Design of an adjustable sitwake seat

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In collaboration with the Willem Hooft Foundation

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Abstract

Sitwaking is an adaptive sport derived from wakeboarding, targeting wakeboarders with a physical disability. Although the sport is growing each year, the accessibility level of the sport is low. Investment costs are high and existing products are targeted towards experienced riders.

Relative to wakeboarding, a different setup is required to practice the sport. A sitwaker is seated in a seat, which is attached to a normal wakeboard with an aluminum frame. At the front of the board, a footpad is installed to strap the rider's feet.

The project has been set up in cooperation with the Willem Hooft Foundation. This is an organisation aimed at improving the accessibility of adapted water sports. It builds forth on a concept design for an adjustable sitkite seat, developed by Marinke Callens. For her project, she did extensive research on the ergonomic aspect of the seat, creating an anthropometric database through measuring the target group and making 3D-scans, to create the shape of the seat. By doing this, she improved pressure distribution and optimized the fit. Her project ended with a fruitful concept.

The aim of this thesis is to take this concept to the next step, validating the incorporation of the research in her design. This is done by creating a design and making a working prototype of an adjustable sitwake seat for beginners with a physical disability, which is easy and quick to adjust. The switch from sitkiting to sitwaking is done to create a more controllable test environment and because the market is easier to penetrate. The end product should be used by both sitwakers and sitkiters. Furthermore, the lifespan of the seat should be extended as long as possible. This is done through a hands-on approach with several iteration cycles.

This thesis is approached with the double diamond method. The classic approach consists of four parts: Discover, define, develop and deliver.
The outcome of the discover and define phase brought valuable insights from extensive desk research, qualitative interviews with the target group, observations and testing comparable products. This led to a list of requirements and wishes. Through rapid prototyping and design by doing, concepts were brought to life to check for feasibility and evaluate with users. This hands-on approach resulted in valuable insights to increase the validity of the design.

The result of the project is a fiberglass seat, adjustable in width and optimized for usability. Emphasis is put on minimizing the footprint and extending its life span. The seat was tested in context to ensure its usability.
Optional straps are integrated to ensure the safety of use for both beginning sitwakers and sitkiters. The final design of the sitwake seat is tailored to the user, lowering the barrier to learning this new sport by decreasing the costs.

Keywords: design, sitwakeboarding, adaptive sports

Contents

Glossary

Box: A flat feature where a rider can glide over.

Cable Park: A place for cable water sports. These parks usually contain multiple features to perform tricks.

Dock: The starting point at a cable park. Riders wait in a queue on a soft surface before they are hooked onto the cable.

FBD: Free Body Diagram

Feature/ obstacle: Floating or stationary object in a cable park to perform tricks on.

Frame: Structural connection part between board and sitwake seat.

Handle/ bar: The bar that riders hold with their hands which pull them forward.

Kicker: An obstacle shaped like a jump.

Rider: Term used for a wakeboarder.

WHF: Willem Hooft Foundation

1. Introduction

This chapter provides the necessary context and background information. It discusses the current state of the field, identifies the gap in knowledge that the research aims to address and sets the stage for the problem statement and research questions. Furthermore, the used approach and a comprehensive reading guide are discussed.

1.1. State of the art

Sitwaking is an adaptive sport derived from wakeboarding, a sport in which a practitioner rides over the water on a wakeboard, usually being dragged forward behind a boat or behind a cable in a designated cable park (see figure 1). Much like sitskiing, sitwaking can be performed by individuals with bilateral lower limb functional impairments, including persons with spinal cord injuries (SCI), spina bifida, bilateral lower extremity amputations (Cooper & De Luigi, 2014), cerebral palsy or muscular diseases (Grew, 2018). For sitwaking, arm strength is required to hold onto the rope. Furthermore, core stability makes the sport easier, but it is also possible to add a backrest to the seat for extra stability for those in need.

One other important difference between sitwaking and normal wakeboarding is that the athlete is usually seated towards the direction of movement, whereas the body of a wakeboarder is perpendicular to the direction of movement.

Figure 1: A sitwaker in context

Sitwaking originates back to when water skiing was firstly introduced to people with disabilities in 1983, (Grew, 2018) It is getting more awareness ever since. However, sufficient material is still hardly available on the market and riders often alter their existing seats to meet their needs. (Nys & Hooft, personal communication)

Relative to wakeboarding, a different setup is required to practice the sport. A sitwaker is seated in a carbon fiber seat, with a foam padding. This seat is attached to an aluminum frame, which is bolted to a board. This board is a regular wakeboard that regular wakeboarders also use. At the front of the board, a footpad is installed to strap the rider’s feet. An additional strap can be used to secure the rider into the seat. The different components are highlighted in figure 2.

With the increasing popularity of sitwaking, competitions and events have become more frequent, drawing in riders from around the world to compete. (Grew, 2018) Overall, the state of the art of sitwaking continues to evolve and push the limits of what is possible on the water.

Figure 2: Components of a sitwake

1.2. Project partners & motivation

This project is a collaboration between the Willem Hooft Foundation, TU Delft and Fieldlab UPPS. It builds forth on the research and concept design of Marinke Callens on the development of an adjustable sitkite seat which is shown in figure 3 (Callens, 2022). The previous research and the design of Callens is used as a starting point for this project and will be referred to as Callens' design.

Figure 3: Callens' design which served as a starting point for this thesis

The Willem Hooft Foundation is a foundation that specializes in the accessibility of adapted watersports, for example sitkiting and sitwaking. They do this by organizing camps & competitions, try out days and organizing several training courses. Next to that, they develop and produce material that is both safe and affordable, and by making instructional videos and spreading information about sports (Hooft, 2022).

Fieldlabs UPPS stimulates innovations around Ultra Personalized Products and Services, in short UPPS, through knowledge, faculties and subsidies (Fieldlab UPPS, n.d.). This field lab works in collaboration with TU Delft. They worked together with Willem Hooft and Marinke Callens on the previous graduation project, specifically on the measurements of the target group. They are also involved with the development of a personalized sitkite seat in collaboration with the Willem Hooft Foundation.

1.3. Target group

Sitwaking targets individuals with a physical disability that are unable to stand; with spinal cord injuries (SCI), cerebral palsy or muscular diseases (Grew, 2018). For sitwaking, you do need strength in your arms to hold onto the rope. Furthermore, core stability makes the sport easier, but it is also possible to add a backrest.

As sitski, it is performed by individuals with bilateral lower limb functional impairments, including persons with spinal cord injuries, spina bifida, or bilateral lower extremity amputations (De Luigi & Cooper, 2014).

Initially, only adult users will be considered for this project, but children may later be included. It is important to include the instructor as a user as well since the beginners require additional assistance. Instructors also might play a role in adjusting the settings of the sitwake.

Regarding sitwaking, different user groups exist due to the varying circumstances under which the sport is performed. Jobe, one of the leading wakeboard manufactures identified three types of wakeboarders that can be translated to sitwaking types - boat, cable and beginner - each catering to a different set of users. Boat riders use their wakeboards behind motorboats, an expensive form of sitwaking popular in the United States, where riders can perform surface and air tricks. In contrast, cable riders are towed by an electrically powered cable at a speed of approximately 30 km/h and often ride over floating obstacles. Beginners often first encounter sitwaking at cable parks where rental gear is readily available.

1.4. Design challenge

The problem is that currently a cable park must buy seven different seats for beginners with different anthropometrics, which is often too big of an investment for a park, especially since the target group is relatively small. Furthermore, looking at the market standard, the time to switch seats for different users is perceived as too long. Next to that, the working principle of the adjustability of Callens' design was less effective than initially expected. It required more attention, especially on functionality, strength, usability, and sustainability. A more detailed description of the design brief can be found in appendix A. Ultimately, the sitwake seat should be able to be used as a sitkite seat as well.

Goal: Design and make a working prototype of an adjustable sitwake seat for beginners with a physical disability, which is easy and quick to adjust. Furthermore, the lifespan of the seat should be extended as long as possible.

This project focuses on beginning sitwakers. A beginning sitwaker is defined as everyone who never sitwaket before to everyone who mastered the wakeboarding basics:

- Being able to start smoothly and stay on the board while on the water.
- Clear a kicker and box while landing smoothly in the water again.
- Perform simple flat tricks (tricks on the surface of the water) like rotations.

Once a sitwaker can perform more complicated tricks, they are considered as intermediates.

With the aforementioned goal, research questions are formulated to provide focus and direction and to clearly define the scope and objectives of the study.

1. What are the specifications of current sitwake seats?
2. What are current points of improvement of Callens' sitkite seat?
3. Is the design transferable from sitkiting to sitwaking?
    a. What are the important differences relevant for the design?
    b. What are the stages that a beginning sitwaker goes through?
4. How is the design experienced in actual use conditions?
5. How can the design be made circular?

These questions are answered in the following chapters and guide to better understand the context with its users along with their needs.

1.5. Approach

This thesis is approached with a slightly altered double diamond method. The classic approach consists of four parts: Discover, define, develop and deliver. For this project, the starting point is when the assignment was initiated. From there, a first discover and define cycle was completed, ending with the project brief (appendix A). The next diamond consisted of desk research, interviews and observations to create a broad understanding. The conclusions are combined into the list of requirements (chapter 2.9.1). In the last diamond, the diverging phase consisted of ideation and conceptualization. Through rapid prototyping, concepts were brought to life to check for feasibility and are evaluated with users. This hands-on approach resulted in valuable insights to improve the design. The last cycle was done multiple times, to tackle different identified problems. A visualization of the approach is shown in figure 4.

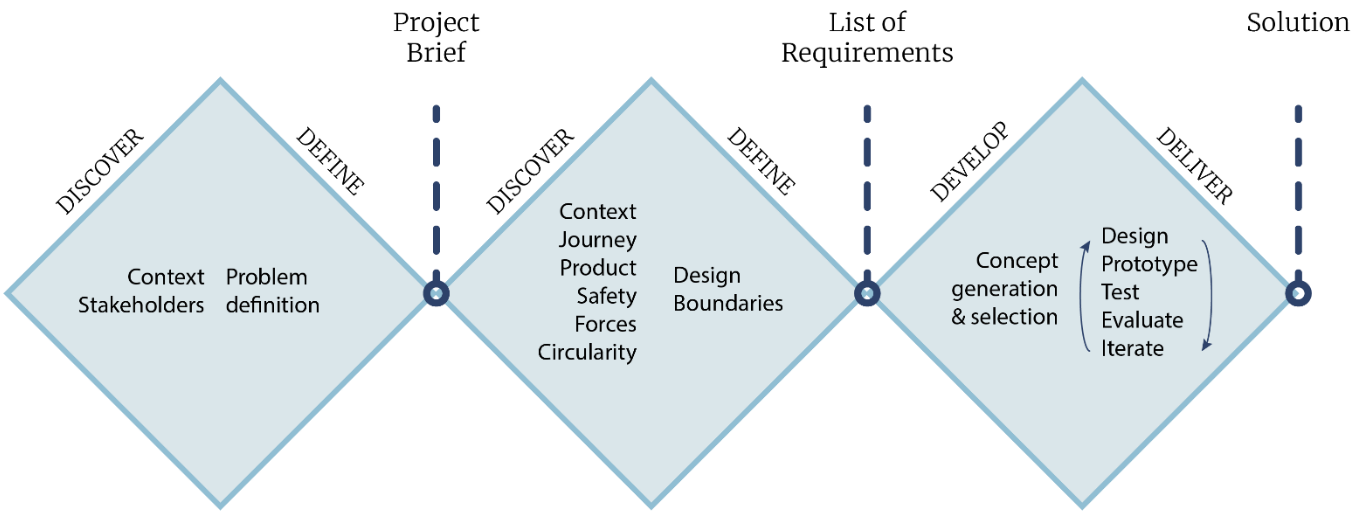


Figure 4: Visualization of the approach

1.6. Reading guide

The report is split up into 4 main phases: Analysis (chapter 2), conceptualization (chapter 3), embodiment (chapter 4) and the final design (chapter 5).

The analysis phase starts by identifying the main stakeholders. Groups with high interest and influence are interviewed, this information is used to understand the sport, the product and its practitioners. Furthermore, a literature review was done to further examine the context and similar products. Where information was still missing, experts were consulted to obtain these missing parts. Next to that, the model presented by former graduate Marinke Callens is tested and evaluated to identify improvement points. All insights are gathered in the list of requirements and wishes. In chapter 2.9.1, the list is shown with references to where the requirements came from.

The conceptualization phase consists of multiple iteration cycles. These cycles use the methods design by doing and rapid prototyping, to increase the feasibility of the design. The design is tested in use conditions and finally one last iteration cycle is done.

The next chapter focuses on the embodiment design phase of the product creation process, which starts with the concept and its key features and ends with a validated prototype of a product. During this phase, focus lays on manufacturability, circularity, materialization and an estimation of the cost price is calculated.

The final chapters contain recommendations (chapter 6), a reflection on the entire project (chapter 7) and the references (chapter 8).

2. Analysis

To design an optimal sitwake seat, initially the context is analyzed and opportunities are identified. The stakeholders are mapped to identify the groups with the highest interest and influence in the project. These groups are interviewed and observed to get a full picture of the context. The current product along with their competitors are researched. Furthermore, other important subjects such as safety, circularity and forces are researched. All findings are concluded into a list of requirements and wishes, which acted as a base for the ideation phase.

The analysis consists of eight parts: Callens' design, competitive products, stakeholders, stages a beginning wakeboarder goes through, forces, discomfort, safety and circularity. From all topics, design requirements and wishes are collected and these are combined in a list of requirements. First, Callen's design is analyzed by doing two tests regarding the ease of dis- and reassembly and the adjustability of the sliding mechanism. Stakeholders are identified, the stakeholders with the highest interest and influence are interviewed to get a better understanding of the sport and its practitioners. These insights are gathered in a user journey, which shows all the steps a beginning wakeboarder goes through. From there, other important aspects are analyzed; discomfort, forces acting upon the seat, safety issues and circularity.

2.1. Callens' seat

Callens' seat, portrayed in figure 5, acted as a starting point for this project. Her envisioned seat is an adjustable carbon fiber seat which main feature is an improved fit. The seat is adjustable in seat width from 30 to 40 cm. The hard parts are covered with a 15 mm closed-cell foam to minimise chances of decubitus (pressure sore). N

The sides slide over the base plate using slots and 6 bolts and nuts. A Velcro strap secures the user and makes sure the model is suitable for different sizes.

Callens' graduation project ended with a test, executed together with Willem Hooft, where new problems arose and insights were gathered. The main take aways are stated below:

- Look into the fixation of the rails in terms of rigidity and
- Look into the fixation of the rails in terms of ease of use
- Look into reinforcing the area around the rails and bolts
- Look into reinforcements of the two sides as a whole
- Reevaluate the positions of the hardware to fixate the seat.

A 3D print of Callens' concept was available to analyze. Two important aspects that still needed to be tested and evaluated after her project was finished to define the feasibility were identified:

- Ease of dis- and reassembly.
- Adjustability – sliding mechanism.

Two tests are conducted to evaluate both points.

Figure 5: Callens' design, render made by Callens

2.1.1. Ease of dis- and reassembly

For the seat to be viable, the assembly time should be reduced compared to switching seats. Also, the user experience should be as optimal as possible. The user in this case is the person assembling the product.

Method

For this test, the following parts were used:

- Tessier Swaik frame
- Wakeboard
- Tessier footrest
- Callens' 3D printed prototype
- Allen key
- Wrench

The test was done in a living room environment. The sitwake was placed on the floor to simulate the ergonomic situation. The base of Callens' design was taken of the Swaik frame and both sides were disassembled as well. From here, the seat was installed at the smallest width. Then, it was changed into the biggest width, by loosening and fastening all bolts and nuts.

Results

Regarding the reassembly, the positioning of the bolts and nuts are difficult to reach for both the instructors and the beginners (seated and out of the seat). In figure 6a, it is shown how an instructor would change the width of the seat. The small parts are easy to lose. In addition, the number of bolts (6) to be tightened while the base is already attached to the frame is still large, so adjusting still takes a relatively long time. The bolts stick out as can be seen in figure 6c, causing potential harm. In Callens envisioned configuration, the frame interferes with the slots, making it impossible to adjust the two halves to the smallest possible width. This can be seen in figure 6b.

Figure 6a: Posture of instructor

Figure 6b: Reevaluating the position of the hardware to fixate the seat

Conclusion

The time needed to adjust the seat takes too long.

- **A new way of adjusting should be designed for the concept to accurately work.**

The parts used to adjust the seat should not be able to easily come loose. The reachability of the bolts and nuts should be improved, to decrease the discomfort of the ones adjusting the seat. The bolts used to attach the base in the front are too long and form a risk of injury, the length should be reduced and the sharp ends should be covered. Sticking out parts are hazardous especially for sitkiters since kite lines can get stuck behind them.

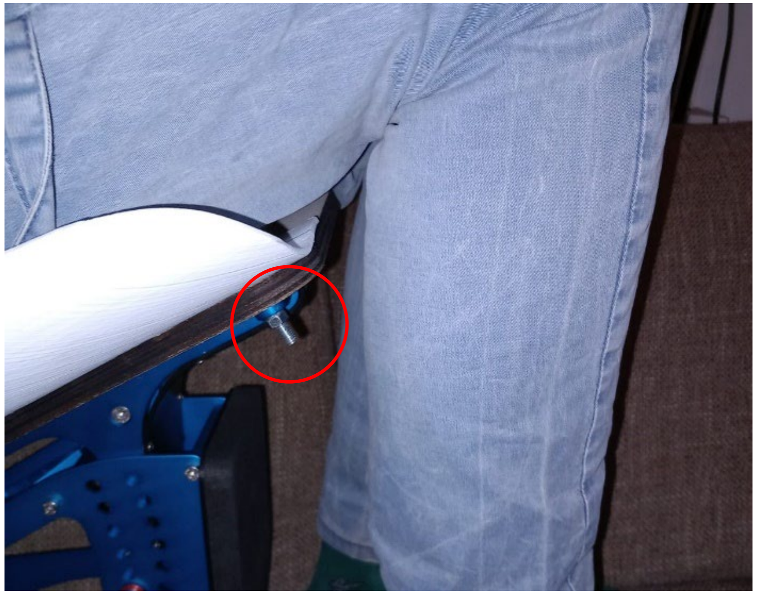


Figure 6c: Bolts causing harm

Requirements

- **The seat should not have parts that stick out (safety regarding kite lines)**
- **User should not touch any bolts or hard material with its body while seated.**
- **Adjusting the seat should take as little time as possible**

2.1.2. Adjustability - Sliding mechanism

Method

Callens' 3D printed base was replaced with a wooden base, as shown in figure 7. This was done because the original base was not strong enough to hold its shape. On this new base, the slots were relocated so that the frame does not interfere with the bolts like shown in figure 5b.
Callens' prototype combined with the wooden base was assembled in the orientation of the smallest size, fixed and from here changed to a bigger size. Vertical lines were drawn on the base to locate the bigger size and to make sure the end position of the two halves were straight. Callens' design contained marks on the back of the base to indicate the position of the two halves. These marks are discarded because the test was done purely to validate the sliding mechanism.

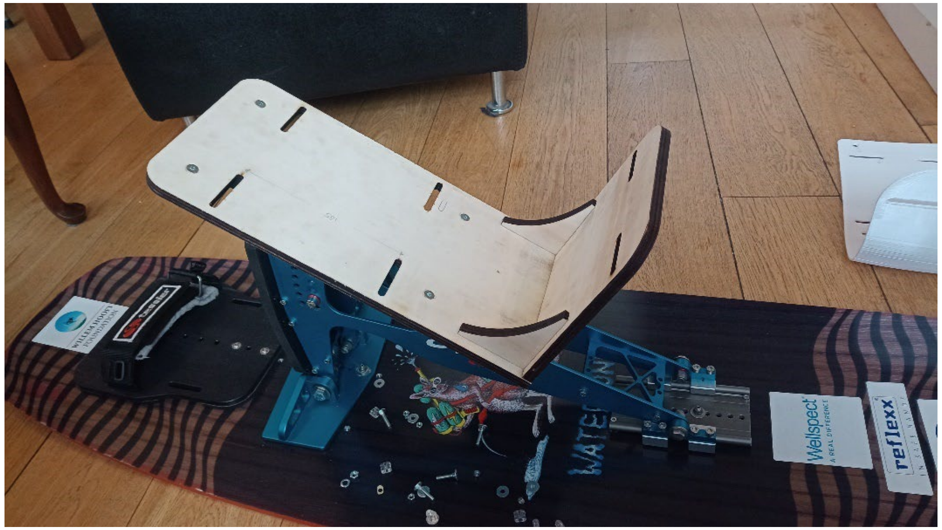


Figure 7: Altered rigid base

Results

Although the use of a more rigid wooden base made the concept stronger and stiffer, it did affect the total weight of the seat. The use of the carriage bolts still resulted in a tilting effect. The smaller head of the carriage bolts was favorable because they integrate better with the seating surface, making them less noticeable when foam is placed.

Conclusion

The use of a more rigid base improves the overall design. The use of carbon for this part is oversufficient since the only function is fixing the seat halves on six different points. A tilting effect still occurred.

- **A new way of adjusting the width of the seat halves should be designed.**

All frames that are currently used with the seat should be compatible with the to be designed seat.

Requirements

- **The parts used to adjust the seat should not be able to easily come loose.**
- **The rigidness of the base is favorable over the envisioned carbon fiber base. For the sliding of the parts to work, the tolerances should be narrow and thus rigid parts should be used.**

2.2. Product

Different types of seats and accompanying frames are available on the market. The design of seats which are currently on the market and Callens' seat will be discussed along with their specifications and improvement points. Since Callens' seat served as a starting point, improvement points are specified as well.
The seat is a subassembly of the sitwake as a whole, shown in figure 8. The following paragraphs focus specifically on the seat.

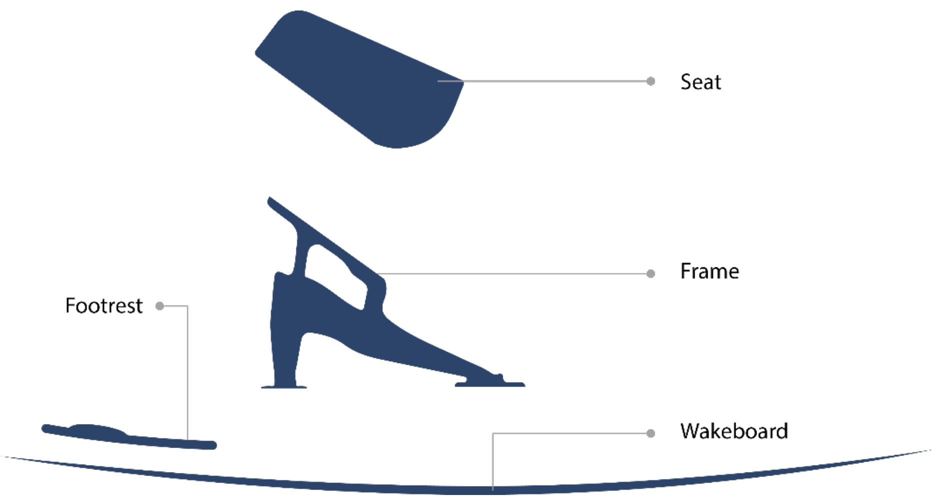


Figure 8: Seat as a subassembly of the complete sitwake

2.2.1. Seats currently on the market

Due to the small market, there are limited competitors. Research is done on the existing solutions, together with the concept seat of Callens. Frames are also briefly mentioned since the seat is connected to the frame.

Method

Characteristics of different seats and frames available on the market together with Callens seat are acquired through online market research and by examining the physical products (Tessier seat and prototype of Callens' seat). These insights are used to develop requirements and to understand the product. To understand better how the product is created, a call with an employee of Tessier was held.

Results

From the market research, three main competitors were identified regarding seats: JL composites, Tessier and Ambrois. The characteristics of their seats and Callens seat are listed in Table 1.
Regarding the frame, the most used ones are the Swaik from Tessier and a frame from Ati Sports for sitwaking. For sitkiting, the Wolturnus frame is mostly used. The ATI frame makes use of a lockable or non-lockable air-oil damper. This system reduces the impact when landing. Next to that, it uses the same roller support as the Swaik. The Wolturnus frame uses vibration dampers between the frame and the board to reduce impact. The most important takeaways are that the holes of the base of the seat are placed in a rectangle of 270mm x 140mm. The size of those holes has a diameter of 8mm, fitting M8 bolts. Seats and frames are interchangeable between brands. A backrest can optionally be connected to most seats with bolts and nuts and is set into an angle by adjusting the length of a strap. Tessier launched a backrest which is adjustable in width and compatible with all their seat sizes.

Ambrois	Tessier
	
• Carbon seat • High flaps around thighs • Front and back strap for security • Drain holes for water excess. • Personalized shape • Mostly used with Ati frame	• Composite material, fiberglass. Full composite or sandwiched with cork • 2 finishes: gelcoat or carbon look • Waterproof foam in the seat and backrest. Memory foam in seat cushion • 7 different models, changing in width • Personalization options • Mostly used with Swaik frame, brand Tessier
Callens	**JL composites**
	
• Carbon fiber • Textile straps, velcro connnection • EVA polyurethane foam cushion, 15 mm thick. • Optional adjustable backrest • Adjustable width: 30 - 40 cm	• Composite, carbon or fiberglass and epoxy • Optional backrest • High density foam & anti bedsore foam of 4 cm thickness. • Personalized shape • Mostly used with composite frame of JC composites

Conclusion

Due to the weight to strength ratio, the logical choice for seat material is fiberglass, it is also already widely used for comparable products. Since Tessier already launched an adjustable backrest, the backrest is placed out of scope, due to the limited amount of time for the project. This is done in consultation with Willem Hooft.

Requirements

- **The holes of the base of the seat must be in a rectangle of 270mm x 140mm.**
- **The holes of the base must be fit for M8 bolts.**
- **The SWAIK universal backrest should be attachable to the seat.**
- **The seat should be attachable to the ATI frame, the SWAIK frame and the Wolturnus frame.**

Left: Table 1: Callens' seat and competitors with their characteristics

2.3. Stakeholders

A stakeholder map is created to understand the influence and interest of different affected groups.

Method

First, a list of stakeholders is created by brainstorming which groups are influential for the project. For this list, the stakeholders identified in the brief serve as a starting point (see appendix A). Then, these stakeholders are mapped according to their interest and influence. This is done by choosing one stakeholder and comparing it with the next one, discussing whether this stakeholder has higher or lower interest and influence with another IPD student that is active in the wakeboarding community. According to the results, the map in figure 9 was configurated.

Results

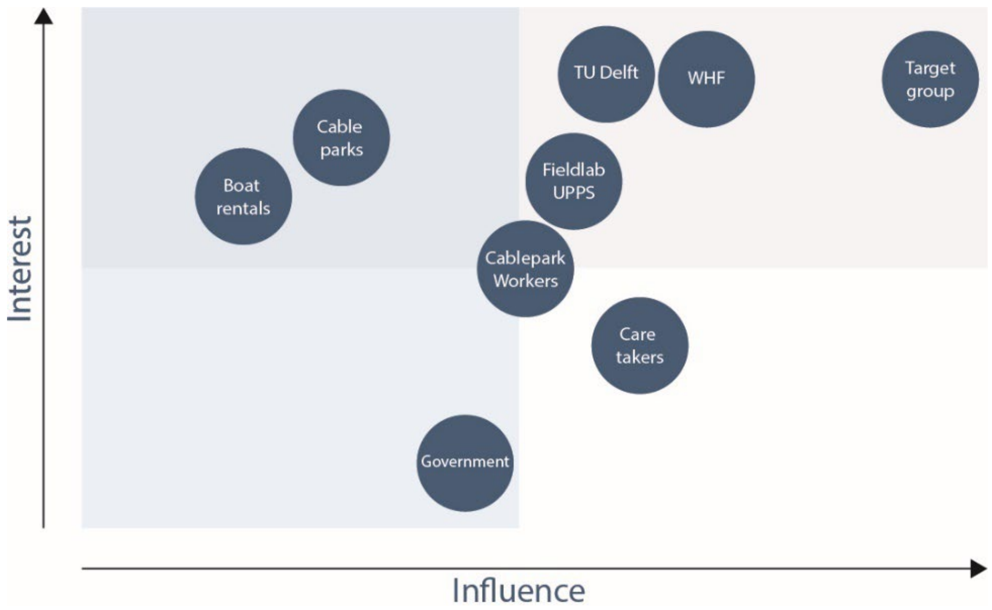


Figure 9: Stakeholder map. On the x axis influence is shown from low to high, on the y axis interest is shown from low to high.

Conclusion

This map is made to identify the most important stakeholders, (top right on the map) their needs should be priority. The key stakeholders will be approached, first to understand the context, later to give feedback on the concept, to make the final product a success.

2.4. Stages encountered by beginning sitwakers

A user journey map is created to gain insight into all the stages a beginning sitwaker goes through while experiencing the use of the product. By creating one, the context can be better understood and it helps to avoid designing product features that lead to incoherent user experiences (van Boeijen, Daalhuizen, van der Schoor, & Zijlstra, 2014).

Method

The information to construct the map was collected through user observations, a product usability evaluation and several interviews of key stakeholders, including disabled sitwakers and instructors (appendix B). User observations were done through photo and video analysis which were provided by a participant of a test day for sitwakers. This participant was also interviewed to support the media and give extra explanations where necessary. To give a more complete view of the user journey, a cable park employee of an inclusive cable park was interviewed as well. Lastly, the product usability was evaluated by testing a seat of Tessier (figure 10), resulting in a better understanding of the process and the identification of extra pain points.
This approach suits the context since design is usually a creative and cooperative act which combines knowledge from various disciplines and stakeholders.

Figure 10: Product usability evaluation

Results

From all methods, a user journey map was constructed shown in figure 11. This gives an overview of the steps encountered by a beginning sitwaker, answering research question 3b.

In the table on the following two pages, the steps are explained in detail. Steps that require interaction with the seat are identified. This is where improvements can be made through design. The steps marked with a blue rectangle are repeated until the time on the cable is over.

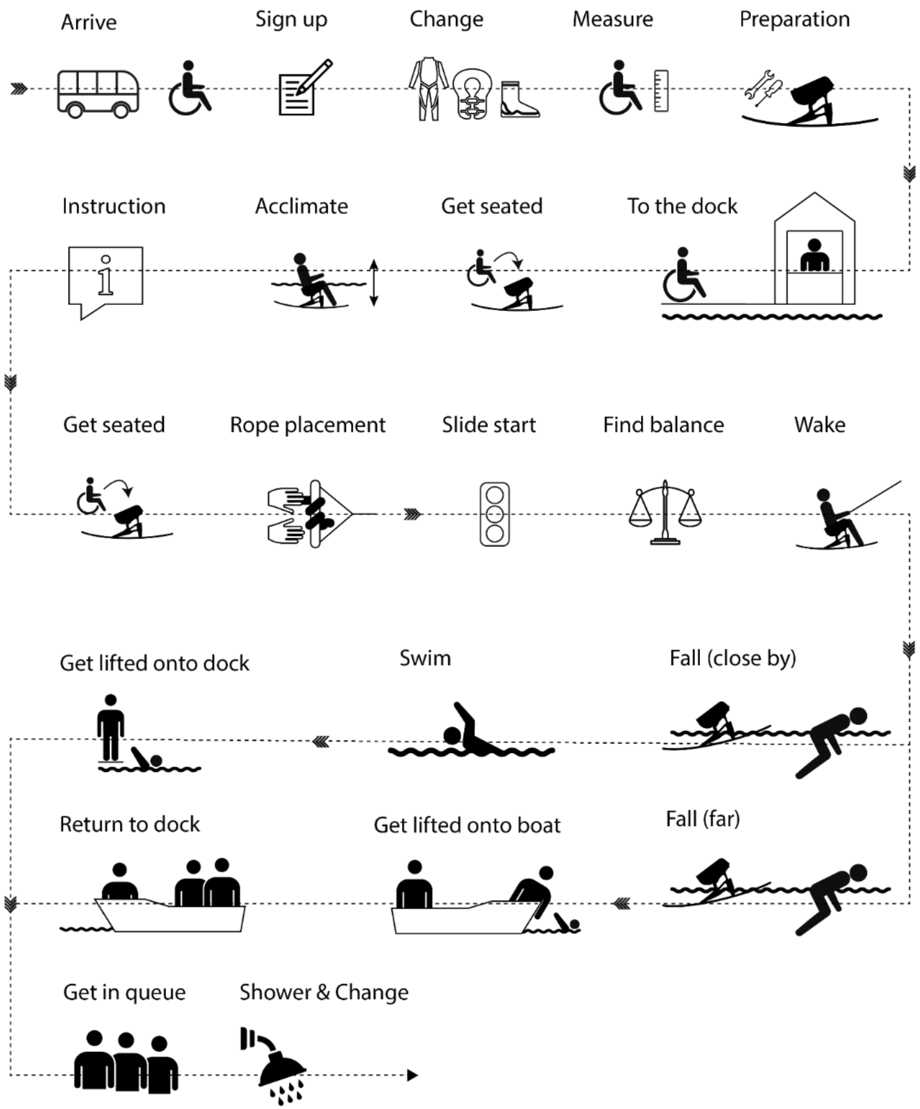


Figure 11: User journey map

Andrew Smith

Amputee, 36 years old

Sitwaking for the first time

Journey step	Arrive	Sign up	Change	Measure	Prepare	Instruction	Get seated	Acclimate	Go to dock	Get seated
 Interaction with seat										
Customer activity	The beginner arrives at the cable park, where they meet other beginning wakeboarders.	First they go to the reception to sign up and get their gear (helmet, wetsuit, lifevest, shoes).	Then they go to the changing room and put on their wetsuit and protective gear.	Beginners are placed in the different seat sizes to see which fits best. Beginners must remember their seat size.		Theory is given about the cable, how to ride, how to get back to the dock, what to do after falling etc.	The beginners get in to their seat and are helped into the water. Some beginners need help, others can do it themselves according to their handicap.	While seated, everyone is asked to get into the water and is submerged and turned around. This is to get a feeling for the seat and the water and minimize risks after falling. It occurs often that beginners panic when they fall, and this minimizes the risks.	After the training, everyone gets into a cue to get on the cable. They can either be seated on the ground, on the somewhat higher jumpstart stroke, already in their seat or waiting in a wheelchair.	The beginners are seated at the slide start, located at the dock. Again, some are able to do this themselves, others need help.
Stake-holder activity		Receptionist signs beginner in and provides the right gear		The team of instructors measure every single one of the beginners and see which seat fits best. They do this by fitting the beginners in the different seat sizes to see what fits best.	The cable park employees set up a couple of sitwakes, beginners that have comparable measurements share the same sitwake.	Theory is given about the cable, how to ride, how to get back to the dock, what to do after falling etc.	Cablepark workers help the beginners into the water when help is needed.	Instructors submerge the beginners one by one, and turn them around.		Instructors help where needed.

Table 2a: User journey steps

Rope placement	Find balance	Sitwake	Fall (closeby)	Swim to dock	Get in queue	Fall (far away)	Get lifted into boat	Return to dock	Get in queue	Change
When seated, they need to wrap a rope which is attached to the frame around the handlebar. They hold this rope when starting, and release it once they are up to speed. This process is explained visually in the 'safety' chapter.	Before being able to properly sitwake, the rider has to find balance by moving their upper body and their board accordingly.	When the rider is on the water, they maneuver around buoys that indicate where the corners are located. They first learn to make their first meters, then to turn, after that they can try to do some tricks on the water like rotating or try obstacles.	When a beginner falls, they automatically get dragged out of their seat. Depending on where they fall, two scenarios are possible. When they fall close to the dock, they swim back.	After releasing the bar, the rider swims back, taking their sitwake with them. One way to do this is by using the rope that is attached to the frame and biting on that while dragging the setup along.	When they are back, they get on the dock, some are able to accomplish this themselves. The sitwake is passed on to the first person in line, the beginner gets back into the queue.	When someone falls far away from the dock, they are picked up by a boat, which is often located at the first turn where they often fall. Some parks also have 'islands' at different spots along the line of the cable, so beginners can be picked up from there.	The rider is lifted into the boat. Before being pulled out of the water, they hand their sitwake to the employee in the boat.	The boat rides back to the dock with the beginners. Sometimes more people are picked up in one run.	The beginners get out of the boat and get back into the queue. Then the process repeats, they get seated, place the rope, etc.	When the timeslot (usually 1.5 – 2 hours) is over, everyone changes and returns their rented gear. At most cable parks, there are changing rooms with showers where to rinse equipment and gear.
A cablepark worker hands the bar to the beginner and gives instructions.					The seat is usually pulled out of the water by someone else. Some sitwakers need help getting back on the dock	Cable park workers operate the boat and pick up fallen sitwakers.	The rider is lifted into the boat by cablepark workers by grabbing them at their life vests. The employee pulls the sitwake in the boat. One employee helps the beginners, another one operates the boat.	A cablepark worker steers the boat	A cablepark worker or fellow beginning sitwakers help getting both the sitwake and the other beginners out of the boat	

Table 2b: User journey steps

Conclusion

In conclusion, the process of learning to sitwake at a cable park involves several steps. Beginners are provided with protective gear and are instructed on how to ride, how to get back to the dock and what to do after falling. They are then placed in a sitwake and given a bar, which they must wrap a rope around to redirect the pulling force from their arms to the frame. If a beginner falls, they are automatically dragged out of their seat and they either swim back to the dock or are picked up by a boat, depending on their location. When carrying the seat back, water stays in the seat, increasing the total weight.

During the user observations, several pain points and requirements that the seat must meet came forward. The conditions in which both sitwaking and sitkiting are practiced, bring forward a lot of restrictions for the materials used in the equipment. Vice versa, the equipment should also not pollute the environment.

Regarding safety, the seat must not form any hazard during all stages of the user journey. Potential hazards are for example drowning and physical damage. These risks can be minimized by optimizing the buoyancy of the product and facilitating exiting the seat.

Overall, it would be favorable to minimize the preparation time needed before a beginner can start sitwaking, while maintaining the safety precautions.

Requirements

- **The seat should sink while the beginner is in the seat, while the head of the beginner remains above the water surface.**
- **The seat is not equipped with straps by default.**
- **It should be made clear that beginners do not use straps.**
- **The design should be able to withstand freshwater.**
- **The design should be able to withstand saltwater.**
- **The design should be able to withstand UV radiation.**
- **The product should not release toxic materials into the water.**
- **Water should be able to leave the seat.**

Wishes

- **The number of steps before sitwaking is minimized.**
- **The seat must redirect the pulling force of the rope when starting.**

2.5. Forces

During sitwaking, different forces work upon the system. These forces are analyzed to design a safe product, able to withstand extreme use situations.

Method

A force analysis was constructed through combining insights from comparable research regarding forces acting on wakeboarders (Weerts, 2014), snowboarders (Brennan et al., 2003) and sitkiters (Callens, 2022). These outcomes were analyzed in consultation with Sander Minnoye, an expert on the field of dynamics and mechanics, especially focusing on sports.

Results

To understand the forces working upon a sitwaker, we first look at the forces working on a wakeboarder. The image shown below is derived from a graduation report of Lennart Weerts, who designed a new binding system for wakeboarders (Weerts, 2014). The images are based on research done by S.M. Brennan (2003) on forces acting on snowboarders.

As shown in figure 12B and 12D, the resultant force of the gravitational and centrifugal forces do not align with the force of the water, resulting in a moment in the ankle joint. This will create a different angle between the board and the water. For sitwaking, creating this moment will result in falling down, due to the rigid structure of the frame and seat and thus not being able to alter the angle of the board. To make the same turns, a sitwaker needs to put their center of gravitation further over the edge of their board.

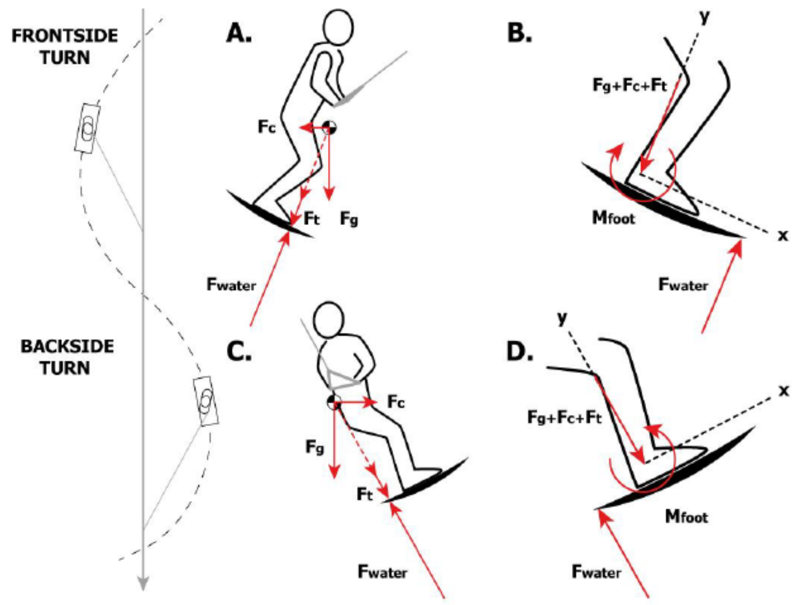


Figure 12 - Forces acting on the body during a frontside turn (A) and a backside turn (C). Forces acting on the ankle joint during a frontside turn (B) and a backside turn (D) shown in the sagittal plane. Image is derived from Weerts' report.

Note that the forces acting on the board do not only pass through the edge of the board, like with snowboarding where the rail of the board only exerts force on the snow. With wakeboarding and surfing, a distributed load along the bottom of the board equilibrates the gravitational and centrifugal forces. With this knowledge, the following free body diagrams were created:

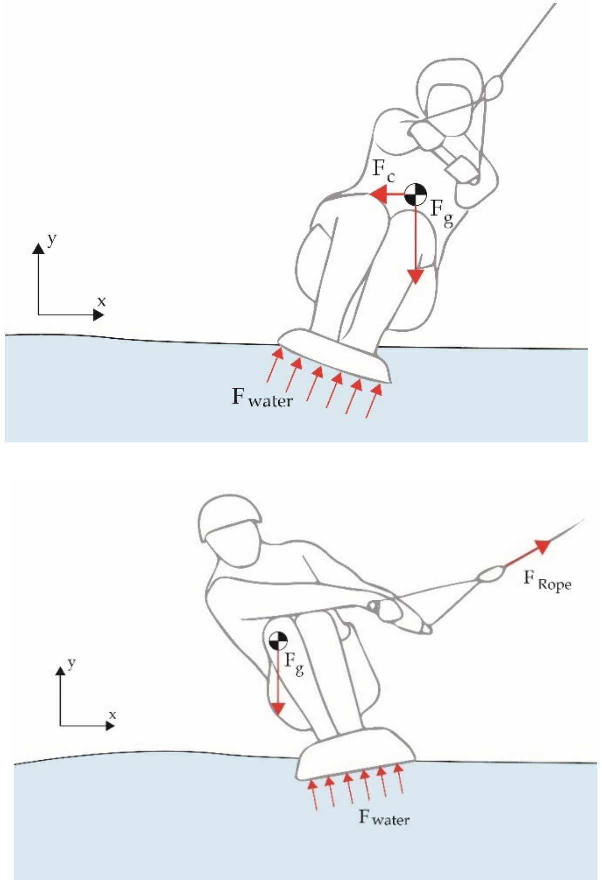


Figure 13a & 13b: FBD of wakeboarder with and without the horizontal pulling force of the rope (Frope), with Fc being the centrifugal forge, Fg being the gravitational force and Fwater being the force exerted by the water

In figure 13a & 13b, two situations are illustrated. The situation on the right is comparable to the snowboard situation. In this case, the pulling force of the cable is in equilibrium with the drag of the wakeboarder and can both be neglected. When turning, the resultant force of Fc and Fg is aligned with Fwater. However, the rope is often used to build up speed, or to reach features that are not in line with the cable. In this case, looking at the cable from a top view (figure 13c), the pulling force of the rope can be divided into two components: one parallel to the cable and one perpendicular to the cable. This is a situation where we have tension on the cable. Sometimes, after generating a lot of speed, there is no tension on the cable for a little while. This is shown in figure 13b.

The scenario with tension in the rope shown in the bottom FBD shows a front view of the sitwaker. In this situation, Frope cannot be neglected. This force is equalized by the rider by leaning in the opposite direction of the rope, altering their center of gravity. In both situations, minimal forces are acting sideways on the seat (Sander Minnoye, personal communication). The vector of the distributed force Fwater is now in line with the resultant force of Fg & Fc in figure 13a and with the resultant force of Fg and Frope in figure 13b.

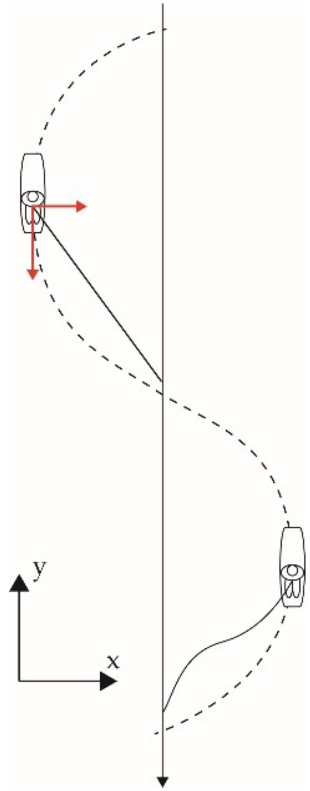


Figure 13c: Top view cable

The Innosport lab in The Hague measured forces acting on sitkiters in cooperation with Thierry Schmitter, an experienced sitkiter (Schmitter, 2012). This measurement focusses on high impact, a different scenario than illustrated in figure 12. Measurements showed that landing with a board flat on the water resulted in a force of 5 kN on the equipment (body + equipment weight +- 80kg). The load of the extreme situation will rarely occur, implying that a safety factor of 1,5 to 2 is satisfactory, since this is “for use with reliable materials where loading and environmental conditions are not severe” according to engineering toolbox (n.d.). This results in a maximum force of 10 kN perpendicular to the board.

We can assume that the large forces that are used to calculate the thickness of kite lines and that were measured by the Innosport lab are mostly working perpendicular to the board rather than to the side (Sander Minnoye). However, in extreme situations like a crash, force is also applied sideways on the seat. To make an estimate of these forces which are needed to define dimensions of the sitwake seat design, Thierry Schmitter is consulted.

Thierry Schmitter is a Dutch disabled kite surfer. He was consulted to discuss the outcomes of the test done by the Innosport lab and to compare the outcomes to the new scenario. It is estimated that the force working on the side of the seat in the event of a crash is significantly lower due to the smaller surface area combined with the round shape. The exact force was not calculated and can only be determined by doing tests in his opinion. Due to the limited time, this is left for future research.

Conclusion

Sitwakers are limited in movement compared to wakeboarders. The lack of being able to rotate their ankles means they must put their weight further over the edge of their board to steer away from the rope, where a wakeboarder can achieve this by rotating their ankles and thus the angle of their board compared to the water. The maximum forces that act flat on the board is around 5kN. The forces acting sideways on the seat are not yet researched, this should be defined through excessive testing.

Requirements

- **The seat should withstand a vertical force of 10 kN.**

2.6. Discomfort

As mentioned by interviewees and in Callens’ research, the comfortability of the seat is of high importance.

Method

A systemic evaluation of Callens’ (dis)comfort research is done to extract data to complement the requirements. Through this approach, the existing knowledge gap considering discomfort was addressed by integrating insights from Callens.

Results

The (dis-) comfort research provides multiple insights, including the importance of the seat supporting a normal spine posture through upright pelvis and lower trunk support rather than relying on the backrest. User research indicates that the backrest primarily functions to transmit forces from the upper body to the board and its necessity depends on the athlete's level of disability and available trunk muscle. Minimizing decubitus for comfort and safety is also crucial and can be achieved through optimal pressure distribution to minimize shear and friction. Decubitus refers to a skin wound that develops due to continuous pressure exerted by the body's weight against a surface, resulting in an open sore. This is especially important for the target group since pressure injuries are well known complications for users with spinal cord injuries (Ash, 2002). The type of wetsuit worn can also affect comfort and performance, highlighting the importance of a continuous sizing system to ensure a proper fit for all users. The use of a removable backrest should be considered based on individual needs and preferences.

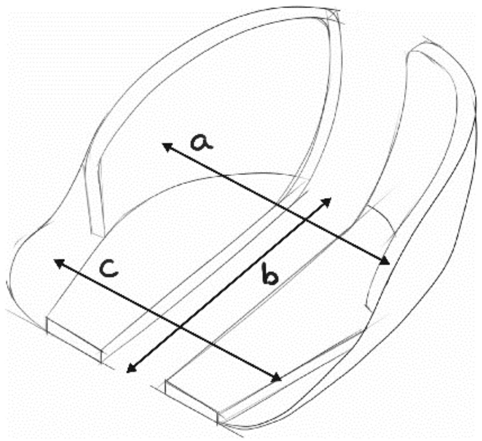
Conclusion

To design an optimal fit to minimize the experience of discomfort, corresponding anthropometric data was collected by Callens and incorporated into the design of the seat halves. She measured the anthropometrics in the correct position, to achieve optimal results. Measurements that were of importance for the seat to minimize perceived discomfort and the possibility of pressure injuries are seat depth, hip width and thigh width. The last two are measured by Callens' through 3D scanning the target group. The measurements are shown in table 3.

- Seat depth: It is important that the back of the knees does not interfere with the edge of the seat, but the upper legs must be supported as much as possible to increase comfort and reduce decubitus. For this measurement, the buttock popliteal depth is used.
- Hip width: The maximum width of the hips, the trochanter, should be located correctly in the seat to decrease the chance of decubitus and to increase comfort. Advanced users stated that they like to be clamped into the seat, so the actual width of the seat might be smaller than the hip width measurements, due to compressed flesh.
- Thigh width: Must be as tight as possible for the legs to not move when using the seat. Callens' measured this through 3D scanning the target group.

Requirements

- **The hip width should be adjustable and cover a range of 30-40cm.**
- **The seat depth is a fixed dimension at 42cm.**
- **The thigh width of the seat should be adjustable and cover a range of 24-38cm but will always be smaller than the hip width.**
- **The seat should support a normal spine posture by supporting the pelvis and lower trunk (avoid kyphosis and lordosis)**



	Measurement	Dimensions
a	Hip width	300 -400 mm
b	Seat depth	420 mm
c	Thigh width	240 -380 mm

Table 3: Relevant measurements

2.7. Safety

As stated in chapter 3.4, straps are not used when teaching beginners. The reason for this is that they might panic while falling, not being able to release themselves from the sitwake. This can result in dangerous situations. Even when doing obstacles like boxes and kickers, it is not required to be strapped to the seat. To prevent a feeling of anxiety, the user should be able to exit the seat within a second.

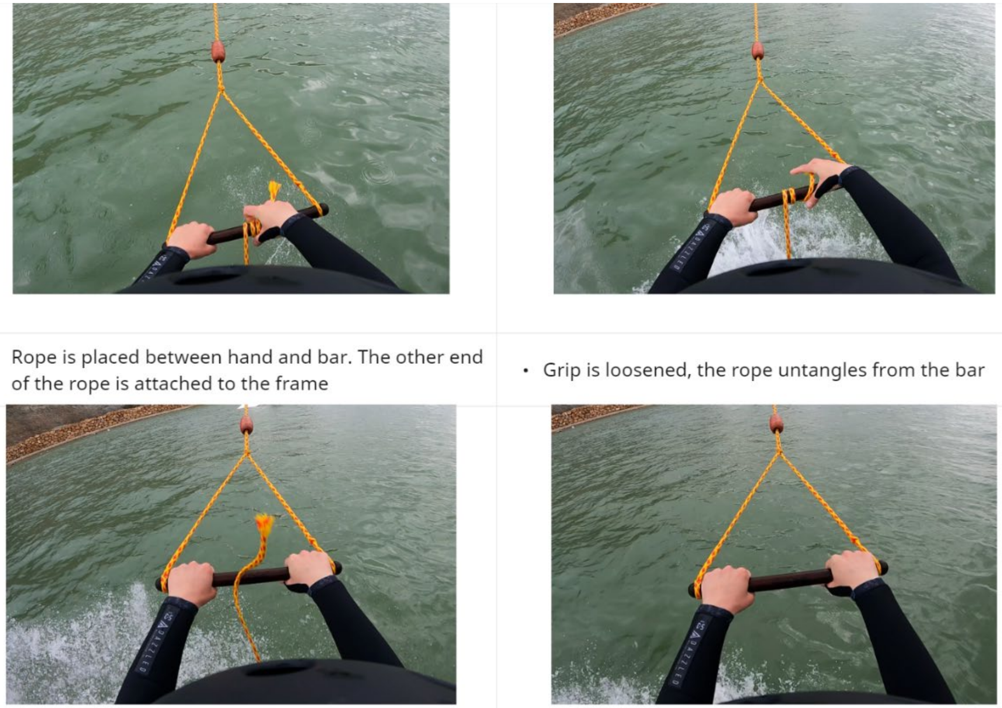
When starting from the dock, a big force is applied on the arms of the sitwaker. Without being strapped into the seat, they could be thrown out once the rope with the handle tightens. Currently this is solved by attaching a rope to the frame and wrapping this around the handlebar when starting. The process is explained in figure 14. After the test conducted in chapter 3.3, a choice was made to eliminate the rope, since it is not needed.

The interview with the cable park employee concluded that for a beginner session, you need the following people to ensure a safe environment:

- One person in the water, helping beginners that fall close to the start.
- One person operating the cable.
- Two people in the boat. One to steer, one to help beginners out of the water.
- One person to hand out the material.

Compared to normal wakeboarding, you need three extra people (two in the boat, one the water).
To ensure safety, protective gear is used: a helmet and a life jacket. The lifejacket ensures positive buoyancy, preventing drowning. This is the same with normal wakeboarding.

Lastly, instructions are given to always be aware of your surroundings when fallen and which way to swim. This is the same with normal wakeboarding.



- Rope is placed between hand and bar. The other end of the rope is attached to the frame
- Grip is loosened, the rope untangles from the bar
- Rope is loose. In the process, the force slowly shifts from the frame to the arms of the sitwaker
- The starting process is completed, the beginner fully absorbs the pulling force of the rope with their arms

Figure 14: Rope placement when starting

Conclusion

Regarding safety, beginning sitwakers are not strapped into the sitwake opposed to experienced sitwakers. This means that the seat should not be equipped with straps by default, but attachment points should be integrated in case the user wants to use them. An extra rope is often used when starting, an attachment point for this rope is favorable. Multiple people are required to ensure a safe environment during beginner sessions. Protective gear and safety instructions are also given.

Requirements

- **The seat is not equipped with straps by default.**
- **The user should be able to exit the seat within a second.**

Wishes

- **Attachment points for straps should be integrated in the design.**

2.8. Circular design

The circular economy seeks to prevent waste through design and to maintain both environmental and economic value. A central idea in the circular economy is product integrity, where maintaining product functionality is prioritized over material recovery. To preserve product value, strategies such as extending product lifespan, recovering and reusing products are employed, while recycling and reusing are used to preserve material value.

We refer to the ecodesign strategy wheel (Brezet & Van Hemel, 1998) which is shown in figure 15 to improve the sustainability of the design. It is a tool to improve the sustainability of a design, some strategies are more applicable in later stages and are included in the recommendations in chapter 6.

- The use of low-impact materials is encouraged whenever feasible. For example, aluminum is preferable for structural components, due to its strength to weight to costs ratio.
- The number of materials is reduced to the minimum. This reduction in material usage not only contributes to reduced weight, but also helps minimize the environmental footprint.
- The lifespan of the product will be extended by designing for ease of repairability and maintenance.
- Materials will be selected to facilitate recycling at the end of life.
- On a system level, many users will use the product.

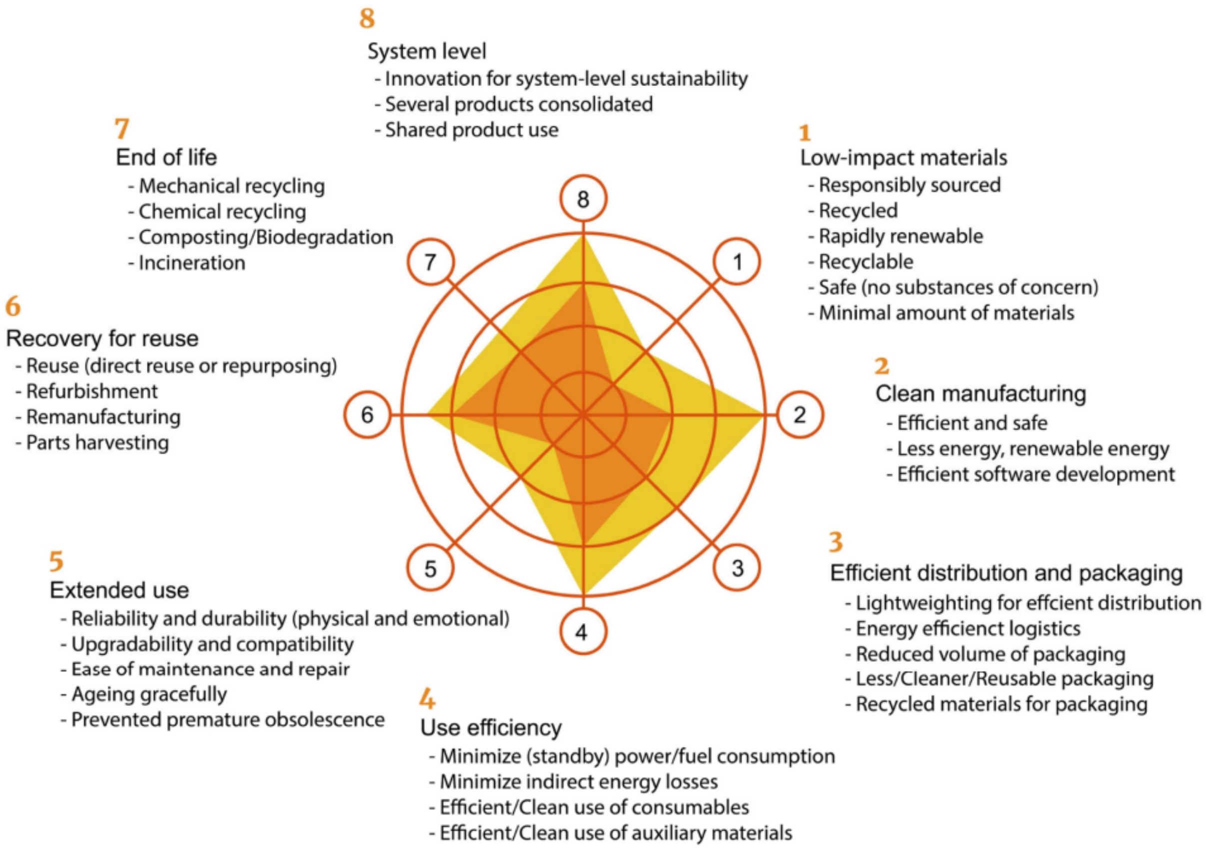


Figure 15: Ecodesign strategy wheel

Composite seat

The Tessier seats are produced with composites, with a traditional sandwich structure and gel coated on the outside. Although it reinforces the structure, traditional sandwich composites are composed of different materials joined with a strong adhesive making them very difficult to be separated and recycled. After their service life, they become waste and are either burnt or buried most of the time (Nehls, 2022). A lot of seats are self-manufactured (I. Nys, personal communication, November 9, 2022) and for example use washers to reinforce the connection parts. However, following the framework of Circular Design of Composite Products (Joustra, Flipsen, & Balkenende, 2021) it is favorable to simplify this and design for disassembly in order for different materials to be easily separated. An example is to eliminate the inserts of aluminum in the prototype of the fiberglass seat (see appendix E). Although having downsides, due to the excellent weight to strength ratio, the choice of composite material is logical for the seat.

To minimize the negative environmental influence, the framework of circular design of composite products is used. In this framework, design aspects for products containing composite materials in a circular economy are listed as can be seen in table 4.

Concept Design	Embodiment Design	
Cluster i: Handling and Rework	**Cluster ii: Product Architecture**	**Cluster iii: Product Specifications**
Accessibility	Connection selection	Material selection
Adaptability	Dis- and reassembly	Structural design
Cleanability	Modularity	Manufacturing process
Ergonomics	Keying	Surface treatments
Fault isolation	Function Integration	
Functional packaging	Redundancy	
Interchangeability	Sacrificial elements	
Malfunction signalling		
Simplification		

Table 4: Design aspects for products containing composite materials in a circular economy, clustered and related to the stages in the product development process.

The design aspects are positioned under the design stages, providing a starting point and a structure for applying them in the product development process. The three clusters are used to complement the program of requirements and wishes. Originally, this table contains a fourth column titled detail design. For this project, the aspects listed under detail design are not incorporated due to the limited amount of time. However, it is strongly recommended to take another look at these aspects when continuing the project.

Conclusion

The circular economy aims to prevent waste and maintain environmental and economic value by prioritizing product integrity. The ecodesign strategy wheel offers recommendations for sustainable design, such as using low-impact materials, minimizing material usage, extending product lifespan through repairability, facilitating recycling and promoting shared product use.

However, the use of composite materials presents a challenge in the circular economy due to limited recycling possibilities. To address this, the framework of circular design of composite products is used to simplify design and enable easy separation of materials. While composites offer advantages such as weight-to-strength ratio, their production process can be energy-intensive and generate harmful emissions. The framework provides design aspects for products containing composite materials. Some are incorporated in the wishes below to minimize negative environmental impact.

Requirements

- **For the composite seat, only use resin and fiberglass**
- **All parts or subassemblies must be removable.**
- **Buy-in components must use reversible connections.**

Wishes

- **Where necessary, select surface treatments to prevent material degradation.**
- **Select manufacturing processes with minimized emissions.**
- **Use recycled materials where possible.**
- **Optimize accessibility and removability of parts and sub-assemblies.**
- **Minimize the complexity of the product in terms of functionality, assembly, appearance and materials composition.**
- **Use standardized parts where possible.**
- **Facilitate DIY adaptations where possible.**

2.9. Conclusions

All conclusions from the previous chapters are gathered in a list of requirements and wishes. This is a list of criteria that the sitwake seat must meet. It defines in a way what the result of the design process should be; it limits the range of possible solutions and is the basis for judging the extent to which a design fulfills its purpose ((Roozenburg & Eekels, 2001). Behind the requirements and wishes, the origin is stated in between brackets. Wishes contain an extra W- prefix.

2.9.1. List of requirements and wishes

A. Environment

A1. The design should be able to withstand freshwater (CH 3.4)

A2. The design should be able to withstand saltwater (CH 3.4)

A3. The design should be able to withstand UV radiation (CH 3.4)

A4. The product should not release toxic materials into the water (CH 3.4)

B. Modularity

B1. The seat should be attachable to the ATI frame, the SWAIK frame and the Wolturnus frame (CH 3.2.1.)

B2. The SWAIK universal backrest should be attachable to the seat (CH 3.2.1)

B3. Attachment points for straps should be integrated in the design (CH 3.7, Appendix C)

B4. The holes of the base of the seat must be in a rectangle of 270mm x 140mm (CH 3.2.1)

B5. The holes of the base of the seat must fit M8 bolts (CH 3.2.1)

B6. The seat must be useable for both wakeboarding and kiteboarding (Project brief)

C. Safety

C1. The seat should withstand a vertical force of 10 kN (CH 3.5)

C2. The user should be able to exit the seat within a second (CH 3.7)

C3. The seat should sink while the beginner is in the seat, while the head of the beginner remains above the water surface. (CH 3.4)

C4. The seat is not equipped with straps by default (CH 3.7)

C5. It should be made clear that beginners do not use straps (CH 3.4)

C6. The seat should not have parts that stick out (safety regarding kite lines) (CH 3.1.1)

C7. User should not touch any bolts or hard material with its body while seated (CH 3.1.1)

W-C8. The design should minimize chances of pressure injuries, by minimizing shear and friction; and maximizing pressure distribution. (Callens, 2022)

D. Performance

D1. Water should be able to leave the seat (CH 3.4)

D2. The seat should be strong and stiff enough for riding on choppy water, transport in cars and jumps of ca 2m on the water (Callens, 2022)

D3. The foam should not be able to move while riding (Willem, personal communication)

D4. Maximum weight of the seat is 5 kg (Willem, personal communication)

E. Ease of use

E1. Changing to the right size should take less time compared to changing the current seat to another frame (ca. 10 min).

W-E1. Adjusting the size should not require any tools. (Willem, personal communication)

W-E2. The number of steps before sitwaking is minimized (CH 3.4)

W-E3. Changing the size should take as little time as possible.

F. Target product costs

F1. 50% less investments costs for schools than 4 adults seats (<3000 EUR) (Callens, 2022)

G. Anthropometry

G1. The hip width should be adjustable and cover a range of 30-40cm. (CH 3.6.)

G2. The seat depth is a fixed dimension at 42cm (CH 3.6.)

W-G3. The design should fit people with different widths in each thigh. Which means the part around the thighs should have the option to be asymmetrical, but still have a width within the range as mentioned in G3. (Willem, personal communication).

H. Comfort

H1. The seat should support a normal spine posture by supporting the pelvis and lower trunk (avoid kyphosis and lordosis) (CH 3.6.)

W-H2. A backrest is optionally (Willem, personal communication)

i. Circularity

I1. All parts or subassemblies must be removable. (CH 3.8)

I2. Buy-in components must use reversible connections. (CH 3.8)

W-I3. Where necessary, select surface treatments to prevent material degradation (CH 3.8)

W-I4. Select manufacturing processes with minimized emissions (CH 3.8)

W-I5. Use recycled materials where possible (CH 3.8)

W-I6. Optimize accessibility and removability of parts and sub-assemblies (CH3.8)

W-I7. Minimized complexity of the product in terms of functionality, assembly, appearance and materials composition (CH 3.8)

W-I8. Use standardized parts where possible (CH 3.8)

W-I9. Facilitate DIY adaptions where possible (CH 3.8)

3. Conceptualization

The requirements and the gained knowledge from the research phase acted as the design space for the conceptualization. During the analysis phase, two critical bottlenecks were identified:

- Sliding mechanism
- Adjustability mechanism

These needed to be redesigned and function correctly to ensure a viable product. To address these challenges, two distinct design sprints were conducted, each dedicated to one of the principles. Furthermore, we identify the seat half, the cushioning and the base. As for these remaining three parts, their working principles were already established, but further detailing was required. These components will be addressed in chapter 4: Embodiment.

3.1. Sliding mechanism

This design sprint focused on the sliding mechanism, which was experienced as insufficient due to the tilting effect as illustrated in chapter 2.1.2. The goal of this design sprint is to optimize the sliding mechanism, resulting in an optimal fit for the user.

The following approach was used: First, Callens' sliding mechanism was explored and different fasteners were used. Then, the analogy method was used to find situations where the problem has successfully been solved, transforming these relationships to fit the problem (van Boeijen, Daalhuizen, van der Schoor, & Zijlstra, 2014). The two most promising concepts were made into prototypes to evaluate their function.

Goal: Make a robust system that enables the two halves constituting the seat to slide to different sizes in a seamless way.

Concept 1. Revised straight slots

To explore the potential of Callens' prototype, some adjustments were made to evaluate the sliding mechanism. Custom hardware was made, with pieces that are connected to the seat halves, with a bigger surface area than the previously used carriage bolts. This way, the tilting effect is minimized. A rigid base was created to better slide. Both changes are shown in figure 16.

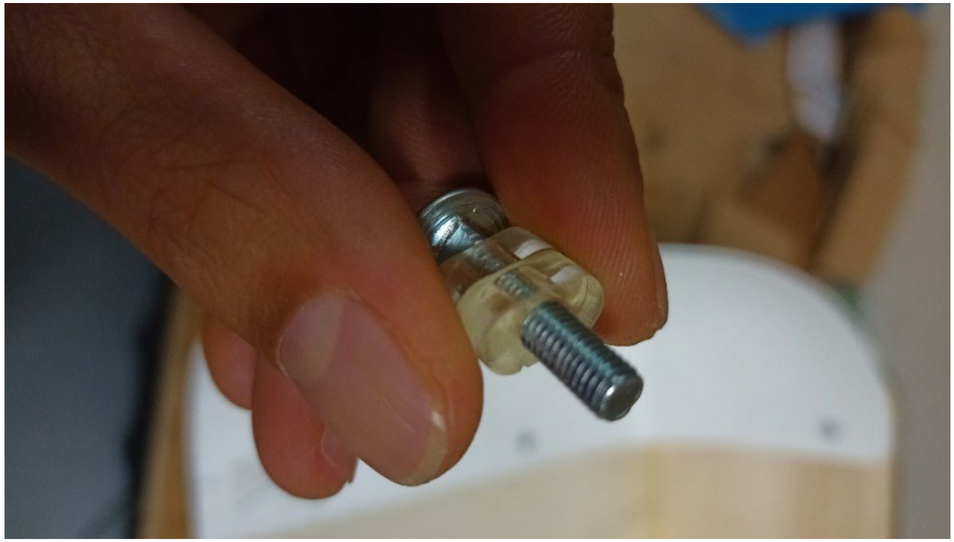


Figure 16: Changes made in Callens' prototype to evaluate the working principle

Concept 2: Rails

For the second concept, linear guide rails were used to make the seat halves slide vertically (see figure 17). Linear bearings are connected and the halves were connected to this beam. For this test, bearings were used, but the envisioned bearings are without steel parts to avoid corrosion.

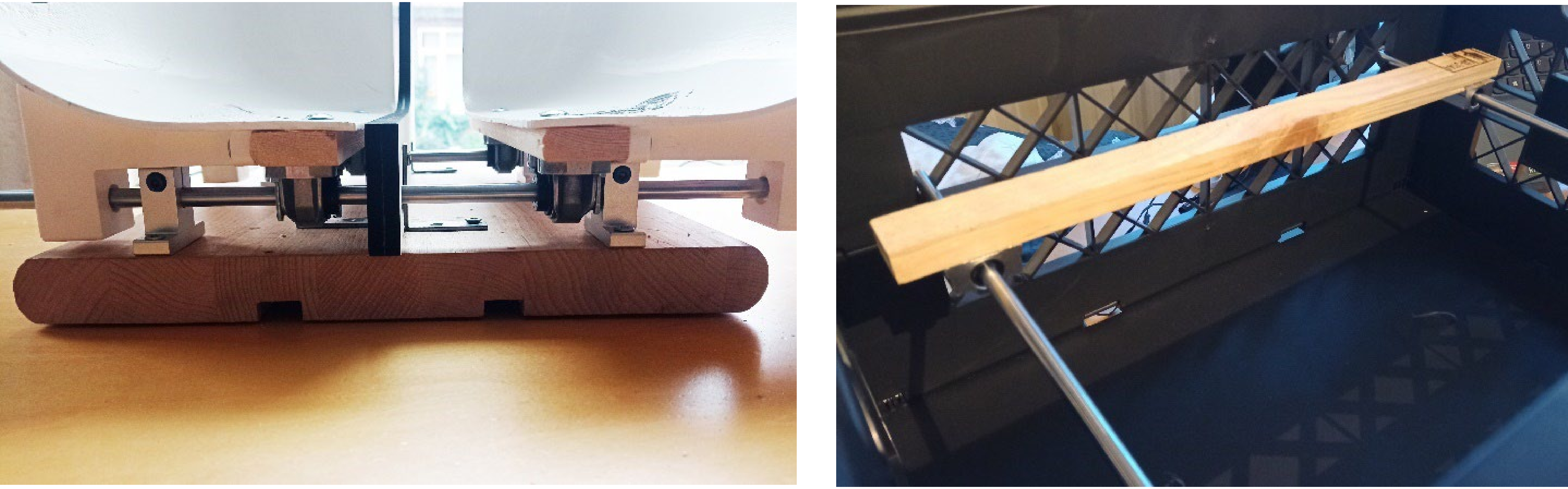


Figure 17: Linear guide rails

Evaluation

A quick test was done, both models were evaluated by sliding the seat halves into the smallest and widest state. A Harris profile (van Boeijen, Daalhuizen, van der Schoor, & Zijlstra, 2014) was done to choose the most promising idea (figure 18). The two concepts were ranked on strength, smoothness, costs, simplicity, lifespan and repairability. The linear guide system was the most efficient, strength wise and regarding smoothness. It also has the longest lifespan, since wearing parts can easily be replaced, although this might not be necessary due to their optimization for this cause. The costs go hand in hand with simplicity, so this must be considered during production.

Conclusion

The rail system is preferred over the revised slots system. The use of a more rigid base improves the overall design. The use of carbon for this part is over dimensioned since the only function is fixing the seat. The parts used to adjust the seat should not be able to easily come loose. The system was discussed with Willem Hooft and is chosen for development.

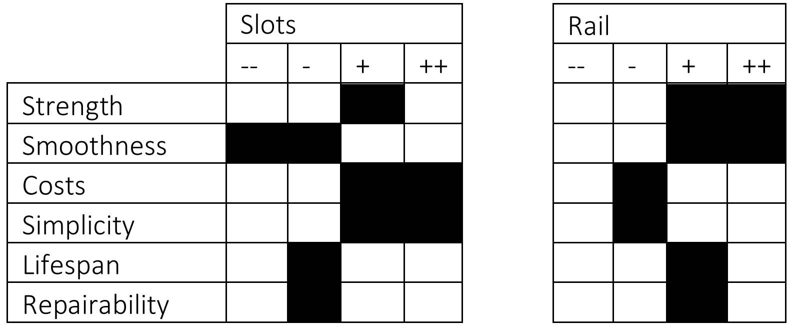


Figure 18: Harris profile

3.2. Adjustability mechanism

Callens' did several design sprints, of which a lot was relevant for the sitwake seat as well. These ideas were taken as an inspiration source and reviewed with the new requirements in mind. SCAMPER, an ideation method, was used to alter existing ideas that did not fit the new requirements. A visualization of the approach is shown in figure 19.
However, to start fresh and diverge instead of following the beaten path, a brainstorm session was done together with two former IDE students. The participants were presented with the following goal but did not receive any extra background information:

Goal: Make an adjustability mechanism which is easy to operate, user friendly and quick.

The following how-to's were used to produce ideas: How can you adjust a seat in width? How can you easily assemble a seat? The outcome of this brainstorm can be found in appendix D.
Two main directions were established: One where the system is secured when the user is in the seat, the other one secures the system when the user is out of the seat.

Callens' ideas were analyzed to see how they can be used for the development of the sitwake seat. To be able to do so, the most significant differences were isolated from the program of requirements and kept in mind:

B1. The seat should be attachable to the ATI frame, the SWAIK frame and the Wolturnus frame.
B2. The SWAIK universal backrest should be attachable to the seat.
B3. Broken parts should be easily replaceable.
C5. The seat is not equipped with straps by default.
W-E3. Changing the size should take as little time as possible.

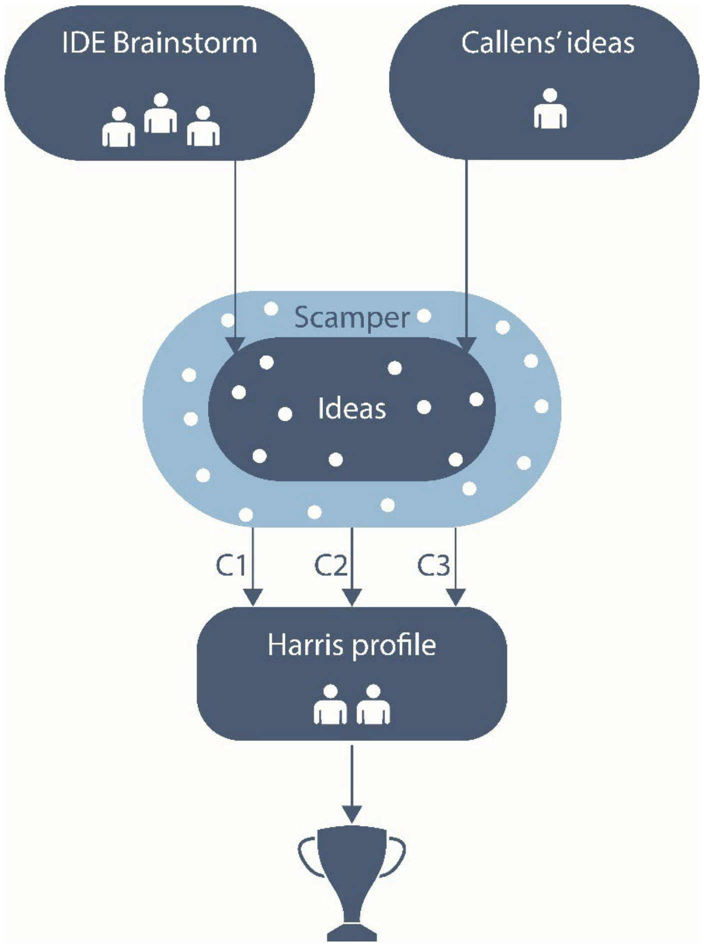
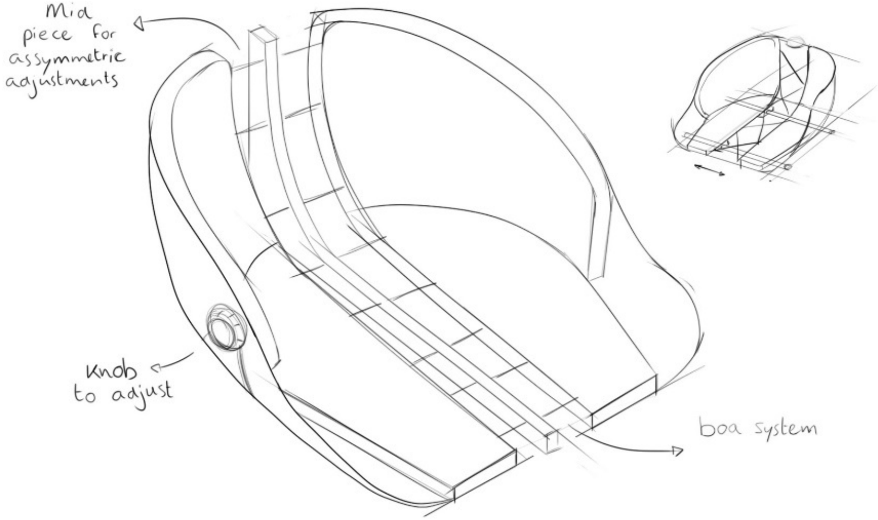


Figure 19: Approach visualization

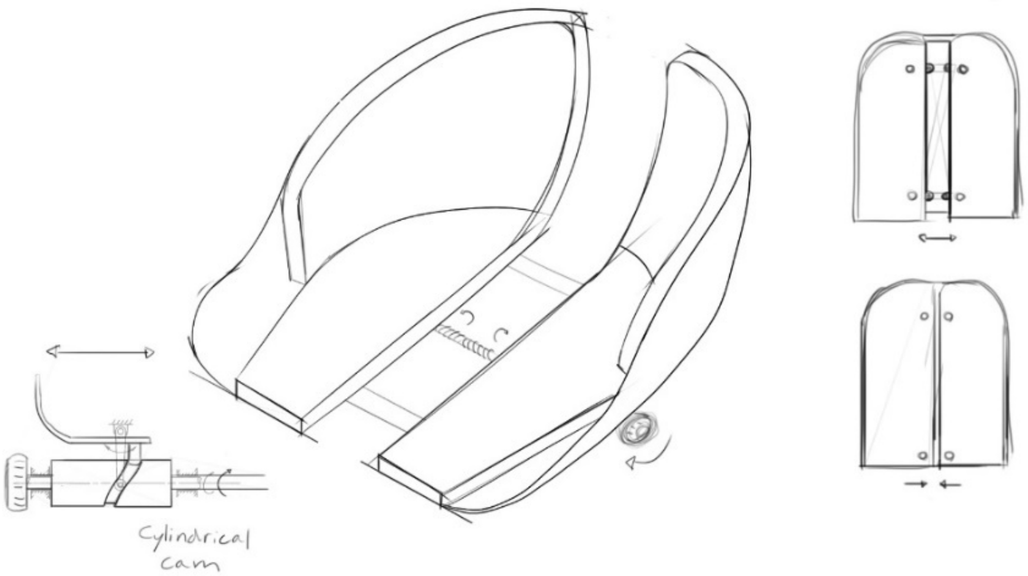
Concepts

The ideation presented in the preceding paragraph resulted in the development of the following concepts. The top right concept makes use of the boa system, a lacing system which is also commonly used in snowboard shoes. The bottom left makes use of a worm wheel, or cylindrical cam. The first two concepts belong to the category 'securing when the user is located in the seat.' The bottom right concept uses clamping levers and belongs to the category 'securing when the user is not located in the seat.'

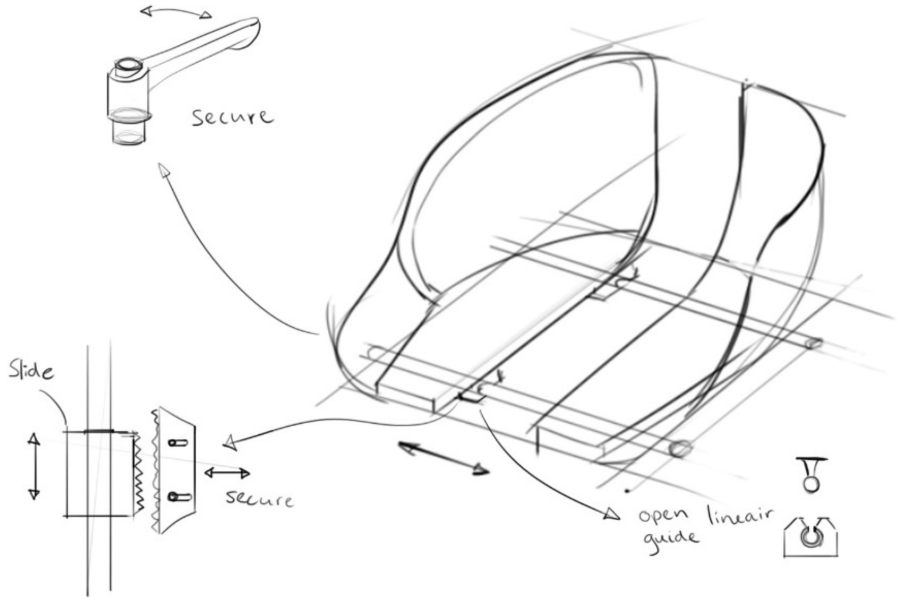
Boa system



Worm wheel



Clamping lever



Selection

The evaluation of the three concepts was conducted in collaboration with Willem Hooft. A list of wishes was generated and subsequently ranked based on their perceived importance. These prioritized wishes were then utilized to construct a Harris profile, which is presented in figure 20.

The clamping lever concept was disregarded due to the preference for adjustability while seated. The ease of adjustment is significantly compromised when users are required to make adjustments before taking their seat. Considering the similar scores obtained for the boa system and worm wheel concepts, both were selected for further development. To assess the working principles of these systems, test models were fabricated using rapid prototyping techniques.

	Boa system				Clamps				Worm wheel			
	--	-	+	++	--	-	+	++	--	-	+	++
Ease of adjustability			■	■	■	■					■	■
Usability			■	■	■	■					■	■
Estimated costs		■					■	■		■		
Simplicity			■				■	■			■	
Robustness	■	■	■	■	■	■	■	■	■	■	■	■
Minimized amount of loose parts	■	■	■	■	■	■	■	■	■	■	■	■
Stiffness			■				■				■	■
Time to adjust seat			■	■	■	■					■	■
Tailored fit			■				■				■	■
Lightweight			■				■				■	
Minimized amount of extra tools			■	■			■	■		■		

Figure 20: Harris profile

Testing

To evaluate the working principles of the different concepts, a prototype was built for both the worm wheel and the boa system, which both scored similarly on the Harris profile.

Goal: Make the adjustability easy, user friendly and quick.

The wooden base with the rail system is used for both concepts.

Concept 1: Worm wheel

To imitate the working principle of a cylindrical cam, a screw thread with star knob is used (see figure 21). The nut is attached to the part of the seat that slides over the rail. The principle was validated, the placement of the thread in the middle worked well. The problem was the number of rotations needed to adjust the width. Due to the small pitch of the thread, the time needed to adjust to the smallest width was still relatively big. The small pitch did allow for the system to be self-locking. When using this system, the following things should be kept in mind:

- System should be self-locking when not rotating.
- The knob should not stick out too much (kite lines could get stuck).

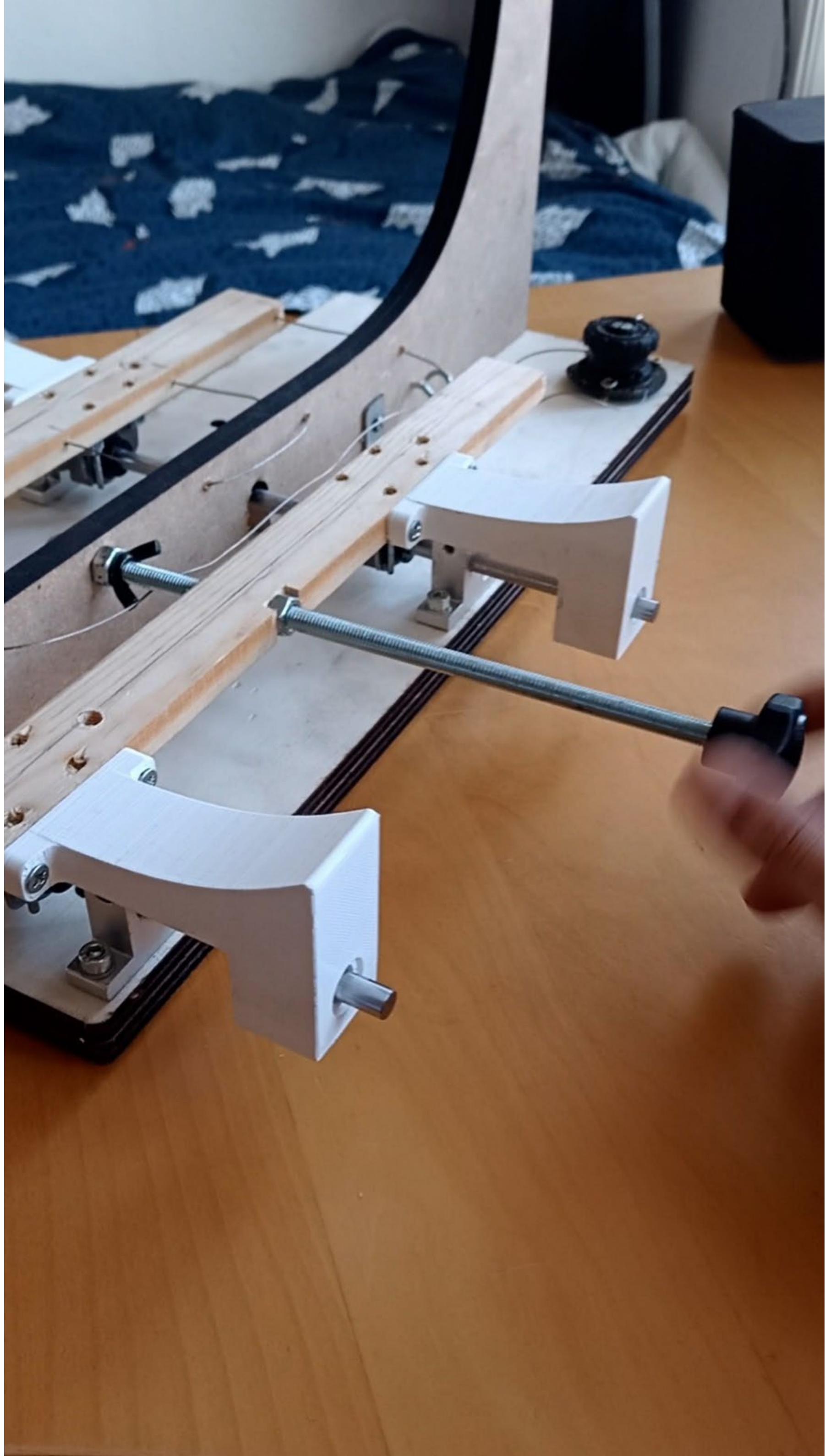


Figure 21: Worm wheel prototype

Concept 2: Boa system

The boa system makes use of a system that is already commonly used in the outdoor sports industry, e.g., safety shoes and snowboard boots. A rotating knob shortens a steel cable which is attached to the sliding seat half. As can be seen in figure 22, the knob is located under the seat. In the envisioned design, the knob is placed on the side of the seat half, so that it can be easily reached, improving the ergonomics of the design.

Conclusion

Both tests showed the feasibility of the two concepts. Regarding strength, the worm wheel is stronger than the Boa system, but as discussed with Sander Minnoye (an expert on the field of dynamics and mechanics), it is expected that both systems will withstand extreme situations.

However, Boa was contacted to see what a possible collaboration would look like, but they stated that they do not want to be involved in water sports and that a collaboration is not possible. Since they patented the technology, the boa system concept was declined, which logically led to the use of the worm wheel system.

Furthermore, after discussing with Willem Hooft, the protruding rails could potentially form a hazard for kite lines getting stuck. In the next version, these should be eliminated.

Figure 22: Boa prototype

4. Embodiment

The embodiment phase includes the activities of designing, prototyping, testing and iterating on multiple prototypes. The product has been systematically deconstructed into components that went through several iterations. In chapter 4.1, the evaluation of the first iteration is explained. The outcomes of this test are explained in 4.2, these improvement points are used for the final design proposal in chapter 5.

The initial concept sketch was iterated upon and resulted in two experimental prototypes illustrated in figure 23. The main differences between the two iterations are shown in the table below.

Part	Callens' prototype	First iteration	Second iteration
Base	3D print	Wood	Aluminum
Seat halves	3D print	Glass fibre	Glass fibre
Cushioning	-	EVA foam + Yoga mat	EVA foam
Adjustability mechanism	Slots, bolts and nuts	Right hand leadscrew with gears	Left & right-handed leadscrew
Sliding mechanism	-	Rails and plastic bearings	Rails and plastic bearings

Table 5: Iterations on component level

Process

The concept was divided into components and each component was subjected to several design iterations. The objective of the component's iterations consisted in reaching a satisfactory level of an experimental prototype; "a refined prototype that accurately models physical components to enable collection of performance data for further development" (Evans & Pei, 2010). Once this level was reached, a test was done for validation which is shown in chapter 4.1. Improvements were needed to accurately collect performance data, which resulted in a second iteration. The use of wood affected the flex of the seat and the gear orientation changed the location and thus the use of the adjustment rod.

This second iteration was prototyped for extra testing. However, due to time constraints, testing with this prototype was deemed outside the scope of this project.

For a comprehensive overview of the prototyping process and the different iterations, refer to appendix E.

Figure 23: Two experimental prototypes.
The bottom one is the last version

4.1. Experimental prototype test

To evaluate the design, the first iteration was made though prototyping and a usability test was conducted in an operational environment. The goal is to show the feasibility of the seat and to evaluate the usability of the design, to improve it. Rapid prototyping was used to eliminate early assembly problems and to make quick iteration cycles. The downside is that the material used for the test is not the envisioned material, however it was discussed with experts to be structurally strong enough for the user test.

Goal:

- How does the new design perform compared to the Tessier seat?

- How can the seat be improved?

- What use cues are used?

Method

To evaluate the prototype of the new adjustable sitwake seat, a mix of methods was used to reflect on the design. The approach consists of a product usability evaluation and a semi structured interview with the test persons to gain insight into the intended and unintended use of the seat which can be found in appendix F. The results are used for the final design.

Three men participated in the study, from which two had no or limited leg function. Both had prior experience with sitwaking. The other participant had no prior experience with sitwaking and had no disability. Due to the limited amount of time, a pilot study could not be performed in time.

The research team consisted of two people, both wrote down observations and took notes, one took pictures for analysis afterwards.

Figure 24: Participant seated in prototype

The study was conducted at a Wet ‘n Wild, a wakeboard cable park. Participants were first asked to give consent (appendix G). Participants first changed into their wetsuits and put on protective gear like life vests. They were asked to sit in the seat (figure 24) and to adjust the width of the seat to their liking. After adjusting, seat size was noted.

During the second stage, participants (N=2) used the sitwake on the water. The sitwake was placed on the slide start (figure 25) and the participant was asked to sitwake. Participants were slightly pushed onto the water to withstand the pulling force at the beginning. During the first two stages, pictures were taken and notes were taken while participants were asked to think aloud. This part took 90 minutes. After both stages, participants changed back into their clothing and the interview was held at a restaurant located next to the cable park. The interviews took around ten minutes per participant.

Results

The results of the study showed that while the seat prototype was generally well-fitting and comfortable, there were several areas in which it could be improved. Specifically, participants noted issues with the construction of the seat, including its rigidity and the use of too many parts. Additionally, it was found that tightening the seat to a comfortable level was difficult, due to the limited sensitiveness in the hips and legs of one of the participants.

Several suggestions for improvement were put forth based on the feedback provided by participants. These included reducing the number of parts in the seat design, supporting the fiberglass more effectively and reinforcing the corners of the seat to prevent breakage. The addition of a strap to attach to the seat, hand rests on the side of the seat and a buckle or Velcro to connect the top of the seat were also proposed as potential improvements.

The wooden base cracked slightly. The flex of the material enabled the top of the seat halves to bend outwards a bit.

Figure 25: Participant in start position

4.2. Evaluation

The usability test described in the previous chapter focused on identifying areas of improvement and providing recommendations for enhancing the user experience. This section presents the findings of the usability test and outlines key recommendations.

Eliminate the rope

After testing with beginning and experienced participants, the idea occurred to eliminate the rope as discussed in chapter 2.7. Both participants had no trouble starting. One of the participants had a lot of prior experience, the other participant did not have prior experience. When comparing sitwaking to waterskiing, the start is remarkably similar. Eliminating the rope stimulates the beginner to learn a better posture in the beginning. The cable operator can help the beginner by pushing them on the water, a technique which is also used with beginning wakeboarders and water-skiers.

Minimize weight

Getting the seat onto the boat was quite hard because of the weight. Decreasing the weight where possible will result in a more positive usability. Less weight is favorable overall, also when it comes to doing tricks.

Minimize the amount of parts

The number of parts should be minimized to extend the lifetime of the product and simplify it.

This is also in line with the framework of Circular Design of Composite Products, which states that the complexity of the product in terms of functionality, assembly, appearance and materials composition should be minimized.

Add handles to improve the ease of use for the target group

Both participants that fitted the target group had trouble adjusting themselves once they were already in the seat. They either grabbed the back of the seat or the side of the seat to adjust their posture (see figure 26). These sides are not ergonomically fitting, a solution would be to add handles to the side.

Figure 26: Participant adjusting their posture

Place the knob to the side of the seat

Two of the three participants preferred the knob on the side of the seat rather than in the front. This positioning prevents potential interference with the lower legs of the participants during use. The current adjustment of the seat is illustrated in the image below.

Figure 27: Adjusting the seat with the knob in the front. In this case a ratchet is used.

Let an instructor adjust the seat

For extra security it would be favorable to let an instructor do the adjustments. The problem that occurred is that one of the participants did not feel when the seat was too tight. This can potentially crush the hips of the participant. This was partly due to the ratchet, which is made to exert a large force. The size of the knob could also solve this problem. Another option is to have the option to disconnect the knob, so that the instructor is the only one who can adjust the system.

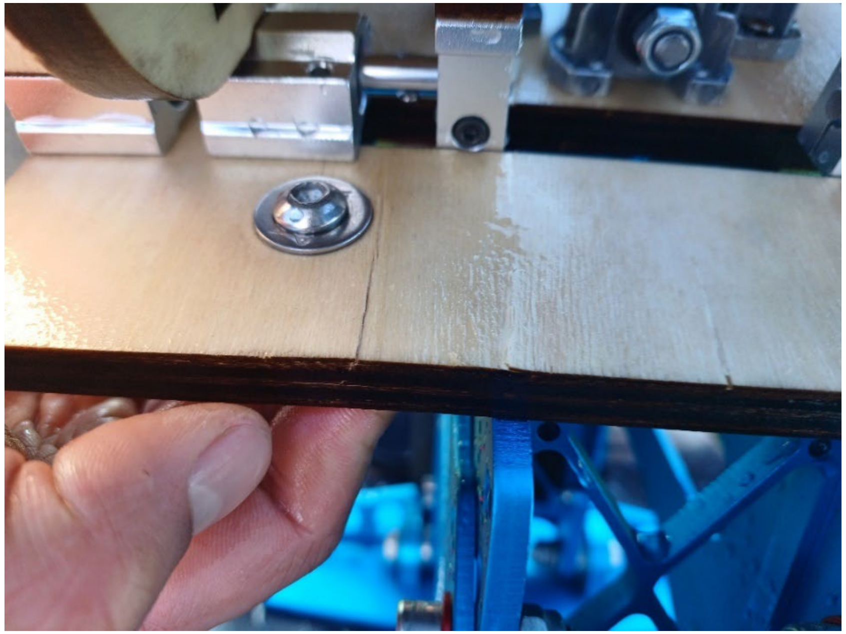


Figure 28: Cracked wooden base

Improve the base

As was already discussed before, wood was not the ideal material for this specific use but was utilized because of the ease of prototyping with the limited time. The wood cracked at the end of the test. Although another material already solves the problem, aligning the bearings with structural part of the frame increases the strength, regardless of the material.

5. Final design - Wakemate

Wakemate is a user friendly, tailored, safe, and circular sitwake seat.
In the following chapter, its key features are explained and the choice of materials and manufacturing processes. Finally, a cost estimation is done.

5.1. Unique selling points

Adjusting time

The time needed to adjust the system went from 10 – 15 minutes in the products currently on the market, to 30 seconds. This works by rotating an axis that is connected to a leadscrew as shown in figure 29, that moves the two seat halves in opposite directions. This can only be done with a torque wrench which will be available at the dock or at kite schools.

Safety

The torque wrench is used to safely adjust the width to the hips of the user. One of the physical tests pointed out the potential danger of not feeling how tight the seat is secured.
Attachment points for a strap are built-in, but the seat is equipped without straps by default. This allows users to quickly leave their seat when they fall, reducing the feeling of anxiety and stress.
An ABS casing is designed to prevent kite lines from getting stuck in the mechanism.

Usability – adjustability mechanism

Next to the reduced time, the position of the user which is needed to change the width has also been improved. Previously, one had to duck to get under the seat to adjust it or lift it to eye level. Now, the user can adjust the seat while seated, as illustrated in figure 30. This is not only more comfortable, but also leads to a tighter and more tailored fit.

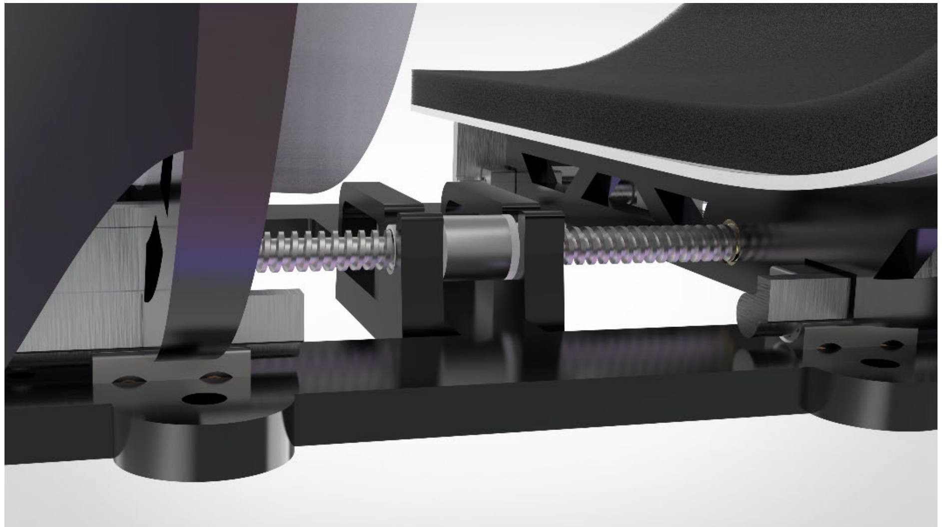


Figure 29: Adjustment mechanism

Figure 30: Posture during adjustment

Usability – Autonomous feeling

User tests showed that participants adjusted their position by grabbing the side of the seat and lifting themselves. In the final design handles are placed to improve this process. The placement is done in a way that the handles do not interfere with back support. It is expected that this will increase the feeling of autonomy.

Circularity

To increase the circularity of the design, all parts of the seat are optimized for accessibility and removability, making it easy to replace a single part instead of having to replace the whole product. Reversible connections are used where possible. However, the structural base is composed of welded aluminum to increase the strength and the lifetime of the product. For the sliding mechanism and connections, standardized parts are used.

Figure 31: Handle

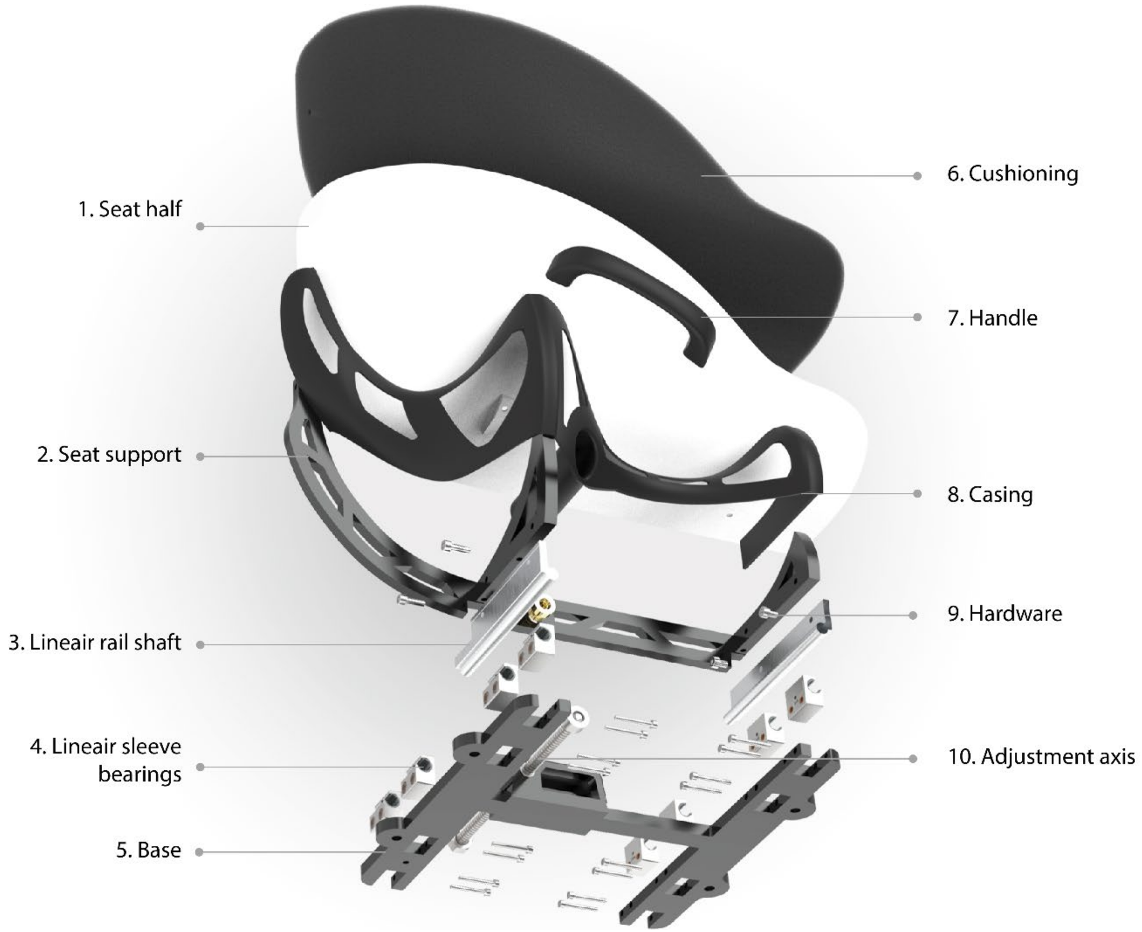


Figure 32: Exploded view

5.2. Manufacturing

The seat consists of various parts, which are shown in the exploded view in figure 32. The production process along with the material choices are explained for every part in the following chapter. We separate custom parts and buy-in parts, starting with the customs:

5.2.1. Custom parts

Cushioning

The cushioning is made from Ethylene-Vinyl Acetate, a closed cell foam. This is the foam that Callens recommended and the foam that was used in the user tests, which proved its viability. The closed cell structure makes sure it does not hold water, which positively influences the weight and buoyancy of the product. EVA foam is already widely used amongst watersports products (MOREVA, n.d.). The foam can either be thermoformed or injection molded. (Clous, 2015). However, starting with a small quantity, it can also be made by heat shaping, which is explained in appendix E.

Seat half

The seat is made from composite material, fiberglass mixed with epoxy. It will be manufactured by hand using the wet lay-up method, where strips of fiberglass are wet with epoxy and manually put over a mold. (Easy composites, n.d.). The orientation of the fibers will be multidirectional to acquire strength in multiple directions, which is needed to absorb forces in multiple directions, since users can fall in multiple ways. Fiberglass is chosen for the good costs versus strength ratio. The outside is gel coated to make the outside smooth and prevent injuries.

Casing

The protective case is made from injection molded plastic. Companies like Plasticbank (2023) integrate reprocessed ocean-bound plastic feedstock into products. Since the case only protects the mechanism from kite lines getting stuck in between, the plastic does not have to have excellent mechanical properties.

Base

The base is made from 7020 anodized aluminum which can be cut with a water jet cutter. Anodizing is used to create a thick oxide film to give a protective layer to the aluminum, to prevent corrosion in the salty environment the product is used in. It also prevents galvanic corrosion.

Figure 33: Marks on the base of the first iteration to indicate the size

Aluminum is light, cheap, strong and easily recyclable. Parts can be 2D CNCed, holes are drilled afterwards. After the machining process, the whole piece is anodized. The support for the adjustment axis is welded onto the base to decrease the number of loose parts and increase durability, this is the part where the sleeve bearings connect with the base. Etched marks on the base give an indication of the size. This will be comparable to the marks on the first iteration as shown in figure 33. Etching allows to keep the material's high resistance to corrosion and abrasive wear (Laserax, 2022).

Seat support

The seat supports are made from the same 7020 aluminum. The vertical and horizontal supports are welded to increase stiffness and durability. Topology optimization will be used to determine the optimal material versus strength ratio. For now, random holes are created for visual resemblance. The seat support is fixed to the linear rail shaft with stainless steel Allen bolts.
The externally threaded nuts (see figure 34) are bolted into the seat support. To make sure they are secured, set screws are used to prevent them from coming out again.

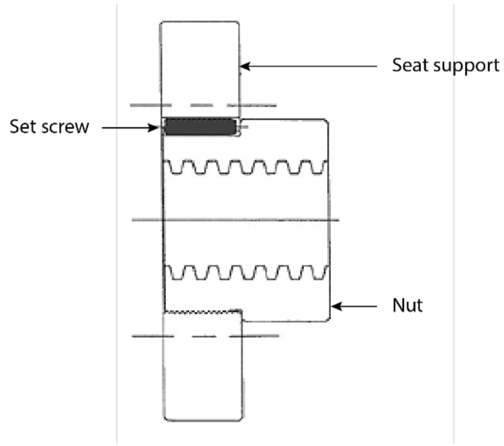


Figure 34: Secured externally threaded bolts. The set screws prevent the nuts from unscrewing. Image originally from Roton Products (2019).

5.2.2. Buy-in parts

Sliding mechanism

The rails consist of a rail made from stainless steel and pillow blocks made from stainless steel housings and plastic bearings. The combination of materials is excellent for the use conditions. One pillow block can withstand a vertical force of 3,8 kN, this effectively withstands the forces exerted on the model during extreme usage conditions (Igus, n.d.).

Adjustment axis

The adjustability axis is portrayed in figure 35. It consists of a left- and right-handed leadscrew, which can be rotated by hand using a torque wrench. Using a torque wrench, the exact force can be defined to not clamp the user too tight. Using both left- and right-handed thread allows the user to rotate the rod at one end, for both seat halves to simultaneously move in- or outwards.
The combination of materials is chosen for their optimal wear resistance and resistance to the environment, including galvanic corrosion: the phenomenon where one metal corrodes when it comes into electrical contact with another metal. The anodization process for aluminum prevents galvanic corrosion. The lead screw is made from stainless steel. The coupling part prevents the axis and thus the seat halves from moving off-center. The sleeve bearings are made from polyamide (nylon) for excellent gliding abilities and wear resistance.

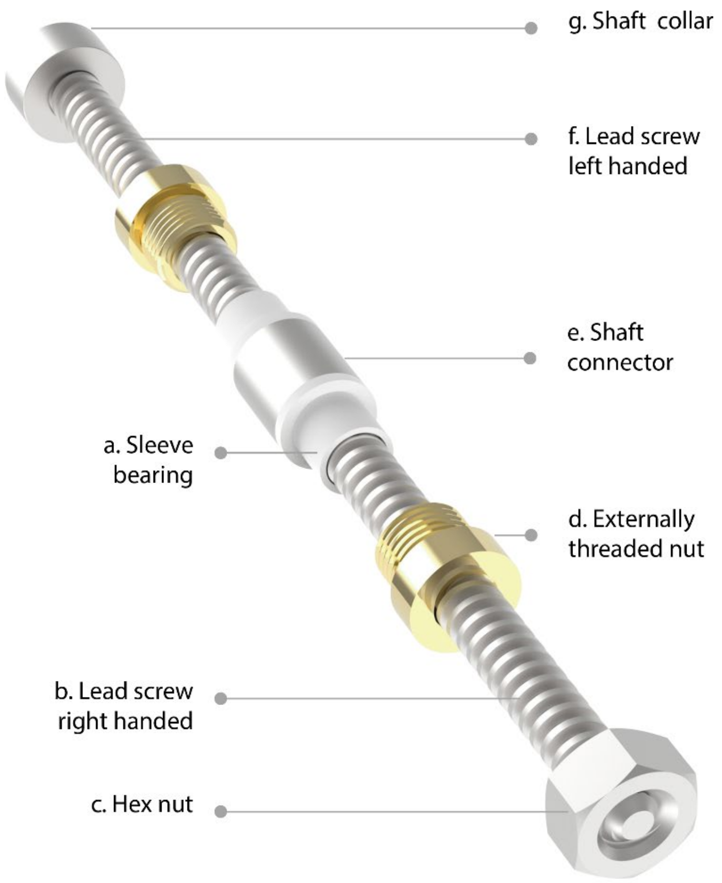


Figure 35: Adjustability axis with all its components

5.3. Cost price estimation

Contacting Tessier, they mention not having any exact data on the number of users. They estimated to sell around 450 seats each year, this includes seats for sitwaking and for sitskiing.
To provide an estimation, the cost price analysis takes into consideration a low volume scenario. Given the potential interest from both cable parks and kite schools, the initial batch size is projected to be approximately 100 units.

To make an estimation of the price, the product is divided in five main expenses: Aluminum parts including the base and the seat supports, the seat halves, the cushioning, the casing and buy-in components. Refer to appendix H for the details. Quotations are requested from manufacturers, comparable products are reviewed and buy-in components are found on several web shops and wholesale sites. A more detailed calculation can be found in appendix H.

Accumulated, this results in a cost price of around €465.-

Note that this price is calculated for all components, but for example exclude expenses such as assembly costs, overhead costs, labor costs, postprocessing and shipping of parts.

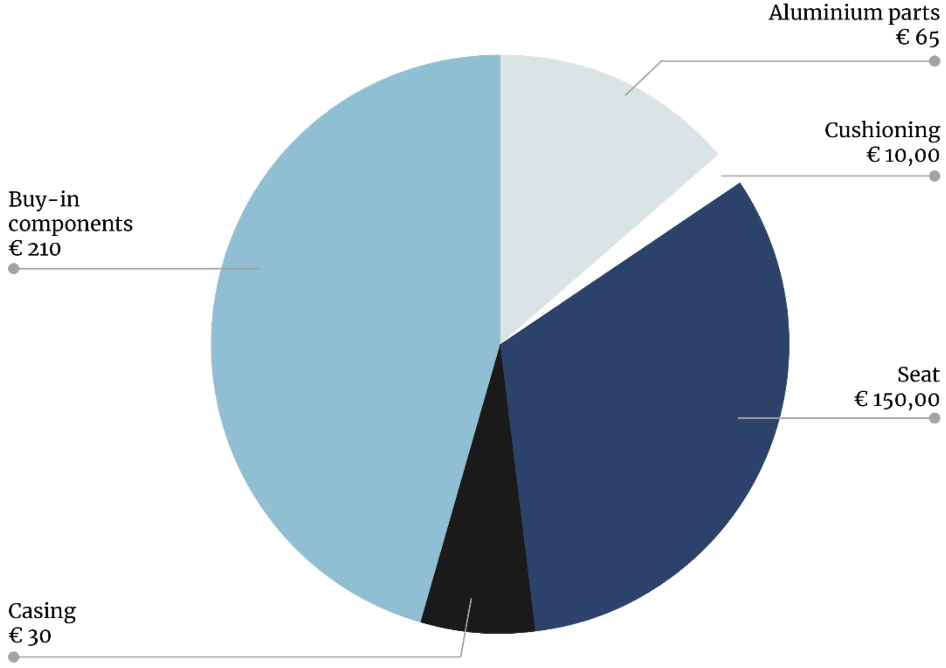


Figure 36: Cost overview

6. Recommendations

For the continuation of the project, the following recommendations are in place:

Conduct more tests with the target audience. During the final test, only one disabled sitwaker used the product, too small a sample may prevent the findings from being extrapolated. It is crucial to gather feedback and insights from the intended users in larger numbers. Conduct user testing sessions to observe how they interact with the prototype, identify any pain points or areas for improvement and incorporate their feedback into the design. This can be done by for example bringing the current prototype to test days for user observation. A similar approach as in chapter 3.3 can be used for this. It is recommended to test both with cable parks and kite schools.

Once satisfactory results come out of these tests, continue producing a prototype of the final design. This will be a pre-production prototype. For this type of prototype, it is recommended to use production components and to manufacture them in small volumes for testing prior to full-scale production (Evans & Pei, 2010). Pay special attention to the buoyancy of the full sitwake when the seat is attached.

Assess the market demand and devise a market strategy: Conduct market research to evaluate the demand and competition in the target market. Based on this analysis, develop a comprehensive strategy for launching the product successfully, including pricing, distribution channels and marketing tactics. Due to limited resources and time, this topic has not been assessed thoroughly. One idea is to find an SPD student to start a new project.

Perform a corrosion test: Subject the final design to a corrosion test to assess its resistance to certain environmental conditions, including temperature, humidity and salt water. If galvanic corrosion occurs between the brass and the stainless steel, try to source a stainless steel nut. This will work regarding the avoidance of galvanic corrosion, however, it is important to note that it may also lead to an increase in cost.

Evaluate the forces acting on the system: Analyse and quantify the forces that will be exerted on the system during extreme use. The frame from ATI sports contains an air-oil damper and can be used to accomplish this: Measuring the compression of the damper during extreme use (e.g., p95 making a high jump) to calculate the maximum force. This evaluation will help ensure that the design can withstand the expected loads and operate reliably.

When these forces are calculated, a collaboration with mechanical engineers is advised to analyse the structural integrity, stability and performance of the product. The base needs calculation to see if it will withstand extreme situations, ensuring that the design meets safety standards and requirements. The structure of the seat is too complex for FEA and needs real life testing.

Source cost-effective materials: Explore options for sourcing affordable yet reliable materials for the manufacturing process. Research suppliers, compare prices and evaluate the quality of materials to find the best balance between cost and performance. This goes hand in hand with making a new final prototype before launching the product.

Take another look at the circular economy and the ecodesign strategy wheel (mentioned in chapter 2.8) while choosing manufacturing processes, suppliers and materials. Some recommendations from the model are only applicable to later stages of the design cycle.

7. Reflection

Throughout the course of this project, I have gained valuable insights and experiences that have significantly contributed to my growth as a designer. Reflecting on the various aspects of the project, several key points stand out.

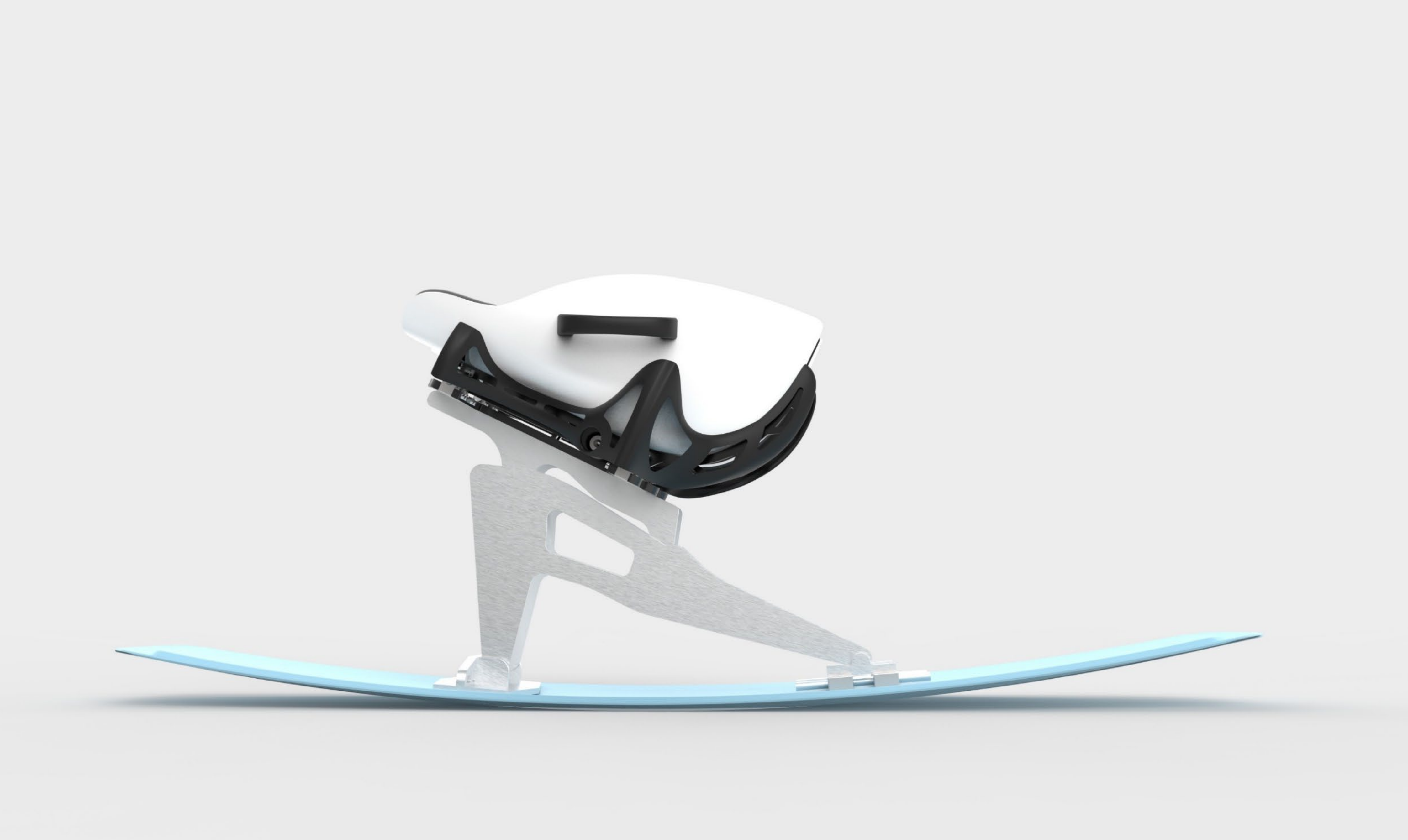
First, I would like to point out the time in this project dedicated to prototyping. It was a deliberate decision to spend a large portion of the project timeline to prototyping and I am pleased to acknowledge that this approach met my expectations. The hands-on approach kept me motivated throughout the project and enabled me to refine and iterate on the design more effectively.

Another aspect was the balance maintained between stakeholders. Open communication played a central role. One of the biggest sources of motivation throughout the project was the appreciation of the target group. Their enthusiasm brought a sense of purpose and passion into the project. This mindset allowed me to view the project as a tool to create value for the end-users, making the journey more rewarding. This is something I never experienced to this extent during a design project.

Furthermore, leveraging the expertise of professionals and seeking guidance from the right individuals proved to be very helpful. By acknowledging my limitations in certain areas, I could spend more time to the aspects where I could make the most impact, thereby maximizing the value of the outcome.

There are certain aspects I would consider changing in future projects. Firstly, finding the right balance between budget, deadlines and expectation management is crucial. In hindsight, allocating more time and resources to manage unforeseen challenges and unexpected iterations would have alleviated some pressure and improved overall project outcomes. Reflecting on my experience with planning during this thesis project, I must admit that I faced significant challenges and struggled to effectively manage my time and resources. It is essential to acknowledge these shortcomings and draw lessons from them for future projects.

The process of structuring the report posed significant challenges for me, considering my chaotic approach. However, I am grateful for the support and guidance provided by my supervisory team, which greatly assisted in achieving a well-organized and cohesive outcome. I am proud of the final result and the efforts made throughout the process.



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Appendix A: Design brief

DESIGN FOR our future

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy". Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Tuankotta

initials: D   given name: Daniël

student number: 4359143

street & no.:

zipcode & city:

country:

phone:

email:

Your master programme (only select the options that apply to you):

IDE master(s): [x] IPD   [ ] DfI   [ ] SPD

2nd non-IDE master:

individual programme: - - (give date of approval)

honours programme: [ ] Honours Programme Master

specialisation / annotation: [ ] Medisign [ ] Tech. in Sustainable Design [ ] Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: Ruud Balkenende   dept. / section: HCD/AED

** mentor: Ruud Balkenende   dept. / section: SDE/DfS

2nd mentor: Willem Hooft

organisation: Willem Hooft Foundation

city: country: The Netherlands

comments (optional)

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

Design of an adjustable sit-wake seat

project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 02 - 11 - 2022 10 - 04 - 2022 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

- Context

Sitwaking, also known as G-waterski, seated waterskiing or disabled skiing, is an adaptive sport derived from wakeboarding and waterskiing. This can both be done behind a boat or at a cablepark (WSV, 2022). The sport targets people with a physical handicap; leg amputees or people with leg disabilities (IWWF, n.d.); individuals with bilateral lower limbfunctional impairments, including persons with spinal cordinjuries, spina bifida, or bilateral lower extremity amputations. (De Luigi & Cooper, 2014).
In the current situation, companies that offer the possibility for people to sit wake have to purchase seven different seats, in order to accommodate for anthropometric variety the possibility to practice the sport (Hooft, 2022).

- Stakeholders

The project is set up in cooperation with the Willem Hooft Foundation. This is a foundation that contributes to making adaptive sports more accessible for everyone with a physical disability. The Willem Hooft Foundation actively contributes to lowering these thresholds by making safe and affordable sit-kitesurfing material available, offering teaching methods and information, and helping to organize wakeboard clinics and kitesurf camps for people with physical disabilities (Hooft, n.d.).

Earlier this year, an IPD graduate Marinke Callens did a project on the design of an adjustable sitkite seat with the use of 3D scanned data of the target group (Callens, 2022). Her research will be used as a base for the development of a new product for sit waking. In consultation with Willem Hooft, the switch was made from a sitkite seat to a sitwake seat, because wakeboarding is a more accessible sport with more supporters, giving the development a higher chance of success. (Hooft, 2022)

The fieldlab Ultra Personalized Products and Services (UPPS) supports companies and organizations in setting up the (re)design process and the production of personalized products, with the use of 3D scanning techniques, the development of measurement systems, parametric design and flexible production techniques such as 3D printing (Fieldlab UPPS, n.d.). This fieldlab is part of the TU Delft.

Other important stakeholders are the international waterski and wakeboarding federation (IWWF), companies that use and rent the equipment and offer lessons (cableparks, boat rentals), instructors and the government for funding.

- Limitations & opportunities

The seats that are currently available on the market come in 7 sizes and cost around 1500 euro per seat. (Tessier, n.d.). If a company wants to offer lessons it requires a huge investment in material. By making an adjustable seat, it becomes more financially interesting. This increases the inclusivity within the sport. Limitations are related to the small size of the target group: Small market, and limited availability of test persons.

space available for images / figures on next page

introduction (continued): space for images

image / figure 1: A sit-waker in action

image / figure 2: The complete setup

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

This project will focus on the design of a sitwake seat for beginners with a physical disability. The existing alternative are several seats of different size that are not suitable for this context due to the high price per unit. Furthermore, the time to switch seats for different users is perceived as too long. (Hooft, 2022).

Callens' graduation project resulted in a fruitful concept design for a sitkite seat. This project ended with a prototype, but currently no attention has been paid to the functionality, strength and usability of this design. Firstly, this design should be translated to a seat for the comparable adaptive sport sit-waking. Then, more attention should be paid to testing and validating the design, in order to make it ready for manufacturing.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

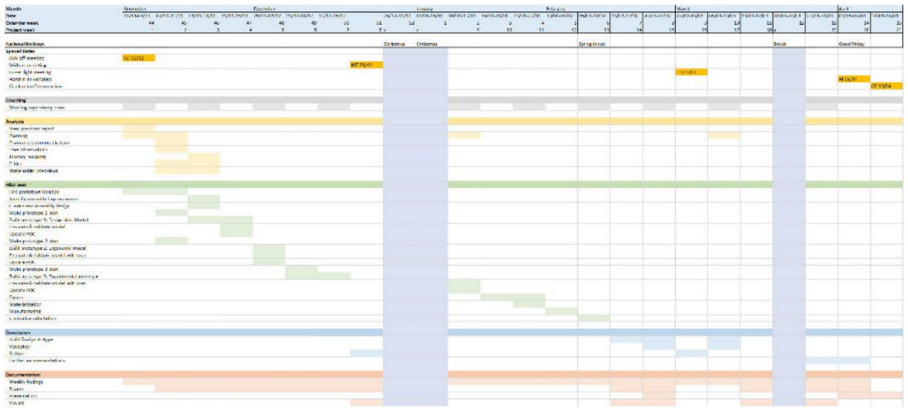
I will design an adjustable sit wake seat for beginners with a physical disability, which is easy and quick to adjust, optimized for manufacturability and extends the life-span of the seat as long as possible.

The assignment starts with translating a 1:1 3D model to a testable prototype. The end result will be a tangible product, ready for manufacturing. Emphasis will be put on minimizing the footprint and extending its life span. Principles of rapid prototyping will be applied, wherein multiple cycles of iterating and testing should result in an optimized design.

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 2 - 11 - 2022 10 - 4 - 2022 end date



I will work on the project for 20 weeks, ca. 5 days a week. During the winter, the cableparks (test locations) are only open on Sundays, so I will work on some Sundays too. During Christmas I will take two weeks of, and I will plan one extra week off in March.

Because I start with a prototype, the analysis phase will be short. At the same time the first prototype will be made.

The goal is to meet biweekly on a regular basis with at least one of my supervisors of the TU Delft. My final deliverables will include a thesis report, final presentation, video and a physical model.

Important dates:

November 2nd – Kick-off meeting
December 23rd – Mid-term report
March 3rd – Green light meeting
April 3rd – Hand in report
April 10th – Thesis presentation

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

I set up this project because I want to combine my love for watersports with the knowledge I gained from my bachelor's degree IO and master IPD in order to make wakeboarding more inclusive. I might want to work in the sports innovation field after I graduate, so doing a project on this specific topic is of great value for me.

I plan to do multiple iteration cycles in order to practice a lot of rapid prototyping. During my studies and jobs on the side, I found myself in a lot of workshops where I acquired a lot of prototyping skills that I would like to apply in this project.

In previous courses, projects often ended in a concept phase. During several jobs I noticed how important it is to design for manufacturing to cut costs and to facilitate overall manufacturability, I would like to take this opportunity to dive into this subject.

Also, I would still like to learn about project management: The responsibility for the planning and execution of this project, along with the communication with all stakeholders.

Lastly, I've been wakeboarding for about ten years now and I would like to extend my abilities and become a sitwaker as well!

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FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

Appendix B I: Interview with experienced sitwaker

Djemie: Hoelang sitwakeboard je al? Hoe ben je hier mee begonnen?

Participant: 4 jaar ofzo. Ik ben begonnen door ‘to walk again’. Foundation. In België voor mensen in een rolstoel, vooral Dwarslaesie patienten. Organiseren sportdagen, toevallig daarvoor ingeschreven, een watersportdag. Eerste uur waterskiën achter de kabel, daarna blijven plakken voor waterskiën. Er waren niet zoveel inschrijvingen, was blijkbaar niet zo populair. 2 Maanden later was er een initiatie dag achter de boot zitwaken. Waterski Vlaanderen contacteerde mij dat ze tessier zitjes hadden aangekocht. Toen kwamen ze langs de baan om dat te tonen en te promoten. Karin zei dat ze volk nodig hadden die aanwezig is omdat het niet goed oogt als ze alleen staan. Gevraagd of ik kon komen, daar is het begonnen. Eerst niet zo vaak, maar erin gegroeid. Nu ga ik dit jaar elke week 2 x. En heel veel kampen in het buitenland

Djemie: Organiseer je die kampen zelf?

Participant: Dit jaar 1 cursus in België georganiseerd, 5daags. En initiatie dagen, dagen waarop beginners er voor het eerst in aanraking mee kunnen komen.

Djemie: Zie je nu dan ook dat in België de sport meer aanhang begint te krijgen?

Participant: In begin 2 man, 2 jaar geleden. Elk jaar komen er mensen die een paar keer langskomen en dan niet meer terugkeren. Nu 5 man vaste aanhang, die ook hun eigen board hebben aangeschaft.
In het begin waren we in geen enkel kabelpark welkom, behalve oudenaarden. En nu met 4 Belgisch kampioenschap. Categorie binnen wakeboarden in België, sitwaken. Je moet het wereldkampioenschap checken in Thailand, IWWF, op YouTube. Nu hebben ze ons gezien op het Belgisch kampioenschap, en zeggen ze goh we hebben jullie nog nooit gezien. En dan denk ik tuurlijk, want eerst belde ik en waren we niet welkom. Nu zeggen ze chapeau, jullie doen zelfs dingen die wij niet kunnen.

Djemie: Als je valt halen ze je met een bootje?

Participant: Sommige mindervalide kunnen niet zwemmen. Benen kunnen geen temperatuur regelen. Daardoor raken ze snel in shock, snel trillen. Duurt een half uur eer dat wij terug op dat dok zijn. Want jij zwemt dan terug naar de naar de dock in plaats van naar de kant natuurlijk. Ja ja, dan moet je terugzwemmen naar het dok, want ge kunt niet naar de kant want wij kunnen niet lopen van de kant naar het dock.
Djemie: Ben jezelf als in die baan in Thailand geweest trouwens, waar ook het WK is?

Participant: Nee kan ik niet betalen al het vliegticket. Allee ja, ik ging normaal mee. Ze hebben allemaal gevraagd of ik meeging tot de jury toe, maar ja, ik kan het gewoon niet betalen.

Djemie: Ik weet wel dat ze daar van die van die mopeds hebben die en dan halen ze je op met je board en dat brengt ze je terug naar de dok. Dat is daar de standaard.

Participant: Ja ja, meme is hij het? En ik heb ook ja, die filmpjes gezien. Dat water is daar zo plat. Allee, daar ziet ge in geen kreuk steken in dat water. En dan denk ik ja, en die obstakels van dat park in Thailand, ik heb dat nu ook gezien. Dan denk ik ja, zo moeilijk. Al die transfers zijn zo zijn vrij. cava als je hierzo hier in de parken in België. Ja, die transfers zijn al direct zo ne kikker om u tegen te zeggen. Als ze zoiets kopen moet het direct extreem zijn of zo. In België of we hebben zo nen pipe of het is allemaal heel laag of we hebben ineens een extreme. Allee dien we hebben precies zo geen park, das zoiets allee van waar ik al geweest ben. Het was zo zicht van zoiets middelmatig of zo.

Participant: Dus nu gaat die. Gaat die poel daar liggen en dan hadden dat heel smal pijpje links. Ah ja, ja dat vond k niet zo super, want dat is weer zoiets waar dat ja wat kon k ik daar pakken? En dus dat smal pijpje. Ja, en die lag, volgens mij lag die deze keer niet goed dat ik die niet kon pakken. Daar lag iets voor of zo denk ik. Of iets achter dat ge zo moest nen ollie doen wat wij niet kunnen op een obstakel, dus wij kunnen niet springen.

Djemie: Zou je mij mee kunnen nemen door de stadia die je doorloopt?

Participant: Ehm. Jaa thuis mijn wakeboard in mijn auto krijgen. LOL en al m'n gerief pakken hé, maar dat is lijk elke lijk elke wakeboarder alleen in mijn geval maakt het net iets moeilijker, want mijn zak is veel groter, veel lomper, veel langer. Allee jullie moet maar een bord om rollen, schouder pakken en gaan. Dus bij ons is da Ja, veel groter en dus ja, dat moet allereerst in mijn auto geraken. Ik heb daar een systeem voor ontwikkeld dat ik dat zelf kan doen. Ehm ja, en dan is het rijden naar het parkje en dan in het park aankomen. Dan ga ik meestal eerst gewoon naar binnen en ga ik eerst hallo zeggen of mij aanmelden of weet ik veel. Vraag ik ook altijd iemand die mijn auto moet uitladen dus die mijn bord komt meepakken omdat daar gewoon alleen niet te doen is als ge toch een stukske naar een dok moet ofzo. Uhm. Ja en dan is t eigenlijk omkleden. wetsuit aandoen. Ik kan dat alleen. Maar er zijn er veel die daar niet alleen kunnen. Allee van minder valide dan. Dat was ook wel een hele onderneming. Ja, en dan ga je op het water eigenlijk. En opwarmen. O je spieren opwarmen. Veel Wakeboarders doen da niet alleen, maar wij doen dat wel echt. Ik denk dat dat ook gewoon ja, meer dan allee ja, ik weet dat niet. Ik weet ook gewoon dat dat helpt. Als ik er dat doe zijn in een dag veel minder stijf omdat je dat niet gedaan hebt.

Participant: Belangrijk. Maar voor de rest denk ik dat het eigenlijk quasi hetzelfde is als bij jullie dat in dat opzicht niet veel verschil ziet. Buiten dat wij inderdaad. Er moet eens iemand mijn wakeboard naar voren dragen of er moet eens iemand mijn rits gaan toedoen van mijn pak of zo maar.

Djemie: Want je hebt dan de je plank met je frame en je en je seat. Ja, die doe je pas aan op het moment dat je op die slide start staat. Dan ga je er inzitten?

Participant: Ja, dan moet er iemand er eigenlijk ook je erin zitten. In mijn geval toch.

Djemie: Oké, dus iemand laat het uit je auto dan, dan kom je bij de baan aan. Dus iedereen heeft dan zo'n zelfde soort set up. Worden die boards dan klaargezet bij die bij de dock, bij de, ja, bij de slide start zeg maar. En dat iedereen dan omstebeurt daar in gaat zitten. Zie ik dat goed?

Participant: Ja allee, ik weet niet of dat ge zowat de foto's al bekeken hebt. Als je zo bij de foto’s die ziet er zo regelmatig dat die daar zo staan te wachten en dan staan die eigenlijk zo op hunne allee als hier seatje staan die eigenlijk zo en dus al licht plat zo eigenlijk. Euhm ja navenant meer hoeveel dat ge zei. En dan staan wij eigenlijk zo recht in een file achter elkaar aan te schuiven, zich maar om te gaan. Ge heb de rij voor de jump starters en je hebt de rij voor de sliders of zo zeggen dat wij altijd voor de slide staan aan te schuiven en da hier ja de mens nog in een jump start kunnen doen. Ja eigenlijk sta wij niet in de weg, allee wij nemen wel meer plaats in dan iemand anders maar wij staan niet in de weg en wij kunnen ook zelf hoppen naar de slider start.

Djemie: Ah oké oh dus je hebt je heb hem wel al. Je kan hem ook al aandoen als je nog in de rij staat voor de slider.

Participant: Goh een beginner doet dat ni en dus dat ge zo een dag hebt met de beginners doet het dan niet echt. Da's meer als ge echt zo wat als ge al weet hoe dat ge moet zitten en in dan gaat de zo al wat aanschuiven zeg maar. Maar nen beginner zit daar echt aan de start in zijn seat, zorgen dat alles goed is. Maar als ge nu zegt van ja we willen meedraaien met de ervaren wakeboarders en dus gewoon als een kabel opengaan zonder speciale sessie, ja dan gaat gewoon mee in de rij te staan.nd. Ja, het duurt langer voor ons om in zitje te kruipen dan voor jullie. Om efkes die nu alle schoenen te stappen en de aan te trekken.

Djemie: Hoe lang doe je daarover? Zou je daar een schatting van kunnen maken?

Participant: Goh. Drie keer zo lang als jullie denk ik misschien. Uhm tja, ik denk dat dat ook heel relatief is, want dat het heel hard afhangt van uw handicap, van wat gij nog kunt bewegen, waar dat alles vast zit of waar gij een schouder hebt, dat iets vast zit op mijn rug of. Ja, hebt de gij één hand dat ook verlamd is of allee. Dus ik denk dat dat heel handicap relatief is.

Djemie: Met wat voor mensen hebben jullie allemaal die beginners dagen gedaan? Wat voor handicaps waren er daarbij?

Participant: Ja dus ja, dwarslaesie is Cerebral palsy.

Participant: Ja. Uhm allee ik denk op CP kan ook het Engelse zijn hoor. Parole CI noemt em dan goh ah en niet aangeboren hersenletsel. Studies in. Aha, dus dat zijn meestal de mensen die halfzijdig verlamd zijn. Dus in de in de. De verticale versie, dus ik ben horizontaal. Goh ja, autisme jongeren of jongvolwassenen die zijn niet in staat om te staan die evenwicht met evenwichtsproblemen. Wim heeft kanker dus heeft zo een heel heup en een stuk van z'n been eruit. Je had eigenlijk alles, iedereen dat niet kan staan te Wakeboarden. Er is zelfs ook een meisje bij ons die die heeft daar. Die wakeboard ook gewoon, maar die heeft haar kruisbanden dan zo meermaals gescheurd en dan heeft hij eens operatie gehad voor echt maanden en dan is hij ook komen Sitwaken bij ons, gewoon om tijdens haar revalidatie nog aan sport te doen. Maar dan ja zie dat hier eigenlijk wel een leuk alternatief ook voor de mensen die kunnen natuurlijk niet meedoen echt aan de kampioenschappen, want officieel hebben die geen een handicap of niet in die mate, maar die kunnen wel gewoon meekomen, plezier maken. Ja ja, eigenlijk alles. Iedereen met een handicap kan meedoen, maar er zijn ook veel en bijvoorbeeld amputaties ook. Maar er zijn ook al veel amputaties die een staand Wakeboarden.

Djemie: Ja, maar met een prothese dan?

Participant: Ja, dat begint nu zo stilaan op te komen. Die speciale protheses enz..

Djemie: Zou je het verschil nog verder uit kunnen leggen tussen een beginner en een ervaren Sitwaker? Want je zijn net aldus dat dat jij op een normale dag mee kan. Maar als je een beginnende wakeboarder heb dan wordt hij nog in het zitje gezet en zijn er meer verschillen.

Participant: Ja, een beginner begint ook best aan een iets tragere kabel. Ehm, omdat de schok in begin voor ons is heel hard, zeker als het gaat over beginners die geen buikspieren hebben. Ehm. Ja. Verder een beginner begint meestal met een touwtje, dus zo aan het frame is er zo'n touwtje. Ehm. Ja ik heb ook nog altijd een touwtje want dat vangt ook gewoon keiveel op. Het was echt gewoon aangenaam. Maar ik denk officieel dat het touwtje niet mag op een wereldkampioenschap, want ik zag ze allemaal zonder touwtje en ik weet dat die allemaal vertrekken met touwtje.

Djemie: Dus hoe werkt dat touwtje? Ik zag inderdaad ook in een filmpje dat hij erom werd geknoopt en ik zag het op veel foto's, maar ik heb het niet in actie gezien. Wat is de functie daarvan?

Participant: De functie is eigenlijk en dus als ge start met wakeboarden rijden zonder keiharde schok. Jullie kunnen de klap opvangen. Bij ons gaat dat niet. Wat er bij ons gebeurt is dat we voorover in het water vallen. Plus ook ons bord schiet in t water. En dat touwtje, dat trekt eigenlijk uw bord omhoog met de kabel. En dat helpt dus gewoon uw spieren in uw armen, uw schouders ook op te vangen. Ja, dat die schok gewoon veel minder zwaar is dat touwtje. Laat ge ook los na de start. Een beginner nog niet direct, maar ja.

Djemie: Ja en waar zit hij dan aan bevestigd? Wat waar zit hij dan verder aan vast?

Participant: Aan de hendel? Dus om de hendel en dan doe ik dat touwtje daar rond. Zo en dan gaat de duim en uw hand daar eigenlijk opleggen en dan wanneer dat ge vertrekt en dus de baan, dan trekt het touwtje niet meer vanaf dat ge vertrokken. Zij laten dat los en.

Djemie: En kan het dan niet zo zijn dat op het moment dat een beginner direct valt, dat het nog vastzit aan de hendel, het touwtje?

Participant: Alleen bij de beginners die hun handen niet kunnen loslaten en dus. We hebben er bijvoorbeeld ene die dan niet begrijpt dat hij zijn handen moet loslaten als hem valt, maar die houdt ook vast. We hebben ook al eens een keer gehad dat de force zo sterk was dat het touwtje den hendel in twee heeft gebroken. Maar ja, ik ga daar dan eigenlijk van uit dat dat gewoon dat hendeltje gewoon al een beetje dom was.

Djemie: En je zegt nu wereldwijd. Ik was aan het zoeken om een beetje te kijken naar getallen, hoeveel mensen dit wereldwijd beoefenen en ik vond het vrij lastig om daar informatie over te vinden.

Participant: Veertig ofzo? Nu op het wereldkampioenschap waren ze met zes als ik me niet vergis, maar dat is nog maar sinds dit jaar. Ehm qua vrouwen zijn we misschien op en al met tien. Ehm dusja echt niet veel. Ik denk dat het ook gewoon ligt aan het feit ja, geen enkel kabelpark kent het. Elke kabel heeft vrijwel schrik denk ik om oei het is een rolstoel Oei oei die kunnen niks. Ehm. Ja er is geen materiaal. Je moet wel effe het geld hebben. Ge moet efkes € 5.000 in uw schuif hebben liggen om materiaal te kunnen aankopen. Frame is dus 2700. 600 voor een sitje, dan nog 300 voor de voetplaat en van die dingen. Ja en dan een wakeboard nog. Zo'n investering gaat ook niet elk kabel park doen om dat daar te leen te leggen. Zeker al niet als ze dan nog eens zes sitjes moeten kopen voor elke maat één. Dus ik denk dat het daar ook wel aan ligt dat het heel moeilijk is. Ja, dat er heel weinig mensen dit doen. Je hebt dan de foundations bij de bepaalde landen die echt al al zitjes hebben gesponsord gekregen. Maar ja, wij, wij zouden dat ook graag doen. Maar daar zitten wij weer met feit. Waar gaan die liggen? Dus dan. Dan allee stel, ik heb in België Sitwaken Belgium. Stel dat ik nu zeg van ik krijg van van ja van een sponsor zo'n heel frame en sitje ja dan moet ik die wel altijd meenemen. Dus dan moet ik elke keer met twee ritjes in mijne auto dus dat gaat ook niet zomaar. Ja. Dus ik denk dat dat ook. Ja, het feit is waarom dat de sport niet zo groot is en ook niet kan worden denk ik.

Participant: Ja ja, want ik weet ook in Nederland krijgen jullie sportmateriaal ook vergoed. Dus jullie kunnen een aanvraag doen voor één sport artikel. Al is het een sportrolstoel en een tennis rolstoel, basketrolstoel. Ja, uw wakeboard valt daar nu ook bij, want we hebben een Nederlander die naar ons komt want die woont op de grens en die heeft dat al gedaan voor zijn wakeboard. Dus jullie krijgen daarin een tussenkomst. In België is dat niet he. Een basketbal rolstoel. Dat is luxe hé. Je krijgt just een fiets bijvoorbeeld. Daar krijgt je wel een tussenkomst in omdat dat dan ja, dat is mobiliteit. Sportprotheses worden soms ook betaald omdat ze dat kunnen verhalen als mobiliteit, maar dat is het helemaal niet. Dus daar hebben jullie Nederland wel geluk mee.

Participant: Maar er zijn wel goedkopere zitjes op komst hè, Want ik heb bijvoorbeeld een ingenieur, Johannes van Duitsland. Die zit ook in een rolstoel en Die is ook bezig met een frame te ontwikkelen, dus het frame. Ja, het is hier vraagt bijna € 3.000 voor zo'n frame alleen sorry maar als ik een aluminiumplaat op het werk bij mij op de frees tafel ligt lig heb ik hetzelfde.

Djemie: Wat voor setup heb jij?

Participant: Ja ik heb die van Tessier. En dan heb je ook nog een ATI. Ja die heeft een goedkopere versie, die hebben een schoolversie nu dat is een goedkopere versie. Ehm probleem van die Ati, die past niet op alle borden, dus die die niet alle borden kunnen op dat frame. Ik weet niet wat daar raar aan is. De service is 0,0.En al die mensen zijn een beetje ego ontploft zo en dat is wel jammer. En hun nieuwe frames zijn ook gigantisch duur. Ze hebben daar nu een frame met een shock demper waar dat ze daar € 5.000 voor vragen. Alleen het frame. Het breekt echt nog supersnel maar ze blijven het ook gewoon verkopen voor de volle prijs. Ik vind als er een soort fabricagefout in uw ding zit dat ge dan moet zeggen van oké we zitten nog in de testfase mannen, we kunnen het nog niet verkopen he. Allee dus ja. Tessier heeft het echt gemaakt met de wereldtop, dus een wereldtop. De wereldtop ziet ook allemaal op die swaik van tessier en die zijn ook allemaal geen fan van ati, dus voor heel veel redenen ook gewoon naar de sprongen. Voor een beginner is dat fantastisch hé. Maar vanaf dat ge gaat springen en zo. Dusja ze vinden ook niet echt een tester he, want de mensen die hun ati frame testen ja dat zijn mensen gelijk mij of misschien zelfs nog een niveau onder mij, misschien meer ja Willem, niveau ofzo van ja, wij kunnen wel een obstakel op en wij kunnen wel eens roteren, maar dat is het ook. Dus dan denk ik ja dan krijgen die frames geen impact. Maar ik denk dat die evolutie wel komt. Iedereen is een frame aant maken. Allee, in Rusland heeft bijvoorbeeld al een echt productief frame. Duitsland, Johannes die is er just mee begonnen. Wij hebben hier nen Belg die z'n eigen frame heeft gemaakt. Gewoon letterlijk een aluminium plaat gaan halen en die heeft dan zelf met een slijpschijf vers versneden en aaneen gelast. Nu ja, die lassen die breken door natuurlijk. Maarja diene heeft wel een frame voor € 55 he.

Djemie: Heb je zelf wel eens op een op een frame met een schokdemper gereden?

Participant: Ja dus ook van de Ati. Daar heb ik al wel ja op gereden. Ehm ja, die tessier trouwens zijn ook anders. Een Tessier zitje heeft niet de juiste gaten voor de Ati frame. Wat ik ook al heel dom vind. Maar bon. Ehm ja die halen hun sitjes bij een andere firma. Maar ik denk allé we zijn al zonen, kleine wereld maakt dat toch universeel. Maarja goed. Dus het was ook wel een nadeel. Dus ja, ik heb dan niet zo goed kunnen testen want mijn eigen zitje kon niet op dat frame. Wat het dan wel heel moeilijk maakt om 100% het verschil te testen ofzo. Het frame kon ook niet op mijn bord en ik had nog gewone ronix (merk) toen ik dat getest had. Allee ik had echt een standaard bord. Dus ja ik moest het ook al testen met een ander bord wat het dan verschil heel moeilijk maakt. Allee is het dan het frame wat zo zwaar is of het bord? Ik vond het langs ene kant wel tof, het is echt wel zacht. Want onze rug gaat er echt wel van kapot hoor. Alleen dit kunt ge gewoon aan dit tempo geen drie jaar doen, zeker niet als ge al een breuk in uwe rug hebt of of een of ander probleem, Allee dat is waanzin. Dus nen shockdemper Ik denk dat dat echt ook wel nodig is. Bij jullie is jullie schokdemper, jullie knieën. Bij ons is er niets dus ik denk dat het absoluut nodig is. Maar er moet ne soort ik weet niet aan en uitknop of zo zijn of naar sensor of zo. Want probleem met die shock is als gewone kicker gepakt en landt is er keitof geland. Superzacht. Maar als ge een transfer doet van een kicker op op een rail of zo, dan vlieg je terug omhoog op die rail. En dat is niet bedoeld, want ge verliest gewoon pure controle. Dus dat is natuurlijk aan die shock. Niet echt. Ja niet geweldig dus daar moet een soort afstelling in komen. Maar Johannes is ermee bezig. Hij probeert iets anders te ontwikkele n, maar die jongen heeft een heel, een hele zware spierziekte. Dus de vraag is gaat dat nog optijd lukken

Djemie: Ik vind het best wel interessant. Als je nu zegt wat hij aan het doen is, is het mogelijk om mij aan hem te connecten dat ik hem hier eventueel ook over zou kunnen spreken?

Participant: Ja ik zal het vragen. Hij wilt eerst het frame en dan de de shock demper eraan toevoegen zeg maar. Je hebt de sitjes van Tessier en ge het dan Embroise in Frankrijk en die maken de sitjes voor Ati. Maar ge kunt ook die Embroise zitjes kopen voor op uw Tessier. Want bij ons heeft iemand zo'n zitje van Embroise gekocht. Dus dat is ja, dat is gewoon een ander soort sitje. Ja, dat is wat ge wilt, dat is puur smaak.

Djemie: Wat vind jij van je setup?

Participant: Ik heb een zitje van Tessier, maar ik ben er ook niet tevreden over omdat ik heb echt nog wel wat billen, alleen mijn billen zijn best nog wel stevig. En heupen als vrouw, en ik vind dat deze zitjes gemaakt zijn op jongens en ook op mensen met heel dunne beentjes. Dus als ik echt kijk naar de mensen met een een totale verlamming waar de beentjes echt superdun zijn. En voor mij is het zitje van Tessier te laag, dus het komt te laag op mijn heupen waardoor dan mijn bekken niet volledig in dat zitje zitten waardoor ik heel veel sturing verlies. En het past ook niet volledig, voor tussen mijn benen is het te smal waardoor ik dan een maat groter moet gaan. Maar van achteren houd ik keiveel over dus ja, ik vul dat dan allemaal op. Wij waren hier in Belgié aan het denken. Dus we hebben een orthopedie die met ons wilt samenwerken om eventueel één kuipje te maken en dan in dat kuipje twee of drie inlays te maken. Dat ge zo van die zit schalen heb voor mensen die heel zwaar aandoeningen hebben, die hebben zo een elektrische rolstoel en die zit dan echt in zo'n schaal. Echt in zo'n kuip. Volledig gemaakt voor hen. Ja dus zoiets, maar dan voor in dat zitje. Ik zag eigenlijk we hebben eén kuip en daar kunnen we die van die inlays drie van die kuipjes inleggen. In de hoop dat die inlays dan goedkoper zouden zijn en dan een park Zo kan zeggen van ik koop één kuipje en vijf inlays of zo. Staat in de kinderschoenen. Als een kabel park eén of twee frames koopt of zelfs gefundeerd krijgt, want in Belgié kunnen als vereniging of als bedrijf ofzo wel subsidies krijgen voor aankopen te doen. Dan zit je met dat frame en nog met vier Vijf sitjes. Als ge daar kunt zeggen we kunnen maar een zitje aankopen en ja desnoods vraag je dat iedereen een inlay zelf koopt. Misschien is dat ook ne start ergens maar dat was ons idee om te gaan bekijken met een orthopedie. Tezien of dat we het zo goedkoper kunnen maken. Maar hoe, wat, waar? Dat weten we nog niet. Dat idee is ook echt nog maar in de babbel en nog niet volledig uitgewerkt. Er is hier orthopedie voor die voor nu voor mij een zitje gaat ontwikkelen in de hoop dat ik dat zitje dan ga testen en dat dat ze dan ook sitjes kunnen verkopen eigeniik. Dus dus binnen Belgie of desnoods ook Nederland

Djemie: Die vorige afstudeerder die heeft dus een heel project gedaan om te kijken hoe die zit verstelbaar kan zijn. En die heeft een aantal mensen met verschillende handicaps ook ingescand om te kijken of die mensmaten Kloppen met het huidige Zitje. Want wat je ook zegt Wilem, die heeft hetzefde. Die heeft een tessier en heeft van het foam de binnenkant eruit gesneden omdat het gewoon niet paste.

Participant: Ja inderdaad, ik zit ook tussen de Tessier maten net tussen de twee en de drie. Drie is vrij knap. Den twee is dan gewoon nee. De drie is cava. Mijn twee is helemaal te klein, ik kan er gewoon niet tussen, maar den die is eigenlijk te groot. ge kunt wel zeggen van ja ik ga het allemaal opvullen maar vanaf dat ge valt is is uw opvulling wég. Dus moet die opvulling dan weer gaan plakken aan das zitje en dus het is allemaal nog niet 100% ideaal of zo, Ja tuurlijk, ja die wereldtop, die hebben allemaal een Zitje op hun maten gepast. Dus ik denk dat dat voor nen beginner ook absoluut niet uitmaakt dat dat sitje te groot of te klein, te klein natuurlijk wel om te kunnen zitten, maar dat u sitje te groot is dat ge begint, dat maakt echt niet uit dat ge daar los in ziet dat maakt ook absoluut niet uit. Het is echt pas vanaf dat ge nen Kicker wilt pakken of nen box op wilt gaan dat ge dan misschien wel eens beter in uw zitje zou moeten zitten.

Djemie: Ik deel even mijn scherm (laat idee van Marinke zien).

Participant: (Gaat over de strap aan de voorkant] Want eigenlijk inderdaad dus aan de voorkant maak het eigenlijk niet uit. Als ge dus een band hebt van voor dat uw benen kan tegenhouden is het inderdaad al voldoende. Maar als ik kijk naar het niveau dat ik bijvoorbeeld als beginner had, of vorig jaar allee of twee jaar geleden of zo. Waar uw bekken vast zitten is het belangrijkste, want daarmee doet ge echt de sturing. Ja, en dan uw benen, uw knieën dat die gewoon vastzitten dus niet kunnen kunnen schommelen. Ja daar kan inderdaad met een band want ik heb dat ook. Dus ik heb mijn kuipje. Dus en hier heb ik mijn band (wijst band aan). En hier in t midden heb ik ook nen band dus ik zit eigenlijk onder mijnen buik vast zeg maar. En dan van voren op mijn knieën zit ik vast aan het zitje.

Djemie: Dus met de ene band wordt je vastgezet in het zitje, met de andere worden je benen vastgezet zodat die niet heen en weer gaan.

Participant: Ja maar alle twee wel aan t zitje. Mijne voorkant daar kunnen mijn benen net
tussen dus dat is bij mij niet te groot. Maar bij sommigen die echt zo stokken beentjes hebben is dat wel groter. Maar er is ook geen rechte lijn daarin of iets dat zegt van ge moet dat zo doen. Dat is eigenlijk ook weer elke sitwaker zn eigen gaten boort in dat zitje.

Participant: Ons hangt eigenlijk, dus dat is voor elke sitwaker anders. Ik ben begonnen met eerst mijn een band vast te hangen onderaan het zitje, dus dat die eigenlijk rond mij zit. En nu ben ik eigenlijk dat ze alleen maar vasthangen aan de zijkant, dus dat ik eigenlijk gewoon van bovenop vastzit. Dus ja, ik denk dat dat voor iedereen verschillend is. Naar de eenen voelt zich vaster op deze manier en een andere voelt zich vaster op een andere manier. Maar ook een hele belangrijke voor de sitje vind ik wel is padding. Het doet heel veel pijn Zo'n zitje tis heel hard. De meesten van ons hebben doorligwonden of veel kans op doorligwonden. Dus zeker onderaan in het zitje moet genoeg mouche zijn en eigenlijk achteraan in de rug en op de rand Ook. En dan mis ik bij Tessier ook heel hard die embroise heeft dat beter. Embroise werkt met twee centimeter kussens met zo'n handig traagschuim achtig iets. Ehm en ja, het moet ook drijvend mag ook niet zinken natuurlijk. Dus dat dat wel zacht is, dat dat aangenaam is.

Participant: Ja, want ge hebt ook nog mémé en die heeft een ander materiaal dan in die Tessier. Meme das nen Italiaan Die is naar een soort boot winkel gegaan en die heeft daar blijkbaar gebruikte boten een speciaal soort schuim in de zitjes voor buiten. Dus de buiten zitjes in boot, die kussens. En dat is wat hij gebruikt heeft en dat is eigenlijk drijvend maar ook waterafstotend. En in al die dingen hoort een soort memory foam of zo. Meme is de wereldkampioen al voor vijftien jaar en en die had tegen mij gezegd dat dat dat, dat dat dus daar haalde. Ik weet dat ze ongeveer een vijftien à twintig jaar geleden zelfs begonnen zijn met de Sitwaken en meteen met Swaik te ontwikkelen. Die zijn ook allemaal begonnen op zo'n buizenframe. En dan zijn ze dus met Tessier die eigenlijk eerst zitski's maakten. Zijn ze in in contact gekomen in Frankrijk. Maar ja, dat was meer dan Bastian enzo. Maar ja, die is nu niet meer zo wedstrijden maar vroeger wel. Die heeft zo ook een foundation zeg maar. Maar dan voor Sitwaken in Frankrijk. En die hebben daar ontwikkeld zo een paar hele goede Franse Wakeboarder allee sitwakers. Die hebben daar een Tessier ontwikkeld en die hebben dat zo ja 5 tot 10 jaar kunnen testen en die hebben dus ook heel veel zijtes omdat die eigenlijk al die test frames zal ik maar zeggen gehouden hebben voor beginners.

Djemie: En hoe heet die foundation?

Participant: Magic Bastos. En dan heb je sitwake crew die zei die zitten in Spanje, dan heb je wake for all en da's Italië. De Russen, dat weet ik niet van buiten. De Sitwake crew wordt gesponsord meer door Ati. Magic Bastos wordt eigenlijk meer gesponsord. Ja, gesponsord is dat niet echt, maar allee door Tessier.

Appendix BII: Interview with experienced sitwaker

One month ago, first tests. Little piece of the sheet is bending. Not so good. It needs to be lighter. Reduce five hundred grams or one kilo. The first design was quite nice, but small changes are required.

What did you study?

Mechanical engineer. Structural analysis.

What kind of setup do you use?

Tessier seat. Thierry Schmitter. Carbon fiber. Is lighter than glass fiber. Just use the Tessier seat. It fits for him. But need the backrest. Moving to the side. Has a nerve disease. Coordination is very weak.

What do you value in a seat?

Most important:

- It should fit. Do not need a fit of 5 cm, should fit perfectly. Sides should fit the best. Size one of Tessier.
- On the butt, on the sides.

He does not use straps at all.

- Because of the angle, it prevents him from the ropes pulling you out. Straps are used more when you do obstacles.
- Does not do obstacles.
- When you get more experience, you use straps. First time some people do not use straps.

What is your first impression of this product?

- Looks very nice.
- Can you move the sides?

What are problems with the current wakeboard seat?

- Foam on the edges comes from the carbon fiber.

He can bring me in contact with a guy that makes chairs for racecars made from carbon. He makes the seat for Johannes. He also reinforces his boards, at the inserts. Problem with sitwaking is that the board has more impact on the inserts, omdat de kracht niet op wordt gevangen met knieen maar direct op het board komt.

Kevin lynn. German most famous sitwaker. First backflip on kicker on sitwake. Carbon guy did a seat for Kevin. He does not make new shapes. Looks very much like Tessier.

As a mechanical engineer, he works with Ansys. Did force analysis for the frame he is developing.

Only two producers, Tessier and Ati. Too expensive. Disabled people, make it more easier to buy their own equipment. 1.500 euros, without spring. First experience with the first frame.

Vraagt of hij het zitje al mag gebruiken op een training kamp in mei. Ik heb gezegd dat dat niet meer aan mij is, maar dat het dan in Willems handen ligt. Wilt graag in de loop blijven, komt goed.

Appendix BIII: Interview with operator cablepark

- *Wat voor werk doe je bij Oudenaarde?*

Hoofdoperator, hoofd van het technisch gedeelte. Zet zich ook in voor aanpassen van zitwaken en vastmaken van mensen in zitjes. Doet alles omtrent materiaal.

- *Hoe vaak komen er sitwakers?*

Beginners komen altijd in groepen. Je moet achter een zitwaker aan gaan. 1 x In de maand worden dagen georganiseerd voor beginnende zitwakers. En dan 1 x in de maand alleen voor gevorderden. Voor beginners sessies heb je nodig: 1 Iemand in wetsuit in water. 1 iemand die de knoppen bediend. 1 Iemand aan grote kabel. 2 In boot, uittrekken en sturen. En dan nog 1 persoon om materiaal aan te geven. Als er 10 man beginnend zitwakers komen, heb je al gauw 5-6-7 man nodig. Niet altijd zo gemakkelijk. Subsidies worden er vrijgemaakt voor zitwakers. Tarief voor beginnende zitwakers is goedkoper dan voor normale wakeboarders.

Als je begint begin je op de 2.0 kabel bij Oudenaarde. Deze gaat niet rond maar alleen heen en weer, en er gaat maar 1 persoon tegelijk op in tegenstelling tot de grote kabel waar er 10 tegelijk kunnen.

-Hoe halen jullie de wakeboarders uit het water?

Zeer gehandicapten moeten soms terug naar de kant gebracht worden.

We hebben een boot waarbij de neus van de boot tot de oppervlakte van het water kan komen. Daardoor komt men makkelijk op de boot. Ik heb ook wel eens gezien dat ze jetski's met floater erachter gebruiken waar mensen zich aan vast kunnen pakken. Vergelijkbaar als wat ze bij tow-in surfen doen.

Mensen doen zelf sitwake op de floatable. Kan niet met te veel mensen achterop, het moet ook nog vaarbaar blijven.

Sinds kort is er meer aanbod vanuit parken om te zitwaken, sinds het WK. Sommige parken doen het zonder bootje, geven minder hulp.

- *Zijn de mensen die werken bij Oudenaarde speciaal opgeleid om met gehandicapte mensen te werken?*

Meeste mensen hebben geen training gehad. Sommigen wel.

- *Waardoor onderscheid Oudenaarde zich van andere banen wat betreft inclusiviteit? Hoe is dat zo gekomen?*

Situatie in Oudenaarde is dat het niet enkel een kabelpark is. Het is ook avonturen park. Sinds 5 jaar geleden is de kabel erbij gekomen. Waren al redelijk inclusief met g sporten, klimtoren bv. Ook toegankelijk voor gehandicapte mensen. We zijn er heel snel op ingesprongen. 2 jaar geleden nieuw beleid, ik met nieuwe manager zijn daarop gefocust. Sitwakers mogen bij hen veel meer komen, meer komen draaien. Sitwakekampen ook gedaan. Heel veel sitwakers leren waken.

- *Heb je vaak dat je het zitje moet omschroeven voor verschillende beginners?*

We zorgen dat alles van tevoren klaarstaat. Omschroeven tijdens de sessie doen we niet, dat zou te veel tijd inbeslag nemen. Dan heb je iemand nodig die 3 uur lang met het materiaal bezig is, daar is geen volk voor. Omschroeven duurt 10 minuutjes tot 15 minuutjes werk.

- *Wat zijn de grootste verschillen tussen beginners en gevorderden?*

Intermediate laten weten wat de instellingen zijn. Proberen ze op voorhand klaar te zetten. Mensen die het nog niet weten, persoonlijk maten doorgeven. Daar is veel tijd voor nodig.

Alles klaarzetten op een bankje, dan allemaal erin zetten en kijken wat het beste is.
Ze zitten met 10 sitwakers op het water. Ze hebben zelf 1 sitwake die van hun is, plus een aantal zitjes. Samenwerking met Anvas sport & de Zitski federatie. Zij hebben een eigen setup, staat bij Oudenaarde. Ook een van de watersport federatie**.** Het wordt daar allemaal neergezet omdat zij het park zijn die daar het meest op in zet.

- *Wat vind je van de zitjes die nu op de markt zijn?*

De meeste bij ons op de baan gebruiken Tessier. En een aangepast zitje maar dat is waarschijnlijk eigen fabricatie, heeft iemand via zijn werk kunnen maken. Zijn goed. Redelijk goed, wat er wel gemerkt wordt bij experienced zitwakers is dat de straps ontbreken. Beginners moeten makkelijk los kunnen. Meeste zijn tot aan hun middel gehandicapped, die kunnen wel loskomen als ze een strap hebben. Zwaardere handicap is lastig om uit het zitje te komen.

- *Wat is essentieel voor veiligheid bij zitjes?*

Als je een strap met een quick release zou gebruiken, zou dit geautomatiseerd moeten zijn.

- *Blijven beginners wel eens in hun seat vastzitten wanneer ze vallen?*

Gebeurt bijna niet. Het is een shock voor mensen als ze vallen. Ineens onderdompelen.

- *Wanneer maak je een strap bij beginners vast? Hoe doe je dit?*

Wanneer ze vlot rondgaan wordt er strap toegepast. Makkelijker sturen en leunen, meer board controle. Pas wanneer ze een beetje kickers en boxen willen doen. Laats voor het eerst gezien dat ze windsurfgordels vastmaken aan het zitje. Dan rubberen strap vast aan hun middel. (Djemie laat de rugleuning van Tessier zien). Ja dat is hetzelfde, maar dan met een extra strap om je vast te maken. Beginners met een hoge handicap gebruiken ook een rugleuning. Maar vaak hard. Omdat ze meer steun nodig hebben. De zachte rugleuning hebben we nog niet getest. Kan zijn dat het wel verschil maakt.

- *Stel je voor dat je een zitje hebt die in breedte verstelbaar is. (Foto laten zien). Hoe zou je dit gebruiken?*

Hoe groter mensen, hoe bredere heupen. Dan moet het zitje ook omhoogkomen voor de benen. Maar dat ligt meer aan het frame (swaik). Het grootste probleem zit hem in de breedte van de heupen. Nu pakken we de tussenweg. Wanneer twee beginners een paar centimeter in heupbreedte verschillen pakken we de kleinste als basis. Voor beginners maakt het niet zoveel uit als ze er los inzitten. Goed systeem met vleugelmoer in principe. Strap op het zitje zelf. Groot handvat aan doen, zodat hij makkelijk los gemaakt kan worden. Normale mensen (geen g sporters) die dat ook geprobeerd hebben. Starten ook zonder strap. Als ze vallen, vliegen ze weg van het board, weg van de scherpe gedeeltes.

- *Wat zijn problemen die zich vaak voor doen?*

Zitwakers proberen zelf te zwemmen. Het is voor hen niet gemakkelijk om hun zitwake mee terug te nemen. Ze nemen dan het touwtje tussen hun tanden bijvoorbeeld. Dan wordt board uit het water getrokken door een medewerker. Sommige mensen hebben hulp nodig uit het water te komen. Anderen niet. Sommige zwemmen met board nog vastgestrapt terug (intermediates). En dan worden ze in het geheel uit het water getrokken. Is makkelijker, omdat ze dan niet opnieuw vastgestrapt hoeven te worden. Wel zwaarder.

Grote kabel starten beginners met een touwtje. Je kan starten zonder touwtje, maar zwaar voor armen. Ook al problemen mee gehad, stokje breekt in twee. 1 Persoon met mentale beperking die het niet onthoudt dat hij het houtje los moet laten wanneer hij valt. Die heeft al 10tallen stokjes gebroken.

Appendix C: Straps exploration and conclusion

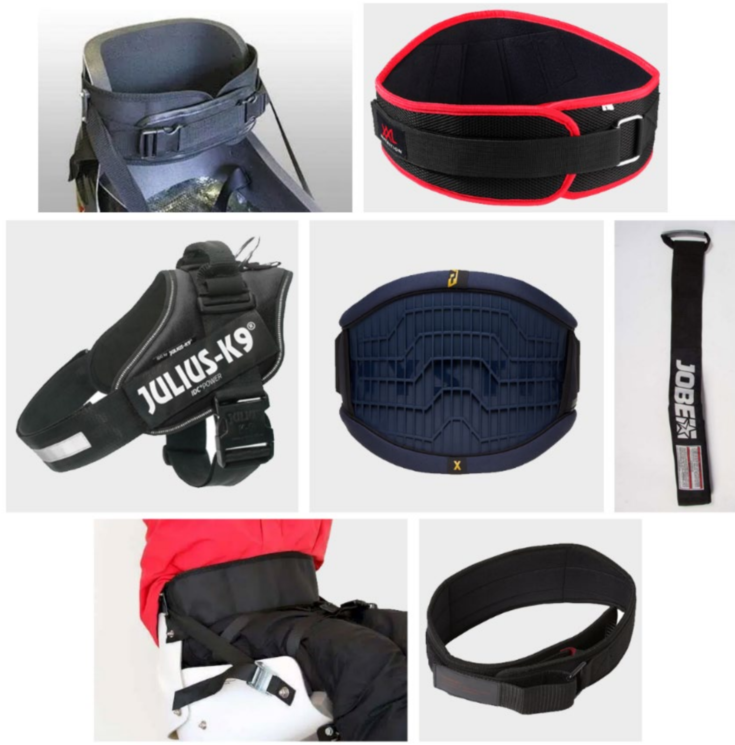
For the strap, different comparable products are benchmarked, some more effective than others. When benchmarking, different questions arose: How are the straps currently attached? Which different orientations are possible?

After an interview with an experienced sitwaker and head operator of an inclusive cable park, it was concluded that straps are not used when teaching beginners. The reason for this is that they might panic while falling, not being able to release themselves from the sitwake. This can result in dangerous situations. Even when doing obstacles like boxes and kickers, it is not required to be strapped to the seat.

When a beginner is in control and wants more than “feeling what an obstacle is,” a belt used for kneeboarding is often introduced. More experienced sitwakers use a weightlifting belt for example, making them more secure. This weightlifting belt has an exclusive double locking system, which makes it possible to tighten and loosen the belt to the maximum in one movement without taking it off. Because of the double locking mechanism, it is not suitable for beginners, because taking it off requires more time.

Design requirements:

- The seat is not standard equipped with straps
- The seat must have an attachment point for straps



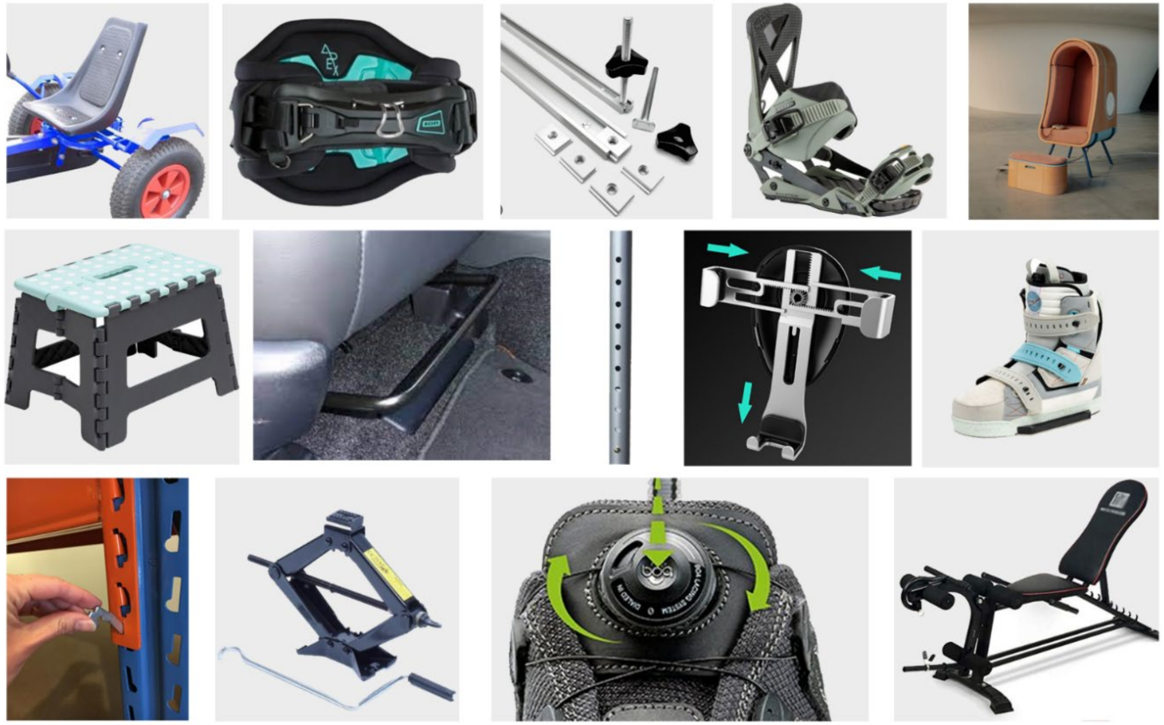
From top left to right bottom: Tessier belt, weightlift belt, dog collar, kite harness, kneeboard strap, Tessier belt version 2, deadlift belt.

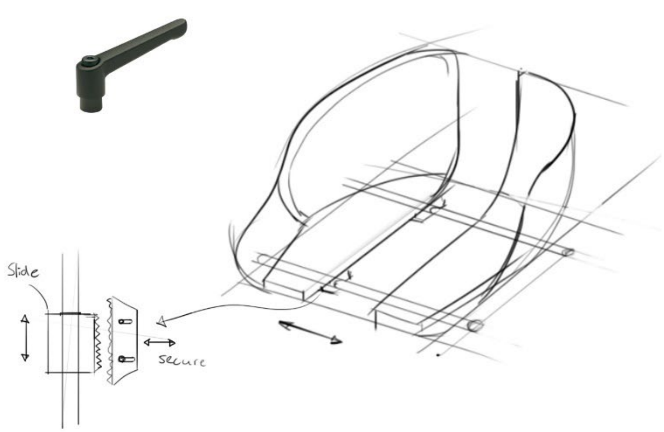
Appendix D: Ideation - Adjustability

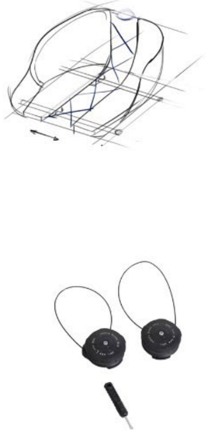
Scamper is a creativity method that can help creating ideas through the application of seven heuristics: Substitute, Combine, Adapt, Modify, Put to another use, Eliminate and Reverse (van Boeijen, Daalhuizen, van der Schoor, & Zijlstra, 2014). This method is used to generate ideas for the adjustability of the seat.

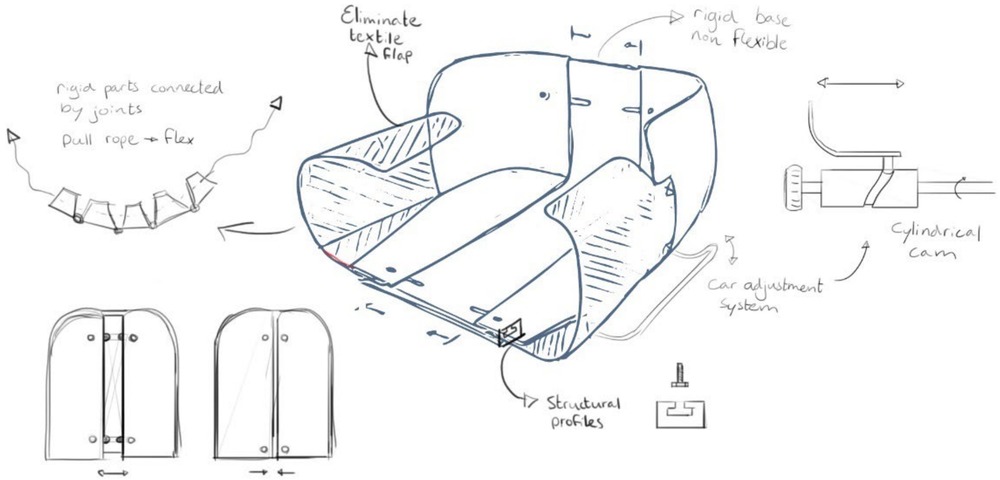
One of the methods includes substituting features of other products into the generated ideas. Since the adjustability method is not working for the sitwake in Callens' concept, other adjustable products were captured in the collection below. These products came up in the research phase, while talking to people about the project and during moments of inspiration.

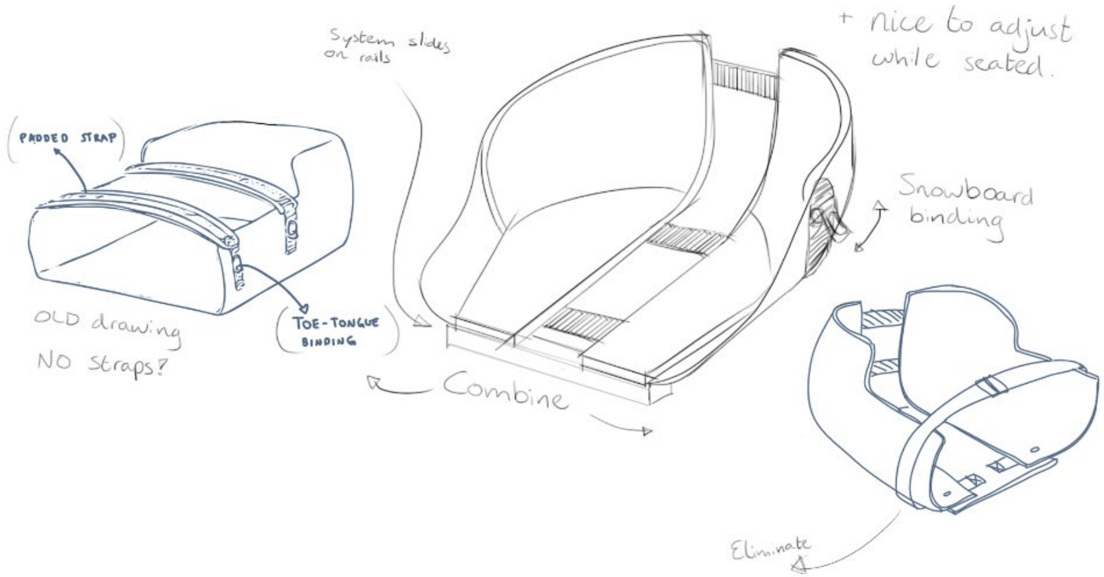
The following pages capture some of the ideation. The blue lines are Callens' drawings, the black lines are SCAMPER ideas.

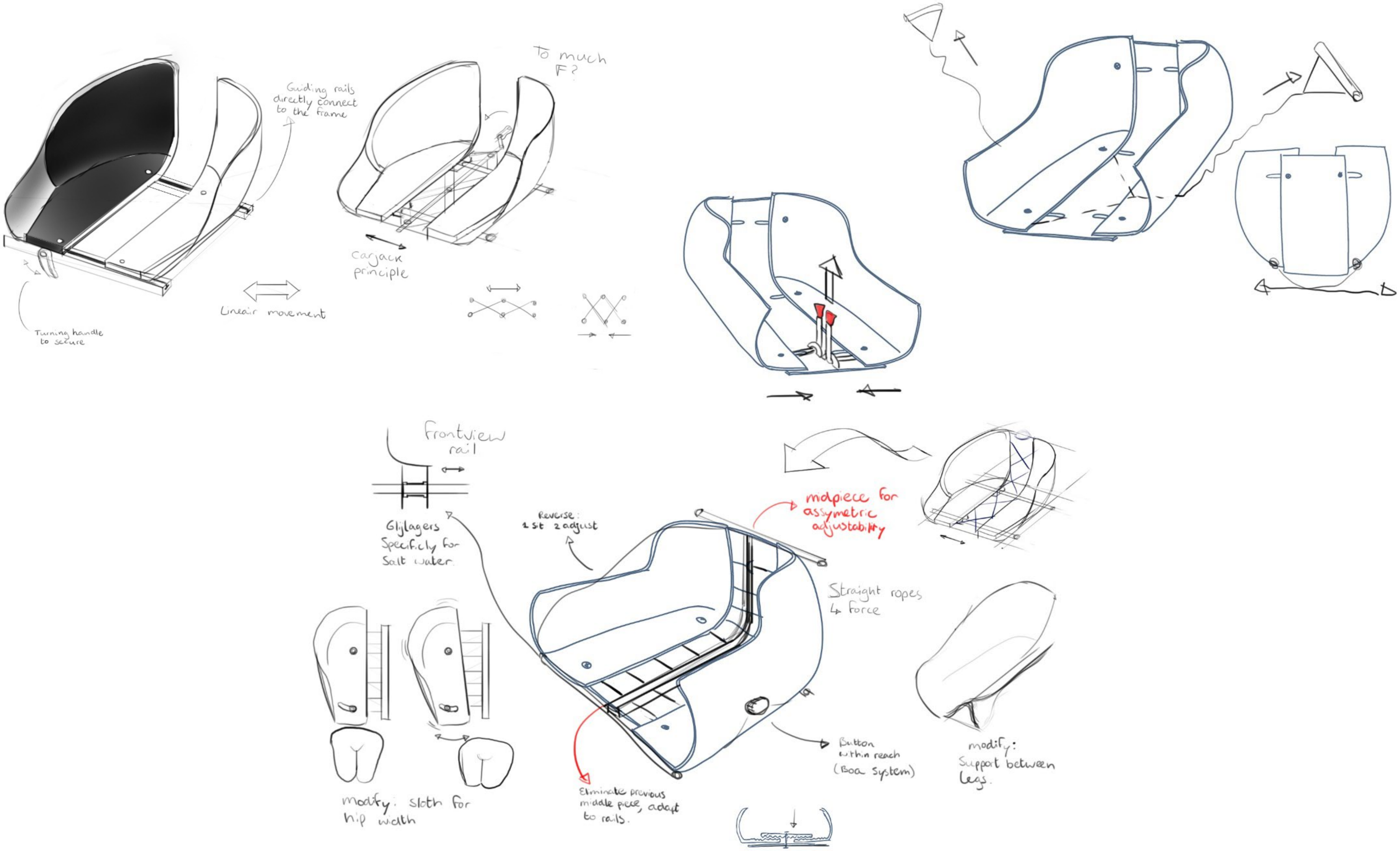



Slide
secure




Eliminate textile flap
rigid base non flexible
rigid parts connected by joints
pull rope → flex
Cylindrical cam
Car adjustment system
Structural profiles


PADDED STRAP
TOE-TONGUE BINDING
OLD drawing
NO straps?
System slides on rails
+ nice to adjust while seated.
Snowboard binding
Combine
Eliminate

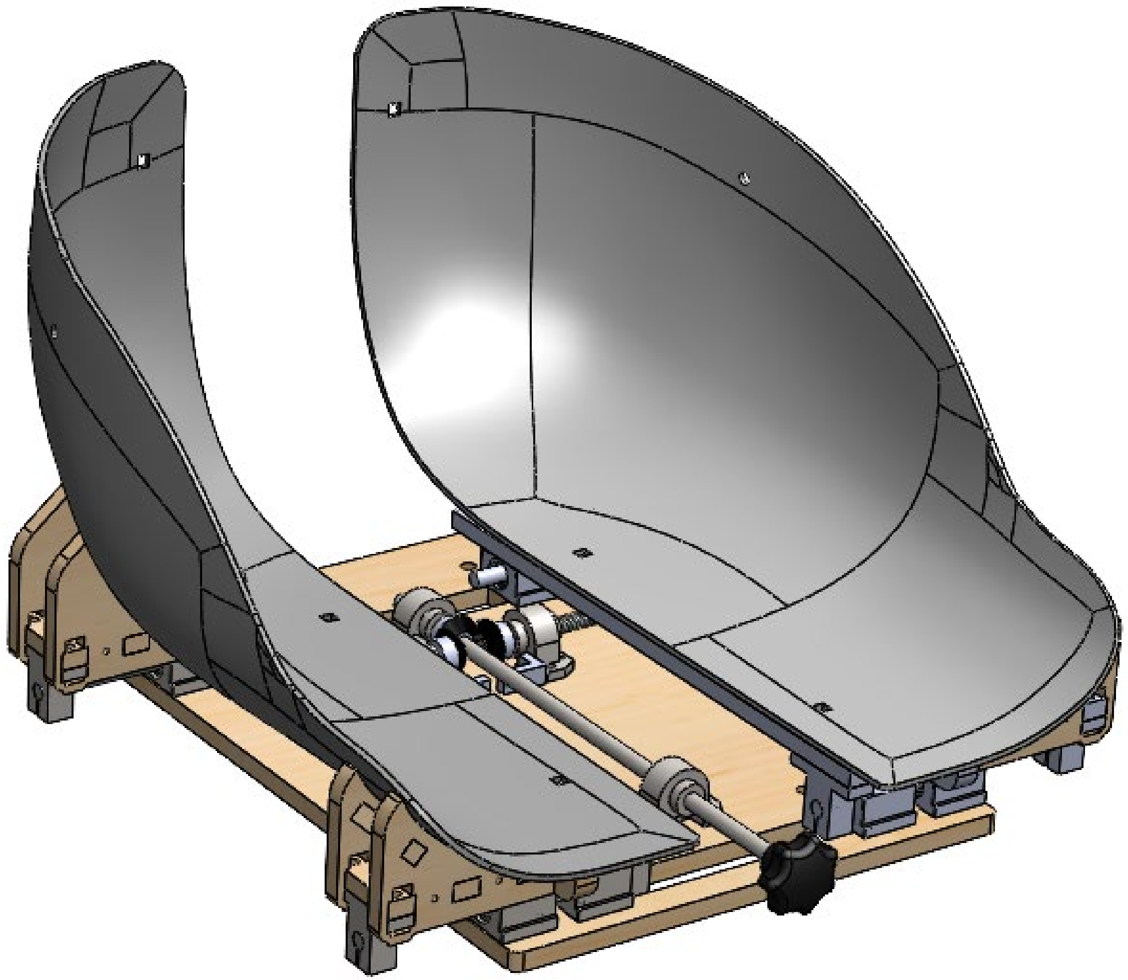


Guiding rails directly connect to the frame
Turning handle to secure
Linear movement
To much F?
Carjack principle
Frontview rail
Glijlagers Specificly for Salt water.
Reverse: 1st 2 adjust
midpiece for assymetric adjustability
Straight ropes 4 force
Button within reach (Boa System)
modify: Support between legs.
modify: sloth for hip width
Eliminate previous middle piece, adapt to rails.

Appendix E: Iterations and prototyping process

To be able to test and evaluate the concept, the outcomes of the different tests from the conceptualization phase were combined into a working prototype. This prototype was then used at Wet ‘n Wild, a cable park located in Alphen aan de Rijn to do tests with the target group to receive feedback.

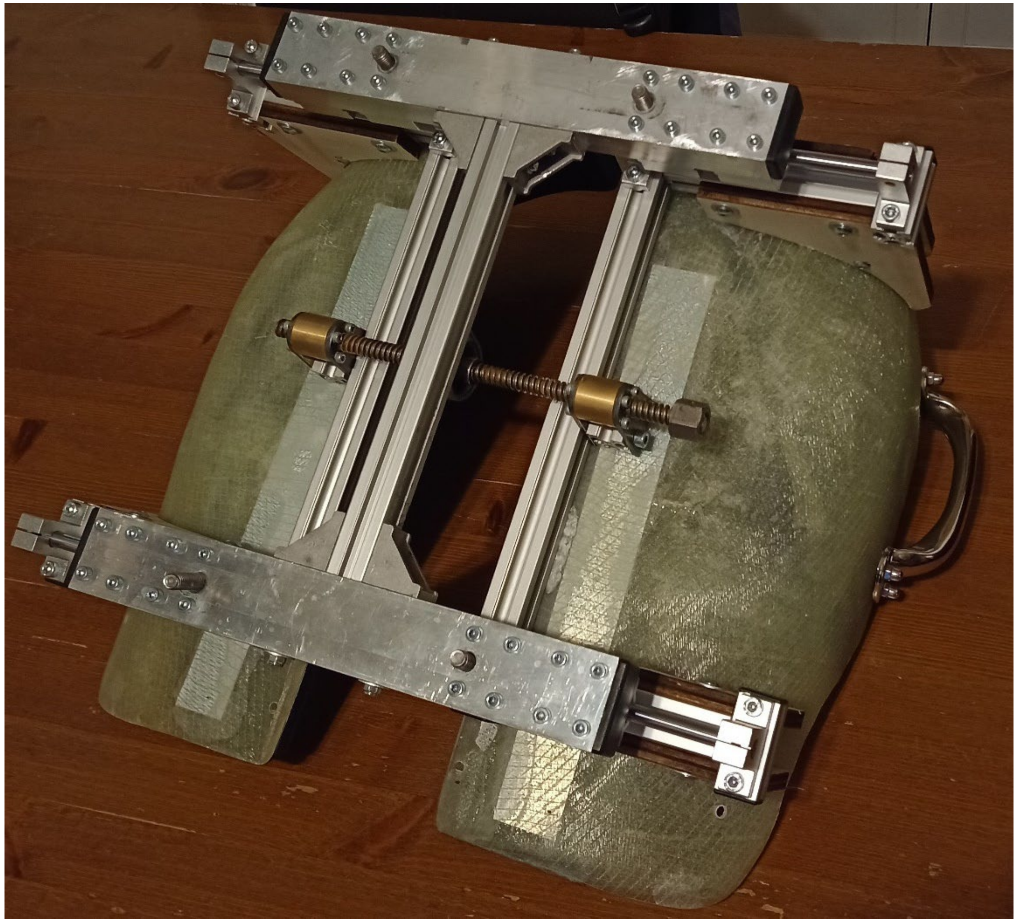
The CAD model in the image on the right shows the configuration of the various parts. Note that this model was made with limited time, meaning that some choices were made to be able to receive the needed parts within the given time, in order to be ready for the test day. The various parts are discussed on the next pages.



Base

The base parts, the supporting parts that connect the rail system with the seat, are made mainly out of wood in the first iteration shown on the previous page. Wood was a perfect material to go through multiple iteration cycles, quickly improving the design through laser cutting. This is not the envisioned final material, but after a discussion with employees of the PMB, 12 mm plywood seemed sufficient for the test. The seat halves are connected to the wooden base with roundhead bolts, to minimize the feeling through the foam.

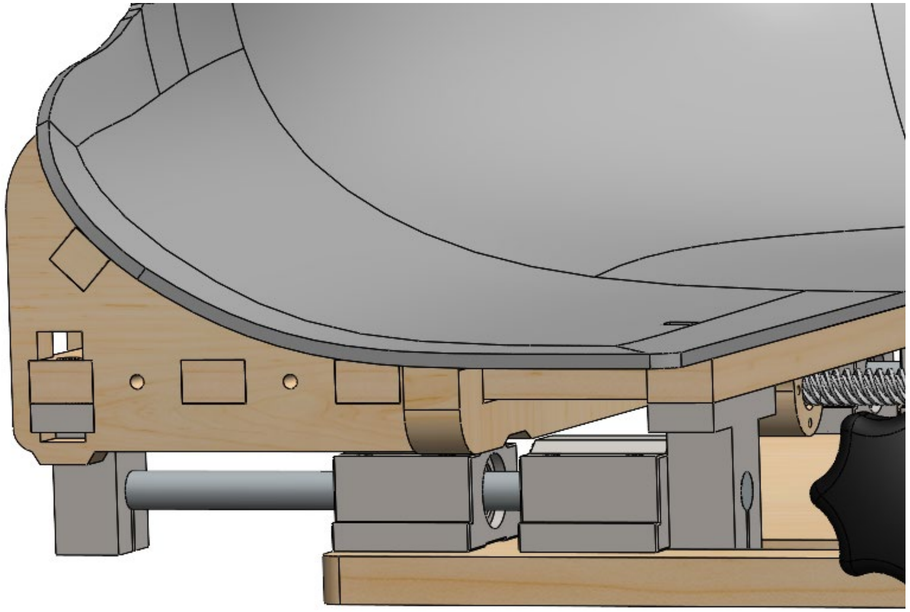
During the test, the fiberglass seat halves bended to the side, due to the wooden base that bended as well. To ensure this does not happen with an aluminum frame, the frame on the right was made. Due to limited time, tests were not conducted with this model. It is recommended to use this model during test days.

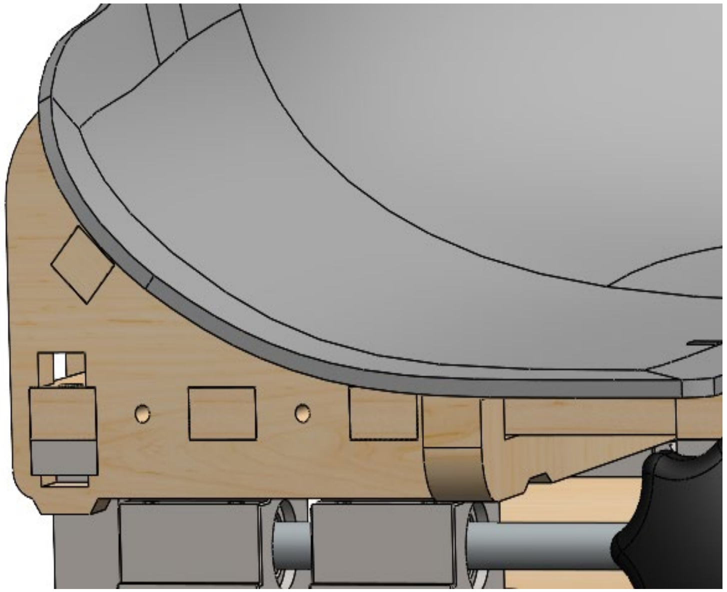


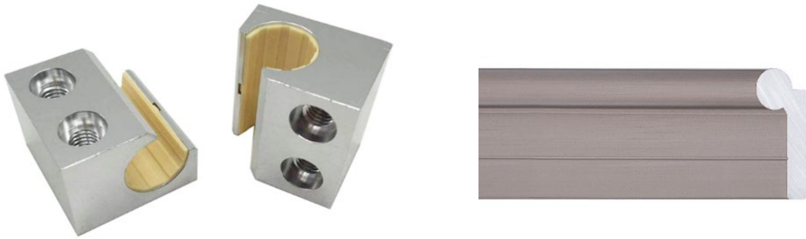
Sliding mechanism

After a consult with Willem, we defined that the protruding rails were unfavorable due to the hazard of kite lines getting stuck behind them. To solve this problem, the orientation of the rails and bearings is reversed, fixing the bearings to the baseplate and letting the rails slide through instead of the other way around. This results in four loose rail parts, which move as shown on the right. The advantage is the increased safety, the disadvantage is the decrease in strength. The closer the bearings are that hold the rail, the more a tilting effect is likely to occur.

The envisioned parts shown below give more strength to the design, because it is possible to put the bearings a bit wider. However, due to lead times, it was not possible to receive these bearings in time for the test.







Envisioned parts for the rail

Seat

The seat halves are made of fiberglass and epoxy. They were produced using the CAD file of Marinke as a base to create a mould. The mould was made using a CNCed foam negative, which was sanded and wrapped in tape to allow for easy release of the mould. Four multidirectional layers of approximately 300g fiberglass and epoxy were applied using the wet lay up technique (Easy Composites, n.d.). This thickness was defined in consultation with the staff of the PMB and after measuring the thickness of the current Tessier seats. Also, an aluminium strip was inserted after the first layer for reinforcement. After curing, the shape was released from the foam mould and cut out using 3D printed parts as a template. The parts were then sanded and holes were patched.

The material was obtained at the PMB and epoxy was partly sponsored by the wind surf association Plankenkoorts, which is the reason for the use of both materials. For the test, the strength of the seat is more than sufficient,

Cushioning

Two types of cushioning that can be used in the seat are either open or closed cell foam. Open cell foam is typically softer due to its structure which allows air to enter, while closed cell foam is more water-resistant and can withstand higher pressures (Polymer Technologies Inc., 2018). Closed cell foam, therefore, is better suited as it reduces the risk of water damage from bacteria and mould. EVA polyurethane foam is a good option due to its resistance to UV and saltwater.

The EVA foam was heated with a heat gun and clamped to the fiberglass seat with the 3d print as the negative shape. After cooling down, the foam stayed in the same shape. Possibilities regarding vacuum forming were explored, but the faculty of IDE did not have the right facilities to process the foam this way.

For the test day, the foam was glued in place, but this is not the envisioned solution, since it reduces the accessibility and removability of parts, which would be contradictory with the framework of circular design.

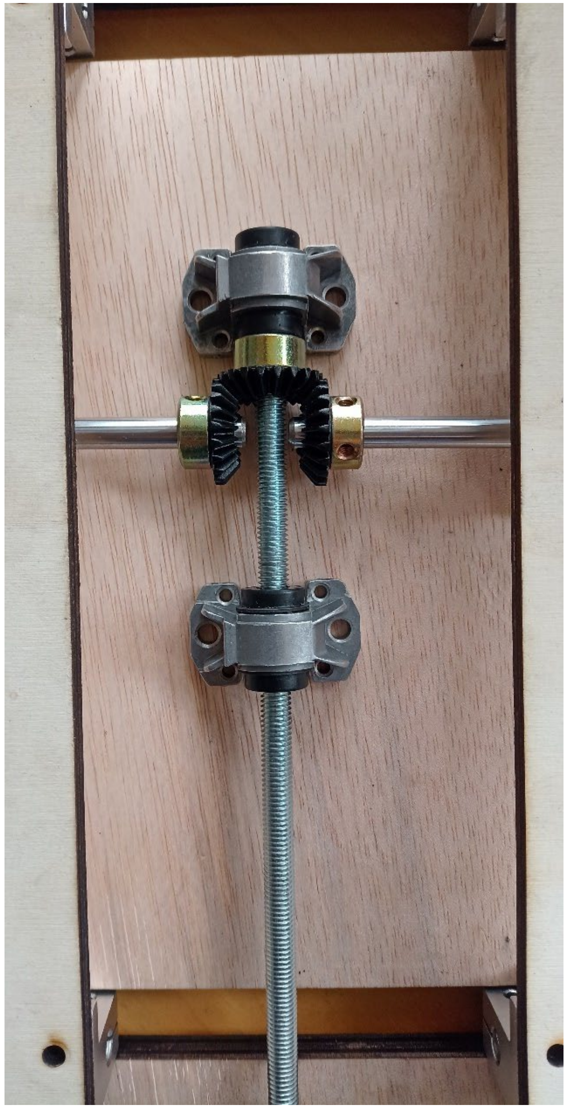
Adjustability mechanism

For the adjustability, the worm wheel concept was chosen. (See chapter 3.2) To be able to move both halves as fast as possible, products with similar working principles were analyzed. A 3D printer must interlock the height, but still must be able to move quickly in all axes. This is done with the use of a lead screw, which is used in the prototype.

To be able to move both halves in opposite ways, a left and right threaded lead screw was the envisioned solution, as shown below. However, due to the long lead times, another solution had to be found to achieve the same result.

Left and right threaded lead screw

Bevel gears were used to enable two right threaded lead screws to rotate in opposite directions. The configuration is shown on the right. This resulted in a rotation point in either the front or the back of the seat. For the test, the rod was extended so that it could be turned in between the legs of the participants, as can be seen in the image on the right.



Bevel gear configuration

In the second iteration of the adjustability mechanism, one axis was used, and the user reaches the turning point from the side. In this iteration, rotating was done with an external ratchet. Here, the envisioned left and right threaded lead screw was used.

Appendix F: Test outcomes

Participant 1: The seat flexes backward and sideways, likely due to the prototype's material (wood for the base) and the lack of attachment of the seat halves around the lower back. The overall stiffness of the structure could be improved, possibly by reducing the number of parts. The seat's fit was perceived as good, even better than seats from other brands like Tessier. The open sides were appreciated, as they provided less surrounding structure and reduced weight in fiberglass. It would be beneficial to have a strap for securing oneself to the seat. Regarding the adjustment of the seat, it is preferred to have the knob located at the front instead of the back. It was agreed to eliminate the gear transition and thus minimize the number of parts. During tightening, it was difficult to feel the tightness. During test days, an instructor should be responsible for tightening the seat for safety. The additional strap was deemed unnecessary for those with reasonable leg or arm function. Maybe it would be nice to explore ways to reinforce the fiberglass support in width to minimize backward and sideways flex. Investigating options for connecting the seat halves at the top, such as a buckle or Velcro, was also recommended.

Participant 2: Side hand rests on the seat could facilitate easy adjustment of sitting positions when hip placement is uncomfortable or not optimal.

Participant 3: Use fewer parts to reduce maintenance and potential for breakage. When the seat is tightened too much before sitting, it is not comfortable. While exiting, participants tend to grab the back of the seat to push themselves out. Some struggle to lift themselves up due to limited space.

Other observations: It is challenging to push the seat into the boat from the water. Here a handle could also come in handy. When exiting, participants use their arm muscles to push themselves up by holding onto either the back or front of the seat. One of the participants places his hand on the left front corner of the seat to lift himself up, while supporting himself with one hand on the wheelchair. The seat provides adequate buoyancy, with the board submerged and the seat's edge just above the water level. The wooden base of the seat cracked. The wind conditions during testing were choppy, resulting in significant impacts on the prototype. However, these conditions were not considered extreme.

Appendix G: HREC

Delft University of Technology
HUMAN RESEARCH ETHICS
INFORMED CONSENT FORM

1: Participant Information/Opening Statement

You are being invited to participate in a research study titled Evaluation of an adjustable sitwake seat. This study is being done by Djemie Tuankotta and Ruud Balkenende from the TU Delft, in cooperation with the Willem Hooft Foundation (WHF).

The purpose of this research study is to evaluate the product usability with the use of a prototype of an adjustable sitwake seat and will take you approximately 120 minutes to complete. The data will be used to identify improvement points of the prototype. After the data is processed, it will be published in the TU Delft education repository. The TU Delft Education Repository is the digital public repository for output made by TU Delft students, including master theses. We will be asking you to perform a series of tasks, including sit-wakeboarding on the adjustable sitwake seat prototype behind a cable in a designated cable park. Before trying that, you will be instructed and have your hip width taken to adjust the seat to your specific measurements. Afterwards, there will be room for feedback. During the product usability evaluation, footage will be taken, both video and photo, to analyse afterwards.

Because of the physical acts during the evaluation, participants are exposed to a couple of risks. These are defined in part 2: explicit consent points.

Regarding personal data, as with any online activity the risk of a breach is always possible. To the best of our ability your answers in this study will remain confidential. We will minimize any risks by de-identifying personal data where possible. Participants will be numbered and named by their number throughout the thesis. Visual material will be handled confidentially and only used to analyse the results. During this analysis phase, the footage will be stored on OneDrive which is secured.

When the thesis will be published on the TU Delft repository, all anonymized data will be open to the public.

Your participation in this study is entirely voluntary and you can withdraw at any time. You are free to omit any questions. or

2: Explicit Consent points

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION		
1. I have read and understood the study information dated [20/*12/2022*], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
3. I understand that taking part in the study involves:	☐	☐
• Capture of information using video recordings, pictures and taking notes.		
4. I understand that the study will end approximately 10-04-2023		
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)		
5. I understand that taking part in the study involves the following risks	☐	☐

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
• Participating might result in a high level of stress and anxiety that fit the experience of sitwaking. • Participating might result in physical or mental discomfort when falling in the water during sitwaking. • Sitwaking is considered an extreme sport, resulting in a higher risk of injury. I understand that these will be mitigated by • Risks are minimized by giving thorough instructions at the beginning of the test. Beginners will try to sitwake one at a time (cableway will not be full). A boat will be present that can pick the beginners up when they fall. Someone will be present close to the dock to help beginners when they fall during the first few meters. • Protective gear will be obligatory: Helmet, lifejacket, wetsuit and neoprene shoes. This prevents injury, drowning, wounds and hypothermia. • The to be tested prototype will be reviewed by a Health, Environment and Safety adviser to assure the safety of the prototype. • Your participation in this study is entirely voluntary and you can withdraw at any time.		
6. I understand that taking part in the study also involves collecting specific personally identifiable information (PII) [Name, physical disability] and associated personally identifiable research data (PIRD) [Videos and pictures] with the potential risk of my identity being revealed.	☐	☐
7. Use of the Cableway is entirely at your own risk. The operator is in no way liable for damage to persons and/or property, nor for damage inflicted on third parties, nor for damage caused by structures, nor for any other damage, however caused. Moreover, the operator is not liable for		

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
damage resulting from the health and/or condition of the participant. By participating in this study, I also agree to the terms and conditions of the cableway.		
8. I understand that the following steps will be taken to minimise the threat of a data breach and protect my identity in the event of such a breach. • Data will be anonymized where possible. Participants will be named by their number throughout the documentation. • Visual material will be anonymized by facial blurring.	☐	☐
9. I understand that personal information collected about me that can identify me, such as names, will not be shared beyond the study team.	☐	☐
10. I understand that the (identifiable) personal data I provide will be destroyed at [*01/06/2023*],	☐	☐
C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		
11. I understand that after the research study the de-identified information I provide will be used for improving the adjustable sitwake seat and that this information will be published in the TU Delft education repository.	☐	☐
12. I agree that my responses, views or other input can be quoted anonymously in research outputs	☐	☐
D: (LONGTERM) DATA STORAGE, ACCESS AND REUSE		

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
13. I give permission for the de-identified visual material, quotes and feedback that I provide to be archived in the TU Delft education repository so it can be used for future research and learning.	☐	☐
14.I understand that access to this repository is open	☐	☐

Signatures

____________________________ ___________________________ _________

Name of participant Signature Date

I, as legal representative, have witnessed the accurate reading of the consent form with the potential participant and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

____________________________ ___________________________ _________

Name of witness [printed] Signature Date

I, as researcher, have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

__________________________ ___________________ _________

Researcher name Signature Date

Study contacts details for further information:

Djemie Tuankotta

Appendix H: Cost price estimation

Part #	Part	Material	Cost	Amt	Subtotal	Source
1	Aluminum support	Anodized aluminum	€ 19,53	2	€ 39,06	247Steel
2	Aluminum base	Anodized aluminum	€ 24,22	1	€ 24,22	247Steel
3	Cushioning	EVA foam	€ 5,00	2	€ 10,00	Minque
4	Seat	Polyester resin & 450g fiberglass	€ 150,00	1	€ 150,00	Muecke-Carbon & Kunststofftechnik
5	Casing	Recycled ABS	€ 15,00	2	€ 30,00	Similar products
6	Leadscrew LH	Stainless steel	€ 31,49	0,5	€ 15,74	Roton
7	Leadscrew RH	Stainless steel	€ 24,44	0,5	€ 12,22	Roton
8	Shaft collar	Stainless steel	€ 5,15	1	€ 5,15	Mcmaster
9	Hex nut	Stainless steel	€ 14,81	1	€ 14,81	Mcmaster
10	Externally threaded nut	Brass	€ 25,19	2	€ 50,38	Roton
11	Linear sleeve bearing	Stainless steel	€ 9,10	8	€ 72,80	Shenzen
12	Shaft connector	Stainless steel	€ 10,00	1	€ 10,00	
13	Handle	ABS	€ 3,50	2	€ 7,00	Rickshandel
14	Linear rail shaft	Aluminum anodized	€ 10,72	2	€ 21,44	Igus
15	Sleeve bearing	Nylon	€ 0,47	2	€ 0,94	Materiaal.nl

Total	€ 463,76