is probably pretty unique for Sweden. The big question is: will it succeed?

4.2.11 Conclusion

On the basis of the product studied, two favorites were found. These were Permobil's Trax and the iBOT from Johnson & Johnson. In common for these two vehicles were that they were pioneers regarding features and functions that the other devices didn't have. The features that stand out are the iBOT and its stair climbing function, which makes the person receive greater movement ability. The chair also has a function were the wheels are put together on top of each other so that it stands on two wheels which gives the user the possibility to get up in the same height as a standing person and therefore be able to work and move around in an environment not suitable for disabled people.

When it comes to Permobil Trax, one of the most important features is the extendable wheelbase. That feature makes it stable and Trax is therefore easy to run off road and yet be able to use indoors through narrow spaces.

Negative attributes among the products on the market today are difficulties to steer the vehicle, clumsiness and difficulties to take apart or put together when to transport it. When it comes to other products on the market there are several features that are interesting. Depending on what area future work will regard, a focus on a particular type of product may be done.

4.2.12 Discussion

The planning that was made in the initiating phase of the Benchmarking process was insufficient. Work would have been easier if additional and more specific goals had been defined. Due to the fact that the needfinding process was not finished the group had to make their own delimitations, which may have led to, that interesting areas have been excluded. The focus on motorized mobility devices led to the exclusion of ordinary wheel chairs in our study. This may have led to a loss of information regarding for example lightweight solutions. It would also have been preferable to have a better direct contact with the users, which may have led to a broader range of solutions.

4.3 Related technology

This work has been done to broaden the field in which solutions to future problems can be found. It has also been done to get inspiration and to have a wide base for the concept development.

4.3.1 Course of action

The subgroup was assigned to gain information about related technology. Since the field is very broad, it had to be narrowed down. A small brainstorming session was held in order to do that. The two areas that were chosen were the vehicle industry and steering devices. The information was then obtained through Internet and library searches.

A problem for the main project is to find an adequate solution to the way that our mobility device will transport itself from one point to the next. Just using four wheels, like an ordinary wheelchair, would be the easy solution, and it might also be the best solution, but if we don't look into other possible solutions, we cannot be sure of that.

4.3.2 The Segway

This is a self-balancing personal transportation device.
The Segway is a combination of a series of sensors, a control system and a motor system. The sensors consist of silicone gyroscopes that detect how the Segway is tilted. That information is then passed on to the microprocessor which determines the speed of the motors that control the wheels.

The Segway in Figure 4.22 is one of three different models.
When the vehicle leans forward, the motors spin both wheels forward to keep from tilting over. When the vehicle leans backward, the motors spin in the opposite direction. When the rider operates the steering grip to turn left or right, the motors spin one wheel faster than the other, or spin the wheels in opposite directions, so that the vehicle rotates.

Figure 4.22
Figure 4.23

Figure 4.22 *TheSegway™*

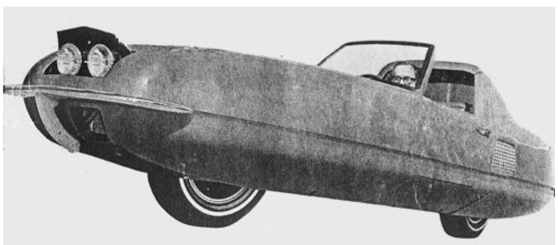

Figure 4.23 *The Gyro-X car from 1967.*

Figure 4.24 *A Russian gyro car from 1913.*

Figure 4.25 *The Tuscan half-track, trail bike.*

Figure 4.24
Figure 4.25

Gyros can also be implemented in a vehicle with four wheels. The gyro can for example control a tilting device that affects the position of the vehicle relative to the ground, and in that way counteract uneven ground and slopes.

4.3.3 The Gyrocar

This is a product that hasn't had a commercial breakthrough, but they are very interesting devices nevertheless. Figure 4.23 and 4.24 are examples of gyro cars that has been developed, but never reached the commercial market.

These cars have the ability to balance even while stationary. The Russian car was powered by a 16 hp engine. An electrical motor powered the gyro which was 40 inches in diameter. The Gyro-X car did 125mph on an 80 hp engine, but even with this great performance, for 1967 standards, it never made it to the stores. In fact, there seem to be a black hole in the history of gyro cars.

The Tuscan trail bike, as seen in figure 4.25, is a spin-off from The Gyro-X car, and it has good terrain capabilities. According to its specifications, it reaches 45 mph, and is capable of climbing 45-degree slopes, which makes it an interesting all-terrain vehicle.

4.3.4 Hovercrafts

The great advantage with hovercrafts is their ability to handle rough terrain. They can handle different conditions on land, like snow, ice, mud and sand, and are also capable to go over water, as the UH-10F does in Figure 4.26.

A hovercraft is propelled by a fan, which is shown in Figure 4.27. The airflow from the fan is then directed either straight behind the vehicle to get thrust, or down to the ground to create lift, or both simultaneously. A hovercraft is a very efficient vehicle. This is because it has virtually no contact with the ground, which reduces friction to a minimum. Rudders are used in order to steer the hovercraft.

Figure 4.26 *A hovercraft moving over water.*

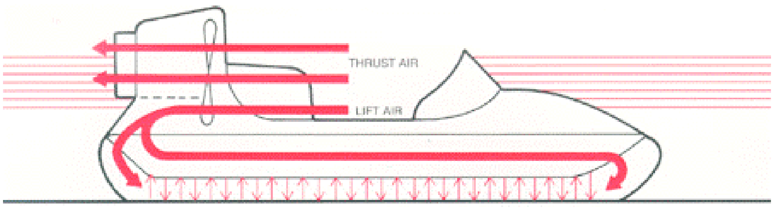

Figure 4.27
Figure 4.28

Figure 4.27 *Showing the airflow from the fan.*

4.3.5 Walking Machines

The walking machines on the market today are merely enhancements to people already being able to walk. But since all transportation devices for disabled people are substitutes for walking, this is an area that should not be overlooked.
The Pedoped, as seen in figure 4.28 uses pedals to go forward, in a way similar to a unicycle. The Spring Walker, as seen in figure 4.29, uses a leveraged exoskeleton to distribute body weight and to increase the leg force. A spring is also coupled to each leg to prevent foot-dragging. The Bionic boots, shown in figure 4.30, uses the impact tension created with every footstep, and then reverts it by using springs, which easily allows humans to run 25 miles per hour.

Figure 4.28
Figure 4.29
Figure 4.30

Figure 4.28 *The Pedoped*

Figure 4.29 *The Spring Walker*

Figure 4.30 *Bionic Boots*

Figure 4.31 *Forestry machine shaped as a spider.*

Figure 4.32 *Lemur robot.*

Figure 3.31
Figure 3.32

4.3.6 "Walking" vehicles

1 Forestry machines

This forestry machine looks almost like a spider although it has only 6 legs. The "spider", figure 4.31, is supposed to be more environmental friendly than the regular with wheels. The feet of the machine can be exchanged depending on which type of surface the machine is working on. A problem with this construction is that when the "spider" works on steep terrain it has a tendency to slip.

2 Lemur robot

The lemur robot is a small, agile and capable six-legged walking robot. These robots are mostly used in rough terrain. As it is shown in figure 4.32 it is a very practical robot because of its flexible use of limbs and effectors. The effectors are also exchangeable.

3 Jumping robot

The froglike robot, pictured in figure 4.33, moves by a combination of leaps and rolls to its desired destination. The frogbot is equipped with a camera, solar panels, sensors and an onboard computer that executes commands autonomously. When the robot is going to make a leap it bends its legs and then makes the jump. It can make a 1,8 m leap on earth.

Figure 4.33

Figure 4.33 *Frogbot*

Figure 4.34
Figure 4.35

Figure 4.34 *Fido rover*

Figure 4.35 *Nano rover*

4.3.7 Rovers

1 Fido rover

Rovers are mostly used in exploration missions. The Fido rover, as seen in figure 4.34, is equipped with a robot arm and a drill to extract and cache rock samples. Several cameras are also onboard to collect science and navigation images. This rover has the size of a coffee table. With a weight of 70 kilograms it can move up to 300 m an hour over smooth terrain.

2 Nano rover

As it is shown in figure 4.35 there are solar cells placed on all sides of the Nano rover so that even if the rover flips over, the rover will always have enough power to activate motors that will allow it to right it self. The rover has a camera that can be pointed straight down at the surface or straight up at the sky.

3 Urbie

A tactical mobile robot is rugged and well suited for hostile environments. The robot "Urbie", as seen in figure 4.36, is equipped with an advanced technology called stereoscopic vision. This technology makes it possible for the robot to accurately and quickly navigate toward its target, seeing and avoiding obstacles along the way. This type of robot is used in mobile military reconnaissance in city terrain, but it is also used in catastrophes.

Figure 3.36

Figure 4.36 *Tactical mobile robot*

Figure 4.37
Figure 4.38

Figure 4.37 *Volvo XC90*

Figure 4.38 *Regular tread vehicle*

4.3.8 Cars

Cars like the XC 90, figure 4.37, are equipped with many different accessories. These accessories could be useful in the finished product. Like Dynamic Stability and Traction Control, Anti Brake System and Roll Stability Control.

4.3.9 Tread vehicle

When maneuvering a vehicle in deep snow some kind of tread vehicle is preferable, as seen in figure 3.38. A wheel driven vehicle is much easier to get stuck in deep snow. The bigger the contact area is between the snow and the tread, the better the vehicle traverses on the snow, though to wide tread makes it harder to turn left or right.

4.3.10 Amphibian vehicles

Amphibian vehicles are very versatile as seen in figure 4.39. The same vehicle can be used in many different terrains such as in water, on snow, on ice, in the forest, etc. They can also be modified for specific conditions.

4.3.11 Sensor controlled vehicles

There aren't many sensor-controlled vehicles on the market today, though there are different kinds of sensor system integrated in, for example cars. One is the system that warns you when the car is to close to another object, like a wall or another car. One device that is completely controlled by sensor is the Trilobite by Electrolux, as seen in figure 4.40. It's a self-maneuvered vacuum cleaner and senses obstacles in its surroundings.

Figure 4.39
Figure 4.40

Figure 4.39 *Amphibian vehicles by ARGO*

Figure 4.40 *Trilobite by Electrolux*

Figure 4.42
Figure 4.41

Figure 4.41 *Tractor with "center-steering"*

Figure 4.42 *Different types of wheel alignment*

4.3.12 Jointed vehicle

In regular steering only the front wheels moves. This cause a problem because the tractors front part does not go in the same line as the wheels. This problem can be fixed with a "center-steering", which is shown in figure 4.41. This means that there is a joint in the front of the tractor, which enables the tractor to go in the same line as the wheels. This technology makes it possible for the vehicle to have a smaller steering radius.

The steering mode module incorporates wheel alignment indicators and steering made selector switch for easier and fast changes of steering modes. The illustration in figure 4.42 shows two-wheel steering for road transportation. In the middle there is the all wheel steering for maximum maneuverability. At the bottom is the crab steering if there is a need to move sideways.

4.3.13 Steering instruments

There are several ways to maneuver different types of vehicles. The most common instrument to maneuver a vehicle is probably a steering wheel of some kind. Here follows other types of instruments that may be used, after some modification, as a steering device.

Today different types of vehicles are maneuvered by some kind of joystick. Vehicles that are used by disabled people such as the wheelchair are often maneuvered with a joystick. In the computer/video game market there are several different types of joysticks, one shown in figure 4.43. The mouse in figure 4.44 is most common in the use of computers, but is also a thinkable maneuver device. When using some kind of game console, like a Playstation, you often use something called a control pad as seen in figure 4.45.

Figure 4.44
Figure 4.46
Figure 4.45

Figure 4.43 *Joystick by Logitech*

Figure 4.44 *Mouse by Logitech*

Figure 4.45 *Control pad by Microsoft*

4.3.14 Touch screen

The touch screen, shown in figure 4.46, is being used more and more every day. Instead of controlling the pointer on your computer screen with a mouse you can use your finger or a special "pointing pen" to navigate on your computer. Just press with your finger or the pen for example on the Microsoft Office icon and the program starts. Touch screens also makes it easier to use camera recorders. Instead of having lots of buttons with specific functions, you can replace them all with one touch screen with a menu system.

4.3.15 Force feedback

Force feedback systems are today widely used in the gaming industry. To give a video game a better feeling to it you can use a joystick, a pad or a steering with a force feedback function. For example, if you are driving a car simulator with a steering wheel with a force feedback function, the steering wheel responds differently depending on what kind of layer you're driving on. It's the same in real life, it's easier to rotate the steering wheel when driving on gravel then when driving on tarmac, at least when the car don't have a SERVO function.

4.3.16 Force feedback

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Figure 4.46

Figure 4.50 *Touch screens*

example, if you are driving a car simulator with a steering wheel with a force feedback function, the steering wheel responds differently depending on what kind of layer you're driving on. It's the same in real life, it's easier to rotate the steering wheel when driving on gravel then when driving on tarmac, at least when the car don't have a SERVO function.

4.3.17 Conclusion

In the market today there are a lot of interesting products, each having their own unique pros and cons. We can see many of the features from those vehicles as potential functions in the future product. The gyro can be implemented as a stabilizing device. The flexibility in a hovercraft and amphibian vehicles is admirable and something to strive for. Sensor controlled devices can be used to manoeuvre the vehicle etc.

Since the Related Technology procedure will be active and develop further during the whole project, and is depending on what choices we make in the future, it is hard to draw any concrete conclusions yet.

4.3.18 Discussion

The Related Technology process is heavily dependent on the results from the Needfinding process, and since all subgroups were working simultaneously, we did not have enough information needed to make the study as accurate as possible. One thing that we've learned so far is that in order to get relevant information from this procedure, a mutual communication between everyone in the project is needed. More time should also have been spent for the planning in the beginning of this phase.

4.4 Final discussion

With the first phase of the project almost concluded, we are now looking forward to put our newly gained knowledge into use. We have learned a lot about disabilities and the market that our project will be adapted to.

The Design Space Exploration phase is over, but as the project moves on, and the goals become more real, the methods used in this phase will most probably be applied many times over. The areas of interest might be different, like getting information about materials, about specific mechanical solutions, about new technology and so on, but since the process will more or less be the same, it is important that we learn from this process and are able to recognize what went well and what didn't. Since the subgroups begun working on their tasks simultaneously, the Benchmarking and Related Technology groups had very little to work with, in terms of user needs. This resulted into a search for what they thought was needed, instead for what the customer actually wants, i.e. what the Needfinding group came up with. However, these search results might coincide anyway, or at least overlap, but if they don't, there is a risk that the way the project will develop in is affected by the somewhat rashly made research. This can make the project take a direction that is based more on assumptions than on actual facts. But as long as the project members are aware of the possible risks with the Design Space Exploration, this issue should be of little threat to the project.

Section 5 Roadmap

In this phase the information gathered during the Design Space Exploration is compiled into a description of the product that is to be developed. The purpose of the roadmap is to stake out the path of where to go in the forthcoming product development process. In order to avoid having to go back to earlier steps of the process it is of most importance that the work done in the phases of the roadmap is detailed and of high quality. One important measure to take is to describe the functions of the device and the needs of the user as detailed as possible. In order to obtain a clear outline to follow for the roadmap phase some studies were conducted on the different design methods. The educations in the SIRIUS-course about design methods were also of importance. In particular the Ulrich & Eppinger book *"Product Design and Development"* has been helpful in understanding these design methods. Through the progression of research the group came to a conclusion that some of the contents were very useful while some of it was not applicable as it in some ways built on a process where a clear definition was given. This is not the case for this project, as the Creativo project is more or less undefined.

To define the path of the project the group established a Mission Statement and Product Characteristics. In the mission statement the needs of the users are compiled and ranked according to how many users wanted that specific function. During the product characteristics the needs are transformed into functions that the device should have.

5.1 Mission statement

5.1.1 Method

The mission statement is established to get a general direction of the project without prescribing a particular way to proceed or a precise destination. It should contain product description, key business goals, primary market, secondary market, assumptions and stakeholders. The mission statement of the CRE[ATIVO]^2 project was developed according to the design method in Ulrich and Eppinger but with a few slight modifications. (Product design and development, P.59-76)

The raw data from the needfinding process was translated into the needs expressed by the customer. When translating the raw data there are several guidelines to follow:

The need should be expressed in terms of what the product has to do, not in terms of how it might do it. This is to avoid narrowing down the design space by focusing on solutions instead of needs.

- The needs should be expressed as specifically as the raw data to avoid loss of any information.
- Positive phrasing should be used, not negative phrasing. It is easier to express product specification later in the process if the need is stated in a positive way.
- The need should be expressed as an attribute of the product not the user. It is easier to express product specifications later in the process if the need is stated in this way.
- Avoid the use of the words “must” and “should”. This is to avoid establishing a level of importance.

The needs were written on Post-Its and grouped based on basic similarities. The groups of Post-Its were then rephrased into more accurate needs according to the rules. The rephrased needs were ranked according to how often the needs were stated in the surveys, and they were also ranked according to the project group’s own opinion. The ideal case, based on Ulrich and Eppinger’s method, would be to send out a new survey so that the users could rank the needs themselves. Due to time constraints this aspect of the Ulrich and Eppinger method was ignored and the previous ranking system was adapted. The results of the ranking method can be seen in the table 5.1.

The needs have been ranked in table 5.1 below according to the project group’s opinion and how often the need was stated in the surveys. The ranking goes from 1-5, where a number one is the most important and the number five is the least important.

5.1.2 Results

1 Product Description

The product description was developed according to the most important needs that are stated in table 5.1. As light as possible was not included because in the end this was considered more of a solution then a need. The most important needs are:

- Allow for general access to non disabled facilities and transportation systems
- To traverse regardless of weather conditions and common terrain
- The device could be easily transported
- Feel safe/ be safe
- Maneuverability

Table 5.1 *Ranking of costumer needs*

	Ranking Project group	Ranking User
Access		
Allow for general access to non disabled facilities/transportation systems	1	**2**
Cost		
Price worthy	-	**2**
Storage		
Convenient storage	4	**-**
Handles		
Keep the user clean, dry and warm	3	**-**
Winter/terrain		
To traverse regardless of weather conditions and common terrain	1	**1**
To be able to use it indoors/outdoors	1	**1**
Reaching		
Being able to interact with the physical environment	2	**3**
Design		
Simple interaction with the device	3	**4**
Comfortable Ergonomic	5	**-**
Faison friendly	5	**-**
Instills pride	5	**-**
Transport		
The device could be easily transported	1	**2**
Interacting		
Social interacting on equal terms	2	**3**
Others		
Repositioning the body of the user	4	**3**
As light as possible	2	**1**
Maneuverability	1	-
Safety	**1**	-

These needs were reformulated into the product description, which reads as follows:
The mission of the CRE[ATIVO]^2 project is to develop a safe mobility device that is easy to maneuver on varied terrains and in multiple weather conditions. The device should also improve user access to facilities and transportation, while being easily transportable.

2 Key business goals

If we were a business the key business goals for the CRE[ATIVO]^2 project would be:

- The device is prize worthy
- The device is a marketable
- Find a company that is willing to put the device in their product line.

3 Primary market

The ideal would be if the product would suit all kinds of people, but the project has to have a primary focus. The Primary focus is Disabled people that want an active lifestyle and the county council.

4 Secondary market

One other area is also viewed as a potential benefactor of the device, the area being Disabled people in general.

5 Assumptions

The product is based on two general assumptions, that there is a need for the device and it is feasible to create the device

6 Stakeholders

Stakeholders are the people and organizations that are effected by the CRE[ATIVO]^2 project:

- The Design for Wellbeing organization
- Tobias Larsson and Andreas Larsson
- Lennart Karlsson, SIRIUS
- Future companies

5.2 Product characteristics

5.2.1 Method

Product characteristics are what come out after translating the needs from the “language of the customer/user” to the language of the engineer. They are supposed to describe what the product has to do not how. Demands, whishes and needs should be ranked.

According to Ulrich &Eppinger
The target specifications are created before the concept design phase and the final specifications are described after the concept design is chosen. Specifications consist of a metric and a value. In Ulrich & Eppinger the target specification process consists of four steps (Ulrich & Eppinger, page 83):

1. Prepare the list of metrics.
2. Collect the competitive benchmarking information.
3. Set ideal and marginally acceptable target values for each metric.
4. Reflect on the results and the process.

The idea for preparing the metrics list is to transform the needs into functions that describe what the device should accomplish. When collecting the competitive benchmarking information similar solutions are studied and their values are compared to each other. Setting ideal and marginally acceptable targets means that every function is given two values. Ideal means the value that the project group aims at and marginally acceptable means the value the project group can accept.

The CRE[ATIVO]^2 method
After studying Ulrich & Eppinger's method the project group came to the conclusion that it was too time consuming and is more suitable for products that have existing competitive solutions. The project group made a slight modification too the method. The modification was that the group sat functions but choose to leave out the values. The group then decided to use the modified version of Ulrich & Eppinger's method described above.

5.2.2 Compiling product characteristics

To translate the ten need areas (access, cost, storage, handles, winter/terrain, reaching, design, transport, interacting and others, see table 5.1) into product characteristics, the user needs were translated into the language of engineers. The translation led to functions that corresponded with the needs. There were a lot of functions in the beginning but they were reduced during the product characteristics process due to function overlapping. The remaining characteristics were based on the same needs as the mission statement.

The functions were put in an order that represents the importance of the functions regarding the needs expressed in the surveys. The product characteristics tree is shown in figure 5.1. This doesn't imply that the functions at the bottom aren't going to be looked into. Instead these product characteristics are the common goal for this project and each and every one should be included at the end.

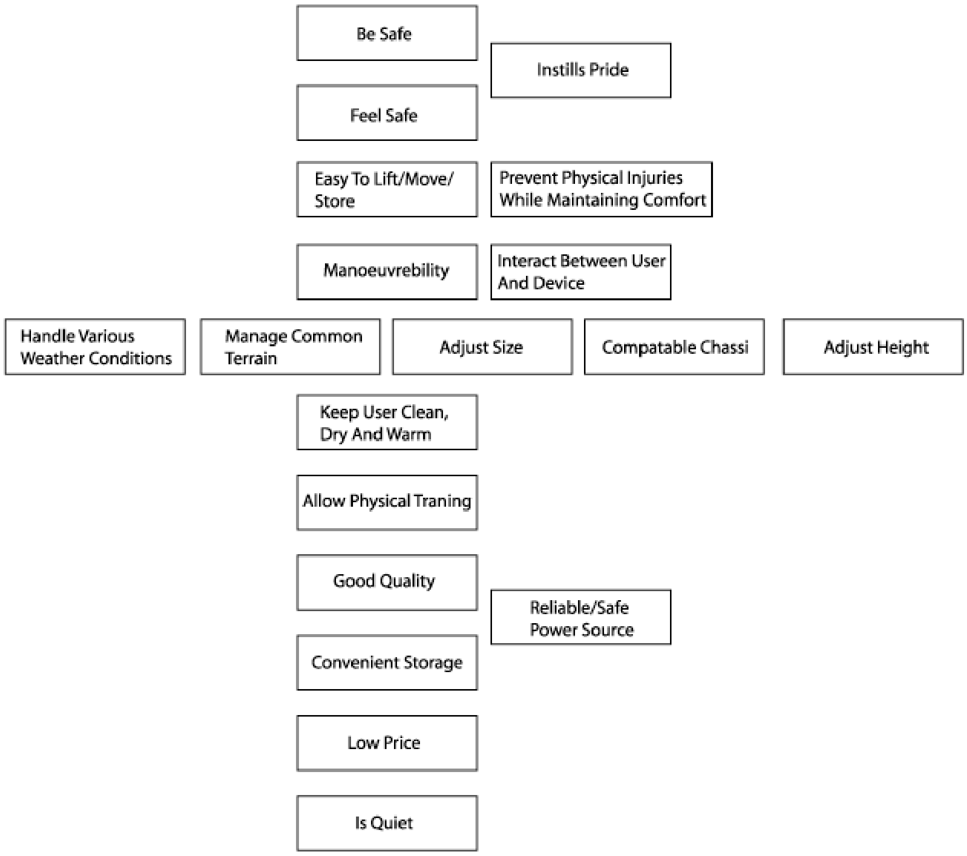

Figure 5.1 *Product characteristics in priority sequence.*

Figure 5.1

5.3 Final Discussion

During this phase we created functions of the needs the users had and ranked them according to which seamed to be the most important. There are many different methods to go by in order to accomplish this. The group decided to base the method on a slightly modified version of Ulrich & Eppinger's design method. As the method was studied it became clear that the method could not be followed exactly by the book due to a shortage of time and that it did not fit into our project. Based on these restrictions the group decided to create a method based on Ulrich & Eppinger but provided a few modifications to suit the needs of the project.

Some of the needs that the users expressed were hard to translate into functions. This mainly depended on how people in the group perceived the words describing the function. The same word doesn't mean the same thing to everybody. The ranking of the functions importance was something that divided the group a little bit, as to some functions needs could be overlooked if the design could be made differently. For example a light weight construction might not be of the essence if another solution made the weight an unimportant factor.

It was also hard not to go into describing solutions to the needs and functions, for example not saying that the need is for warm handles but instead saying that the desired function is to keep hands warm and dry. The solutions should come in the concept design phase and not in the roadmaping phase.

Another thing that was difficult was to get all or even most of the group members to the meetings because it is next to impossible for everybody to be available at the same time. As this is the future of the project it is important to get everybody’s view and keep everyone informed.

Another thing that was frustrating was not being able to shorten the process down, but to take all the long discussions, even though a mission statement and a product description can be produced in little time. As a result of putting in all the hard and long hours the mission statement produced was exceptional and ambitious. It is also of great importance to document this phase carefully so if in the future problems with the design should arise there should be no problem to go back and check out the product characteristics and jump start the process again. The group feels pleased with what has been produced. It is an ambitious mission statement. Or as they say “shoot for the stars and land on the moon”.

Section 6 Concept Design and Prototyping

The Concept Design and Prototyping phase is divided into three sub-phases:

- Concept Generation,
- Concept Evaluation
- Concept Selection.

The first sub-phase is the divergent phase where a lot of concepts are generated. It is important during this phase to suspend judgment, encourage new wild ideas and try to get a quantity and variety of ideas. The concepts were based on gathered data and then sketched during brainstorming sessions. With the new ideas, new questions needed to be answered so during this phase a more detailed benchmarking was done in certain areas. A user interview and a visit to the Aid Centre were also conducted.

The Concept Evaluation is the convergent phase where the range of concepts is narrowed down and the phase is intertwined with the concept selection phase. The evaluation phase includes making, testing and evaluating physical prototypes. It also includes further development of the concepts ideas. It is important to remember the users' needs and the pre-defined product characteristics.

The Concept Selection phase is where the idea/s that satisfies the needs and product specifications were chosen. The selection was based on the results of the concept evaluation. This is also when the concepts are refined and combined.

Even though the Concept Design and Prototyping phase is divided into three sub-phases, the phase is iterative and not sequential. For example, some evaluation has been done during the Concept Generation phase.

6.1 Concept Generation

This phase started off with a brainstorming that was based on the product characteristics from the Roadmap phase. The ideas were divided into subgroups to for a better overview. Below is a summary of that brainstorming. To get a more detailed summary, please refer to Appendix C, Table 1.

6.1.1 Brainstorming

In the **Quiet** subgroup, there are ideas ranging from *silencers* to *electrical parts instead of mechanical*. The **Storage** subgroup consists of ideas like *drinkholders*, *inner pockets* and *lock boxes*. In the **Power** section, ideas like *gel battery* and *plug-ins for computers* are present. In the **Training** subgroup ideas are ranging from *hand cycles* to *electro training*. The next area is **Clean/Dry/Cool**, in which *heated handles*, *rain ponchos* and *enclosed cockpits* can be found. The **Height** category consists of ideas like elevated seats and adjustable arm- and foot support. The **Chassi** subgroup includes *removable seats*, *alarm systems* and, of course, *lightweight*. The **Size** subgroup features solutions like o*ne size fits all* and *fit into doorways*. In the **Weather** group, solutions like *anti corrosion*, *cover for wheelchair* and *fenders for wheels* are included. In **Common Terrain**, there are ideas like *threads*, *four wheel drive* and *retractable spikes*. The **Interact** subgroup features ideas like *touch screen*, *intuitive way of folding* and *color codes*. In the **Easy to Lift**/**Move**/**Store** area there are highlights like *composite frame* and *camping table bag idea*. The **Prevent physical injury** subgroup includes *gel sea*t, *low center of gravit*y and *safety harness*. In **Maneuverability** group includes ideas like *GPS* and *blow and suck steering*.

When the Stanford students visited Luleå, another brainstorming was conducted. The session was about the interaction with the device and its environment, because this area was considered to be the most important one. The interaction with the device area was divided into three subgroups:

- Operation in various weather conditions
- Operation indoor and outdoor
- Interaction with surrounding objects

The project team also split into three groups, doing separate brainstorming sessions. This was done to get a better group interaction. After the separate sessions the ideas were drawn and presented to the rest of the team. The result can be seen below in Table 6.1.

6.1.2 Design Space decisions

The project was still very broad, as can be seen in Appendix C. Due to the time limit placed on the project, the team took a decision to narrow down the design space. Another thing that contributed to that decision is that the Stanford team has a different design process than the Luleå team. The Stanford students need more concrete product characteristics since they are building physical prototypes throughout the whole process.

There was a discussion on whether or not a complete wheelchair or wheelchair accessories should be made. Another important issue that has been present throughout the project is whether or not a manual, electrical or a hybrid wheelchair should be developed. At

Table 6.1 *Brainstorming Results*

Learning-sensors Robot that learns the placement of furniture and stuff.	Tires underneath the wheelchair with angled wheels – separating the tire from the user.	Attachable track snowmobile track for the chair – tank style traction
Remembers where hazards exist	Wheel with wheels that rotate	Balloon that lifts the seat only
Jogging stroller	Smooth ride, keep from attracting attention	Detachable seat looks more like a office chair
Separate the handrim	Expandable tire width	Remote control W.C.
Moving the front casters that raises the wheel chair up	Unicycle	Seat with holes in it to allow water to run out
Adjustable CG	Floppy sloppy tire	Hydraulic seat
Exercise the legs	Adjustable height.	Oblong wheelchair rims
Sled in between the two front wheels Front/back skids	Balloon jack	Hydraulic seat raise
Bouncy ball	J-rim	On/off paddle wheel

this point there was enough knowledge to make a well grounded decision.

The whole group unanimously decided to make a manual wheelchair, perhaps with electrical features. This is because there are a many electrical wheelchairs that are specialized in different areas on the market today including winter terrain. The manual wheelchair has had more or less the same design for years. A lot of attempts have been made to change the design, but few have been successful. In fact, the winter adapted manual wheelchair area is relatively unexplored.

6.1.3 Wheelchair testing

There are a lot of problems with winter use that needs to be addressed. Some of these problems were encountered during a manual wheelchair test that was conducted at this stage. On the wheelchair that was used in the test, the most eminent issue was that the back wheel traction was insufficient. The back wheels lost traction on most winter road conditions, like snow, deep snow and ice. When one wheel lost traction it was very hard to get on the right track again. The back wheels, as well as the casters and wheelie bars had a tendency to sink down in the snow when subject to pressure. The front casters got stuck when they came across deep snow, holes and bumps, and the footrest got stuck when the wheelchair went through deep snow. Another problem was that it was hard to go over curbs, thresholds, and through doors. The metal parts became cold very quickly, and snow got stuck to various parts of the wheelchair, like the footrests, the wheels and the skirt guards. The positive things were that the wheelchair is stable on ice, and the side skirts gave the user a fairly good protection.

6.1.4 Defining and distributing the tasks

The team chose to split up the tasks between the Luleå and Stanford group before they went home. The areas to develop further were identified by using a manual wheelchair as a reference. Problems associated in every area were identified. The issues were ranked according to the Product Characteristics and previous experiences. The Product Characteristics can be found in the Roadmap phase.

Primary Issues:

- All condition traction
    - Handle various weather conditions
    - Manage common terrain
    - Accessibility
    - Outdoor/indoor
- Human interface
    - Staying clean
    - Propulsion
    - Improve comfort
- Comfort
    - Body temp
    - Posture
    - Getting in and out of the chair
    - Ergonomics of the seat

Secondary Issues:

- Storage
    - Keeping hands free to propel
    - Removable and permanent
    - Easy access
    - Features (such as cup holders, etc.)
- Height
    - Raising/lowering the user
- Foldable
- Socially adaptable

Since the Stanford team had already started to look into the human interface area by making critical function prototypes for solving the hand rim and cleanliness issues, they continued working in that area. The Luleå team was assigned the other two primary issues, traction and comfort, since those areas requires testing in a winter environment. The secondary areas will be addressed if time allows. Before the split-up, a brainstorming was conducted in order to get everyone's opinions and ideas on the primary issues. A summary of the brainstorming can be found in Appendix C, Table 2. In the all condition traction area, ideas ranging from threads, knobs and spikes to oars that allow the user to dig out of the snow arose. In the user interface area the ideas included a *Widget lever drive, Wheel cleaner/ brush* and *Grips that attach to the rims.* In the comfort area the ideas ranged from t*emperature sensors, MP3 Player* to *heated gel seat*. More information and thoughts about the Stanford students' visit in Luleå can be found in Appendix D. After the Stanford students went home the Luleå students split into two groups, traction and comfort.

6.1.5 Benchmarking

To deepen our knowledge in the traction and comfort area, the sub-groups started off with doing some benchmarking based on the results of the brainstorming with the Stanford students. It was important to have a good view of the market today, in order to avoid "reinventing the wheel". Below are the highlights from that benchmarking presented.

1 Electrical assistive motors and power units

There are a number of wheelchair power units and electrical assistive motors, including E-Glide, Vortex, Little Viking, E-fix and Via Mobil. The E.motion, as seen in figure 6.1, is a good example. The wheelchair can maneuver as a manual wheelchair, but when pressure is applied to the handrims, it engages the power-assist motors to help the user propel forwards. Batteries are mounted in the wheel hubs and can be removed while seated. The wheels are easily removed, and can be replaced with manual wheels.

Figure 6.1

Figure 6.1 *E-motion*

Figure 6.2

Figure 6.2 *Sand ladders, mohair and snow cuffs*

2 Electronic control systems

Electronic Traction Control (ETC) systems are mostly attached to cars. It applies braking action to a spinning wheel and holds back the throttle, all in an attempt to propel the vehicle forward. ETC is usually designed to work in conjunction with the vehicle's Anti-lock Braking System (ABS), and is adapted primarily to passenger cars rather than heavier duty vehicles. Even with light duty applications, performance results are inconsistent. No similar systems were found together with manual or power wheelchairs.

3 Traction aids

Sand ladders, mohair and snow cuffs are three good examples of accessories that can be applied when there is a need for improved traction, as seen in figure 6.2. The mohair can be fastened underneath skis to improve grip while climbing hills. The snow cuffs are attached to the wheel with clips.

4 All terrain wheelchairs

There are a lot of all terrain tires that have large casters and large back wheels, as seen in figure 6.3. Other solutions for the same purpose have features like tracks instead of wheels and cranks or handcycles for propulsion. One example is the Tremor wheelchair. It is made for sand and other similar terrains where big tires might be advantageous. The construction is lightweight for its size (16 kg), which enables the user to operate it without assistance.

Figure 6.3

Figure 6.3 *All-terrain wheelchair with big wheels*

Figure 6.5
Figure 6.6

Figure 6.5 *Frogleg shock absorber*

Figure 6.6 *Knobby tire*

5 Suspension Systems

The market for manual wheelchair suspensions is relatively unexplored. It is nevertheless an important area since most of the vibrations in a wheelchair come through the front casters. One suspension example is the Frog Leg (http://www.froglegsinc.com), a seen in figure 6.4. An interesting feature with this suspension is that when the wheelchair hits an obstacle, like a curb, the momentum will force the wheelchair over the obstacle, since the casters will bend backwards. There are also bike suspensions that may be implemented onto wheelchairs.

6 Tires

There are different tires for different terrains. Tires that are used indoors are often thin and slick. In winter conditions, knobby tire are used on different kinds of vehicles, as seen in figure 6.5. Most wheelchair users chose regular tires in the winter as well, since it is harder to propel with knobby tires and they get dirtier.

7 Three wheel wheelchairs

The wheelchair in figure X is a model from Motivation designs, which is designed for rural or mountainous areas. The wheelchair in figure X is a steel frame chair re-designed into a wheelchair and has the third wheel at the back. Both models presented are designed for developing countries and there are several more. The wheelchair in figure X is the Panthera Micro. It is designed for small children and has three wheels to improve maneuverability. There are also three-wheeled manual wheelchair for tennis and other sports.

Figure 6.7

Figure 6.7 *Shows different types of three wheeled chairs*

8 Changing the centre of gravity

The position of the rear axel can be adjusted to change the centre of gravity. There are few wheelchairs, if any, that can adjust this feature while the user is in the chair. One example is the Panthera that has a solution where the rear axel slides on one bar horizontally. It cannot be adjusted vertically. There is also a solution where the rear axels are attached into a plate with holes. That makes it possible to change the wheel vertically, but the disadvantage is that it is not steeples. There are also solutions where the seat can be moved, which change the centre of gravity.

9 Seat cushions and backrest

There are a lot of seat cushions on the market. There are cushions for different kinds of body types, body weights and if you have injuries that make it hard to sit or hard to sit in a certain way. There are many backrests in different materials and shapes as well. In figure 6.8, a lightweight carbon fiber backrest can be seen. A good example of a cushion is the Action wheelchair cushion, which reduces skin stretch, pressure and soreness from sitting long hours at a time. It has air cells that distributes the weight evenly and conforms to the body.

10 Frame

A frame can be manufactured in a variety of materials. To keep the

Figure 6.8

Figure 6.8 *The Action wheelchair cushion and a carbon fiber backrest.*

Figure 6.9

Figure 6.9 *Titanium frame with spider wheels*

frame light it can be manufactured in titanium, aluminum or composite, but those materials are more expensive compared to regular steel. Composite constructions are cheaper than titanium and stronger than aluminum, though they might be harder to manufacture. Another aspect of the frame design is simplicity. The simpler the frame design, the easier the construction and assembly will be. An example is the chair in figure 6.9, which is made of titanium and is a very simple and light. A problem with titanium is that it's hard to work with.

11 Fabrics

What fabrics used for the cushion depend on the needs of the individual user. The most common fabric is Nylon, but there are also several other materials in use, like the natural fibers Wool, Cotton, Silk, Linen, Hemp, Ramie and Jute. Manufactured fabrics include Acetate, Acrylic, Lastex, Nylon, Polyester, Rayon, Gore-Tex, Windstopper and Airvantage. There is a lot of military research about self-cleaning, waterproof and breathable material to be used in uniforms. This research is concentrated on nanotechnology. These materials are also supposed to improve the soldier's survival, with the ability to stabilize wounds and broken bones and to protect against chemical and biological weapons.

12 Hand rim materials

Today most hand rims on manual wheelchairs are made of metal. A metal exist, which is a god heat conductor. If this could be used instead, with the help of body warmth or an electric heater, the hand rim would not get that cold. There are also carbon fiber tubes or plastic tubes with copper in it for heating.

13 Office chairs

There are many office chairs with advanced seating technology that may be implemented onto a wheelchair. The chair to the left in Figure X is an example of an unusual model. It can be

Figure 6.10

Figure 6.10. *The Freedom saddle and an office chair with a split backrest.*

implemented onto a wheelchair when for example the user has an amputated leg but still can move the other, because it gives more flexibility. The other picture illustrates a chair with a split backrest.

6.1.6 Meeting with a wheelchair user

A 26-year-old woman from Luleå was kind enough to visit us in the project room. She has been using a wheelchair all her life since having a neurological disorder. The wheelchair she uses is a Panthera U2-small with spider wheels and she's been using it for 7 years.

She uses this wheelchair because off the low weight, which is beneficial in many situations, like when the chair is lifted into a car. The chair is also compact and has small casters. This makes the chair more maneuverable indoors, and helps it being able to approach and reach things. The compact design also brings the legs further to the body, which is good if you suffer from a neurological disorder. The downside is the decreased performance outdoors, because of the small casters and the narrow wheel configuration.

She is active in the the Swedish Association of Neurologically Disabled. This means that she travels a lot, mostly by airplane. She can't go by train, since the doors are too narrow. Her experiences concerning traveling by air are that the chair is worn while being handled in the cargo area. The spokes are being bent, which lead to a distorted wheel, and that is why she uses spider wheels. The spider wheels are heavier but she still prefers them because of its strength. The hand rims on the spider wheels also get less slippery than regular hand rims, because they are made of PVC.

In wintertime it is very slippery outside, it's bester when it is just a few degrees below zero. In the spring when the temperature is about zero degrees, it's not easy to move around. Deep snow or ice on the ground makes it difficult to move. Sometimes she gets stuck and has to ask for help. If she gets stuck on an ice spot she can “jump” with the chair to get better grip. On slanted sidewalks she has to use one arm more, and if she starts sliding there’s not much for her to do about it. What seems to be a good solution for this is knobby tires, but she chooses not to use them, because they are heavy to propel, uncomfortable and get dirtier than smooth tires.

She must plan where to park during this season, so that there will be people nearby if she needs help. Most of the time she park her car close to the places she want to go, because it’s more convenient and safe.

To be able to climb curbs you must have speed and timing to raise the casters in the right moment. For higher curbs, a higher speed is needed.

She thought it would be convenient to be able to change the CG rapidly, for example when shopping or traversing in hard terrain. She also thought that suspension and bicycle breaks would be good. Another feature would be to have a “reversing lock” so the user don’t roll backwards uphill, but “if you attach something, it should either be lightweight or detachable”. The team proposed having a differential axle for the back wheels. She thought it could be good, but that it would add weight to the wheelchair. A removable mudguard would be great, since the wheelchair is gathering dirt and dust.

An adjustable camber angle would be good when going through narrow doors. When the wheels have a big camber angle the chair tends to go straighter. The Panthera has a pocket under the seat for the cell phone and wallet, which is a good thing. When she’s resting she prefers comfortable chair with a higher backrest and adjustable features.

She thinks that in the future disabled people will only have one wheelchair, for economic reasons, and that the users find their favorite chair after a while. Therefore it would be good to have detachable features.

6.1.7 Evaluation in the Concept Generation phase

Based upon the gathered information several concepts were developed. The concepts are a mix of old, new, functional and creative ideas. Since this is a divergent phase, no solution is discarded as wrong or far-fetched. The group choose to make some physical prototypes. This was because the number of ideas covered a too widespread area, even for a divergent phase. The ideas made into prototypes were the ones that were most critical to the future direction of the wheelchair design. The reason was to se what concepts could be excluded, and which of them that should be worked further on. The team choose to make physical models instead of computer simulations since it is very time consuming to simulate human and environmental factors in a computer program, and evaluating the results may prove difficult. The models that were made are functional prototypes, since that was the area of interest.

6.1.8 The Generated Concepts

After the brainstorming, benchmarking and testing, the concepts were sorted into different areas (see Appendix F). The frame will be developed after the other features have been designed in more detail since the team doesn't want a set frame design to limit the other designs. The team decided not to develop a cushion because the ones that already exist are well developed, and can be implemented on most wheelchairs. What cushion the user likes is very individual, so a common solution is hard to reach. The different concept areas of interest for further development are presented below.

1 Changing CG

Being able to change the CG rapidly may be advantageous in different situations like when having a heavy backpack, going up/down steep slopes, shopping groceries etc. The ideas can be sorted into two areas, changing the position of seat or back wheels.

2 Suspension

To increase comfort suspension can be added to the wheelchair. There are three categories in this area suspension on casters, back wheels and suspension in the seat. Solutions in this category are: rubbery material in bearings, flexible material as suspension for casters, chock absorber, springs, bike suspension etc.

3 Caster design

A problem with the casters is that they are not efficient enough in rough terrain and especially in deep snow. Ideas of solving this includes: mono-caster, sphere-shaped caster(s), detachable extra caster width, skis on casters etc.

4 Back wheel design

This are was to give the hub and spokes a nice design and keep the wheel free from snow.

5 Traction

The back wheels can be modified to suit winter use better. To traverse deep snow one idea is to have extendable tires. These can be folded, rolled or telescoped out. To make it easier for people with one arm it is possible to make a chair with a differential lock for the wheels. To solve problem with slipping in winter conditions a number of concepts was presented. These are: Clip-ons in various shapes, and different mountain bike tires. A difficult dilemma is to find a balance between as little friction and as much traction as possible.

6 Backrest

There may be advantages with a longer backrest. The idea is that it should give more support without compromising the mobility of the upper body. The ideas to solve the problem with increased size include foldable/extractable backrest and detachable upper backrest. To keep the seat clean a changeable seat cover can be used.

7 Accessories

A dilemma with this area is the weight issue. To solve this we have made all the accessories detachable or integrated into already existing features. The concepts are: blankets, tray, cup holder, tray holder etc.

6.2 Concept Evaluation

To narrow down and evaluate the range of concepts from the generation phase the evaluation phase was carried out. Through personal conversations with teachers from Luleå University of Technology, brainstorming sessions and practical testing of functional prototypes, ideas were developed and tested. Concept improvements and retesting followed. As a result some ideas were eliminated. The goal is always to develop the best concept not just to choose it. The group identified key concept selection criteria and ranked the different categories in order to get there importance. After that the group looked into each category to find the best concept. This was done by a concept selection method called Pugh’s method.

6.2.1 Brainstorming and testing

To evaluate all the concepts from the generation phase, a brainstorming session was performed. In this session all the categories were worked through thoroughly to get most benefits out of the idea development. The whole group participated which was important in order for all members to have one common direction. All new ideas that emerged were sketched down to become understandable to the whole group. To control the level of the functionality of the different concepts some practical tests were carried out.

To make the evaluation easier and more accurate for the group during testing, an evaluation form was written. Each group member wrote down all comments, positive and negative about the different concepts. The form was divided into different testing areas which were: going uphill, going downhill, capacity of stopping, going in varied depth of snow and on ice.

Discussions about a three wheel wheelchair versa a four wheel wheelchair led to a modification of a four wheel wheelchair, where the two casters were replaced by one front caster attached under the footrest. The pivot point of the caster wheel was attached to the footrest such that it was at an angle to the floor. Because of the leaning pivot point the chair was hard to maneuver and turn. A new prototype was built where the pivot point was vertical and adjustable back and forward. This was done through placing the wheel in holes at two different locations from the seat. The first hole was close to the seat and the second was 200 mm further ahead. This was done to compare the stability and maneuverability between a three wheel wheelchairs versa a normal wheelchair with two caster wheels as seen in figure 6.11, picture A.

To see if it would help having a wider caster wheel while going through deep snow, a test was performed where the outer parts of the wheel came in contact with the ground just when the middle wheel dug down far enough, see figure 6.12.

To increase the ability to traverse in different terrains modifications of the caster wheels were done. Through adding two plastic bottles

Figure 6.11

Figure 6.11 *Shows testing of a three wheeler in A, extendable tires in B and a high backrest in C*

Figure 6.12

Figure 6.12 *Shows the wider caster wheel*

under the front wheels the surface area increased, and tests were conducted to observe the risk of sinking down in deep snow.

Another way to increase the ability to traverse in deep snow was to put all weight on the back wheels. This was done by balancing on the back wheels while keeping the front wheels in the air. To facilitate the use of this technique an idea with supporting skis attached under the chair arose. The skis came in contact with the ground only when the user got out of balance.

A new test with broader back wheels was made to see if this would hinder the wheels to dig down in deep snow. The group tested a modified variant of the extendable tires that had been tested earlier during the generation phase. To increase the grip threads were attached horizontally as seen in figure 6.11, picture B.

A way to improve the comfort while resting in the chair would be to have a higher backrest. A high backrest decreases the ability to move the arms and shoulder blades. Different concepts with different heights and widths were tested out on the group members to find the optimal size of the backrest. It must have both comfort and support but also a shape for continued movement, see figure 6.11, picture C.

6.2.2 Results and discussion about the testing

To improve the ability to traverse tests were done with mountain bike tires to get a better grip against the surface. Tests were also done with regular tires for comparison. A problem using the mountain bike tires was that the chair at the same time became harder to propel and snow got stuck on the tires because of the pattern.

It was discovered that the tipping risk for the three wheel wheelchair were greater than for a four wheel wheelchair, but the chair was easier to maneuver and turn. In the downhill test the three-wheel wheelchair was acting differently depending on which hole that was used. When the hole closest to the seat was used the chair was going straightforward when using no hands to steer. The front wheel wobbled. When the chair went fast it was important to keep it straight to prevent tipping over. By using the hole further out from the seat, the chair went faster and was more stable which made it feel safer than using the first hole. When going in varied depth of snow the user had to go on the back wheels sometimes to traverse with the three-wheel wheelchair because the caster wheel dug down easier in the snow. Results of comparing the chair with three wheels versa four wheels showed that the three-wheeler is easier to turn inside, less weight with one caster wheel and it’s more innovative. The bad things were that the wheel could be in the way of the footrest and it is easier to tip over when you reach for stuff with the caster wheel in the position closest to the seat. It is easier to get stuck with one caster wheel because of the double amount of pressure. Ways to solve these problems are to have a split or bent footrest, tipping protection and/or wider wheels.

The wider caster wheel had some effect on the stability when going over curbs, bumps and through deep snow. There wasn’t a great difference between this wheel and a regular caster wheel regarding positive and negative effects on the steering and stability qualities.

The plastic bottles didn’t sink down as much as regular wheels in deep snow and the turning abilities didn’t get any worse. Although an amount of friction was developed and this led to certain noise that could be experienced as annoying. The friction also led to less speed downhill. Because the bottles were wider then regular wheels they needed more space when turning. Ways to solve these problems are to let the wheels go through the bottle and use the bottles just as support when going through deep snow. Using a surface like skis on the bottles will probably decrease the friction.

In the case with the supporting skis positive things were that they didn’t sink down through the snow, they helped you to be in a wheelie position all the time, the front wheel didn’t get stuck and the hole idea is very innovative. The problem was that the support depended what kind of snow is being traversed during that specific moment. The skis have to be adjustable for different snow types and this feature would be very advanced and heavy. A lot of problems arose going downhill with the supporting skis since they were not meant for giving support in leaning paths with packed snow.

The results of the testing with the extendable tires were also dependent of the amount and the type of snow. The traction was improved and the wheelchair did not sink down so much in the snow. It was hard to propel the wheelchair because there were no hand rims or other grip. Snow got stuck inside the tire and the treads were not fastened well enough so some of them came of. From the results of testing the group evaluated the concepts, improved and eliminated them based on the failures found in the testing.

6.2.3 Meeting with teachers at LTU

To get a new aspect of the problems concerning the ability to move the center of gravity and the changeable camber angle a meeting was conducted with Stefan Lagerkrans, subject teacher in machine element at Luleå University of Technology. After discussions concerning these areas, Lagerkrans came up with some suggestions concerning changing the CG-point by moving the back wheels. Ideas about adjusting the camber angle were also generated.

Elisabeth Kassfeldt, senior teacher in machine element at Luleå University of Technology, visited the group at a meeting in this phase to discuss the problems with a three-wheel wheelchair. A Discussion was made regarding moving the caster wheels backwards, to increase the maneuverability inside. Concepts and proposals for different solutions were developed together.

6.2.4 Contact with expert within the field

To get some professional opinions the group decided to contact Recruitment Group, an association for active rehabilitation (www.rekryteringsgruppen.se,). The questions asked were what experiences and information they had concerning stability, accessibility and ability to traverse with a three-wheel wheelchair. Also questions concerning the CG-changing and the adjustable camber angle were asked.

The contact person at the Recruitment Group, who is an active wheelchair user, answered that there is a lot of parameters that are affecting concerning the usage of a three-wheel wheelchair. An important issue is the user’s ability to maneuver and handle a wheelchair when it comes to areas such as stability in sideways, back and forward. In every instance when the wheelchair has to be easy to maneuver a three-wheeler is preferable, like for instance wheelchair racing, wheelchair tennis and some other wheelchair sports. For users that are very week in their arms a three-wheel wheelchair is a way to get them out of an electric wheelchair. Stability is more important when it comes to for example wheelchair rugby and for the majority of the wheelchair users, stability is essential in daily life.

The most important things according to the contact person were to have a lightweight wheelchair, which is easy to take apart and lift in and out of his car, 10 to 15 times a day. When working or at school the sitting comfort is most important. During shopping it is important to be able to move around without hitting groceries in the store and also to have certain stability sideway when carrying around a basket of groceries in your lap.

The contact thought it would be beneficial to improve the comfort of the chairs driving and seating characteristics. He thought that the biggest problem would be to keep the chair lightweight and he had concerns regarding things sticking out from the chair that could hinder him when lifting it.

6.2.5 Pugh’s method

Pugh’s Method is used for evaluating multiple options against each other, in relation to a reference. It is used to narrow down the number of concepts and to improve them. The method was invented by Stuart Pugh, University of Strathclyde in Glasgow, Scotland as an approach for selecting one or more design concepts to pursue in detail.

When using the Pugh’s method there are some guidelines to follow. A short brief follows bellow (Pugh, 1990).

- Choose one design concept as a reference and compare the rest to it.
- Evaluate each concept according to its expected performance for selected Mission Statement criteria.
- The evaluation is qualitative using symbols to indicate differences:
  + The proposed design is better than the reference.
  0 The proposed design is about the same as the reference.
  - The proposed design is worse than the reference.
- The winning concept in the evaluation is the one with the least -'s. If this produces a tie, then choose the concept with the most +'s in addition to the least -'s.
- Since design is an iterative process, the potential designs listed on the table may be reworked to eliminate –'s and the table can then be redone. The goal of the iteration is to eliminate all the -'s from each potential design. When no further modifications can be made, the process is terminated and the latest table is used to select the winning design.

Figure 6.13

Figure 6.13 *Panthera Wheelchair*

By using the Pugh Method winners and losers will become visible at an early stage. The fact that every category is thoroughly analyzed through discussions means that the group in an early stage can recognize winners or losers and optimize the concepts which are important for preventing later surprises.

The criteria used were based on the Creativo mission statement (see section 5.1.2) written during the roadmap phase. Qualities the group though were important to fulfill the mission statement were also added to the criteria list. The reference used for the category ranking was a regular Panthera wheelchair with no extra accessories as seen in figure 6.13. By this method the group ranked the different categories in order to get their advantages and disadvantages compared to the Panthera.

The categories were: three wheel, changing CG, moving backrest, shape of backrest, suspension back, suspension in caster, composite spider wheel, frame, saucers on caster, skis on casters, skis under, mountain tires, extendable tires, camber angle, trey holder, cup holder, changeable handles, hubbles wheel, metal spider wheel and clip on's. To find the best concept in each category the group evaluated them against relevant criteria. This was done for the majority of the concepts by using the Pugh method, where one design concept was selected as a reference for each category. These categories were moving backrest, storage of backrest, shape of backrest and traction on back wheels. For the rest of the categories detailed discussions were carried out and decision were made from subjective and objective matters. For Pugh matrixes see Appendix G. When all the categories had been evaluated the points were summarized and the concepts were ranked.

6.2.6 Result and Discussion

The discussions with people within the field were important. To get comments and feedback from a person not involved in the project is very valuable for the process to get an understanding for the problems and by that develop a good product.

The Pugh method showed that the frame closely followed by changing CG and composite spider wheels was the highest ranked compared to the reference, on the basis of the criteria that were selected. The rest of the ranking can be seen in Appendix G. After ranking the categories and concepts the group looked into each area and tried to think of ways to improve what they were lacking. Some concepts were improved and some eliminated based on matrix followed by discussions and contacting users. The goal was always to develop the best concept not choose it.

The Pugh Method was interesting to use even though sometimes it was a problem with certain definitions, for example what do we mean by maneuverability? Discussions and decisions had to be made before starting the process so the whole group was on the same page concerning the meaning of each category and function of the different concepts. This had to be done before the ranking could be made correctly. Since the group members are no experts on this method, different interpretation might have been done in different situations. It was hard using the method when some concepts were not completely developed and some were. Some of the criteria’s were connected to each other in terms of what we want the chair to perform. For example weather and accessibility is closely connected regarding the ability to traverse. Another issue when using the Pugh method was that the concepts are only compared to the reference and not to each other. For example, the Panthera wheelchair is used as a reference in the first analyze. A good result (grading +) when comparing the concept of the frame to Panthera’s frame could mean either that the concept is good or that the Panthera frame is really bad. A negative result could mean the opposite. That means that the ranking can’t be used without questioning the result of it.

Another problem with the Pugh method is that the participants might have favorite concepts and therefore fail to see some of the negative qualities about those. Another risk is that the participants who have good ability to highlight their opinions might persuade the others to vote like them. In this work it is important to be objective and have a clear understanding of what the purpose of the process is.

The ranking from the Pugh method gave the group some guidelines about which categories to focus on. Some categories had a high-ranking score even though they were not that interesting and important from the group's point of view and some categories with low ranking were more important than the Pugh method showed. This has to do with the fact that some of the criteria were not as developed as other. Because of this there were difficulties comparing them to each other. To get a more accurate ranking more criteria could have been used.

6.3 Concept Selection

The concept selection phase is closely intertwined with the evaluation phase. According to Ulrich & Eppinger (2000), the concept selection is the process of evaluating concepts with respect to customer needs and other criteria. The phase also involves comparing the relative strengths and weaknesses of the concepts, selecting concepts for further investigation, testing or development. Although the concept selection phase is a process of narrowing down ideas that best satisfies the needs and product specifications, it is frequently iterative and may not produce a dominant concept immediately. The final decisions are built from the results of the concept evaluation phase and the following ideas are moved forward to the next stage of development:

- Ability to change the wheelchair's centre of gravity while the user is in the chair and without using tools. This will increase comfort and allow the user greater flexibility in interacting with the environment.
- The ability to adjust the camber angle of the wheels while seated and without tools. This will improve traction and manoeuvrability.
- Identify a lightweight composite construction of the frame. If the chair is lighter more features can be added a lighter chair is easier to move.
- Clip on/ snap on traction with a lightweight hub design. This will increase traction in the winter.
- Design an adjustable backseat. This will significantly increase the comfort.

The concept selection phase is aiming towards selecting good ideas and brings them forward for further development. The ideas that were selected are based on the questionnaires from the Design Space Exploration phase, testing results, contact with teachers and experts within the field, the Pugh method and our own knowledge and opinions. This is a good foundation for the future Detail Design and Manufacturing process.

Section 7 Detail Design and Manufacturing

The Detail design and manufacturing phase is where the concepts from the Concept Design and Prototyping phase are turned into a product. Thoughts regarding manufacturing cost, cost of components, etc had to be kept in mind during the entire process. CAD/CAE/CAM software tools were used to design and evaluate the product. Virtual prototypes enabled quick evaluation and facilitated changes to the product, before it would be too costly to correct the mistakes. To be able to build a physical prototype some materials were needed. To find the right material some research was conducted, and companies were contacted. Some of the companies also prepared the material for manufacturing. Most of the metal parts of the prototype were manufactured by the CRE[ATIVO]^2 students at the machine shop at Luleå University of Technology. To minimize the weight a majority of the parts were made in composite material. These parts were also manufactured by CRE[ATIVO]^2 students at APC- composite, located in Luleå.

7.1 Detail design

During this phase all the selected concepts from the Concept Selection phase were analyzed. All project members sketched their own ideas and suggestions of detail solutions for the concepts developed. These solutions were then discussed and brought together to create the final concepts. The selected concepts were adapted to the manufacture procedure as well as to fit the other parts in the prototype. From these detail designs, illustrating sketches were drawn to demonstrate the function of the different components as seen in Appendix H.

To have the ability without any tools, to change the wheelchair's centre of gravity while the user is in the chair, the project group developed the following solution. The first step is to lock the brake (1), then lift up and turn two sprints (2) one on each side of the seat. These sprints are attached to a slider (3) on which the wheels are attached. The user then adjusts the CG point by grabbing the tires and pushing the seat either forward or backwards. The seat rests on a roller, which now can roll freely under the seat, thanks to the bearings in the slider. The sliders also facilitate the movement by stabilizing the motion as seen inn figure 7.1.

To increase the comfort without decreasing freedom of movement, an ergonomic backrest was designed with inspiration coming from office chairs. The height of the backrest was designed to fit an average user and it was also narrower at the top. The frame of the chair was made of composite material to minimize the weight. If the chair is lighter, more features can be added while keeping it lightweight and a lighter chair is also easier to propel.

Figure 7.1
Figure 7.2

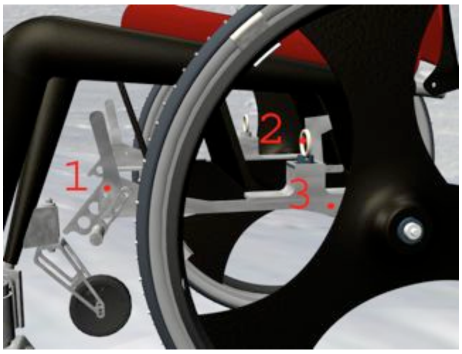

Figure 7.1 *Shows 1. The brake, 2. The sprints, 3. The Slider*

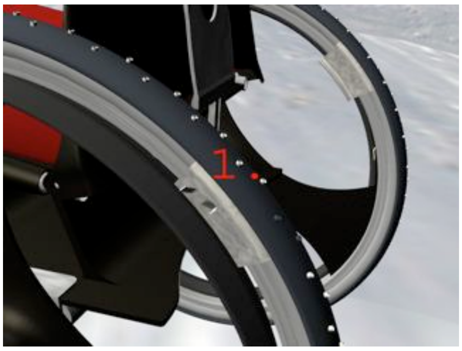

Figure7.2 *Shows the clip on´s*

To increase traction in the winter, clip on's were developed as a separate part from the wheelchair. The clip on's have five snaps that can be attached to the wheel one by one. After attaching the first snaps (1) the wheel has to rotate about 90 degrees before attaching the second snap fit. Essentially, a rubber band equipped with metal nubs is placed around the tire.

In order to avoid snow from becoming stuck in the spokes a new wheel design was developed as seen in figure 7.2. The plan was for the spokes spokes to be made in composite in order to minimize the weight.

The ability to change the camber angle was dropped after a long discussion in the project group. The disadvantages seemed to be greater than the advantages, for example the added weight would make it harder to transport and propel. The original thought was to have the ability to combine studded tires with regular ones. With a greater camber angle the studs would interface with the ground and thereby increase the traction. For a more detailed drawing see Appendix F, page 22. The decision to drop was also based on the fact that the needfinding didn't show there was a need for this feature. The reason this function has followed the group throughout the process is because the function seemed like an important one in the beginning, but when further investigated, the reasons listed above caused the camber angle change to be dropped.

7.1.1 Working in USA

The work began by showing the Stanford team detail drawings. This created the base for new brainstorming sessions, which were held in order to see if there were any shortcomings with the existing solutions and if there were improve them. Brainstorming was also used to see if new ideas could be identified. The brainstorming was conducted in smaller groups but in the end the groups were gathered together for a final discussion. After this discussion the group realized that the existing solutions were fulfilling the stated needs. During the visit the Stanford team demonstrated their cleaning device and discussions were held. For a more detailed travel report see Appendix I.

7.1.2 Working in Luleå

After returning to Luleå the project group was divided into two subgroups, which handled different areas. All the components were sketched in the CAD program I-DEAS version ten. Calculations were made and parts were drawn in master modeler. In drafting modeler drawings were made so the manufacturing could begin right away. After an intense week of 3D modeling the group was once more divided into subgroups, and the goal was now to turn the virtual prototype into a physical one. The subgroups were assigned manufacturing at APC-composite, LTU-manufacturing and assembling of the 3D- model.

7.1.3 I-DEAS and Assembling

To see and understand all the drawings and to see if the parts fit together, 3D-models were drawn in I-DEAS version ten. The CRE[ATIVO]^2 team was assigned their own team in I-DEAS where all the project members drew their parts. To share the parts in- between the group the library in I-DEAS were used where you check in finished parts. All team members can go in the library and look at parts that other team members have drawn and take measurements from them if needed. To see if all the parts fit together the model was assembled in I-DEAS master assembly. A screenshot from I-DEAS master assembly can be seen in figure 7.3.

7.1.4 Alias Autostudio

When the parts had been assembled in I-DEAS they were exported as STEP-files and imported to Alias Autostudio. This program was used to visualise the wheelchair by making pictures of it with different colours on each part. This work was made partly for the

Figure 7.3

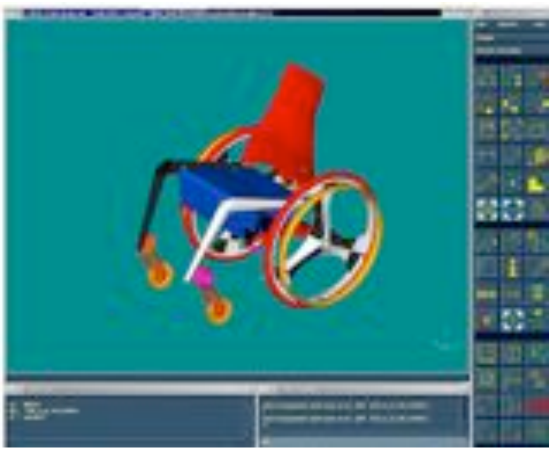

Figure 7.3 *Screenshot from I-DEAS*

presentation but also as a way to decide which colours the wheelchair should have. To show the different functions and features on the wheelchair two animations were also created in Alias Autostudio. The pictures were captured in Autostudio and then the film was rendered in Adobe Premiere.

7.1.5 Discussion

It was very intense work throughout the Detail and Design phase. Ideas were flowing and the group could have spent unlimited time on this phase. Due to the fact that all of the sketches were to be finished before the group left to visit the project members in Palo Alto, USA, there was a clear limit of how much time could be used. During this week all members were not able to attend every meeting. As a result some of the arguments and ideas did not emerge in the discussions. Everyday a different concept was evaluated so a decision had to be made even though all members weren't present. During this time the CRE[ATIVO]^2 group was very focused on the work that had do be accomplished, it was carried out in a very effective manner. It was an excellent experience to see that the group could achieve such a good result despite the time pressure. The result was accomplished by trusting each other's knowledge. Lessons learned from this phase were that everything takes more time than expected and if there would have been more time available, it could have been spent on even more detailed solutions and optimizations.

During the transference of the models from I-DEAS to Alias Autostudio a couple problems arose. Some of the parts did not look the same in Alias and several actually had to be redrawn which took extra time. Another problem was when rendering the pictures for the animation, there was not enough space on the student user and this led to some time consuming activities.

7.2 Manufacturing

7.2.1 Manufacturing at the university

The wheelchair mainly consists of carbon fiber and aluminum. The aluminum parts could be made at the university, and because of the fairly advanced shapes of the parts, most of the shapes had to be made in an NC milling machine. The milling operations also required CAM-files, which were made for the slider parts and the castor fork and its attachment. A lathe was used as a complement to the mill and for details like iron bars. Other tools were used too, for example a TIG welder and a manual mill. The aluminum parts were bought in large stock, and then cut and milled to the appropriate square shapes before the details were milled.

1 Slider

The slider, as seen in figure 7.4, is built with three main pieces; two were made in the mill, and one on the lathe. The pieces are glued together with Loctite Hysol. During manufacturing, the sprint mechanism was slightly re-designed, and the handle was made into a small pin instead of a ring, since that was considered to be more ergonomically correct. The sprint and handle is made with the lathe, and then welded together. A bearing for the wheel axle is also glued to the slider.

2 Castor fork and holder

The castor forks, as seen in figure 7.5, are made with the mill, and consist of three parts: a top piece that is connected to the wheelchair and two sides that are glued to the top piece. The holder is made out of two parts: a pipe that is glued to the chair, and the castor wheel holder, made with the mill that is glued to the pipe.

3 Backrest holder

This piece is a pipe that has a milled track and a hole in it, and is made manually in the milling machine. It's glued to the side parts, one on each side, and holds the backrest pin in place.

4 Footrest holder

The pipes are cut and bent manually in a pipe-bending machine, and a carbon fiber plate is glued on top of them, see figure 7.6.

5 Roller

The roller is a titanium pipe, with end plugs in aluminum that are made with a lathe. A steel pipe with threads on it is screwed into each side of the end plugs. On those pipes, the slider is attached.

6 Discussion

The milling proved to be quite difficult, since most parts were thin and long, which made them hard to clamp. This and the fact that

Figure 7.4
Figure 7.5

Figure 7.4 *Showing the CG slider.*

Figure 7.5 *The front castor.*

Figure 7.6
Figure 7.7


Figure 7.6 *The footrest*


Figure 7.7 *The roller.*

the milling machine is rather old, made it possible for vibrations to spread through the material, causing the precision to decrease, or at least making the finish a bit rough. With some polishing and sand blasting, a satisfying surface could be achieved. Another difficulty was the fact there is only one NC milling machine in use, and high demand for it, which made it very hard to gain access at decent times, or even any time at all to use the machine. There is also a somewhat steep learning curve for the mill, since the controls aren't all that intuitive. Some of manufactured parts turned out a bit different from the IDEAS drawings. One reason for this was the limitation of the machines that were used. The NC milling machine, for example, could not make the sliders as thin as they were supposed to be, and the pipes for the footrest could not be bent in the exact shape that the drawings showed. The limited time span also had an impact on the kind of materials that were used. For example, the sliders and the castor parts could have been made in titanium, and the weight could have been significantly decreased on most parts, if there had been time for any weight optimization.

7.2.2 Manufacturing composite

Moulds for the different parts of the wheelchair had to be manufactured in order to cast the carbon fibre details. Before manufacturing of the parts could start, the team needed to gather some know-how about composites. This information was gathered by talking to another student, who had worked with composites earlier and by talking to people that worked at the company where the parts were later manufactured. The team obtained some information about how to manufacture the parts and also how to create the moulds for the different parts. Now the team had sufficient information to start manufacturing.

1 Casting process

When building in composite there are several factors to consider. To gain an understanding of this a description of the process is presented below.

The moulds had to be waxed and/or a release fluid had to be applied to make the composite detail release from the moulds. Epoxy was then applied to the form to make the first carbon fibre carpet stick to it. More epoxy and another carpet were then applied to create the first layer. It is vital to soak the part that is being constructed with epoxy, by doing this all the air in the part is forced out and the pores are minimized. The epoxy is also the plastic matrix that binds the detail together. Each layer consisted of one fine carbon fibre carpet, as seen in figure 7.8 and one rough carpet, as seen in figure 7.9. Where the fine carpet ensures a nice looking surface, the rough carpet is placed there for strength. In some parts a foam core is placed in the middle to enhance the stiffness of the part by separating the two composite layers. The next thing to do is to put on some felt, as seen in figure 7.10, that will remove leftover epoxy so these carpets are easily removed after the casting is finished. The last step is putting a plastic bag around everything, then using a vacuum pump to force the epoxy and carbon fibre to fill out every corner of the mould. There is also the option to let the part harden without vacuum, but this method is mostly used on simple moulds. The detail then needs to harden for several hours. Putting the component in an oven can speed up this process.

2 Post processing

When the part has hardened it is removed from the form and the carpets that have been used for absorbing the leftover epoxy are also removed. If there are visible pores on the part they can be filled with epoxy. The moulds were made larger than the finished parts, because the edges of the detail had uneven surfaces and they had to be cut away. Thereafter the sanding begins. It is important to sand every part very smooth otherwise when the part is painted every little uneven surface will appear. After the sanding is finished it is time to paint the sides of the parts. Painting the sides is for concealing the foam core. The last step is to put clear coat on it.

Figure 7.8
Figure 7.9

Figure 7.8 *Rough carpet*

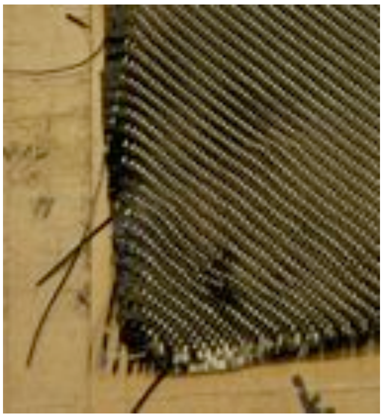

Figure 7.9 Fine carpet

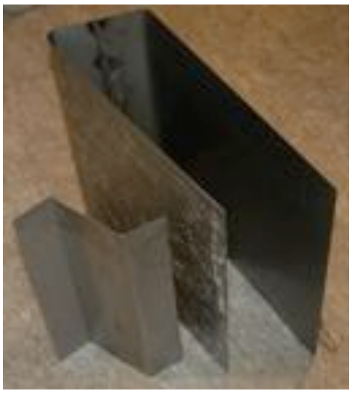

Figure 7.10
Figure 7.11

Figure 7.10 *Felt*

Figure 7.11 *Moulds for seat*

3 Seat

The mould for the seat was made in bent sheet metal, and then the seat could be casted. The team had a local company (Erlandsons, Verkstad AB) manufacture this form, as can be seen in fig 7.11. This is one of the parts that utilise a foam core. The foam core was necessary for getting the part stiff enough to sit on.

4 Side parts

The moulds were milled out of polyurethane. To mill out the moulds, contact was made with the person responsible for the mill in the industrial design department. He provided some advice on how the I-DEAS model had to be constructed to fit the mill. He also helped with the cam software of the 3D model and milling of the moulds. The forms can be viewed in fig 7.12. Each side part consisted of two moulds. These had to be sanded and puttied to obtain a smooth surface. When this had been achieved they were lacquered. When the lacquer had hardened the casting began.

These parts were made without a foam core and with two rough carpets instead of one. To be able to glue one side part together, a glue surface had to be made with carbon fibre and epoxy. There also had to be two aluminium pipes glued inside each side, these were needed to attach the backrest.

Figure 7.12

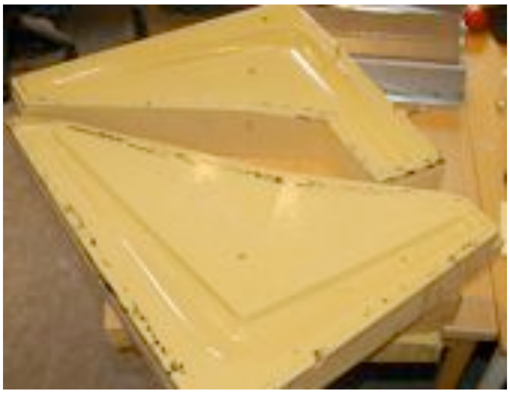

Figure 7.12 *Moulds for side parts*

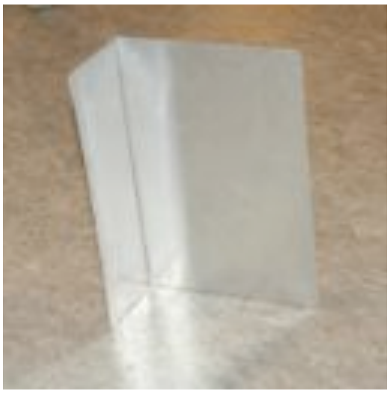

Figure 7.13
Figure 7.14

Figure 7.13 *Mould for the footrest plate*

Figure 7.14 *Mould for backrest*

5 Footrest plate

The mould for this was made in bent sheet metal, as seen in figure 7.13. Two fine carpets and one rough were used for this detail. This part was made without vacuum suction.

6 Backrest

The negative of the form was cut out of Styrofoam with hotwire. A thin coat of epoxy was then applied to protect it from harmful chemicals. Then it was puttied and sanded to obtain a smooth surface. When this was done it was lacquered. Then gel coats were applied to the negative of the form which had to harden for a couple of hours. After it had hardened a glass fibre mould could be manufactured on top of the negative of the form. When the mould had hardened it could be separated from the negative of the form. Finally the backrest was cast in the glass fibre mould as seen in figure 7.14.

7 Discussion

Using metal for the moulds is recommended because of the simplicity while moulding and a nice finish is achieved. These moulds can also be reused several times. If the mould is not sanded so it has a smooth surface, you have to sand the part and fix it for finishing. Styrofoam is not recommended because it requires more work and it breaks easily. A simple part is easy to manufacture, so in the words of our coaches “keep it simple”. Remember to have a release angle, so it is possible to take the part out of the mould. We had to make some changes to the seat because the experts told us that it would not be stiff enough without a foam core. It is very difficult to make carbon fibre components exactly during these conditions, when you have to cut out the exact form of the part after it has been cast. If you make a mould in polyurethane there is considerable work on it before it can be used and it breaks easily when the part is taken out of the mould. Always remember: "You can never have too much epoxy" a quote from every worker at APC.

7.2.3 Assembling physical prototype

When all parts were manufactured, both at APC and LTU, the group brought everything to LTU for assembling the physical prototype. The project group was then divided into subgroups where one group started assembling the wheelchair and the other group prepared the presentation.

The first thing to do was glue the supports inside the seat. Before the sides were glued onto the seat, the footrest attachments were glued into the side parts. It was not possible to fasten the attachment when casting the side parts, because they couldn't be fit inside the form. Next the holes for the sprints, that the sliders have, were drilled in the seat. The sliders that had the housing for the back wheels attached were then fitted to the seat. When this was completed the backrest was fastened to the sides, by fastening screws thru the side part and the backrest. Holes had been drilled in the backrest for the screws. The footrest was then fit into the footrest and castor attachment, which was already attached, as stated earlier. Next the attachments for the castors were glued to the sides and the castors were then screwed to the attachments. The only thing missing from the wheelchair was the back wheels. So finally the back wheels were fastened to complete the wheelchair.

1 Discussion

It is advisable to sand off the lacquer before gluing two parts together otherwise they do not stick. During the assembly we learned that not every part fit exactly as we wanted. It depended on human errors or different tolerances. So we had to perform some minor changes to fit every part together. These minor changes could be that we had to sand different parts. There could be problems if different people assemble the different parts. Maybe they do not know how the parts have been manufactured so they could damage the parts. We had also some problem when painting and drying different parts. We do not think that we had enough space to paint and dry the parts properly. After working on a project for four quarters it is a nice feeling to have a prototype completed at the end of the course.

7.3 Discussion

During the work in the Detail Design and Manufacturing phase many lessons were learned. It is an important and intense phase where you are verifying all the ideas and solutions that you have developed throughout the project. This is done both by drawing it in 3D-cad and building a physical prototype.

It is a big difference to have everything on paper and then draw it up as 3D-models in a CAD program. During the assembling some problems with different parts were discovered. Modifications and some redesign had to be done on those parts so they could fit together with the rest and become manufacturable. A very important thing was to clearly name each part so everyone understood what it was, where it fit, and where it was supposed to be assembled. This step was important so nothing would be forgotten. Due to lack of time the manufacturing of the composite parts started before the assembly was finished. After talking to experts in this field some changes of the drawings had to be made. The assembly had to be updated several times before the definitive virtual prototype was finished.

Another important thing during this period was to have an open communication within the group in order to reduce the redesigns and to help each other. Sometimes the project group didn't communicate enough and this led to time spent on non-essential tasks. To avoid some of the miscommunication, a calendar and a list was placed on the walls in the project room so that every group could fill in what they were doing. The other members could then read and know what's going on and also know who to ask if questions arose. A group without any miscommunication is very rare and it is also very hard to achieve. Daily meetings might be needed to keep each other up to date. This could have been viewed as irritating when time short and everyone was feeling the pressure.

Section 8 Product Launch

8.1 Product description

Imagine yourself going up a steep grade in the heart of the winter season. There is a light dusting of snow and a small layer of ice on the ground because it was warm the day before. You can barely keep yourself from falling let alone walk up the hill. You know how you do that bird flapping motion with your arms to keep your balance but it isn't helping. Now imagine that same scenario but this time in a wheelchair that is meant for traversing linoleum floors. If you thought you were getting nowhere walking, try spinning around for a while.

When the Cre[ativo project started during the fall of 2003, there was no set assignment, only three lead words: active, winter and leisure time. Based on these lead words, extensive benchmarking, and needfinding the team formulated their own assignment. This led to a unique product which fulfils the needs of the users: a winterized composite wheelchair suited for active users.

During the wintertime it can be hard even for a person who has two fully functional legs to get through the snow and over the icy patches. It is even more difficult for a person who is sitting in a wheelchair. To address this problem the Creativo team developed a clip-on. The clip-on is a rubber band equipped with metal nubs which is placed around the tire with five snaps. With the clip-on traction can be improved during the winter and the clip-on can easily be removed when going inside.

One of the problems with the wheelchairs today is keeping it and the user clean. In a regular wheelchair tire, dirt and snow get caught between the spokes. The Creativo team solved this by developing a new spiderwheel with three spokes. With this solution you can easily avoid the majority of dirt and snow. The main cleanliness problem is keeping the actual tire with the traction pattern clean. The Stanford team solved this problem by developing a tire cleaner to help the user to clean the chair before entering the house, especially during the late winter and early spring when the pavements are wet and dirty.

The cleaner is a detached part and it's to be used either outside before entering or inside in the hallway. The cleaner consists of two parts, one that cleans the wheel and one that dries it. To clean the wheel the user rolls the wheelchair backwards up on the cleaner, seen to the right in figure 8.1. The cleaner part consists of two unidirectional rollers that make it possible for the wheel to turn, two rotating brushes and a container with water. When the

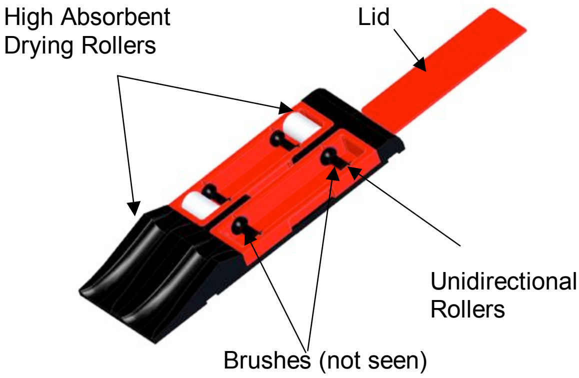

Figure 8.1

Figure 8.1 *The Stanford team's wheel cleaning device*

wheel is turned, the brushes and the water make the wheel clean. Then the user rolls down and then up on the left side, the drier. The drier also consist of two rollers as well as of two high absorbent drying rollers.

This cleaning device removes 90% of the dirt and debris from the tire tread. The user stays clean during use and no harsh chemicals are required. More information about this device can be found in the report ME310c, Tools for Team Based Design, made by the CRE[ATIVO]^2-team at Stanford University

If you had the option of sitting in a nice comfy office chair all day or a simple hard wooden chair, which would you choose? The Creativo team wants the active wheelchair user to have that same option. This is why the team developed a higher, ergonomically shaped backrest. The backrest is more comfortable and gives more support for the back without being in the way of the shoulders when propelling the chair.

Another problem which was encountered was the backpack issue. Many active wheelchair users use backpacks on their backrest. When books, groceries or other items were put into the backpack the centre of gravity shifted backwards which forced the user to lean forward to avoid tipping backwards. This posture is both uncomfortable and not ergonomic. To solve this problem the Creativo team developed a unique mechanism which enables the user to change the centre of gravity without any tools and without getting out of the wheelchair. To change the centre of gravity the break is locked and two sprints are lifted up and turned. By grabbing the tires and pushing the seat, the wheels slides on a roller with bearings into desired positions. After changing position the wheels are securely fastened with the two sprints.

Although the Creativo team added these extra features the weight was kept at a minimum by making as many parts as possible in

Figure 8.2 Figure 8.2 *The virtual product on the left and the physical prototype on the right.*

composite. The parts, which were not made in composite, were made out of lightweight metals like titanium and aluminum.

All these features, which have been described, are included in the virtual prototype, see figure 8.2. Due to the lack of recourses the physical prototype hasn't incorporated the spider wheels or the backrest adjustment. The intention with the physical prototype was to give the audience a possibility to actually see and touch the CRE[ATIVO]^2 product and this was achieved more then well by the physical prototype.

8.2 Product Display and Presentation

While the intense work with producing and assembling the prototype was carried out, a small group of students prepared for the product launch in another way. This was done to sell the project to the customer. A company can have the best product in the whole wide world, but if they do not know how to sell it or market it, no one will buy it.

This might seem like a simple task compared to carrying out the whole project or just one of the phases for that matter. But how to present roughly 10,000 hours of work in 12 minutes, or this entire report in the same amount of time, to people who have no idea of what has been done? This was the task that had to be dealt with. The fact that the audience was a mixture of students, executives and press didn't make it any easier.

Since the team now was so familiar with the problem solving process, the students knew exactly where to start. By watching and analyzing last year's presentations a good ground to build on was founded. What made a successful presentation successful? After answering that question based on the old product launches, the work with CRE[ATIVO]^{2}s product launch began.

The product launch on the 13th of May 2004 consisted of four main parts: an oral/video presentation, a display case where the audience could view the physical prototype, a web-page, and a brochure that presents all the SIRIUS projects in text. The first step was the presentation. After observing last year's presentations the team decided to go with a sales pitch of the wheelchair that would be informative but still entertaining to listen to. Since it is more or less a tradition to have video clips that introduce the team and show part of the product development process, one person was immediately assigned to start the video editing in Adobe Premiere 6.5. Since no one had ever worked with that program before, there was a learning period and a limited amount of time. Despite this the videos turned out really well. The presentation mainly consisted of pictures and images that illustrated both the needs and the

concepts of the product. By using rhetoric like story telling and illustrating by examples, the audience gained a feeling for what people with disabilities have to deal with every day. To be able to attract people to a display case, the product can not just be left there. Putting the wheelchair on a podium and surrounding it by posters to attract passing people's attention accomplished this. For a view of the CRE[ATIVO]^2 display case see figure 8.1.

When it comes to both the webpage and the brochure they also were sales pitches. The brochure was handed out in connection with the presentation while the webpage can be visited on the web at anytime. On the web it is also possible to look closer at different details of the virtual prototype.

Figure 8.3

Figure 8.3 *The CRE[ATIVO]^2 display case*

Section 9 Project Reflection

This chapter reflects on some of the core parts that have contributed to give this project its unique shape. Reflections are made on the way the project has evolved, on what kind of structure that has been present and on what guidelines the project has been following.

9.1 Team work

The Creativo group has been a mix of students with different backgrounds and knowledge, with different ways of seeing issues and solving problems. Having such a diverse group is very valuable, since the solutions are more likely to have been viewed from many different areas of knowledge. Meetings and consultations have been held in a rather informal manner, with the project leader(s) setting the agenda and making sure everything is headed in the right general direction. This method has worked well and has been reflecting the general spirit of the project. With the overall loose structure, the group members can switch work, giving people the opportunity to try different things, and keeping everyone's spirit up. During each phase the group has split up into subgroups working with different areas or aspects. Communication has occurred between the subgroups, but the flow of information could have been better, in order to keep double work and misunderstandings to a minimum. Communication is a key word in a project like this. Sometimes it has worked well, and sometimes not. The fact that two languages have been used has been a barrier at times. But at other times, people have spoken the same language, and still misunderstandings have occurred. This has made us aware of just how important good communication really is, and expressions like "open communication", "tell the same thing twice", "get everyone on the same level" has gained new meaning to the project members.

9.2 Project goals

In the beginning of the project, a mission statement was created. The mission statement was made based upon an initial design space exploration. At this stage, the project was still very broad, which in turn made the mission statement equally broad. In retrospect it can be observed that, even though a large design space exploration had been conducted, the knowledge that we possessed then wasn't enough to decide the fate of the rest of the project. In the end, the goals were reached, but some were fulfilled to a greater degree than others. Since the core of this project is about exploring and inventing, it is very hard to have an idea of where the project is going to end up at an early stage, and new insights might make previous goals outdated, or even wrong. If the project goals had been regularly updated and redefined, and considered to always be in motion and evolving, the goals could have been made more detailed, and it would have given us more freedom to follow the way that our increasing knowledge pointed. Goals also serve as a way of keeping the project focused, and as a way to make everyone work in the same direction. This was well achieved with our goal, even though it was rather broad in the beginning. The ideal would have been to find a good balance between chaos and order, or focus and creativity.

9.3 The Master Plan

The master plan was created by the group's coaches to give an outline of the project and to help keep the project moving in the right direction. Since none of us had previous experience with planning a project of this size, having predefined milestones saved us a lot of time. As the group progressed through the project, the Master Plan became more and more utilized. The Master Plan acted as the blueprints to the planning for our project. We followed the suggested road map and were able to accomplish our goals. The Master Plan didn't tell us how to meet the deadline; it just gave us the deadline and what was expected. The rest of the planning was up to us. We have learned how important it is to have a master plan as a foundation for the project. Since it only gives "the big picture", and doesn't interfere with how the work is done, it is not constraining the project. The master plan is also a way to keep everyone informed on how far the project has developed. This is something that could have been emphasized more throughout the project.

9.4 Coaching

The coaching was quite unique in this project. We had very little interference by the coaching staff. The project and its outcome were basically in our hands. This has made us feel that it is our project and that the things that have been accomplished are a product of our own competence and knowledge. The coaches did give us pointers at each of the phases, but their main function has been to be there as a resource and a place to bounce ideas off of. The fact that most decisions were made by us has led to a stronger self-confidence in decision-making and also improved our skills to analyze the options, and base our decisions on that analysis.

9.5 Project planning

The project planning was based on the master plan. The ways to approach the deadlines were developed by the project leaders and then agreed upon by the project members. Having the whole group agree on the plan ensured that nothing was overlooked. During the meetings, each member would trade off on secretarial duties and have 24 hours to post the meeting minutes on the Project coordinator. Tasks were laid out at the start of each meeting and people were put in charge of each one. This planning method worked very well for our group. We were able to address all of our goals. Most importantly, we learned that planning is essential when working in such a large group. The only way to keep everyone focused and unified in approaching the project is to all be on the same plan of attack. However, it's also important to get a balance between group decisions and independent work. Some things are suitable for a common discussion, and some are not.

9.6 Resources

Our coaches did not provide us with a set amount of money that we were allowed to use. This gave us the liberty to think of every option for the development of the wheelchair. The negative side with this approach was that it was hard to know how much we could spend on the different parts of the project, such as the prototype manufacturing. The resources could have been planned better. It was hard to know what we needed until we were done with the design, but had we been ordering materials as the parts were being completed, manufacturing could have progressed much more smoothly. For communication, the tools of choice have been the videoconference system Confero, phone conference, ICQ and MSN. We have also used the Project coordinator and a physical project room. Most of the problems with the technology have been associated with the Confero system. The reason for this has been a lack of knowledge from our side, as well as technical errors. During the fall, these problems contributed to the fact that the relations with the students at KTH became forced. Poor communications between our teams led to misunderstandings, which in turn led to more misunderstandings. Stanford University had better technical equipment than KTH, which made the communication with them much easier. The Project coordinator gave us the opportunity to share documents and ideas, which worked very well.

9.7 Conclusion

Overall this project has provided a unique learning opportunity for our team. We learned to depend on one another and to trust each other to fulfil their commitment to the team. The project leaders were important in keeping the team on track but it was really up to us as individuals to do our share and help the team accomplish its goals.

Communication, communication, communication! The importance of that word can not be stressed enough in a group process. Communication within our group and communication between our group and Stanford or KTH are equally important. The results of poor communication caused the loss of involvement with the KTH group and led to Stanford and Luleå working on separate projects with little in common. Conversely, good communication allowed our group to meet each of our deadlines and create a product that met our stated goals within the timeframe that was provided.

Our group is unanimous in feeling that this project was an excellent tool to improve our team working skills, our communication skills, and to learn about the design process through a distributed team.

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Appendix Table of Contents

Appendix A

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2.Age: 42, 29, 33, 43, 52, 42, 44, 48, 27, 26, 54,

3.City: Kungsbacka, Gothenburg 3, Tjörn-Kållekärr, Uddevalla, Bohus, Skövde, Stockholm , Uppsala, Kiruna,Boden

4.Disabled = YES

5.What is your disability?:
Neurosedynskadad - are completely dependent of electric wheelchair.
Herniated disc
Herniated disc
Pain when moving
Tretlaplegi
CP-cerebral pares, spastic dipelgi??, some broken bones, a crushed heal.
MS since 15 years
Disabled
CP-cerebral pares, spastic dipelgi
Hereditär spastisk Parapares-the legs are straight out
Rheumatic

6.
Active politician for disabled persons

7.Are you using any devices? YES

8.What kind?
Electric wheelchairs, wheelchairs, adapted car with a lift, automatic door opener in the home.
Using manual wheelchair inside, sometimes outside. For longer distances outdoors = permobil(electric..)
Wheelchair, shower stool, an adapted car
Psoa.pall- expensive, weak, complicated to adjust
Lift, electric bed, electric wheelchairs, adapted car and tractor.
Wheelchair XLT Nordic. Support handle in the bathroom, shower stool without wheels. Electric bed and electric WC. Sometimes a companion. A PC with adaption of the mouse, mouse-trapper.
Crutch, zimmer frame, wheelchair, electric moped, working chair, shower stool.
Wheelchair, electric wheelchair. Lift and hygiene chair.
Electric wheelchair, wheelchair, Crutch, working chair
Wheelchair, Crutch, zimmer frame, tipping board
Electric wheelchair, door opener, house telephone, lift for the stair, kitchen devices.

9.+ and –
It is difficult to change wheelchairs and get help directly. It is hard to find devices who suites me. I am in a wheelchair and have short arms.

I have two wheelchairs, one is slower than the other, otherwise it is just positive things with my devices
My wheelchair is light and easy to handle
Without my devices I would be isolated.
+ That the devises exist.
- Take to long time to get them delivered to you, you have to contact a lots of people before you get the devices. It takes long time to get something repaired-especially during vacation. Home-help-service, companions, chauffeurs and workmates do not know how the devices work all the time.
+Increased freedom and movement and increased equality in living aspects.
-The administration , long queues, expensive limitations of the selections.
I have more freedom now with an electric wheelchair, and I do not have so much pain in the body as I had before.
-Wheelchair: there is no practical storage spaces, it is hard to get an optimal wheelchair when you have the legs standing straight out, it hurts after a while if you fasten your legs.
+comfort seat(Pantera S2) light, nicer than years before
Crutch – unpractical when you want to transport them with the wheelchair, bad grip=it hurt in your hands
- The devices are not strong enough, they break.
+It is good that they are existing so you don't get so dependence of other people

10.changes:
It is too expensive with all devices. The adjustments are difficult to change and it is hard to repair them.
The electric wheelchair with three wheels is not as stable s the one with four wheels.
It would be great to have better "link"wheels(the small wheels) for the wheelchairs. They get stuck in gravel path.
It would be better if the devices are more adapted to each person. The car is easy to get adapted for my needs but electric wheelchairs are more difficult. It depends on different governments. The adaptation is difficult.
Should be cooler zimmer frames, it is not only the "old" people who use it. The electric wheelchairs should also be better, cooler and stronger.
The electric wheelchair: smaller, more flexible and more simple.
The manual wheelchair gives me pain in the body, it should be more easy to roll. shock absorber, gears, and other things to move the wheelchairs with instead of pushing the wheels.
Devices for shower my hair, an light shower towel. The electric wheelchairs should have a hanger for my bag, I can not reach it if it is behind the chair.

11. No changes
almost everything
The XLT Nordic wheelchair (with board to put the feet)=changes= the pole where the board is attached to is to long when you are sitting higher then normal. You get stuck with you feet. Suggestion: Make the pole shorter but not sp it will affect the safety.
Better adaptation in the home.
The lift.
The seat comfort

12.Problems in the society today?

I am having big problems getting forward with the electric wheelchair, general transportation, taxi, premises, lack of available toilets etc..

I always have to go with the transportation service for the disabled, or that some relative is picking me up. There is not so many pubs, discos for a disabled person.

Availability. Ex high sidewalks, heavy doors. Something it is hard to find a parking spot for disabled.

Availability is still a problem.

Availability, high sidewalks, snow/slipperiness- poorly sanding and shoveling. The access to bus/train- don not get on board. Sport/leisure

Availability

Availability, the snowbank.

Difficult to go everywhere with the wheelchair when it is winter.

Availability still suck in Sweden, the climate make its hard to roll sometime, expensive with sport equipement

On wintertime I am having problems with the snow and it is slippery.

13.Activities

I can use it at my physiotherapist, when I was working I could use my wheelchair there.

I can user my devices for the activities that I am aware of.

The wheelchair- I can do almost every thing indoors, if not narrow doors/stairs or high step prevents me. I can go on asphalted streets but having problems in the forest without any help.

Floorball

14.Any activities that you can't do today?

A lot, the availability is a big problem

I can not go to all restaurants because of the lack of availability.

I choose the activities after what I can do.

Be in the forest/nature. Travel abroad or travel in Sweden. Limitations of transportation equipment. Fishing –access to suitable boats/bridges. It is hard to get information from ex tourist information if we have the possibility to go to certain places and user the activities there.

The limitations are not from my device, it is from the society.

I can not be outdoors in the nature

15.

That it was possible to get about in a wheelchair everywhere.

In the nature, stairs, tight spaces.

Go to more pubs/restaurants than I can do today.

Sport/ leisure/ travel

Diving

To be in the nature without any problems. On wintertime I have the possibility to use snow mobile , but when it is no snow it is not funny.

16. Other
A mobile basket back on the electric wheelchair. The thought is that it could swing forward to the user. Nowadays it is very difficult to reach the basket.

Not disabled:
1. Male Device-technician

6.
my wife is disabled

9.
- the tip protection should be better, there is to much friction against the ground
The seat comfort is not ergonomic

10. Want to change the manual wheelchairs

11.
High sidewalks

Appendix B

The experiment:
I decided to spend three entire days in a wheelchair and pretend as best as I could that I was handicapped from the waist down. The only time I was allowed to be “non-disabled” was when I was at home as it is not equipped for disabled access.

Goal:
The goal of this experiment was to try to understand part of what it means to be disabled and to be using a wheelchair. It was also used to pick up on some of the issues that come with operating such a device on a day to day basis, by experiencing it personally.

Diary:

Day 1 (This was my first day so I thought I would get myself used to operating the wheelchair around campus, and follow my usual schedule)

Slanted sidewalks: One of the first things I noticed as I was pushing myself around the campus is that I constantly had to rectify the trajectory of my chair. On long straight sidewalk runs, I would almost only be pushing myself with one of my arms. This is due to the fact that most sidewalks are slanted. It was quickly very annoying and tiring for the arm that was doing all the work. For anyone who snowboards, it is kind of when you are on a long catwalk and you have to stay on your toes or on your heels for the entire run.
Wheels rubbing against clothing: When I was riding around, my coat and even my pants were rubbing against the turning wheels constantly. As it was in dry weather, the only issue was the wear of my clothing articles but had it been slightly wet, I would have been drenched and dirty. When I was not wearing a coat, my pants were taking all the rubbing and this was accentuated even more when I had things in my side pockets like my phone and my keys.
Dirty hands: I noticed very quickly that my hands were getting very dirty very fast. When I was operating the chair the weather was fine (dry and sunny), but I can imagine how bad it could be with the slightest rain let alone snow. As a result I had to wash my hands more often, especially before eating anything. One thing that came up when using public bathrooms to wash my hands is that as soon as you are done, your hands get instantly dirty from the unsanitary bathroom floor which is probably even more dirty than the outside floor. So it is kind of like a little vicious circle.
Sink: When I was washing my hands in the public bathroom, I noticed that the sink level was a little too high (and I am pretty tall so I cannot imagine how it is for shorter people). I had to stretch myself into these wired positions to reach the soap and my forearms had to rest against the soaked sink surroundings. This was not comfortable or very hygienic.
Pants pocket use: The first time my phone rang while I was in the chair, I missed the call as I couldn’t get the phone out of my pocket. It became clear that the use of my side pockets was limited due to the fact that I was in sitting position all the time. Soon after, I realized a similar problem with my back pockets, where I usually keep my wallet, as I went to buy a drink.

Carrying drinks/food: After buying myself that drink I was confronted with a new problem…where do I put this drink as I cannot hold it with either hand as they both have to be working to allow me to move? I decided to place the drink between my legs but a little down the road it ended up spilling as I went over the door frame. The same problem appeared when I tried answering my cell phone as I was moving. When moving, both hands are needed to operate the vehicle.
Table heights: Usually most tables come with appropriately sized chairs (i.e. high tables in coffee shops have high stools, low tables have shorter chairs). However, I was always at the same height and I had to deal with the tables that were there. The first example that comes up to mind is when I went into a coffee shop and all their tables were high stool tables. As a result, not only could I not use the tables to put my drink but I felt I was not part of the group that was at that table. The other example is at our teleconference with Luleå. The table was too low for me to put my legs under it, so I had to sit sideways and had to stay in that uncomfortable position during the entire meeting.
Awareness necessity: When I was moving around, I had to be a lot more aware of what other people are doing around me. When I was in the wheelchair I was not at eyesight level so people didn't always see me, especially around corners. Cars backing up of driveways or at intersection are other issues. To top it off, even if i saw them, i could not get out of the way as easily and as fast as if I was walking. As a result, i had to be more careful and anticipate what other people were going to do.
Planning: After being late to two of my classes I figured out that I needed more planning. Indeed everything took me longer now that I was in a wheelchair. Not only that but I couldn't just go anywhere I wanted. After a while I realized that before going anywhere, I was thinking of the route I was going to take. I was trying to avoid steep uphill, I needed to think about where the disabled entrance was, I couldn't take the old shortcuts that I was used to as there were steps or patches of grass…basically I had to plan!
Slaloming and constant road watching: No road or sidewalk is perfectly clean or flawless. As a result, I had to constantly keep my eyes on the road surface in front on me to avoid any holes, bumps, edges, olive pits…anything that would cause my front wheels to lock up and throw me out of the chair. In addition to this, I had to learn the art of the "wheelie" in order to avoid some obstacles such as imperfect road to sidewalk transitions, or to get out of sticky situations.
Vibrations: All the vibrations from the ground and its deformities were transferred to me through the wheelchair. After a while I started getting used to it but they were still being transferred to me and they drained me physically seeing as I was on the chair the entire day. You could compare it to driving an old beat up car on a cross country trip as opposed to a nice new BMW 7 series: you get used to it but at the end of the day, you pay the price.
Crowded environment: I found it very hard to get by in tight spaces and in crowded environment even though the chair I was using was very maneuverable. In busy places I think the main problem was that people didn't see me so they wouldn't get out of the way. I constantly had to tap them on their hands or on their legs, which is an awkward place to be tapped for attention (the hand being very personal and the leg being very unusual).
Backpack: Just like in the case of my clothes rubbing against the wheels, I found that it was hard to carry my backpack without having it in contact with the wheels. There was nothing to attach it to prevent it from dangling or swinging from side to side.

Bathroom: Although this has not much to do with the wheelchair itself, my experience trying to get out of the chair to use the bathroom was very valuable. I found it very difficult to push myself off the chair. I would have rather have had a bar to pull myself up in the style of a pull up.
Brakes: The first time I had to use the breaks on the wheelchair was during my bathroom experience. Although they were effective, they were definitely not user friendly. I had to put myself in a strange position just to reach them, and then the linkages that they are composed off caught my finger multiple times.

Day 2 (The second day I didn't have any classes so I decided to explore a little bit more by trying out public transport, common social places like a restaurant, library and others)

Narrow passages: One thing I noticed when going through narrow entrances or corridors is that I would always be afraid of catching my hands against one of the sides. Even when there was enough room, I would take my hands off the rims. The fact that my hands were the first thing that was going to hit if I ever got into contact with anything was in the back of my head anytime I went through a narrow passage.
People: The second day I was observing people a lot more as I felt more confident in my chair. I noticed that even though they are not always careful or prudent in general, once they saw me they were always very helpful and attentive.
Asking for directions: In a lot of the public places, I had to ask for directions in order to find the access for disabled persons. One example is at the Stanford bookstore, I was trying to find the elevator to get to the lower floor but after going around a few times I had to ask. This happened frequently on my second day as I explored many public places and I felt I was depending on people a lot.
Marguerite (bus): I took the bus to get from campus to the Caltrain station. The buses were equipped with all the necessary equipment (kneeling function, foldable electric ramp, wheelchair reserved area…) so there were no issues there. The only thing I can say is that it took quite some time: 1 minute for the whole operation and 3 minutes waiting because the electric ramp was not functioning properly and would not deploy. As a result I felt like everyone was watching and waiting for me.
Caltrain: My experience with Caltrain was definitely one of the best. First of all everything was clear and there was no need to ask for directions. There was a zone for me to wait in marked with a big blue disabled marking on the ground. Then when the train came in, someone directed me to the train doors that I was going to be boarding through. Once everyone has cleared that entrance, it took less than 30 seconds for me to get in. In addition to that, all the staff was very pleasant and talkative. Inside, the designated space was clearly indicated and there was no need to be strapped down like in the bus.
Crossing rails: Once I got to my destination, I got off the train and needed to cross over to the other side of the platform but there was no tunnel so I had to cross over the rail tracks. This proved to be a very strenuous and dangerous task as it was rugged terrain and the gaps between the tracks and the wooden planks were pretty significant. My front wheels got stuck a couple of times and they could have gotten seriously stuck. This was definitely very risky, especially considering that a train could have been coming and I could have been alone.

Restaurant: At the end of the day, my team and I decided to experience a meal at Pluto's in Palo Alto. For those who don't know this restaurant, it is a salad place where you just point to the ingredients you want. The only problem I encountered is that the counter was very high so when the waiter ask me to point, I told him that I could no see anything. This is also a general problem I came about, a lot of counters are too high and it is difficult to interact with the people behind.

Day 3 (The third day I was pretty busy and I spent a lot of the time in the design loft so I didn't experience many new issues. By that time I felt very confident riding around in the wheelchair and I had gotten used to a lot of the issues I have already pointed out.)

Dry hands issue: For some reason, on the third day my hands were very dry and I found it a lot harder to get grip on the handles. The only thing this caused was less traction.
Cold handle rim: When I was operating the wheelchair at night, it was very cold outside and the handle rims became cold very quickly. This was very uncomfortable and I can imagine how much of a problem this could become in more severe winter conditions.

Conclusion:

These 3 days were very intense but very enlightening. I learned a lot and I think it gave me some good insight into what it means to be in a wheelchair. After the first day I was very tired physically but when the third day was over, not only was I exhausted physically, but I was drained mentally. Overall I was very happy with this experience and I hope this will help us in our design.

Appendix C

Table 1. First brainstorming in the concept generation phase

Quiet
Lubricated parts
Insulated mechanical parts
-Sound absorbing materials
Electrical instead of mechanical if possible
Silencer, put noise behind or away
Storage
Movable compartment
Drawer under seat
Front basket
Holder for shopping bags
Drink holders
Small inner pocket
-cell phone, hands free phone, radio, MP3
Storage in armrest
Protected lockable storage
Lockbox for accessories
Storage behind legs and under seat
Electrical moving storage
Storage on back
Hitch-trail
Child carriage adapter
Power
Gel battery
Heated battery compartment
2 stroke engine
Solar cell
Regular batteries
Hybrid
Electrical charging while manual
Electrical charging while breaking
While moving, light comes on
Back up power

Breaking without power
Signal when low batteries
GPS
Plug-in for computer
Wall plug
Jumpstart with car battery
Change battery
Safe wiring-less worrying
Charge cell phone
-hand free phone
-radio
Training
Pedalling
Rowing machine
Rubber band
Move by training
Adjustable wheel ring size
Change length for training
Gyros for stability
Anti tip system
Button to start training mode -leg training
Variable resistance
Walking machine
CC-Skiing
Restrict and not restrict parts of body
Electro training
Clean/Dry/Warm/ Cool
Rain poncho
Bubble protection
Heated handles / seat
Cooling handles / seat
Heated wheel ring, composite? CU^{2+}-wire
Warm/cool Arm/Foot support
Air circulation- like aeroplanes, BMW
Air conditioner
Fenders, Covers below

Enclosed cockpit, BMW scooter
Pedalling for the handles
Height
Stander /sit
Elevator seat
Pump seat-hairdresser
Screw for adjusting height
I-bot
Legs that come out and raise whole vehicle
Gyro-Control balancer
Reaching arm
Lowering ability
Lay down
Adjustable arm- and foot support
Chassi
Light weight
Removable seat
Removable modifications- standard sizes
Add-ons -GPS -TV-on Stars
Standard interface- USB
Table mod
Security system
Alarm

Size
One size fits all
Enter weight suspensions
Fit into doorways
Cant step over the user
Weather
Anticorrosion
Heavy weight preferable during hurricane
Umbrella holder
Cover for wheelchair
Waterproof for cleaning

Heating system/engine heater-timer
Fenders for the wheels
Removable cover for easy cleaning

Common terrain

Snow chains/spikes
Retracting spikes – toy car
The "flapper" for curbs- different sizes
Treds- tank, snowmobile
-change from treds to wheels
soft front wheels varied suspension
Portable ramp
△ Wheel system
Adjustable driver height
Changeable tires
Individual wheel suspension
4 wheel drive All wheel drive
Change diameter of the wheel

Interact

Require little training
Choose the symbols that you want to use
-Inclusive, universal, design for all
Sound, touch, resen…
Touch screen
Game control controller
Wheel protection- mud flaps
Servo pushing system
Adjustable handlebars
Intuitive way of folding- colour codes
Intuitive operation
Keep in mind current standard

Easy to lift/move/store

Composite of light strong material
Mag material
AL material
Take wheel of, fold like a child carriage
Telescope construction
Camping table bag idea
Illuminate crane lift for the trunk
Inflatable seat-jump
Netting seat

Prevent physical injury

Airbag seating/protection
Gel seat
Chemical warm/cool jelly
Medical icepack snap things-football
Plastic wheel rim
Rock/dirt deflector for the legs
Cover for legs/hands with electric heating/cooling
Flipback protection
Body adjustment device
Support for standing function
Wheels go wider for support
Role cage - levelling device
Rotating seat
Low cg
Safety harness – 5pt
Lower centre of gravity

Manoeuvrability

Joystick
Touchpad
Steering wheel-like in the mini forklifts
GPS-system
On star help
Turn radius that varies with speed, BMW 360 degrees system
Adjustable viewing mirror
Power steering
Electric gearbox for wheels
Scooter steering steeringrod
Blow and suck steering
Pivoty rear and front wheels180 degrees turn
Disc brakes- manual wheelchairs
ABS breaking, antispin
Adjustable wheelchair
Hand/parking break

Table 2. Brainstorming addressing primary issues.

All condition-traction
Mole hair
Snowtire
Stud tires
CG changing
Skiis
Saucers
Treads
Sand injector
Spikes
Retractable spike and studs
Snow crusher
Plow
Variable width tires
Tracks like snowmobile
Electric assist motor for when you get stuck
Ski pole for pushing your self up
Anti-spin suspension
Snow blower
Chemical
Wheelie bar modification/saucers
Steering system for front wheels
Adjustable wheel configuration
ABS
ETC
Chains
Flowers
Snap on knobby tire
Big wheel on the front
gearing system
Dual front tires
Big front tires
Adjustable tire pressure
Inside out tires
Folding tires
Thicker/thinner tire
Dog pad traction
Self cleaning tread
Blow dryer that blows out the snow
Extra weight ballast
Another wheel underneath
Booster rocket extractor
Big anchor
Hamster wheel
Spheres as wheels
Hopping chair
Baby seat cradle
Add on dualies
Double pair of wheels
Control CG using leg position
Front wheel drive
4 wheel drive
Sand ladders
Traction mat
Wheel weights
Moving wheelchair components to change C.G.
Oars that allow the user to dig out
Human interface
Wheel rim
Lever drive
Hand warm
Separate handrim and wheel
Widget lever drive
Oval shaped handrim
No handrim at all
Improve skirt guard
Wheel cleaner/ brush
Wheel crank
Getting in and out of the wheelchair
Detachable pushing handles and retractable
Put hand rims on the inside
Tilted tires
On star
Bubble chair
Self cleaning gloves
Grips that attach to the rims
Grips that attach to the axle
Latex suit for WC
Hubless wheel
Headlights/reflectors
Spotlights
Disco ball
Magnetic propulsion interface (don't have to touch the handrim)
Rowing human interface
Harness the retraction energy of the hand rim interface
Comfort
Bean bags
Ski boots for warmth
Heated gel seat
Temp sensors
Electrical changing of position
Seat with massage and vibration
Suspend the person in liquid
Have them sit like those kneeling chair
Removable sides
Reclining
Adjustable lumbar support
Changing positions like office chairs
Heated footrest
Heated everything
Movie screen blanket
Mesh seat
Hammock seat
Solar mirror to focus the suns energy for warmth
Frictional heat
MP3 Player
Speakerphone
Media center

Appendix D

Thursday 22/1 **040122-040128**

Since I was stupid and gave John the time that the Stanford team departure from Stockholm and not the one the arrived in Luleå, he and Jimmy H was a little more than an hour early at the airport to pick them up. This meant that we got behind in the schedule the very first thing we did.

Finally in Luleå they took the airport coaches to the University. We all met up in the project room and went over the schedule for the week. Andreas also popped in to introduce him self. Another thing that was mentioned there was the fika-rule that we have here in Luleå and since Brett was that one staying the furthest away I had to teas him a bit… That's when he said the expression for the first time; "Fika my ass!"

After that we had lunch in the "Centrum" Restaurant, and I can inform you that it is not easy to hold a table for 11 people there during lunch. While digesting the food we showed them around in our workshops, just to give them a feeling of what we are able to produce and what our limitations are. They were a bit tired so we tried to keep them awake by taking them to "The House of Technology" (Teknikens hus) where everyone got the opportunity to try different things out, like what happens when you shift gear while driving or what does it feel like to operate a forest machine? And it seamed like they all enjoyed it. Boel also showed them the starry sky with some northern light in the planetarium.

After a lot of fun it was time to find their way to there accommodation, Karlin Brett and James got to stay with there buddies while Jeremy got stuck with me. There was time for a shower and some small talk before it was time to catch the bus down town for dinner with Andreas and our professor, Lennart Karlsson, at Exotic. We all had different dishes for main course but on Lennarts initiative we all decided to try the cloudberries with ice-cream for dessert. After a long day for the visiting team we all decided to call it an early night and went back home to go to bed.
I think that the Swedes slept well while the Americans woke up around 3 in the morning and had trouble falling asleep again.

Friday 23/1

After a "good" nights sleep, we had arranged a typical Swedish breakfast in the teachers launch at Polhem. The Americans tried things like sour milk and Kalles kaviar. I'm not sure that they liked it, but they kept up the good mood. With full stomach's we split in to three groups about four persons and the groups departed in different directions only to discuss the same thing to get as many ideas as possible. John had planned the brainstorming secession well. We had many questions to discuss, but he had 3 sub categories to help us get going. To help we had pens and paper, magazines for inspiration and some ideo cards. A lot of ideas were generated and all groups had good discussions.

We all met up before lunch, just to gather everyone so that we could start directly after we had had some food in our stomachs. At Kåren the served dear, so we recommended another spatiality from northern Sweden today, I want say if it was good or not, but you can't expect too much from the chefs at Kåren. You have to keep in mind that they even let me work there.

After the refill of food we went back to the conference room in Polhem and all the groups presented the ideas that they had come up with and some new once were generated. We categorized the ideas in to three groups; operation in various weather conditions, operation indoor and outdoor and the interaction with surrounding objects, and then we voted on the once we thought were interesting or had potential. We all had 5 votes each and had to put at least on in each category. This process to quite some time, but there were some good ideas that came out of it. A discussion started on weather we were doing accessories or a ground up wheelchair. To be honest we didn't really know what was expected of us. This lead us in to a discussion of the laws in Sweden for devices for disabled. Since there are very strict laws on what you are allowed to attach permanently to your chair and still be fully insured. And also if they will restrict our project or if we want let them do it. How and if we can work around the laws. After a long and productive day, we decided to wrap things up and go down town for a little after work at Bar 1. There we had the taco buffé and some bear, which we all agreed on that we deserved. A round of pool is a must when you are at a pool place. We stayed until Jeremy by accident poured bear on the table, then we more or less ran out of the place after leaving some money on the counter. After this incident some people decided that it was time to go home, while for others the night had just started. They went to a disco called Cleo to check out the Swedish women.

Saturday 24/1
More or less recovered form last night we met up by the bus, fully dressed and equipped for a day at Ormberget where we were supposed to give the Americans an idea of how it is to play in the snow. We took the bus in to town where we had to change to another bus. While waiting we decided to check out the harbor. We had lovely morning and some entertainment from Jeremy who decided to try out the ice. The ice was just fine, but there were some trouble getting back up on the quay. Well at Ormberget we tested everything from sleds to skies with different results depending on the user. For lunch we made a barbecue with sausages and "pinnbröd" and of course we had also brought hot chocolate. Things that are a must when you spend a whole day in the slope. After a long walk home and quite tired from all the fresh air the guys were forced to take a sauna while the girls prepared the meatballs for the meatball party! It was a good party with; excellent food, a compulsory pop quiz including games and some heavy socializing. When we felt ready we moved on to the Student Union, Kåren for some serious dancing.

Sunday 25/1
Some of the faces were really tired this morning at brunch. We had a good breakfast, and then we started working. Since it sometimes can be really frustrating to work with out a clear focus, we once again came in to discussion on what we are doing, are we doing a power chair or a manual, are we just doing a kit for a wheelchair, and what type would that be? This subject is kind of hard to avoid so we decided to take a round where everyone had the chance to say what he or she was most interested in doing. The answer was unanimous, we all wanted to do a manual wheelchair in some form. To see what the biggest problems are with a manual chair in winter climate, we decided to take one out and test it. This was a new experience for more or less

everyone. Lots of tests were done and new ideas generated, we went back in again when we couldn't stand the cold any longer. All the observations were listed on the board, such as problems and good things that we experienced. Then we tried to come up with some solutions. But time flies when you are having fun, and we were all pretty tired from last night so we warped things up and went to Old Brodies for dinner. With full stomach's we needed to recover so we decided to watch a movie. John had brought his DVD´s and the majority settled for Old School. The once who didn't fall asleep during the movie probably did it just a while after home at their accommodations.

Monday 26/1
We met really early in the morning at uni to get a good start for our long drive. The destination for the day was the Icehotel in Jukkasjärvi, but on our way there we stopped both at the Arctic Circle and in Kiruna to have lunch. After about 5 hours in the cars we reached our destination. We paid the entrance fee and had a quick look in the shop before we started to explore the hotel. Lots and lots of pictures were taken. We were all very fascinated by the amazing design. Before leaving we all ended up in the Absolute bar to try out the ice glasses that the hotel are so famous for. Then we had a long drive back again. Since every one was tired and hungry when we came back, we just decided to grab a pizza at Porsö pizzeria before calling it for the day.

Tuesday 27/1
To get a good start of the last day we had set up a meeting at 8.15. During this meeting we tried to wrap things up, where were we supposed to go from here, who is suppose to do what and when is it due? We managed to divide things in to primary issues and secondary issues. Within the primary issues we did a split up between the two nations, Stanford was supposed to look at the human interface while LTU where focusing on all condition traction and comfort. But to help each other and to make sure that we didn't lose any ideas in the process we had one last concept generation together in all three fields. After lunch at Exotic we planned the rest of the project. This we did by comparing due dates, making travel plans, checking out each other's schedules and so on. When we felt more or less pleased with the timeline that we made up, we generated some more ideas before going down town to buy souvenirs. At night we had a "good-bye" dinner where Jimmy H served "Sausage stroganoff". It was really delicious! Then we watched all the digital pictures that were taken during the week, and that were a few. The really brave once went to Kåren afterwards, but most people went home.

Wednesday 28/1
At 6.15 the taxi for the airport left from Professorsvägen 11 and all the Americans were in it and that's where the trip ended…

Appendix E

Backrest testing

General comments:
We cut of the backrest plates and the comfort increased.
We still want support for your lumbar. We tried different heights.
It is good when you're resting that the backrest is high but it shouldn't be higher then the shoulder blades.

Concept 1

High backrest

Positive things:
Support for your back.
-we should need some support for the lumbar.
-you want to sit straight
Good when you want to sit and rest

Negative things:
It is touching the shoulder blades
It feels weird to wheel if you lean back.
The weight distribution is a cause of habit.

We didn't use the part above the head

Concept 2

This one is 20 cm shorter than concept 1. Almost up to the shoulder blades.

Positive things:
Support for your back.
-we should need some support for the lumbar.
-you want to sit straight
Good when you want to sit and rest
The comfort is the same as in concept 1.
When you lean back you get support between shoulder blades, it is very comfortable.

Negative things:
The same as in concept 1

Concept 3

This backrest is not as wide as the others. This test was made just to feel how the comfort would change if we had a thinner backrest.
Some of the testing student found it comfortable and some thought that it felt the backrest between the shoulder blades. It has to be made in more comfortable and soft material.

The original

After the testing the original backrest was tested and all thought that you didn’t felt any support and you got a worse sitting position.

The following tests were made on fairly hard snow, with a layer of powder snow on it (around 5-15 cm)

Skiis

We put a pair of skiis underneath the seat. They are in such a position that when the user is doing a wheelie, the skiis become horisontal to the ground, supporting the wheelie-position. When on a wheelie, the skiis don't touch the ground, except from when the balance is disturbed.

Pros

- The front wheels dont touch the ground, which puts most of the pressure on the back wheels, which increases the grip in snow
- The wheelchair becomes less sensitive of rough ground
- It's very easy to regain the wheelie balance since the skiis prevent big motions.

Cons

- Adds weight
- Might take a moment to learn the technique, especially when going in higher speed.

Note: Other things can be used instead of skiis, for example a pair of wheels. The effect will still be noticeable, since the point is that very little pressure is put on the skiis/wheels/whatever.

Coca-Cola bottles instead of front casters

We attached 1.5l coca cola bottles on the front castors, to find out how they would deal with the snow.

Pros

- They go, or plow through snow more easily than a pair of front castors
- Less sensitive to uneven ground
- They turn quite easily

Cons

- Adds weight
- Only works well in snow

Testing different concepts

The traction group conducted tests with modified wheelchairs. The surface where the tests were made consisted of mostly packed snow. Further testing will take place when the ground is covered with powder snow.

General experiences:

- the wheels skidded on the packed snow a lot, almost all the time
    - to reduce this I had to bend over so my weight is straight above the wheel (the contact surface)
- It's hard when the ground is leaning- you slip or just turn in that direction
- Depth snow??
- It was cold, the legs and hands start to freeze pretty early in the test even though I could stand up once in a while
- Good that the possibility of changing the tires position exist
- The skirt guard/handles fell off when you were trying to lift the wheelchair
- Sometimes it's hard to go straight forward, ex one wheel slip and the other…….
    - idea a bottom that lock the axel so it becomes one axel, the wheels roll exact equally
- Hard to get some acceleration, need some friction

Saucer underneath front casters

The group thought that the saucer prototype could maneuver over small bumps without getting stuck. The saucer may work better in powder snow. That will be tested later.

A problem with this concept was that the saucer had a large contact surface with the ground which led to high friction. This caused problems with maneuverability and the noisiness. Another possible problem is how to use the saucer indoors.

Possible solutions to the problems above are a smaller contact surface and maybe two smaller saucers, one under each front wheel. Maybe a "mouse wheel" could me attached instead of the saucer.

Skies on wheeliebars

The idea with this test was to see if the skies would help the user to position its CG so most of the force would be transferred to the back wheels.

During this test the group thought that the skies prevented the wheeliebar from sinking in and getting stuck in the snow.

It was hard to get the right angle on the chair to transfer most of the force into the back tires. There is a problem depending on the angle of the surface. Even a small upward angle can lead to that the user feel that he will fall backwards. The wheeliebars were also too weak. One of them broke down during the test.

A possible solution could be a kind of cradle that the seat is located in. This will hopefully lead that the CG will be as favorable as possible. That means that most of the force will be transferred down into the back tires.

- Good that the possibility of changing the tires position exist
- The skirt guard/handles fell off when you were trying to lift the wheelchair
- Sometimes it's hard to go straight forward, ex one wheel slip and the other…….
  – Idea a bottom that lock the axel so it becomes one axel, the wheels roll exact equally
- Hard to get some acceleration, need some friction

To prevent the wheels of skidding we attached two pieces of tape each 10 cm long with thumbtacks poked through the tape. They were positioned 180 degrees apart.

Mini skis on casters

One par of mini skis was attached to the casters with steel wire and straps. This was to prevent the wheel from turning and keep it firmly stuck to the skis. If this was to be manufactured the wheels would not be there and skis would be attached directly to the bars. This is just a rough prototype.

The idea was that it would prevent the wheelchair from digging into the snow. These are the results:

- It was hard to maneuver with the skis, mainly because it was hard to turn.
- The skis were too long so they got caught under the wheels.
- Another problem is that a lot of the weight is distributed forward, which changes the centre of gravity in an undesirable way.
- The skis where much nosier then the casters
- They prevent the wheelchair from digging into the snow though the skis often spin around and create other problems.
- Easier to get over small bumps and holes.

This test should have been carried out in more snow. This could have given a different result. The original idea was that the mini skis were going to compress the snow, making it easier for the back wheels to drive over the snow. In this test the mini skis was not in line with the back wheel, so the snow compressing idea could not be tested. Because of the primitively mounting of the skis the turning maneuverability was decreased. This issue can be solved if it were decided to pursue this idea.

Extendable tires

One metal sheet with small holes was bent around each rim. This gave the metal sheets a smaller diameter then the original wheel. The sheets were 15 cm wide.

The idea was to prevent the wheelchair from digging/sinking into deep snow. When going on firm ground the extended part would not be in contact to avoid unnecessary friction.

These are the results:

- There is no grip in deep snow, since the tires and extensions are flat and has no spikes, knobs or other grip aid
- The snow gets trough the small holes and makes the wheelchair sink into the snow
- The feet dug into the snow. This was mainly because the wheelchair that was used was not developed for outdoor at all.
- The wider the tire the more snow needs to be compressed which makes it heavier to propel

There needs to be another test which excludes the holes and includes some grip aid. The wheelchair rolled as it did before on firm ground. The extended part did not slow it down. The footrest needs to be higher up and the feet need to be held together to prevent them from digging into the snow. This idea with “extendable tires” could be combined with the “skis on casters idea”.

Modified extendable tires

In this test the sheet metals were taped so the holes were excluded. Wooden treads were also attached.

The results were:

- traction was improved and the wheelchair did not sink down so much in the snow.
- It was hard to propel the wheelchair because there were no hand rims or other grip.
- Snow collets inside the tire.
- The treads were not fastened good enough so some of them came of.

Poles for propelling in deep snow

Regular slalom poles where used to see if they could help in deep snow.

The results were:

- It was harder to get trough the snow with the poles.
- When using the poles the user needs to lean forward which get the user into a dangerous postion.
- It is harder to control the movements of the wheelchair
- The arms are high up and wide apart which leaves the body in a none ergonomically position.

Three wheels

The two original casters were removed. Two steel plates and one caster were attached with a screw onto the foot rest. This was done to test a wheel chair with three wheels. It was thought to be easier to maneuver, but be a bit unstable

The results:

- The screw to the caster was not straight over the pivot point. Therefore the wheel had trouble spinning

- It was as stable as with four wheels.

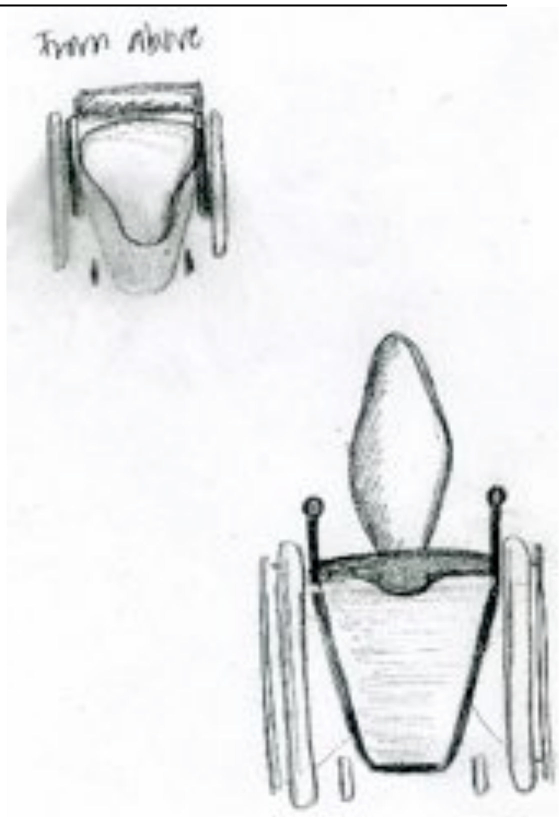
The idea was to test the turning radius with this configuration, but because of the poor mounting this could not be tested. The wheel just wanted to turn forwards. The caster was further out then the original caster, which led to more stability, at the cost of decreased turning ability and increased size. One idea is to replace the tire with a sphere. The sphere would not sink into the snow as a caster would. The mounting of the caster made the wheel pointing forwards. This made it very stable going forwards. This can be very useful when the user temporarily only can use one arm for propelling (when getting a soda for example). One idea is to have switch between “stable forward mode” and regular mode.

Appendix F

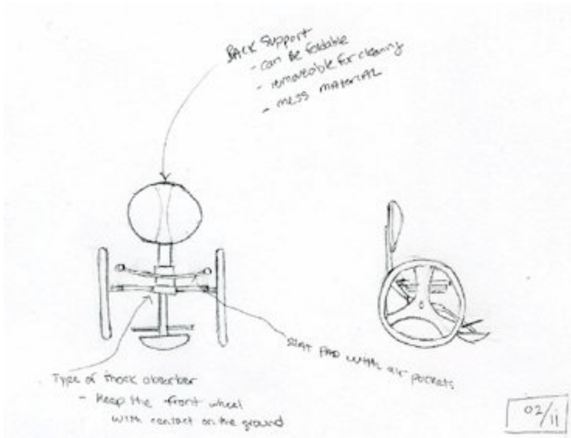
Backrest and cushion

1. Bowling Pin shaped backrest

2. Foldabel backrest

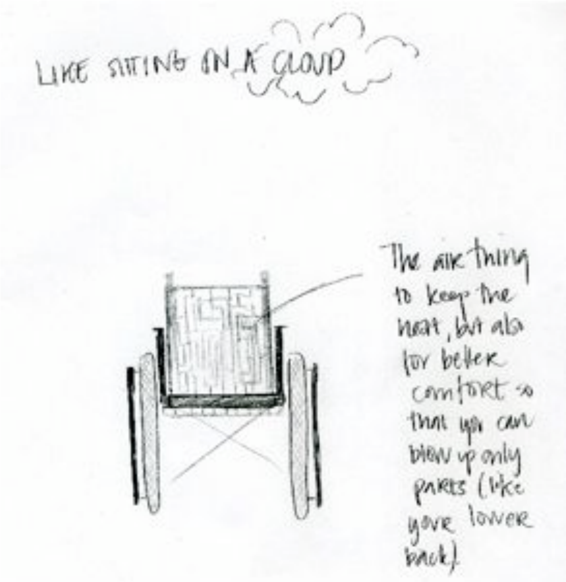


3. The saddle



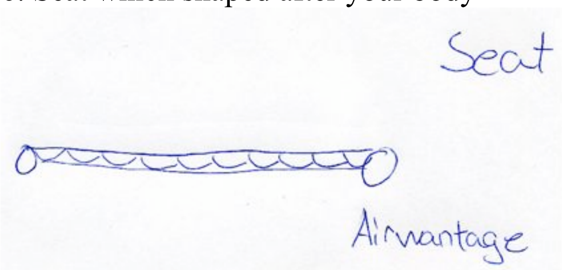
4. Backrest that can be foldable and removable for cleaning/seat pad with air pockets/shock absorber

Backrest and cushion

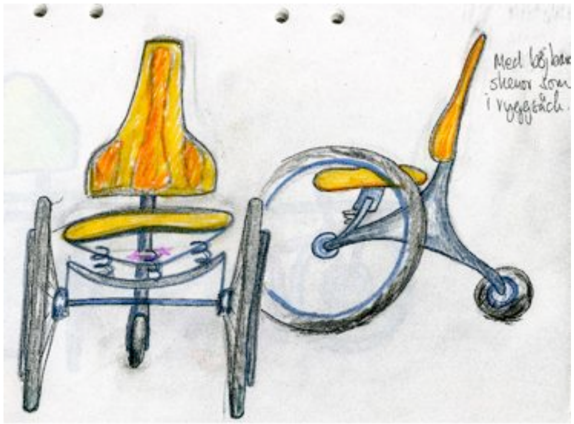


5. Sitting on a cloud

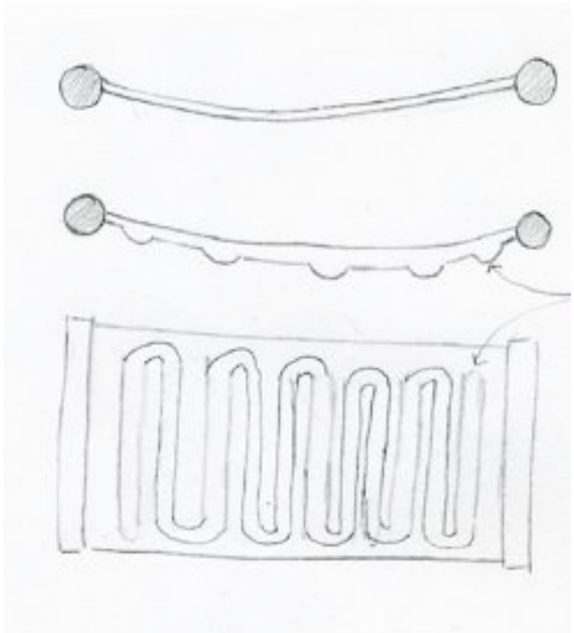
6. Seat which shaped after your body



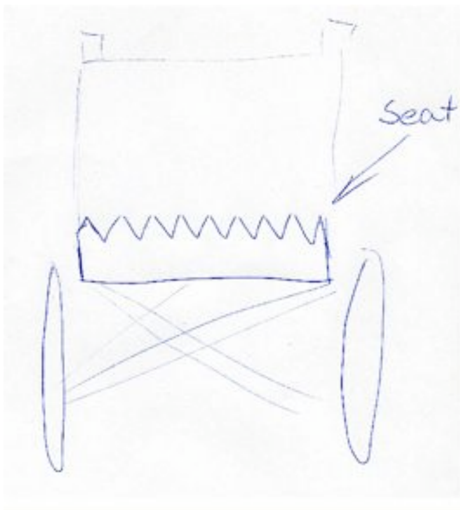
7. Seat, Airvantage



8. Changeable seat cover and chock absorber

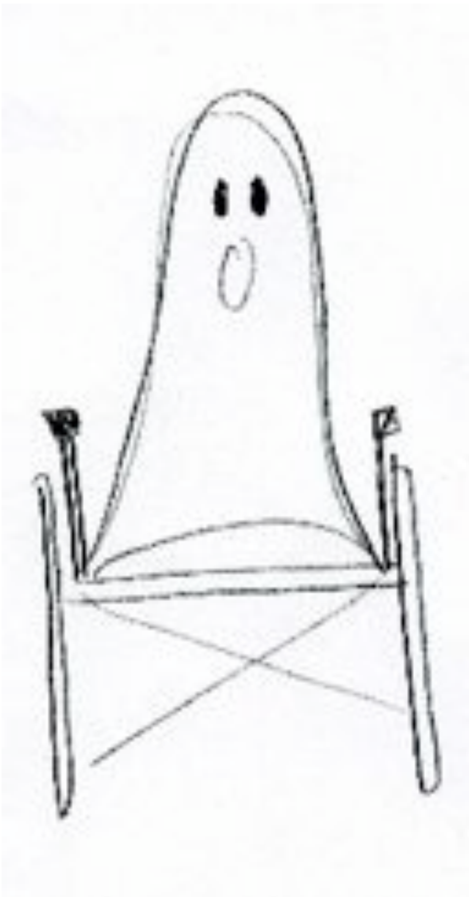


9. Seat, air-pockets, which inflates by blowing in a tube



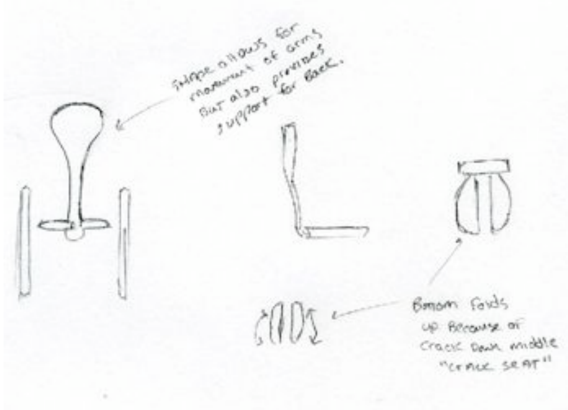
10. Seat design

Backrest and cushion



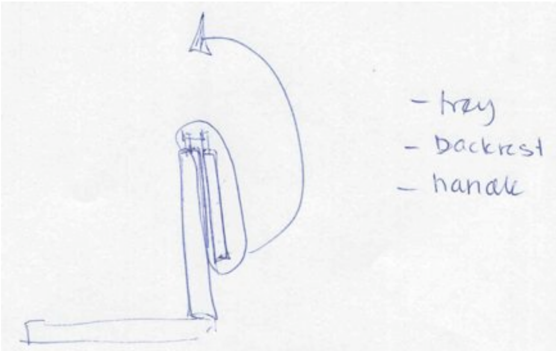
11. Goast chair

12. Office chair seat

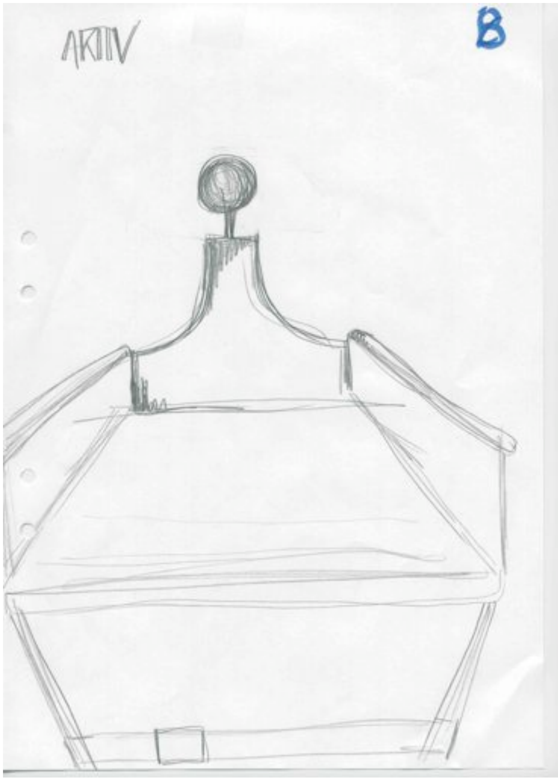


13. Bottom folds up because of crack down middle/shape of backrest allows for movement of arms and backsupport

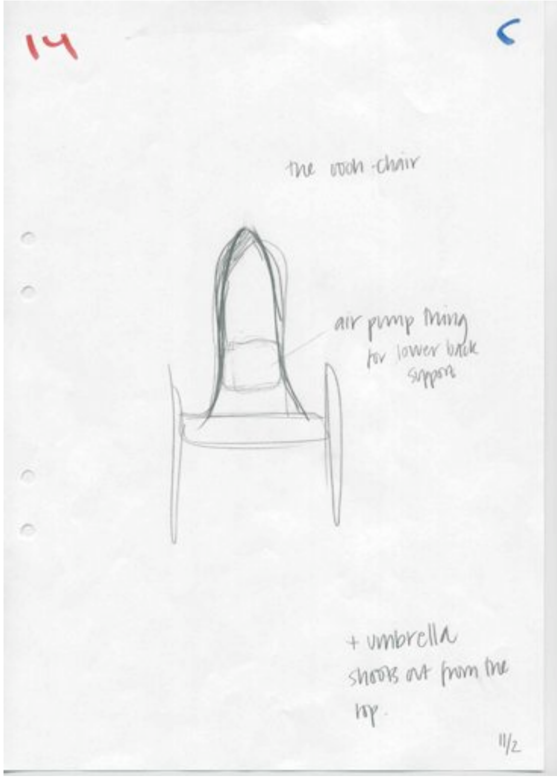
Backrest and cushion



14. Backrest which folds back and can serve as tray and handle



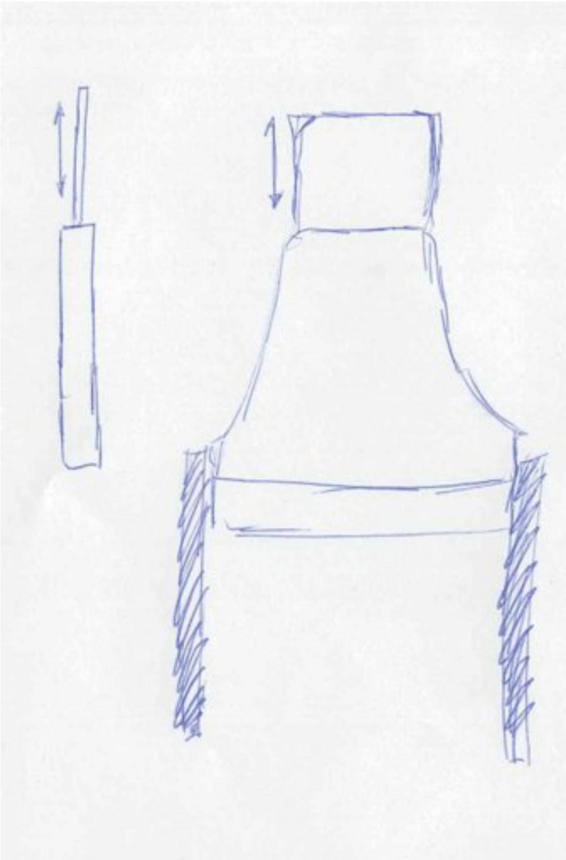
15. Head support

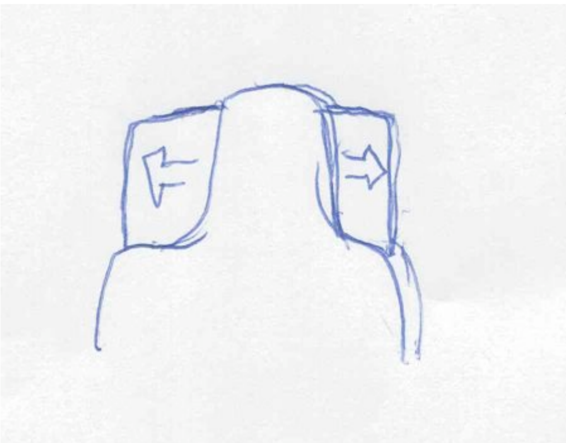


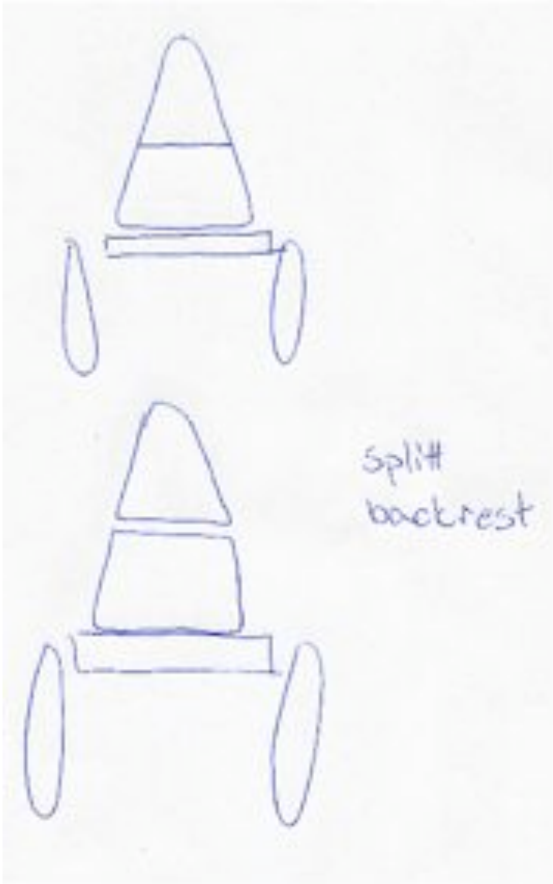
16. Shape of backrest, lumbar support

17. Seat with links

Backrest and cushion


18. Extractable backrest

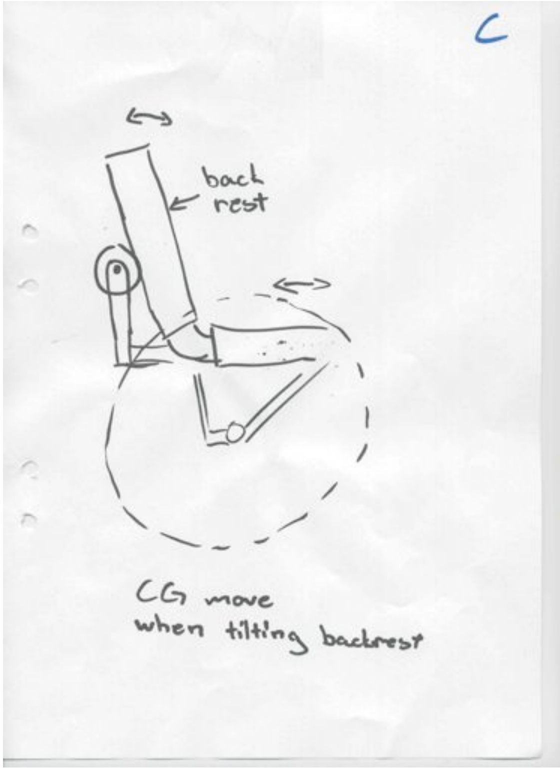

19. Extractable side support on backrest



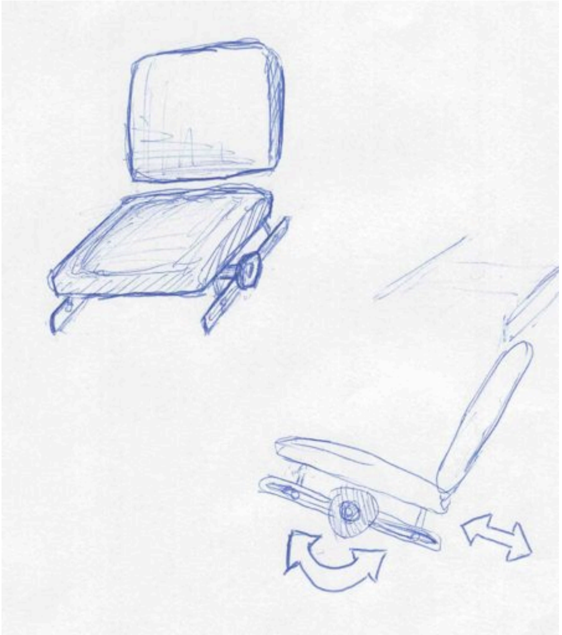
20. Split backrest

Changing CG

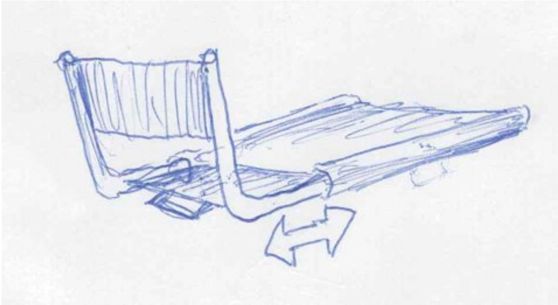
21. Movable seat



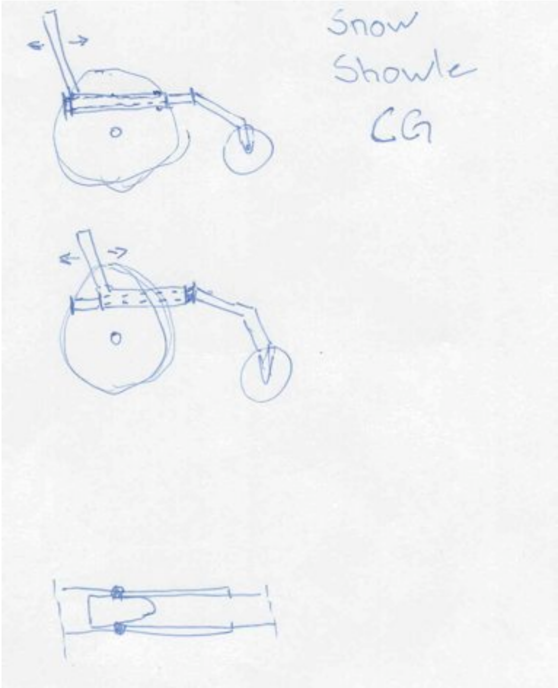
22. The seat works like a stress-less chair



23. Seat can be moved by a roller

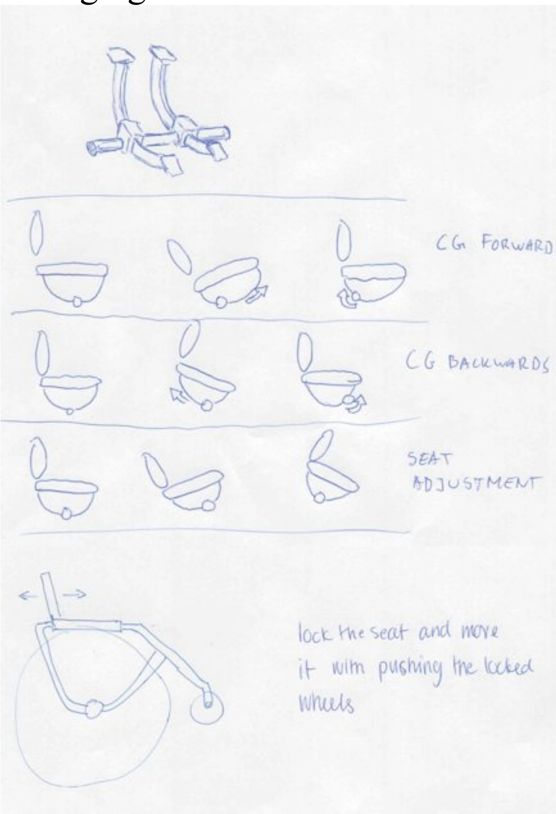


24. Seat slides back

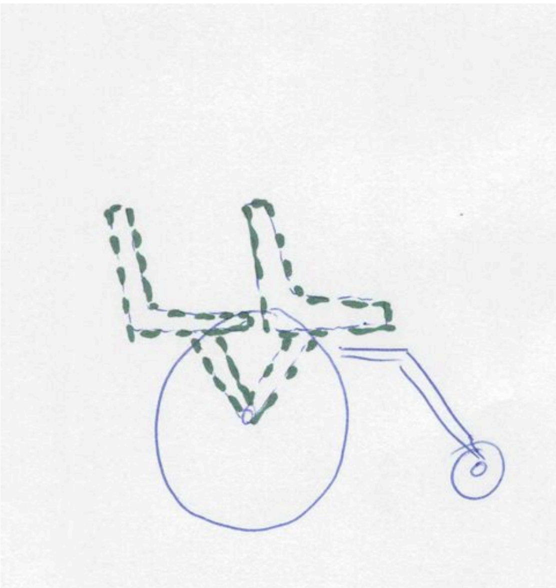


25. Seat slides back, pipe in pipe

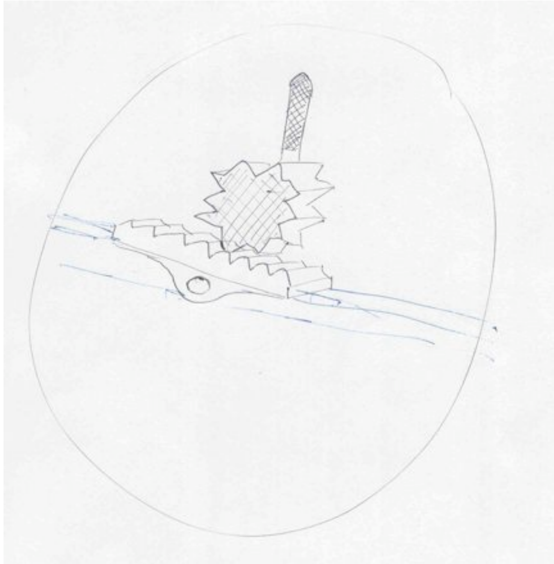
Changing CG



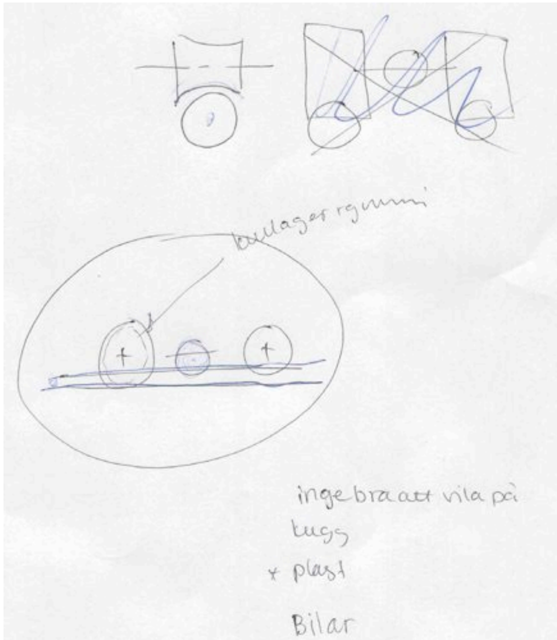
26. Moving seat and CG like a baby cradle



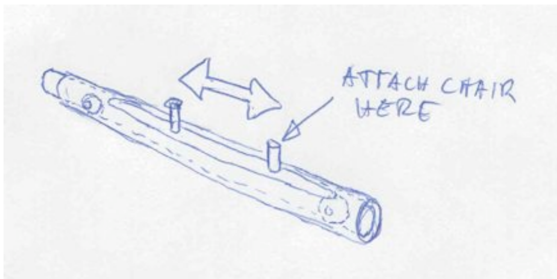
27. Seat moves and changes Cg



28. Crank for moveing CG/seat

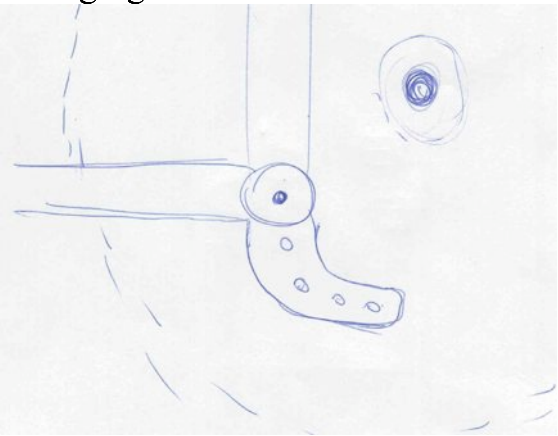


29. Bearings for moving CG/wheel

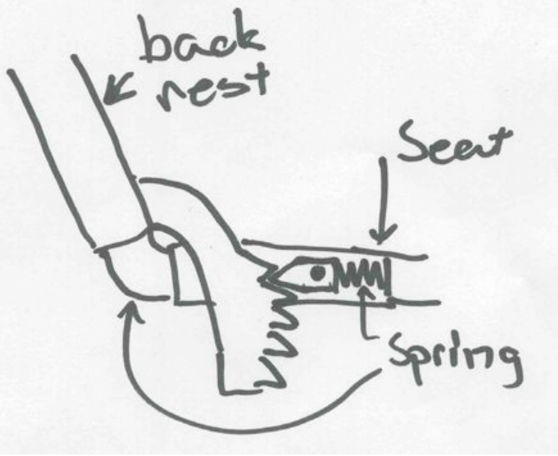


30. Pipe in pipe solution with locking mechanism

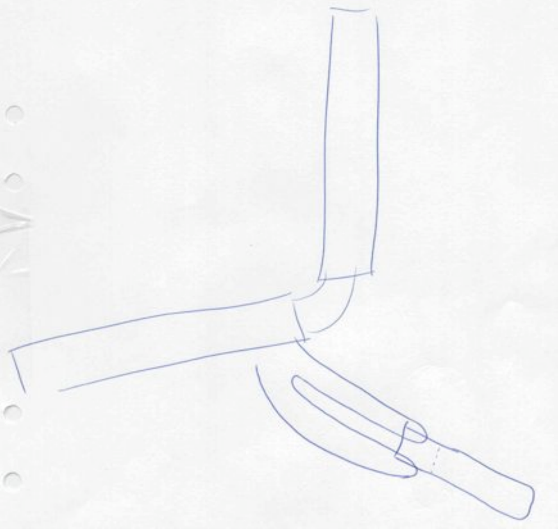
Changing CG



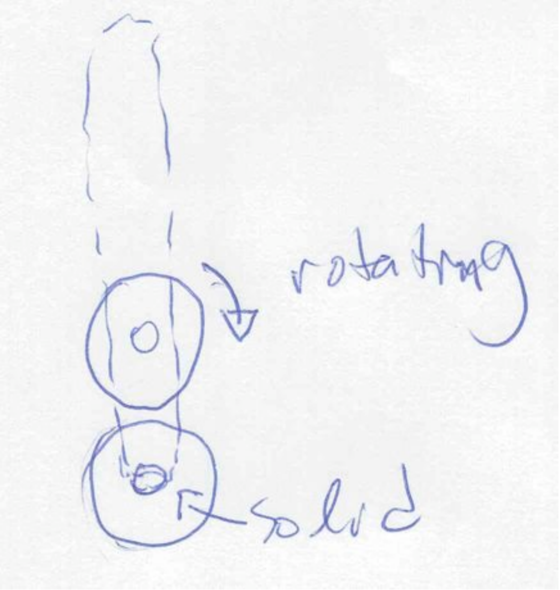
31. Backrest tilting mechanism



32. Backrest tilting mechanism

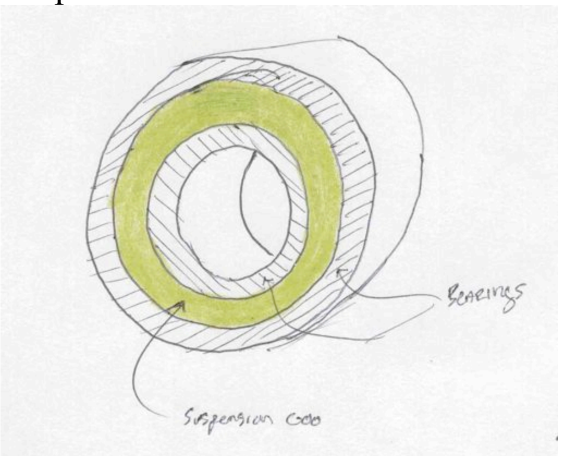


33. Chair tilting mechanism



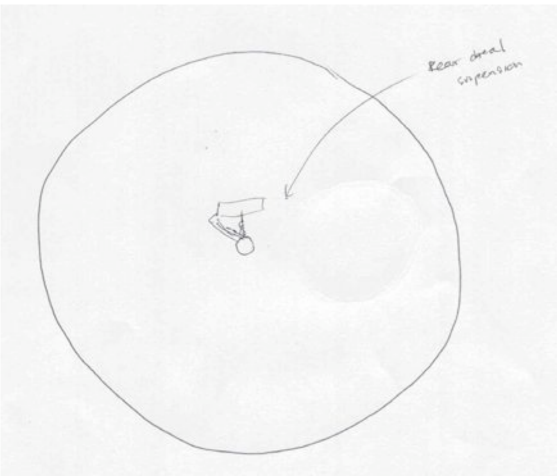
34. Changing backrest like a car seat

Suspension



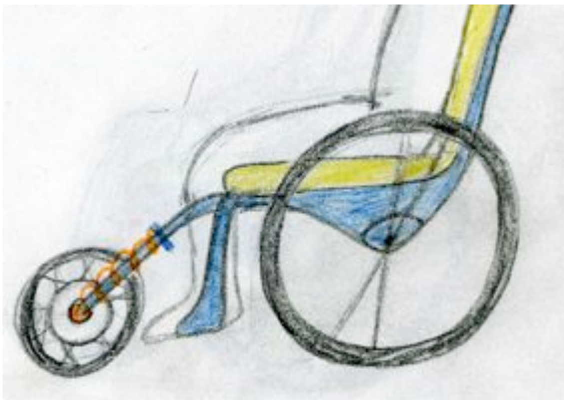
35. Rubbery suspension in bearings

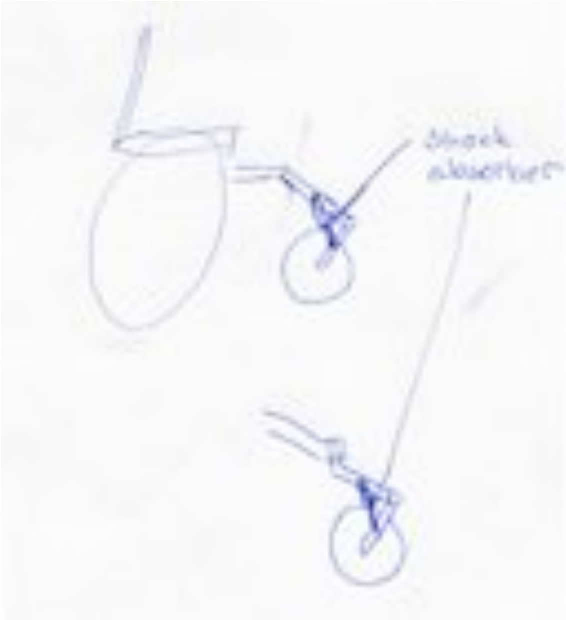
36. Bike suspension on castors



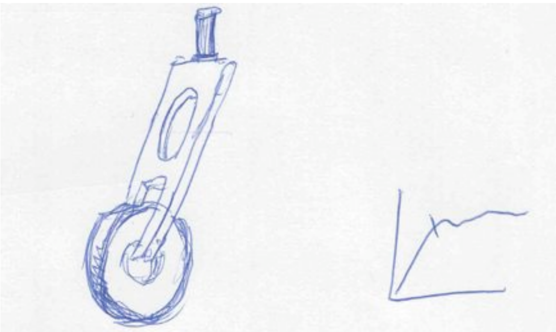
37.Rear axel with spring suspension


38. Frogleg style suspension


39. Castor suspension

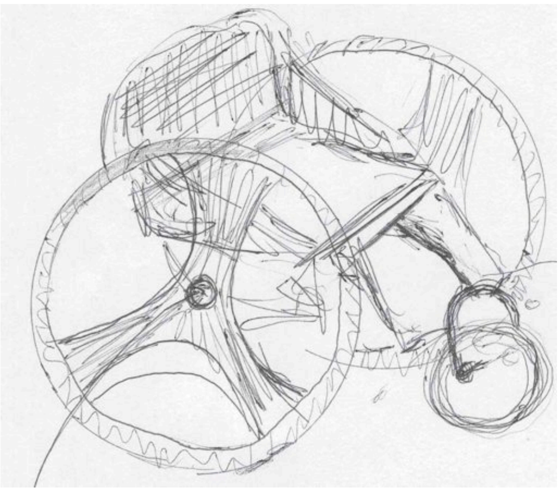


40. Chock absorber



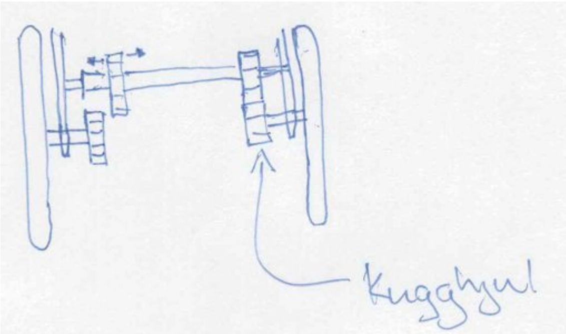
41. Suspension bending material

Wheel design

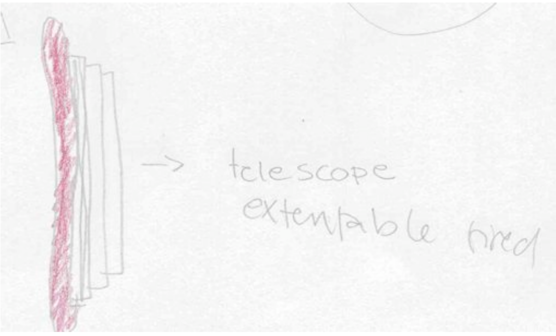


42. Three wheel with sphere as castor and spider wheels in the back.

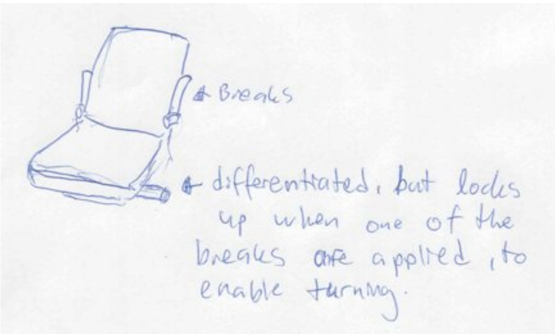
Traction



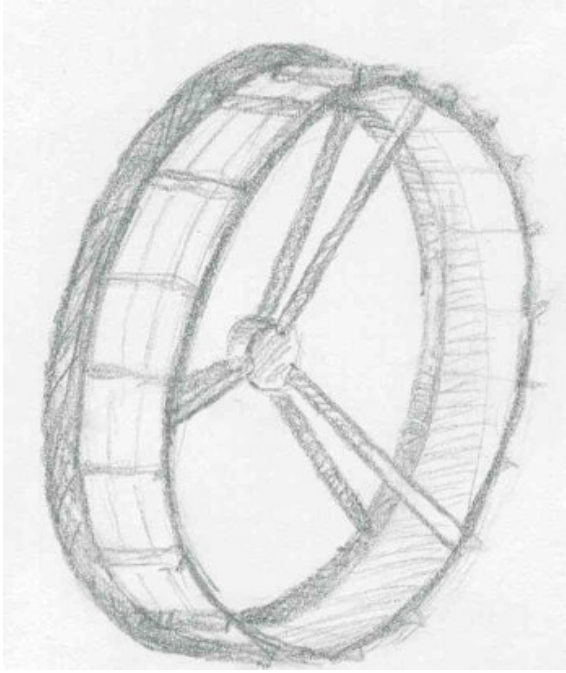
43. Common axel for both wheels that can be de connected



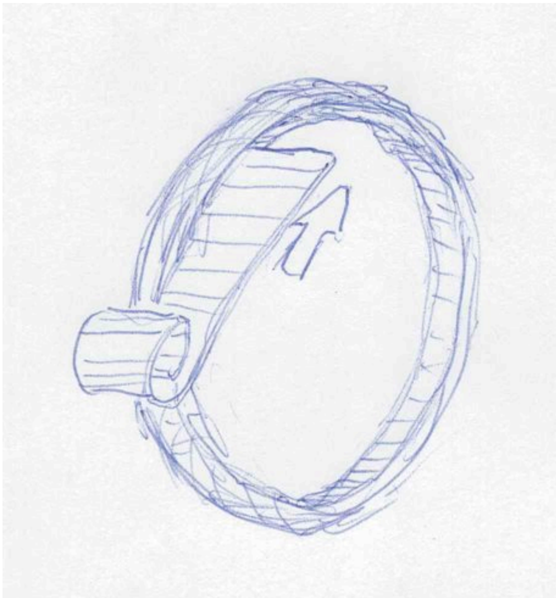
44. Tires that extends like a telescope.



45. Differentiated locks on back wheels. Brakes near elbow that unlocks the wheel and breaks one wheel, to be able to turn

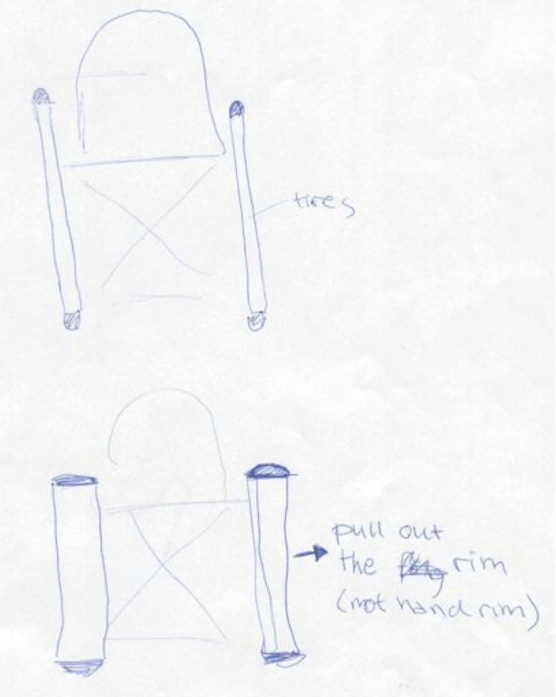


46. Extended tires



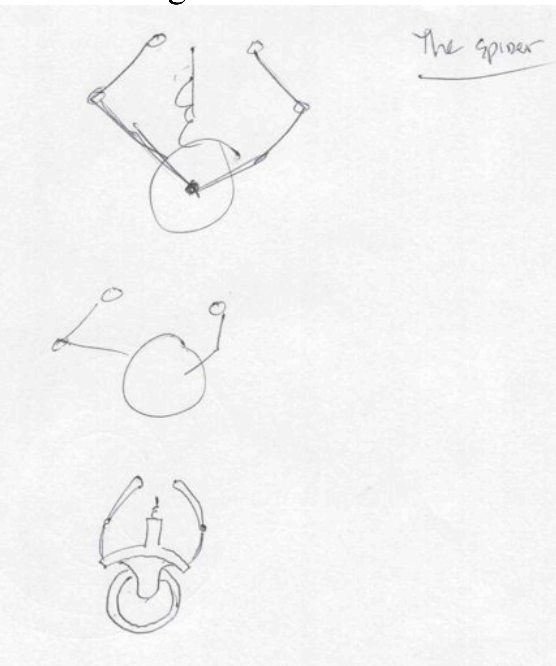
47. Detachable extended wheel

Traction



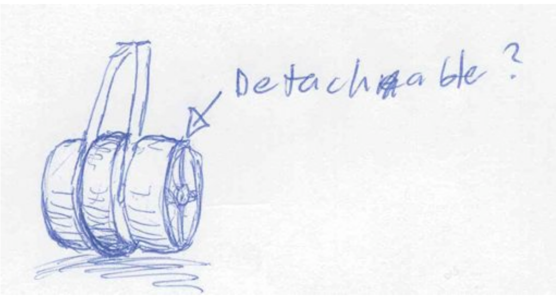
48. Inflated tires. Pull out the rim to get an extended tire

Castor design

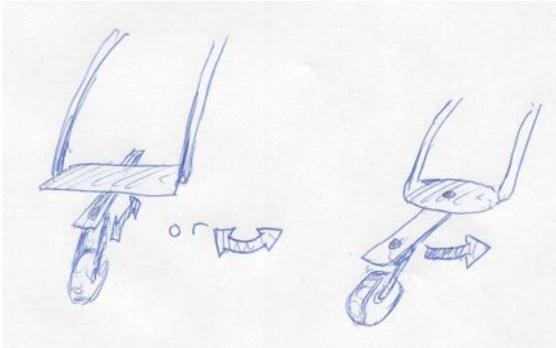


49. Castor suspension, that bends when it hits a curb

50. Sphere castor with a thin edge for indoor use



51. Detachable castor wheels for extra width.

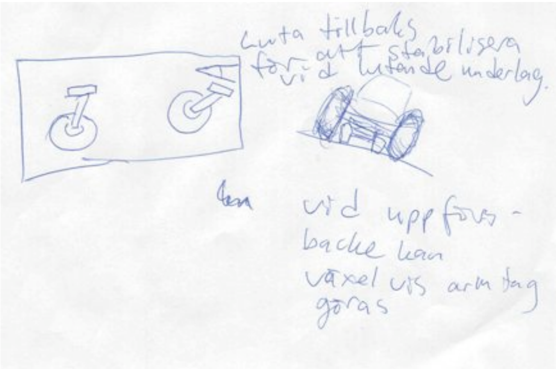


52. Way to move front castor on footrest to different positions

53. Castor on footrest

Castor design

54. Ski on castor

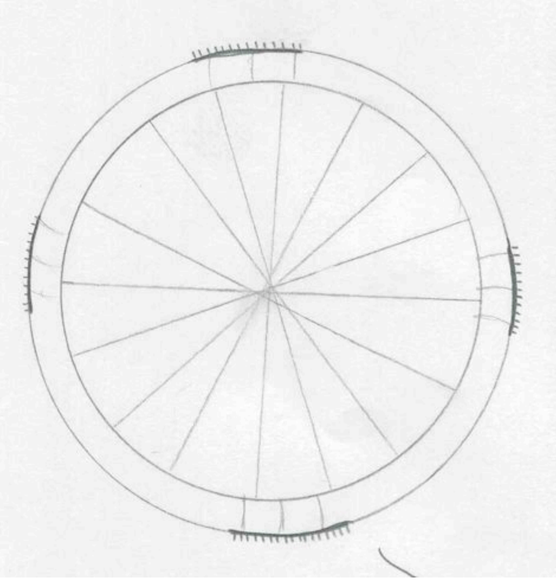


54. Changing castor pivot angle to go straight on a tilted path

55.Adjustable castor to fit indoors

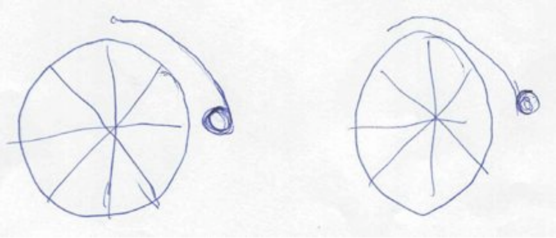
56. Combined saucer caster/camber angle change

Tires

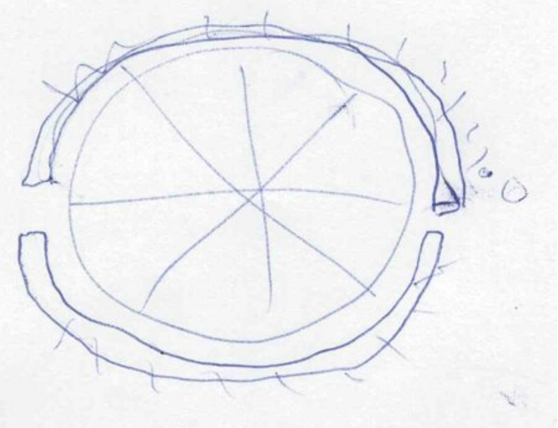


57. Clip ons

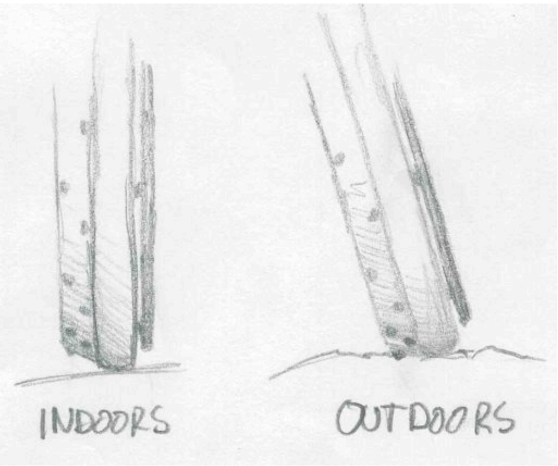
58. A way to strap the clip-on to the tire



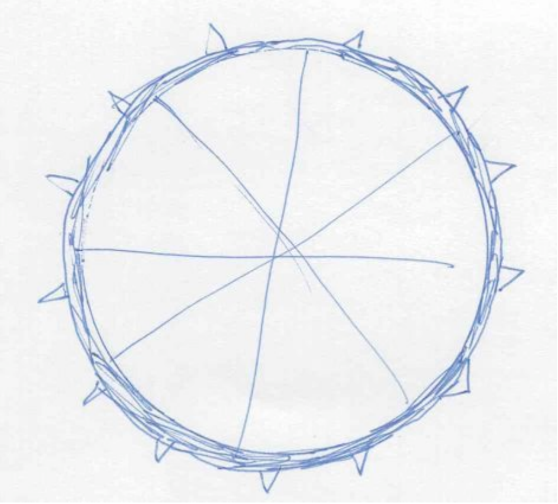
59. Strap on that rolls out like a rolling curtain
surface on tire in contact with the ground.



60. Two clip-ons that can be detached

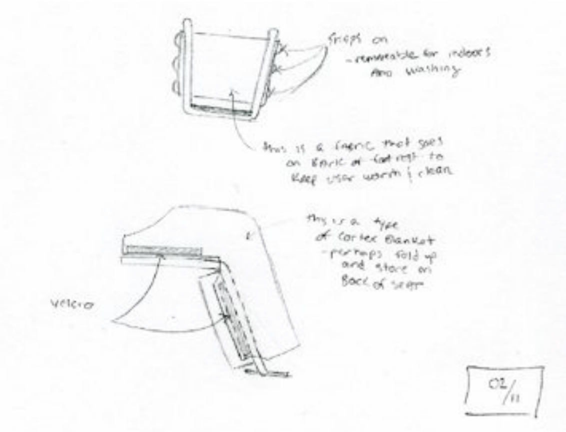


61. Camber angle change to get a different

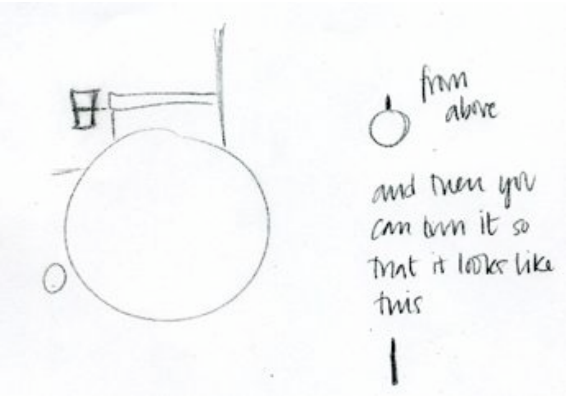


62. Mountain bike tires width spikes

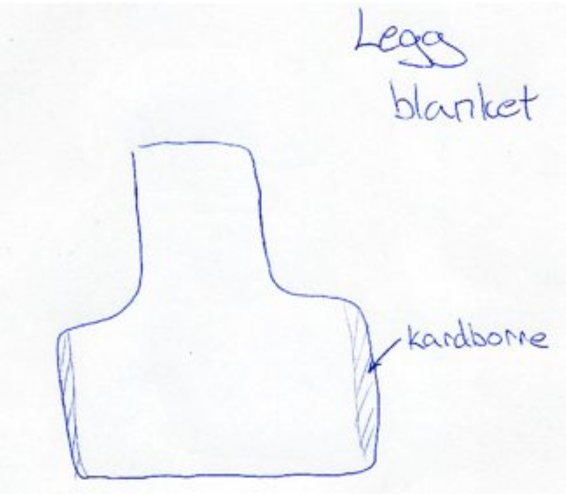
Accessories



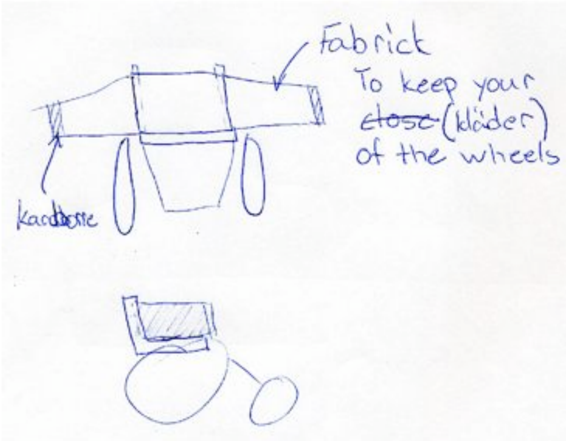
63. Removable clothes protector in Gore tex which snaps on and may be stored in back



64. Cupholder which can be folded in

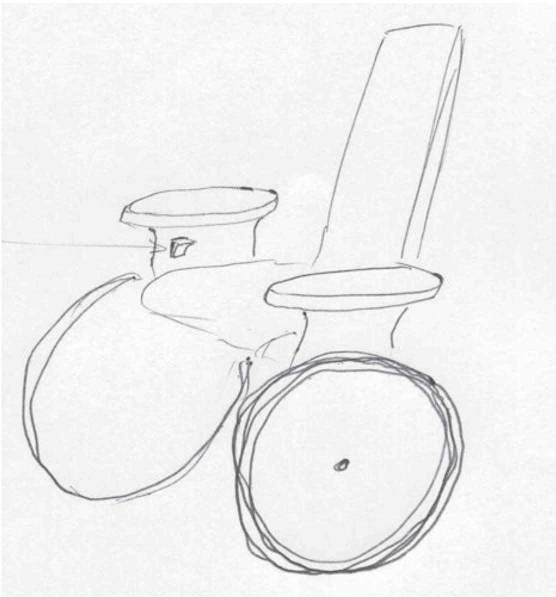


65. Leg balnket



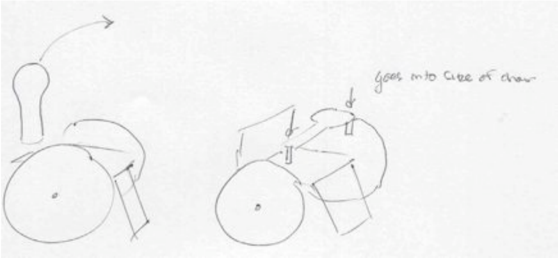
66. Fabric to keep your clothes of the wheel

67. Tray

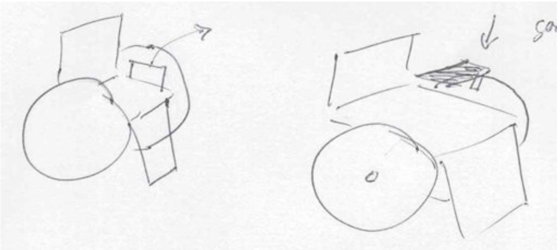


69. Tray holder on the armrest

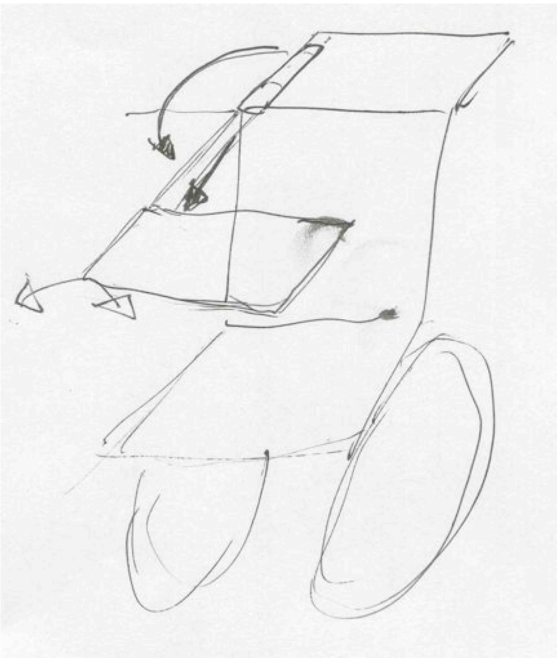
Accessories



70. Backrest which transforms into a tray on the armrest



71. Skirt guard can be changed into a tray



72. Backrest that transforms into a tray

Appendix G

Criteria	Panthera	Three wheel	Changing CG	Moving backrest	Shape of Backrest	Suspension back	Suspension in castor	(composite spridelwheel)	Frame	Saucer castor	Skies on castor
Maneuverability	0	+	+	0	0	0	0	+	+	-	-
Safety (feel safe)	0	-	+	0	0	0	0	0	0	0	0
Comfort	0	0	+	+	+	+	+	0	+	0	0
Stable	0	-	+	0	0	0	0	0	0	+	+
Weight	0	+	-	0	-	-	-	+	+	-	-
Traction	0	0	+	0	0	+	+	0	0	+	+
Transportable	0	+	0	0	-	0	0	+	+	-	-
Accessibility (in/out)	0	0	0	0	0	+	+	0	0	-	-
Weather	0	0	0	0	+	-	-	+	+	-	-
Sum of +'s	0	3	5	1	2	3	3	4	5	2	2
Sum of 0's	9	4	2	8	5	4	4	5	4	2	2
Sum of -'s	0	2	1	0	2	2	2	0	0	5	5
Total score	0	1	4	1	0	1	1	4	5	-3	-3
Rank	16	8	**2**	13	14	8	8	**3**	**1**	19	19

Criteria	Skies under	Mountain tires	Extendable tires	Camber angle	Trey holder	Cup holder	Changable handles	Hubbles Wheels	Metal Spiderwhe el	Clip on's
Maneuverability	0	-	-	+	0	0	0	+	0	+
Safety (feel safe)	0	+	0	+	0	0	0	-	0	+
Comfort	0	0	0	0	+	+	+	0	0	0
Stable	+	0	+	+	0	0	0	0	0	0
Weight	-	-	-	-	-	0	0	+	-	-
Traction	0	+	+	+	0	0	0	0	0	+
Transportable	-	0	-	0	0	0	+	+	+	0
Accessibility (in/out)	-	0	0	0	+	+	+	0	0	0
Weather	-	-	-	-	-	0	0	0	+	-
Sum of +'s	1	2	2	4	2	2	3	3	2	3
Sum of 0's	4	4	3	3	5	7	6	5	6	4
Sum of -'s	4	3	4	2	2	0	0	1	1	2
Total score	-3	-1	-2	2	0	2	3	2	1	1
Rank	20	17	18	5	14	7	4	6	12	8

Moving backrest					
	Concept				
CRITERIA	Sun chair adjustment, A	Added holes to current design, B	Roller back adjustment, C	Car chair adjustment, D	Bike sadle adjustment, E
Easy to adjust	0	0	0	-	0
Weight	0	+	-	-	0
Large variety of positions	0	-	0	+	+
Safety	0	+	+	0	0
Sum of +'s	0	2	1	1	1
Sum of 0's	5	1	2	0	0
Sum of -'s	0	1	1	2	0
Total score	0	1	0	-1	1
Rank	4	1	3	5	2

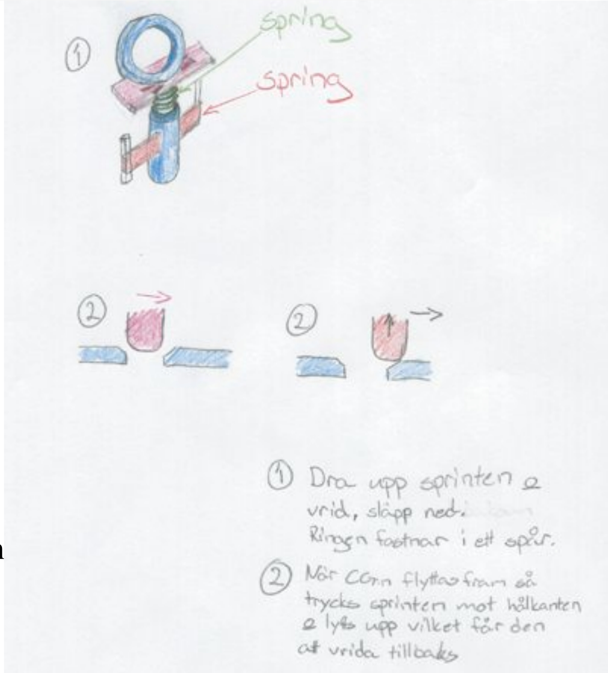
Shape of backrest				
	Concept			
CRITERIA	Higher but thinner, A	Higher but thinner with head rest, B	Higher and wide, C	Ellipse formed, D
Provide support	0	+	0	-
Comfort	0	+	-	-
Weight	0	-	+	+
Stable	0	0	-	-
Sum of +'s	0	2	1	1
Sum of 0's	4	0	1	0
Sum of -'s	0	1	2	3
Total score	0	1	-1	-2
Rank	2	**1**	3	4

Traction back wheels								
	Concept							
CRITERIA	Regular mountain tires for wheelchairs, A	Small c§lip on's, B	Mountain bike tires with steel knobbs, C	Two big clip on's, D	Extendable tires, E	Snow chain, F	Cambered wheel with inner traction, G	Wider tires(pull out the rim), H
Ease of use	0	-	0	-	-	-	-	-
Storage	0	-	0	-	0	0	0	-
Weight	0	0	-	-	-	-	-	-
Safe	0	-	-	-	-	0	0	-
Cleanable	0	0	0	+	-	0	0	-
going in/out	0	+	-	+	+	+	+	+
Traction	0	+	+	+	0	0	+	+
Sum of +'s	0	2	1	3	1	1	2	2
Sum of 0's	7	1	3	0	2	4	3	0
Sum of -'s	0	3	3	4	4	2	2	5
Total score	0	-1	-2	-1	-3	-1	0	-3
Rank	**2**	4	6	3	8	5	**1**	7

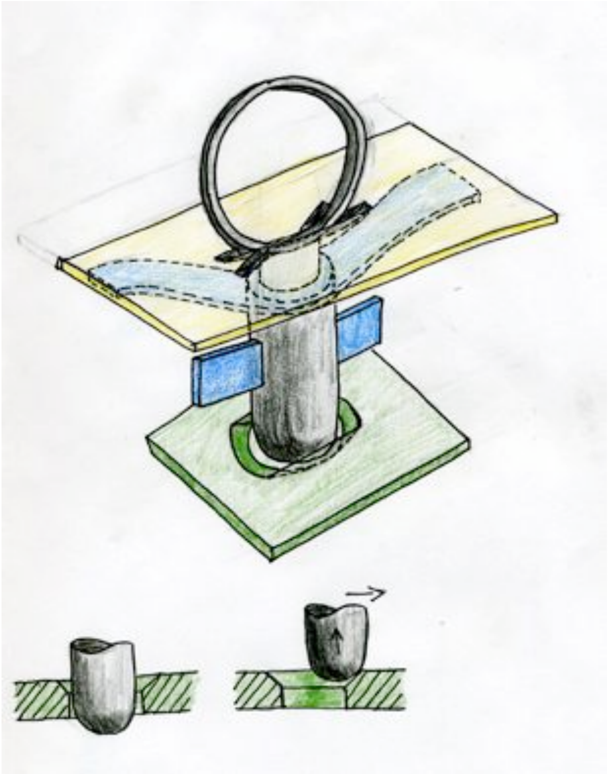
Storage of Backrest					
	Concept				
CRITERIA	Foldable, A	Going inside the lower backrest, B	Foldable horizontal, C	Skeleton seat, D	Removable top part, E
Space consuming	0	0	0	0	+
Convenience	0	0	0	0	-
Weight	0	0	0	-	0
Easy to use	0	0	-	-	0
Safe	0	+	+	-	+
Sum of +'s	0	1	1	0	2
Sum of 0's	5	4	3	2	2
Sum of -'s	0	0	1	3	1
Total score	0	1	0	-3	1
Rank	4	2	3	5	**1**

Appendix H

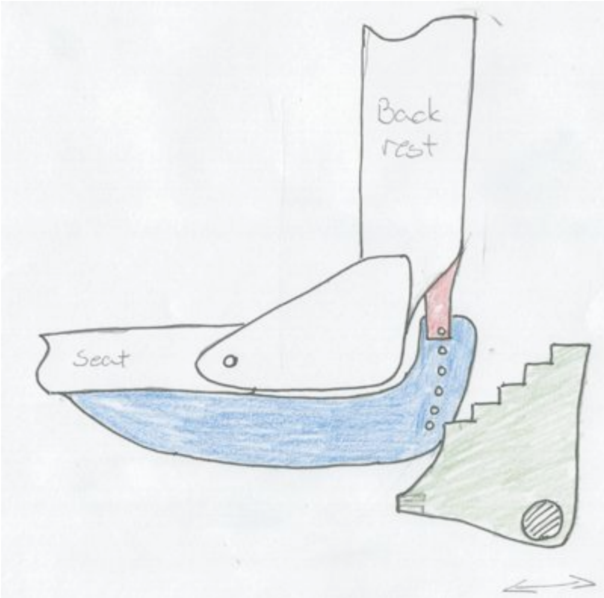
Design of the slider, the backrest folding mechanism, an the overall shape of the chair



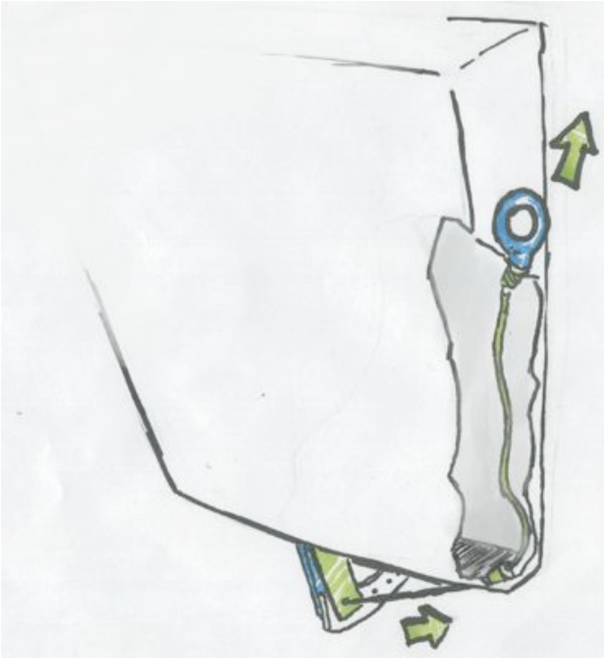
Further explanation of how the sprint works



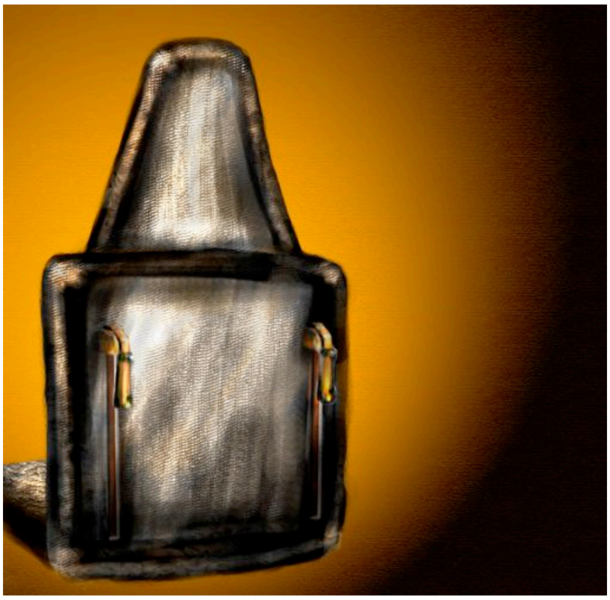
The sprint in the slider that locks the chair into different CG positions



A closer look at the backrest folding mechanism, complete with the tipping protection fen, a.k.a. the shark fen



The wire and spring steel mechanism that controls the position of the backrest



Concept sketch of a backrest that can be folded into the seat

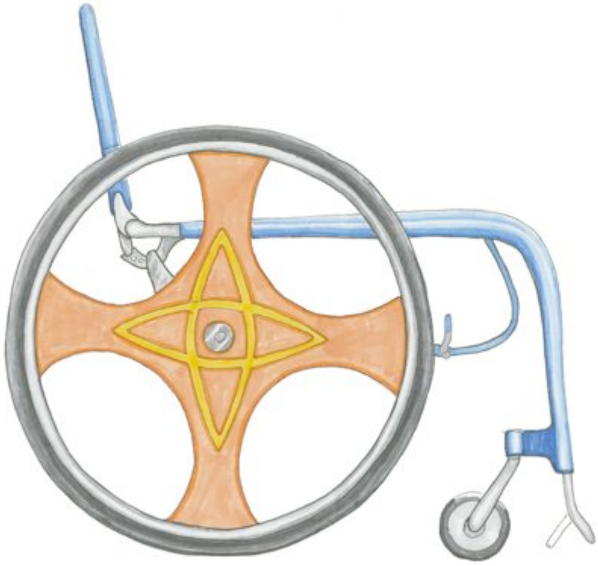
Close-up on the locking handles for the above backrest

Concept sketch on the frame

Sketch of the seat and side parts

Concept sketch featuring a rim interface with disc brakes

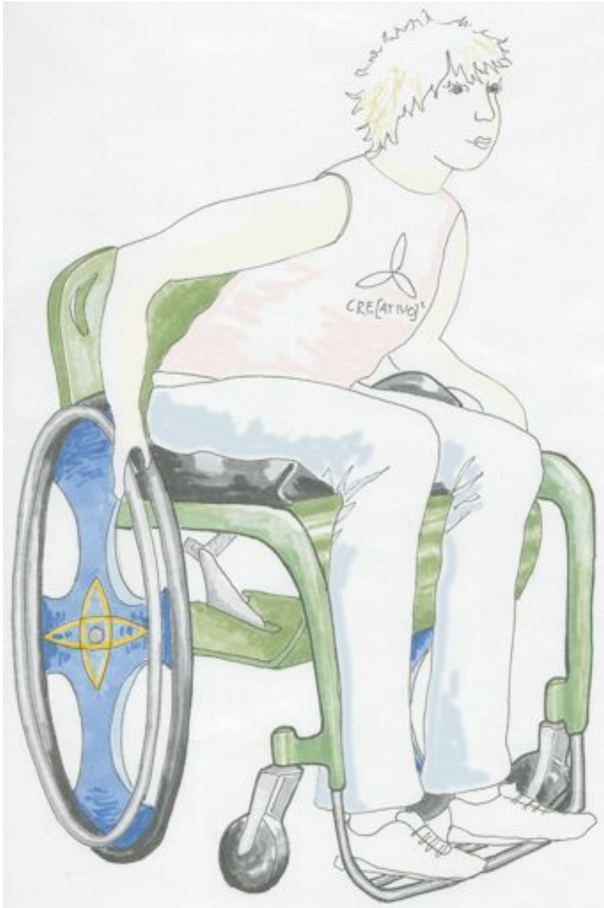
Sketch showing the overall design of the wheelchair, featuring the “Sirius wheels”



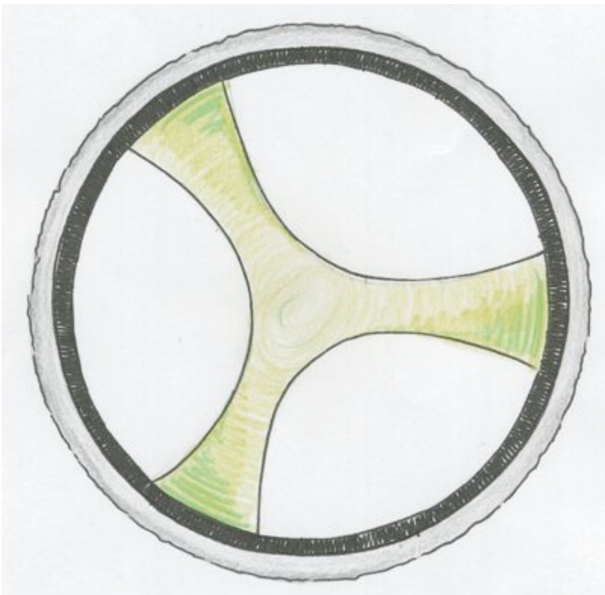
Side view

Front view

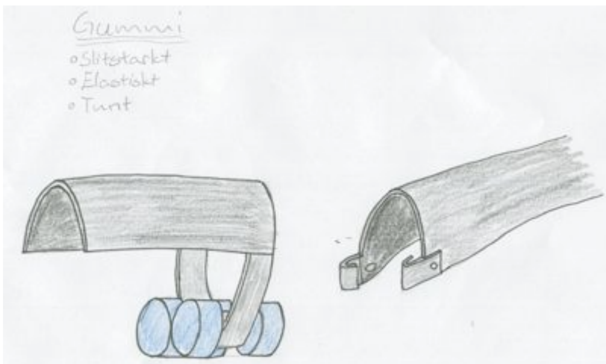
Color study of the wheelchair



Color study



Sketch of the composite spiderwheel



A locking mechanism for the clip-on

Appendix I

Monday 29/3 040329-040405

Departure from the hotel in Stockholm in the middle of the night to go to the airport. We checked in and waited for about two hours before it was time to board the plane. Approximately 1 hour and 50 minutes later we landed in Frankfurt, Germany. After going through a strict security check we went on the next plane that would take us to San Francisco. There were some troubles with the aircrafts instruments so we were delayed already before take off. When we finally were airborne we had to sit in our given seats for about 11 hours, but we made it safe to the other continent. Well at the airport in the US Andreas tried to pick up the rental cars that were reserved for us. That was not the easiest thing in the world. We were supposed to have two cars and one 12 persons van and apparently there are some rules for who are allowed to rent those vans. If you are a group you need some papers from back home saying that you are insured and so on. But Andreas finally managed to convince them to give us the van anyway. After talking to Brett on the phone we decided to head for the hotel to take a shower before going to the loft to meet them. Hans was our driver to go there, and he did a great job considering that he had 7 co drivers in the backseats. Even though we missed our exit on the 101, Muffet Boulevard, we managed to find our way to the Quality Inn in Mountain View where some of us were supposed to stay. We all had a shower and a change of clothes; some even found the time to do number two that lead to a broken toilet in the coaches' room. No names mentioned, starts with a H and ends with ans. After that we headed for Stanford University and the Loft to be more precise. There we met up with James, Jeremy, Brett and Karlin. We all got our schedules for the week, which also included contact information to the hosts. We were all pretty tired and hungry so we headed for downtown Palo Alto. The plan was to eat at Pizza my Heart and then to have dessert at the Cheesecake Factory, but everyone was so full after the pizza, so there was no room for any cheesecake, but we did take a tour around the city center and bought some supplies for our hotel rooms since the water didn't taste good. After that everyone headed in their own direction, and I know that the ones at the hotel passed out immediately.

Tuesday 30/3

After a whole night sleep it was time to visit some companies in the area for inspiration. First up was a tour of IDEO. We met up at the loft and traveled there all together. The Stanford students had arranged so that the founder and chairman David Kelly gave us the tour in person. IDEO is a company that offers innovation strategy and design services. They identify opportunities for innovation by understanding latent user needs, technology factors, and business requirements for success. They evaluate potential solutions through user observation and iterative rapid prototyping. Their multidisciplinary teams include specialists in human factors research; business strategy; industrial and interaction design; environments design; mechanical, electrical, software, and manufacturing engineering; design validation; and more. And Dave showed us around his company and told us about all this in a very inspiring way. I think that every single one of us wanted a job there after the tour. After having lunch at the university it was time for the next tour. After a wrong turn or two the Swedish team finally made it to Onomy labs. A much smaller firm, but in the same business as IDEO. Onomy Labs designs and creates evocative interactive systems that enable audiences to experience the future. They work with the most advanced technologies, as they emerge fresh from the lab bench. Also they had a multidisciplinary team. The tour was given by one of the founders, Anne Balsamo, the only female of the 5 co-workers. Even though the group was a bit tired in the afternoon everyone listened with great interest to what this inspiring woman had to say. Back to Palo Alto again, and this time we managed without getting lost. It was time for the first serious meeting after arrival. I don't know if it was the best time, considering that we already had had a long day and that the jetlag had started to kick in. In the meeting both teams' progress was discussed. It started out with the Stanford team showing us Swedes how their wheelcleaning device worked. After a short review it was time for a quick dinner at Tresider on campus. Then back to work again. Since the Luleå team had a busy week before departing to the US, we informed the Stanford students about all the decisions that were made while they were on spring break.

Wednesday 31/3
An all day long meeting, with information from both teams and the brainstorming sessions to help each other on the way. After all that hard work Jeremy reworded us with a Moroccan dinner at Brett´s place. But before going there some of us had to go to IKEA to buy pillows, cause the once at the hotel were killing us. The food was excellent, but I must disappoint Jay and say that the sleep on the new pillow was even better.

Thursday 1/4
Well rested after a good night sleep it was time for breakfast at the loft. Today's meeting took another turn from the day before. Instead of coming up with new solutions we decided to focus on the once we had. This was done by looking at the issues that we could come up with on the different designs, what problems needs to be addressed. Discussion on possible solutions to the problems and brainstorming on how the parts can be built. This way of working was much more giving then the way we worked before. With a full stomach from a sandwich lunch at the loft, the Luleå team took off to another tour. It was time to see Lunar Design. Lunar believes successful products reflect three key ingredients: enabling technology, market wisdom and personal insight which integrates the two into something meaningful to people. This visit wasn't as inspiring as the other two, but perhaps that had something to do with the fact that this was the first contact ever with this company. When we came back to the loft it was time to meet Stanford's teaching team for the first time. We sat in on one of their meetings, where the students presented what they had accomplished thus far to their teachers. When the meetings where finished it was time for SUDS. Every Thursday one of the student teams orders food to the loft for everyone and then there is a party. This night we had Chinese food and later on we played some games and some of us even went out dancing.

Friday 2/4
We had the day off and went to the beach. The beach trip included activities like soccer, volleyball, American football, Frisbee, a good old American cookout and of course some sun tan. We drove out to Half moon bay and stayed there for more or less the whole day. After a well needed shower and a change of clothes it was time for a night out in Palo Alto. Everything started at the Japanese restaurant Miyakis. A crazy restaurant where the waiters were as drunk as the customers, since they had probably

twice as many saké bombs as anyone paying for them. This was followed up by a pub-crawl around the city center of Palo Alto. I say no more, cause no one remembers.

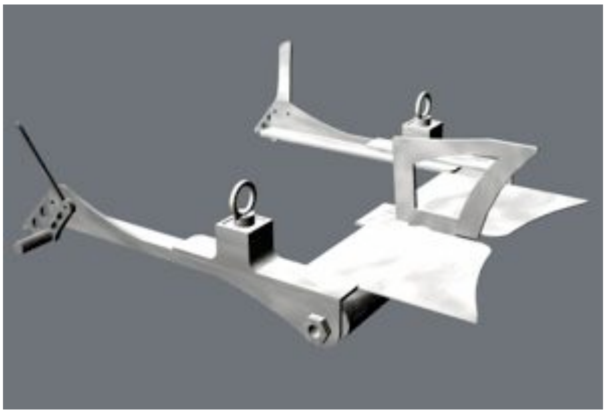
Saturday 3/4
This was the big split up day! The girls went shopping and the guys went to the amusement park Great America. Do I need to say anything more? At night we all were invited to the Van der Loos residence for dinner. An amazing house in the mountains with an extraordinary view over the ocean. Unfortunately this was a cloudy evening so we couldn't see the ocean, but the sunset was still very beautiful. Most of us went home directly, but there were some that tried out a fraternity party before going to bed.

Sunday 4/4
If your are going to San Francisco don't forget to wear flowers in hair… I think every one forgot that, but we did go to San Fran. We started out at Pier 39, probably the most tourist place in the entire state of California. After looking around, we had lunch there at The Hard Rock Café. Then we toured the city center by car before going to the Golden Gate Bridge where we went for a walk. Later in the afternoon we took the "Scary" tour on Alcatraz. It wasn't scary at all, but what do you expect from an audio tour. We didn't even get to be inmates for a short while and be locked up in the cells, like they do in the Rock. After a long tourist day, we had dinner on our way home along the 101. The rest of the night we spent packing our belongings together.

Monday 5/4
A quick goodbye at the loft and then some last minute shopping at the local shopping mall in Palo Alto. During the short time we were there we managed to loose Emma so a search patrol had to go out and look for her. After the third attempt we found her. She was on the verge of a breakdown, but there was no need, we made it to the airport without any trouble. Then it was just the long flight back to Sweden…

Appendix J

Details of the wheelchair



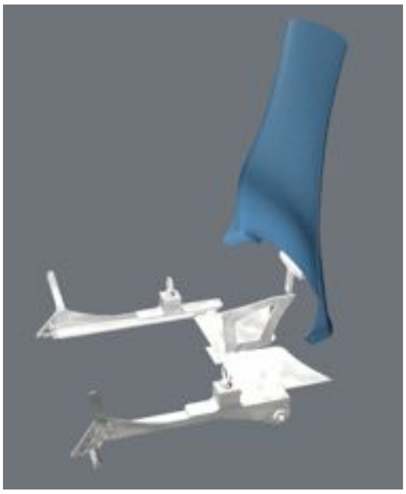
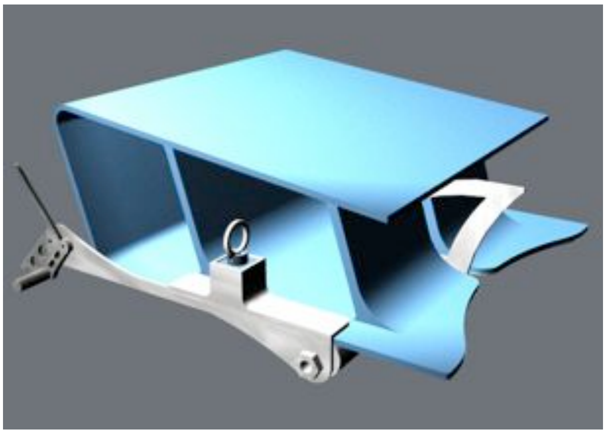


Fig shows slider, break and roller… *…with backrest.*



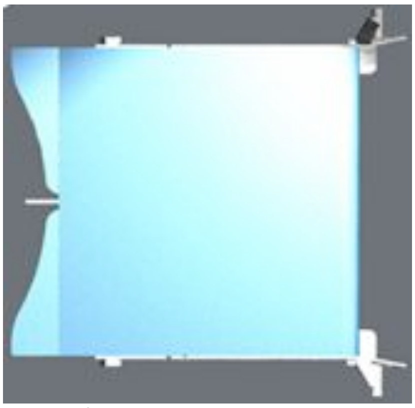


Fig shows slider, break, roller and seat…. *…from the top.*

Fig shows slider, break, roller, backrest and seat… *…with sideparts, footrest and casterwheels.*

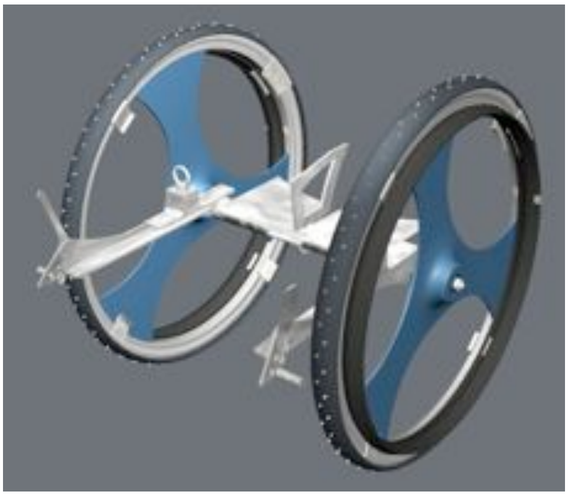
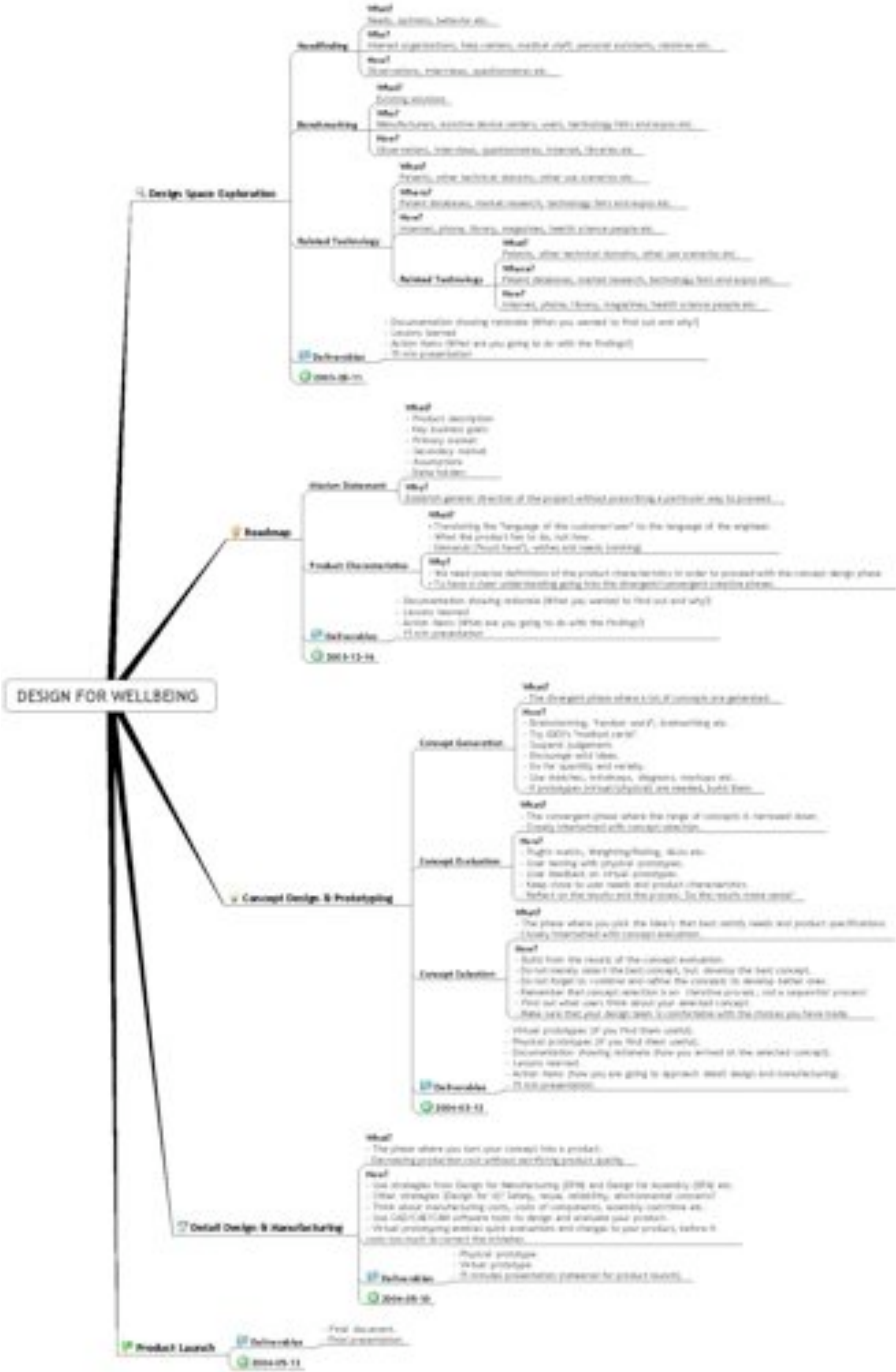


Fig shows slider, break, roller, wheels and clip on´s…

..the whole chair without cushions.

Fig shows the whole wheelchair

Appendix K


DESIGN FOR WELLBEING
Design Space Exploration
Roadmap
Concept Design & Prototyping
Detail Design & Manufacturing
Product Launch