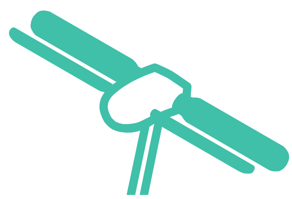
biKit

Adapted bike accesories for
children with CP

Process report



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Emma Díaz González
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ABSTRACT

This report is part of my Master's Thesis in Industrial Design, in Aalborg University. Its purpose is documenting the process I have gone through to achieve the final result.

It deals with designing a bike solution for children with mild to moderate levels of Cerebral Palsy. During research it was found out that the best choice was not designing the whole bike, but a series of accesories to be fit onto regular bikes.

Through the development phase, several tools like sketching, model making and user testing were used to reach a final concept for a bike saddle and handlebar. Both were ergonomically designed to meet the needs of children with CP.

This concept brings value by offering a more affordable and accesible solution to having an adapted bike.

ACKNOWLEDGEMENTS

I would like to thank everyone who in one way or another has helped me realise this project.

The assistance provided by both my main and technical supervisor was greatly appreciated.

I would like to specially thank all the physiotherapists and occupational therapists that have given me a bit of their time to help and share their ideas with me.

I am grateful for all the parents and children that have cooperated in this project, and particularly Raquel and her son, Gabriel.

And finally, I would like to acknowledge my family for both the moral and technical support provided.

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INTRODUCTION

Children need to play, they love playing. But for kids with Cerebral Palsy (CP) it becomes a bit harder for them to do so, as well as other common daily activities. Cerebral Palsy is a disorder that affects the motor function of the body. For a child that has this disorder, actions like seating, standing or walking are not as easy to do as for other children. Therefore, they need to work hard to get to do these things, and they sometimes need some equipment to help them do it. The aim of this project is to design a bicycle for children with CP, so they can use it and play like any other kid, allowing them to have some mobility freedom.

ALIGNMENT & RESEARCH

This section presents the problem that this proyect deals with, and gives an overview of the different research stages carried out to deepen the knowledge in this subject.

THE PROBLEM

Cerebral Palsy is a disorder that makes it a bit harder for affected children to do their daily activities. But they are still children, and they need to play. One of the toys that children love is a bicycle. There is a small selection of bicycles in the market aimed to children with this or similar disorders. However, it is a minority of the children that actually have one.
In a preliminary overview of the bikes in the market some issues were found that could explain this:

They are expensive.

They have many accessories and many adjustment possibilities, which makes them look more like a medical instrument and less like a toy.

They are too heavy and not easy to transport.

They might not fulfil all the needs a child with CP has.

WHY DO THIS?

The aim of this project is to design a viable solution so children with CP are able to enjoy riding a bike and play like any other kid, while at the same time satisfying the needs of their parents, who will be the ones to facilitate this activity.

WHO BENEFICIATES FROM THIS PROJECT?

Children with CP
More children with CP will be able to enjoy riding a bike, making their lives a bit more fun

Parents
They are going to have more options available if they decide to buy a bike

Society
More opportunities of social integration
Healthier children decreases the expenditure on treatments

Specialists
Kids will keep improving at home, suffering less step backs in between treatment sessions

Bike sellers
More products available will broaden the market, and they will be able to sell more

CEREBRAL PALSY

Cerebral Palsy is the term for a group of disorders that causes a variation of the muscle tone of a person, affecting his ability to move, his posture and balance.

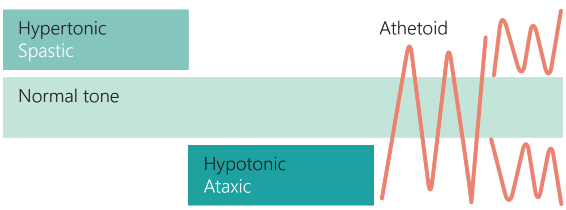
It is caused by a lesion on the immature brain of a fetus or a baby, so it can occur during the last months of pregnancy, labour or the first years of life.

It is a permanent disorder, meaning that the neurological damage is irreversible and persists throughout the person's life. This damage does not change, it neither grows nor diminishes. But the consequences can improve or worsen, depending on their treatment, both medical and physical therapy.

The lesion can also affect other functions like perception, memory, language or reasoning.

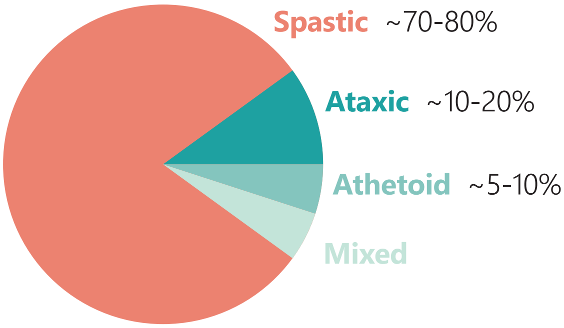
Muscle tone, also called residual muscle tension, is the continuous and unconscious contraction of a muscle while at rest. This state of innervation helps the muscles respond automatically if a pull or stretch occurs. Most of the people have a normal muscle tone, which is inside some limits. A muscle tone above normal is called hypertonia, and causes muscles to contract too much. When the muscle tone is below normal is called hypotonia, and causes the muscles to be too relaxed[1].

MUSCLE TONE



TYPES DEPENDING ON MUSCLE TONE

- Spastic: they have high muscle tone, they are hypertonics. About 70-80% of the cases of CP are spastics.
- Ataxic: they are hypotonics, with low muscle tone. About 10-20% of the CP cases are ataxics.
- Athetoid or dyskinetic: they have mixed muscle tone, that is both hypertonia and hypotonia mixed with involuntary motions. About 5-10% of the CP cases are like this.
- Mixed. Sometimes a person can have mixed muscle tone in different parts of his body[1].



TYPES DEPENDING ON SEVERITY LEVEL

There are two common classifications that take into account the severity of the disorder. The traditional classification is still in use, but there is a new system proposed by the World Health Organization that focuses more on what a child can do, instead of his limitations.

Traditional classification[1]

Mild – A child can move without needing assistance and can be active and independent, so he is not limited in his daily activities.

Moderate - A child will need bracing, medications, and adaptive equipment to be able to do daily activities.

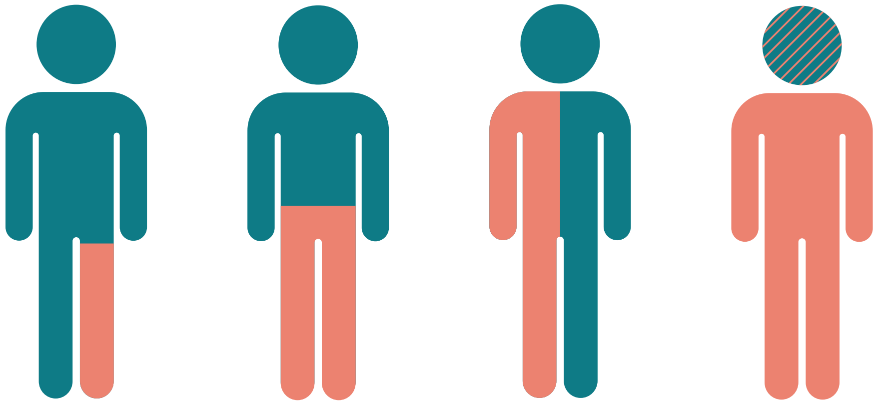
Severe - A child will have to use a wheelchair and it will be significantly challenging to accomplish daily activities.

GMFCS Classification Levels[2]

Level I - Walks without limitations.
Level II - Walks with limitations. Limitations include walking long distances and balancing; may require use of mobility devices when first learning to walk, and may rely on wheeled mobility equipment when outside of home for travelling long distances.
LEVEL III - Walks Using a Hand-Held Mobility Device.
LEVEL IV - Self-Mobility with Limitations; May Use Powered Mobility.
LEVEL V - Transported in a Manual Wheelchair.

TYPES DEPENDING ON TOPOGRAPHICAL DISTRIBUTION (affected zone)

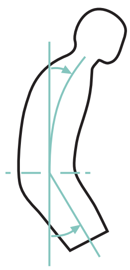
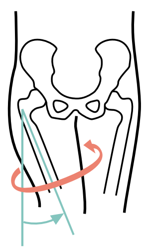
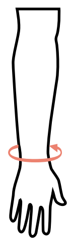
monoplegia/ monoparesis	diplegia/ diparesis	hemiplegia/ hemiparesis	quadriplegia/ quadriparesis



CHARACTERISTICS OF SPASTICITY

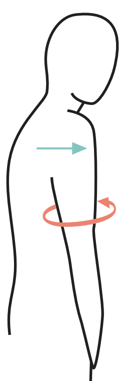
Since spasticity is the most common type of CP, it seems logical to focus on its characteristics when developing a new design.

Following are the general changes that a spastic body suffers.

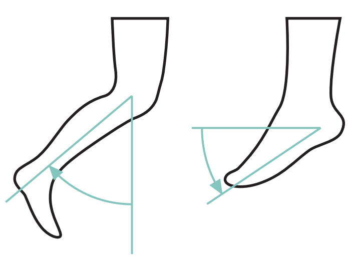




The trunk tends to be in flexion. The hip joint -articulation of the pelvis with the femur- tends to be in flexion, adduction and internal rotation

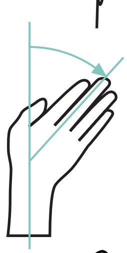
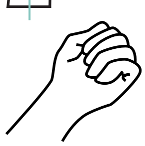
From the elbow the arm tends to be in pronation



The shoulder joint -articulation of the scapula with the humerus- tends to be in internal rotation, adduction and protraction

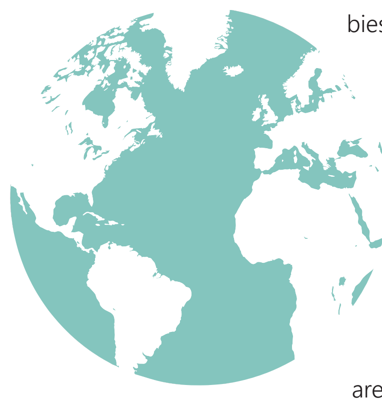


The knee tends to be in flexion and the foot tends to be in plantar flexion

The hand tends to be in ulnar deviation and fingers tend to flex, to grasp

SOME NUMBERS



2 out of **1000** babies are born with CP every year

This number is the same worldwide. It varies slightly depending on the studies - some are 2,0 others 2,1[3].

In Denmark, around **180** babies are born with CP every year.

There are between 3000-3500 people under 18 years old with Spastic CP in Denmark[4].

TALKING WITH THE PARENTS

In order to find out about the thoughts and the needs of parents that have children with CP, I conducted an interview to a mother, distributed a simple questionnaire to several other parents and looked at support forums.

INTERVIEWING RAQUEL

Raquel is the mother of Gabriel, a 6 years old boy with a mild spastic hemiparesis. She is Spanish and she has a job with middle-low level income.

Following there is a summary of the most important points that she talked about. For a transcript of the whole interview, please see Appendix B.

"Gabriel at first had a regular bike, but he could not ride it. His feet and hands would fall off the pedals and handlebar and he would get hurt. Then my husband and I bought him a balance bike with side wheels. Although he still had some problems, he could use it, but now it is too small for him.

We have looked for bikes in big stores like Toys"R"Us, but have not found a suitable one for him. We have also thought about adapting a regular bike, but we do not know how to do it or if it is going to cost too much.

I think that the bike should look like a bike, it should be a toy, not treatment equipment. Gabriel has to be comfortable with it, otherwise he will get frustrated and stop using it.

With his age, it does not seem logical to spend money on a bike, because he is going to outgrow it soon, but it is when he most needs it, because he needs to play.

I would even spend 800€ (~6000 DKK) on a bike, if he could be happy with it."

Gabriel and his mother

QUESTIONNAIRES

The specialists that I talked to in different centres helped me out by distributing a questionnaire to the parents of their patients (See Appendix C). I was not present when the parents filled them out.

There were 9 questionnaires filled out. In 5 cases the children had a bike and in 4 cases they did not.

The main reasons given why they did not have a bike were two: they had not found a suitable bike or they were waiting for the child to grow up.

As for the ones that had bought a bike for their children, they did not know of the existence of adapted bikes for children with motor problems. They bought regular bikes and adapted them. But some stated that they are not happy with the adaptation because it is not optimal.

They all bought the bicycles in common big stores.

Most of them would not spend more than 400€ (~3000 DKK) on a bike. Only one said that if the child is independent, she would not mind paying.

The most important things they would care about when buying a bicycle are the adaptability to the child, the price and the durability, in that order.

Stina[6]
"My daughter has just turned 8, and we took the training wheels off, to try to see if she can learn."

Cæcilie[6]
"I got my first bike with training wheels when I was 7. I wanted to have a regular bike, but my balance was poor."

Charlotte[6]
"My son was 6 1/2 [years old] when he learned to ride. [...] He got a special saddle, and it was also possible to change the pedals. Now he is 8 and he rides a common bike."

FORUMS

I have found a couple of support forums for parents to children with CP, and it has been really useful to read the conversations.

Jakeys
"My son is 6 [...] He has a bike that he is unable to ride yet which has stabilizers[...] He didn't have enough strength in his legs to push the pedals[...] I asked about it in another forum and I got a reply saying that some children with spastic diplegia can't pedal because of the stiffness in their ankles . It was weird cause I never even thought of that because like I say my son can walk."

b8s
"There are lots of different special needs bikes on the market. They are more expensive but you can apply for charity funding to help.
It may be that you can get a standard child bike which could be adapted. Our OT fitted straps to a standard baby trike when our daughter was younger, so we were able to delay getting specialist equipment."

CONCLUSION

Most of the parents do not want to spend a lot of money on a bike. If they do, it has to last many years.

Parents do not usually go to specialized stores looking for a bike. Most of them just look in common stores. Parents want to feel that their kids are "normal".

It seems like adapting a bike is the most common option for parents to children with mild CP.

The age of 6-7 years old is quite common among children with CP to start learning to ride.

Parents prefer two-wheeled bikes with training wheels instead of tricycles.

TALKING TO SPECIALISTS

In order to gain a bigger insight on the problems and needs of the children that are going to use this bike, as well as establishing contacts for future queries, I visited three different places. All of them were in Spain. The first one was San Juan de Dios, a centre for attending adults and children with different levels of dependency due to disabilities. It provides with both health and education related assistance. Then I also visited the Canarias University Hospital, where in addition to talking to the specialists, I met some children with CP and saw how they received treatment. And finally, I visited the Health Centre Doctor Guigou, specialised in children rehabilitation.

Thanks to these visits, I managed to talk to around 10 physiotherapists and occupational therapists (See Appendix A for a detailed list). They shared with me their thoughts on what the bike should be like, and made me aware of the main problems and the most basic considerations I needed to have in relation to this disorder. They also showed me other types of equipment these children use, like chairs, walkers, or standers.

We sustained a long discussion about what they thought the bike should have. I have made a selecton of the most relevant points that the specialists mentioned based on the scope of my project. They are grouped by the zone of the body they relate to, but there is no particular order.

SPECIALISTS' COMMENTS

Hands should be closer to the level of the shoulders.

There has to be a strap or something to hold the hand on the handlebar, because the kid's hand tends to fall off.

It would be interesting to have the possibility of changing the hands position on the handlebar.

For some kids is hard to use the brake.

It is very important to always hold the pelvis in position. To better hold the pelvis, it could be used a strap.
The separation between the legs is important. The seat has to have an extended part in the middle, because the kids tend to close their legs.

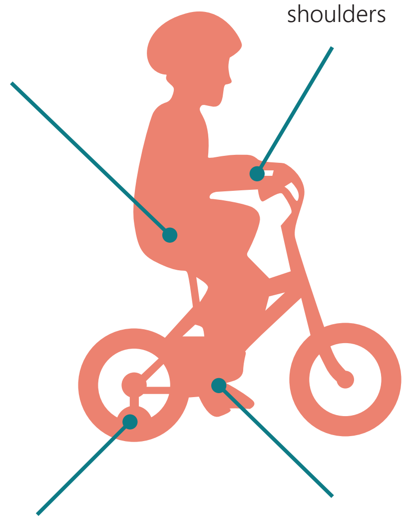
The rotatory movement needed to pedal is hard. It could be nice to have an up-down alternate movement. It is better if the angle of the feet is a bit open.
Feet must be hold somehow, so they don't drop while trying to pedal.

There has to be something that helps them keep the balance. Most of them cannot use a regular two wheeled bike. But it is also important that they exercise to improve balance. The tricycles do not allow that, because they are always stable. It should be possible to allow for adjustment on the balance help, so a kid can improve his balance and maybe get to a point where he does not need balance help anymore.

Hypercorrection is going to have the opposite effect to what is wanted. So the bike has to adapt in some level to the problems they already have, but allowing for improvement.

CONCLUSION

The most important points, or rather the things that are going to define the most the design of this concept are the ones shown in the following illustration.



MARKET RESEARCH

There are several options in the market for handicaped children. All of them are prepared to attach different accesories to them, depending on the kind of support the child needs. These accesories are not included in the main price, and they have to be paid upon it. Most of them have different sizes available, depending on the age of the child.

Rifton

Small 7000 DKK   Medium 7740 DKK
Large 11000 DKK
Prices increase with add-ons, like a bigger seat or a back pad

MOMO

Price 7320 DKK + accesories= 12540 DKK
Sizes
12" 1-3 years   16" 3-6 years   20" 5-8 years
24" 8-12 years   26" 12 and above

Micah

Price 11350 DKK
Adjustable frame length, seat height and position

AmTryke 1416

Price 5400 DKK
Age 6-12 years

While analising these tricycles, several issues came up. The first one is that they are tricycles. As mentioned in the previous section, a bike designed for children with CP should allow for the possibility of improvement in balance. That is not possible if there are always two wheels at the back.

Some of these bikes have self-levelling systems that are supposed to help pedaling, but this does not really help reduce the effort to iniciate the movement. They are also rotatory, which, as discovered earlier, might not be the optimal solution.

These bikes are designed to fit several disorders, and all degrees of CP. Consequently, they have many accesories, which makes them expensive and adds an important amount of weight to the bike. It also makes them look like medical equipment.

The weight is another issue found with these bikes. They all weight around 20 Kg. That is excessive for a child's bike, especially if the kid has motor problems.

Finally, the prices are really high. Buying a bike like these supposes an important investment for the parents.

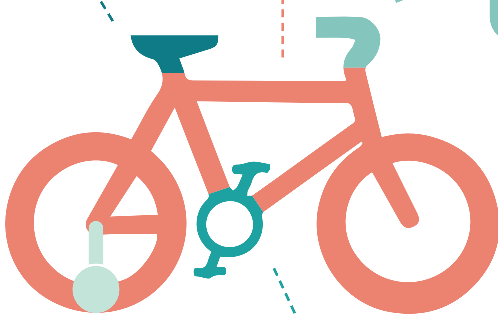
ESTABLISHING REQUIREMENTS

At this point, I was able to put some general requirements for the bike.

The bike should be designed to be used by a kid with Cerebral Palsy in its mild or moderate levels, or levels I or II according to GMFCS Classification Levels.
A child between the ages of 5-7 should be able to use the bike.
The bike should be light.
The bike should be attractive to a kid.

The seat must be adjustable in height. The seat must be comfortable, hold the pelvis in position and prevent adduction of the legs.

The handlebar must be adjustable in height. The handlebar has to have a thick, padded grip. There has to be some sort of system to hold the hands in position. The bike should have a brake that could be used by either hand.



The bike must have something to help with the balance. This equipment should be possible to adjust in height and to remove.

Traditional rotatory movement is not adequate. There should be an alternative up and down movement, in a linear pushing direction. Feet must be hold to the pedals somehow, so they do not drop while riding. A kid should not have to make a big effort to start moving the bike.

Other considerations:
The bike is going to be used both in interior and exterior environments.
The bike is going to be a toy, an entertainment, not a training tool.
The bike is going to be a consumer product, that can be bought by the parents.

BIKE OR BIKE PARTS?

After listing all the requirements that I had so far, I realised that they were focused in four parts: the saddle, the pedals, the handlebar and the side wheels. There were not many technical requirements for the bike frame or wheels. For that reason, the idea of doing only those parts as accesories came up as a plausible option. The accesories would be designed so they could be put onto a regular bike.

In order to figure out if this idea was actually feasible and if it solved in a better way the problems, I made a comparison of the two options, and I started by comparing prices.

	BIKE	Saddle 	Handlebar 	Crank+pedals 	Wheels 	TOTAL
Therapeutic bike	Haverich 16/16  8147 DKK					8147 DKK
New bike + accesories	Everton Miniz 16”  1599 DKK	419 DKK	793 DKK	1219 DKK 245 DKK	100 DKK	4375 DKK
Re-used bike + accesories	My older syster’s bike  0 DKK	419 DKK	793 DKK	1219 DKK 245 DKK	100 DKK	2776 DKK

Prices from bjoern-nielsen.dk and cykelpartner.dk

The bikes and accesories shown in this matrix are in a medium price range. Even if the accesories were more expensive, the price difference would still be considerable. It is a smaller investment for the parents, making it more possible that they actually decide to make it.

With the small amounts of bikes that would be manufactured in a year, it would be quite difficult to make a bike that is cheaper than the existing ones. So if the purpose is to make the possibility of having a bike more affordable, it seems more feasible to do so with the accesories option.

After comparing costs in both options, I also analised other differences in the two systems. I found two more advantages of doing the accesories idea.

The first one is customization. Cerebral Palsy has many degrees and different ways in which affects the body. That makes it complicated to make a universal solution that fits every case. With the accesories concept, parents could be able to buy only the parts that their child needs. The kid may need all of them, or maybe only the saddle, or the handlebar. But this way they do not spend money on something he is not going to need.

The second is accesibility. They could buy any bike, anywhere. They can even use their neighbour's or the older syster's bike. They would just need to put the accesories on to adapt it to the child's needs.

In conclusion, the idea of developing accesories that could be fitted onto a regular bike have four main advantages:

- + AFFORDABILITY
- + FEASIBILITY
- + CUSTOMIZATION
- + ACCESIBILITY

That is why I decided to continue with that idea.

REFLECTION

The research carried out about Cerebral Palsy was very productive and it gave me a very good insight about the disorder. Talking with the specialists that work with this type of problems was the most important part of it. They see it everyday, so they have great knowledge about it. They also have some thoughts on how things can be improved, which is very valuable.

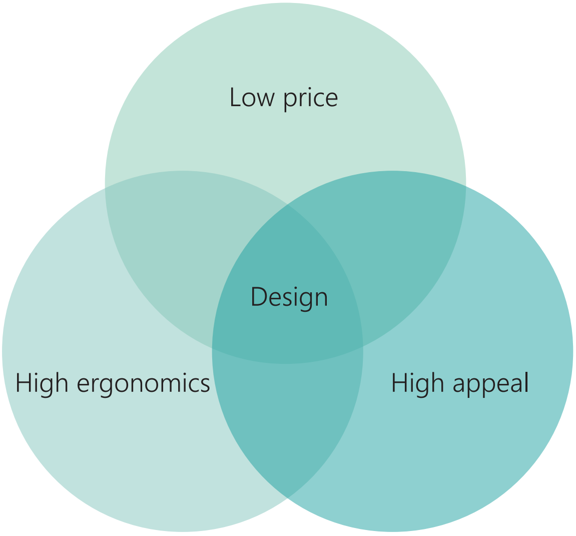
Regarding the user research, I would have liked to be able to talk with some more parents. The questionnaires were not very helpful. They did not give much information. After having done it I realised I should have done different questions. It is better to be able to exchange information in person, because people oen up more, and you can guide the conversation towards the aspects you are more interested in.

The change of path was the right choice, because it made more sense based on the information available. It gave a new perspective to the project. It was different from what I expected, and because of that it became more interesting to me.

CONCEPT DEVELOPMENT

This section describes the steps followed to develop each of the products, from the first ideation to detailing.

DEVELOPMENT FRAME



When thinking about the design of the accesories there were three main aspects that came into play, and I used them as some sort of design requirements for my concepts.

Price

For this concept to work, the price of all the accesories has to be significantly lower than the price of a therapeutic bicycle. The low price should not compromise the quality, so the aim is to make the parts technically simple, so they do not need complicated or specialised manufacturing processes. It is also important to try to make assemblies as easy as possible.

Ergonomics

All the parts have to adapt to the needs of children with CP found during the research phase. The size and shape have to be appropiate and comfortable, respecting the indications of the specialists.

Adjustability is also an important side of ergonomy. Not all children have the same proportions, so the products will be more succesful if they fit to a wider range, inside some limitations.

Choice of materials not only influences the price, but also ergonomy. For example, the hardness of a material, or whether it feels cold or warm, can affect the comfort when it is used.

Appeal

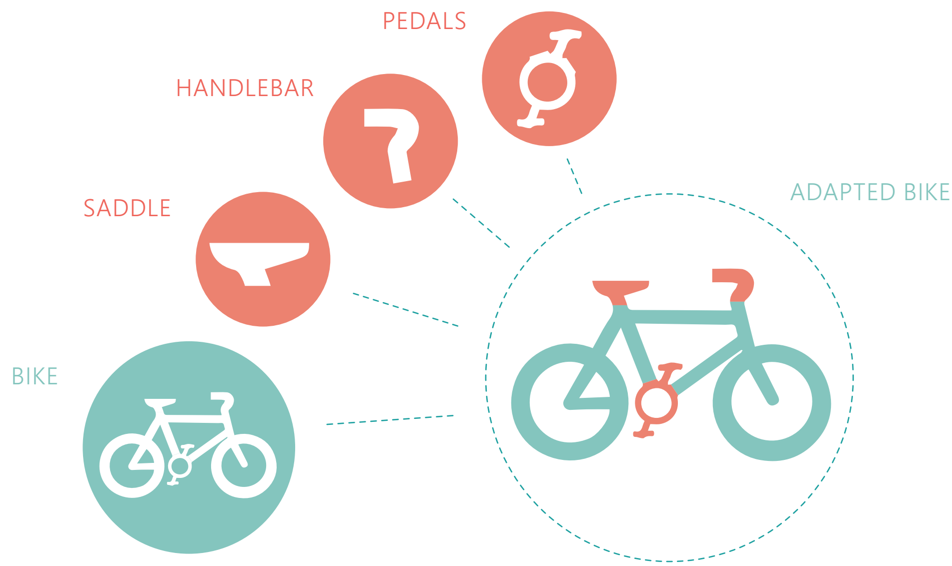
The parts have to be attractive for a kid. They are part of a toy, so they should not just fulfil a function, but they should call the kid's attention, and have some kind of playfulness in them. At the same time, they need to fit aesthetically with the existing bikes.

SO WHAT DO CHILDREN LIKE?

In order to get a better idea on what sort of toys children like around the ages 5-7, and also to become more familiar with how they look and their height, I created this moodboard. The idea was to put some limits to the age range through images, because I was having trouble separating these ages from the rest.

THE CONCEPT

With this system the parents only have to buy those parts that they think their child needs. They can buy a new bike, or a second hand one, or maybe just get it from someone else. Then they can either put the parts themselves, which is done with common tools, or they could go to a bike store and ask someone to do it for them, at a small cost.



The three parts shown on the illustration above are the ones I decided to develop: the saddle, the handlebar and the pedals. I first thought of working on the side wheels as well, but even though the existing ones are not optimal, they are good enough, and users have been already using them. Therefore, since the timeframe was quite tight, I ruled out the idea of a re-design of the wheels.

In the following pages I present the process I followed to develop each of these parts.

All the measurements and sizes chosen for the different parts, are based, at least initially, on data taken out of "The measure of man and woman", by Alvin R. Tilley. An extensive series of dimensions is available for every age. So for example there are average dimensions for children with 5 years, with 6 years, and so forth.

HANDLEBAR

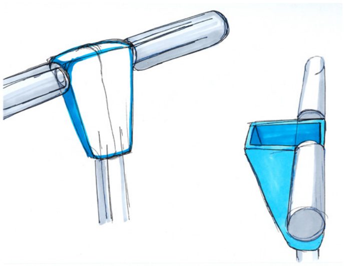
MAIN REQUIREMENTS
Brake easy to use with either hand
Strap that holds the hands
Thick handles
Adjustable in height
Adjustable in angle
Longer grips to allow for multiple hand positioning
Has to fit into regular quill stem system

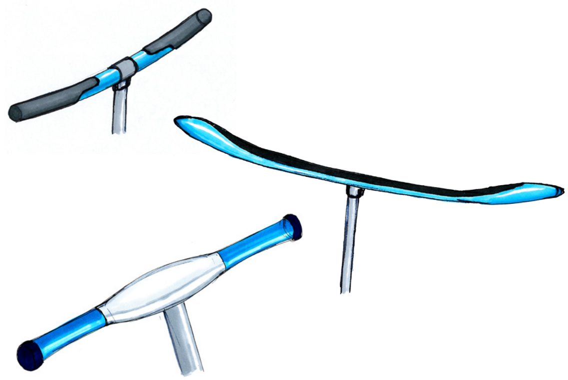
To start developing this concept, I first spent some time getting familiar with how existing handlebars are assembled, and the different parts they have. The first decision I made was that the handlebar should have what is called a quill stem. Its alternative, the threadless stem, its becoming more and more popular, but the quill stem is still the most commonly used, and the only type used for children's bikes.


Quill stem


Threadless stem

After that, I started sketching on general ideas, without paying attention to whether they were possible or not. The main objective of this was trying to get away from the designs that already existed, and also trying to find out what could children like.

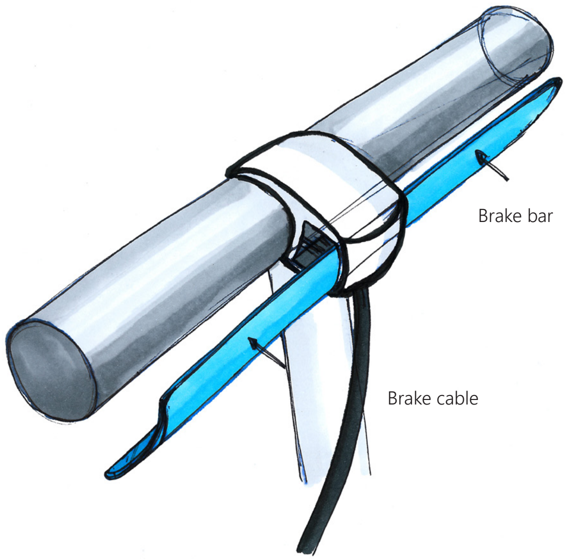




This exercise helped me realise that it was not easy to get away from the design of something that already had so many variations in the market.

Therefore, I started to think about how to make the braking system for both hands, which led me to something with a more interesting and distinctive look.

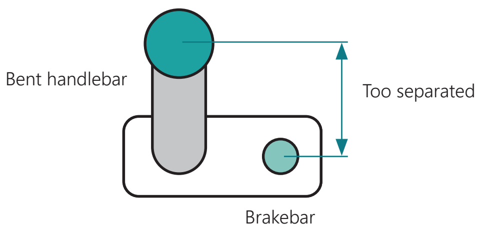
MAIN CONCEPT
The concept I came up with was a braking system that was maneuvered through a bar that run along the whole handlebar. The mechanism is enclosed in a casing situated in the centre of the bar.



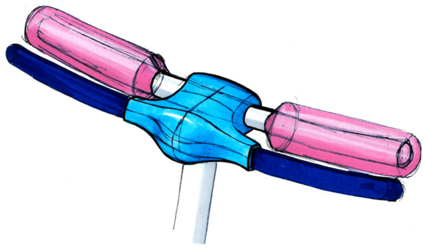
This concept allows the kid to pull the brake with both hands at the same time. That way, the effort is divided between the two hands, working out evenly and with half of the tension on the muscles.

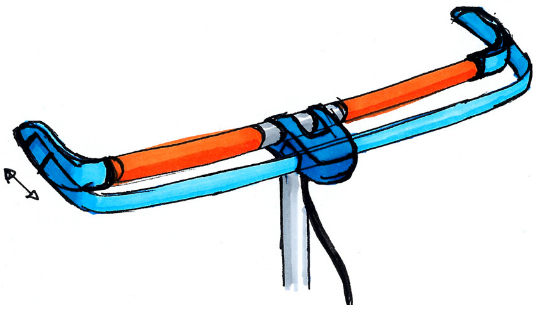
This system defined the whole shape and styling of the handlebar.

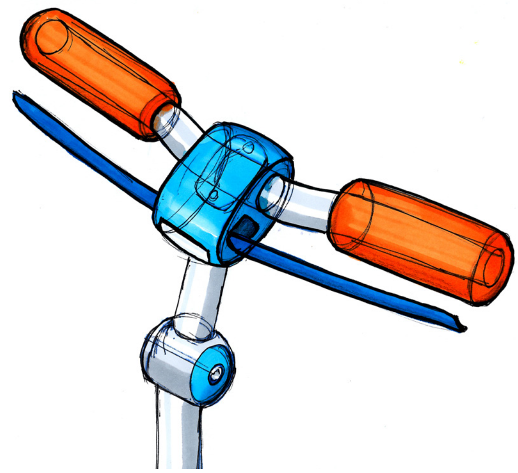
The first limitation that this concept put in the design was that the handlebar couldn't be vertically curved, because the brake bar would not be reachable.



With that in mind, I kept on sketching on this system, trying to think about different options for the overall styling and also the shape of the brake bar.

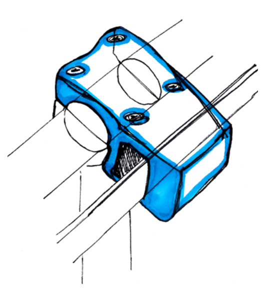


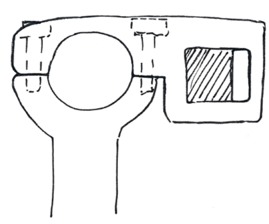




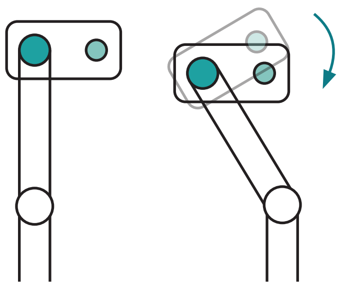
The design in the second image was ruled out because it would need to add two more parts -the ones that hold the bar on the sides- and I was trying to make it with the least parts possible.

Trying to make the casing smaller, I came up with a concept where the faceplate of the bike and the mech-anism could be the same. The faceplate is the part that holds the handlebar in position. In some bikes is screwed to the stem, and in others is welded.





This concept was dismissed because it would not allow for the rotation of the stem, which was in my requirements.

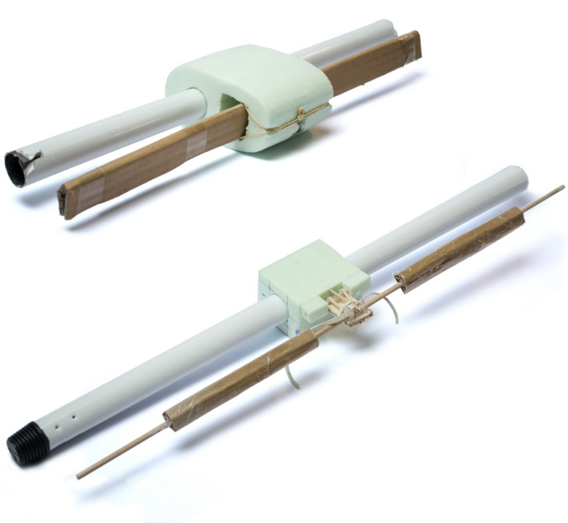


After this, I added some further requirements to the brake system casing: It has to be independent from the faceplate; It has to be able to rotate to adjust the angle, and it should be easy to change the brake cable.

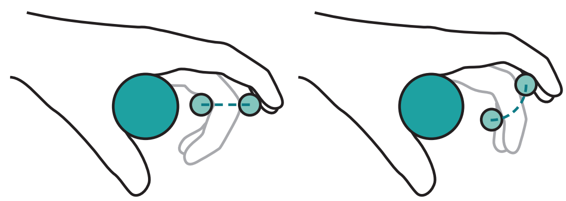
When I got a general idea about how it was going to be positioned and the main elements that would have, I tried to figure out how it was going to work, because that was going to condition the size and the shape.

MECHANISM

I made different foam models, trying a linear and a rotational movement for the bar.



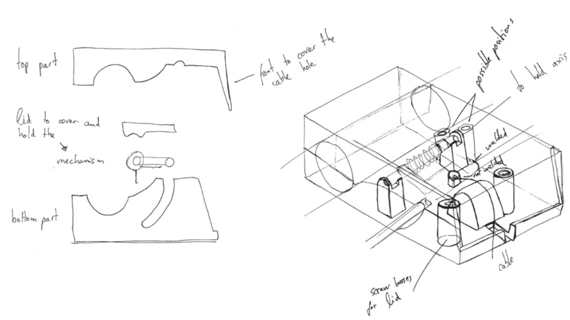
I also made a comparison on how these two different movements would affect the movement of the hand.

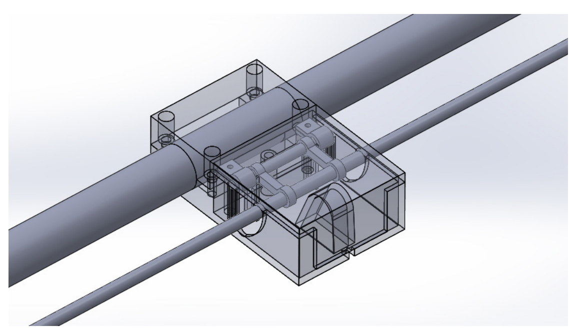


It was clear that to brake with the rotational movement, the fingers would not need to contract as much as with the linear system. This was ergonomically better, and was confirmed as a better option from the specialist I was in contact with.

Additionally, this type of mechanism was easier to manufacture, and it would work more smoothly.

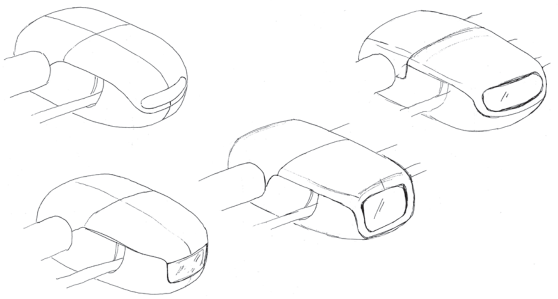
After this, I started detailing the mechanism, first on paper and then on CAD.



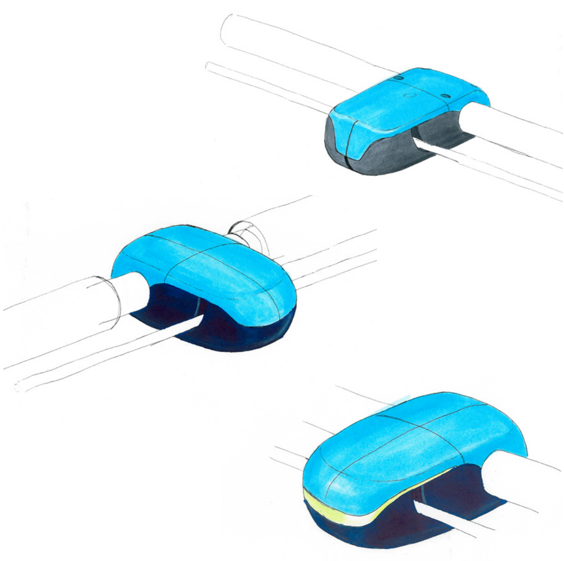


STYLING

Knowing the proportions the mechanism had, I sketched a bit more on the shape of the casing, and the shape of the bar. I was at the same time thinking how the casing would be put together, to have an idea about the different parts, and the split lines and so on.

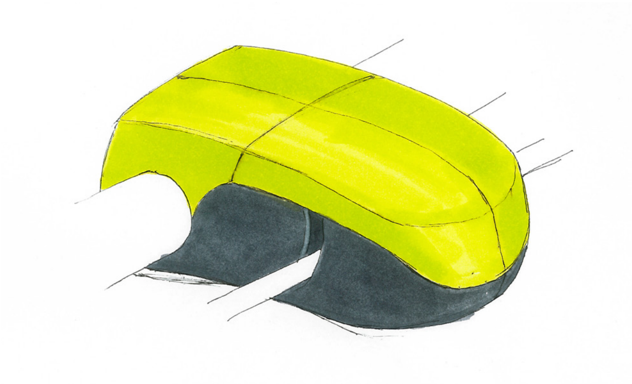


I rejected the concepts with the light, because it would be difficult to develop in such a tight timeframe. However, it certainly is an interesting feature to be considered in the future.

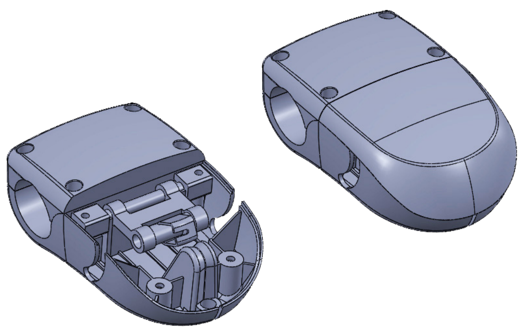


The sketches above are examples of the different ideas I went through. When working on the styling, I basically was playing with the partition line between the lid - in light blue - and the main casing.

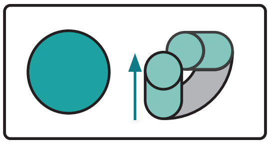
At the end, I decided to choose something like the sketch shown below. It has a bit more tension on the lines, giving more sense of speed, which is appropiate for a bike.



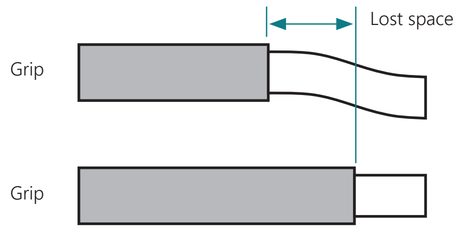
I made that shape in CAD, adding all the details, including the small parts and screws, just to make sure everything would fit and work together.



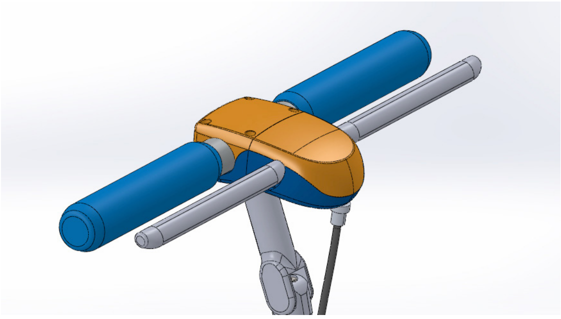
When detailing the brake bar, I decided to make it straight, because otherwise it would not work with the rotating system. The end points would face upwards when the bar was in the lowest position. The illustration shows the problem from a side view. The small circles represent the end point of the bar.



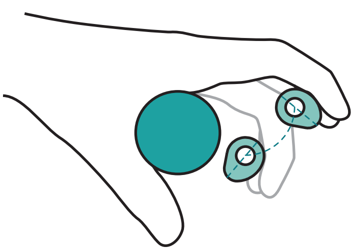
I also decided for the handlebar to be straight, because one of the things mentioned by the specialists was that it would be better to have a longer grip than usual so there is more freedom on where to place the hands.
If the bar is bent, then that space is lost.



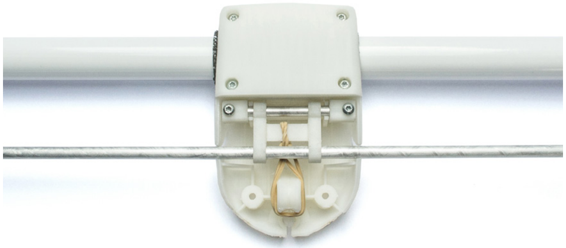
The next step was to model all the parts in CAD. It was easier to style the handlebar and the brake bar when everything was put together. If designed separately, they would look as independent products.



The shape of the brake bar is the result of looking at how the fingers would be in contact with it in its different positions. It is flatter when the brake bar is at its starting position, to give more surface to press. Then it continues with a circular line at the top, to facilitate the rotational movement.



The last step in relation to the casing was 3D printing the parts. The purpose of doing this was to have a feeling about how it looks and feels for real. The second objective behind this was trying to see if the mechanism really worked, and if it would fit together.

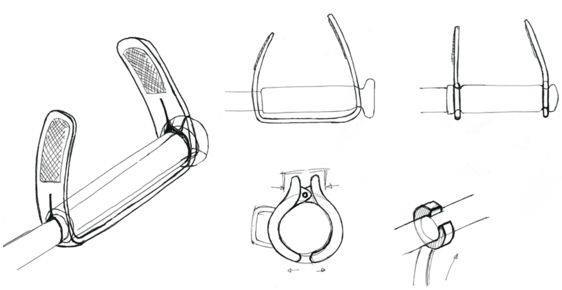


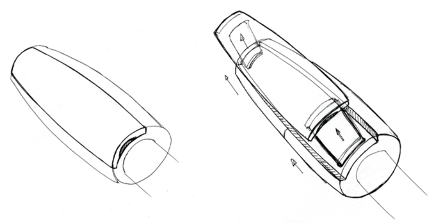
Unfortunately, the only 3D printer used did not have small enough tolerances to make the model reliable. Therefore, the fittings could not really be check based on this model.

However, some small issues did come up, related to the ease of assembly, that would need to be corrected in the future. For example, when trying to screw the top back part that attaches the casing to the handlebar, it would slide sideways. It could be fixed by adding some sort of lip, that prevents the part from sliding.

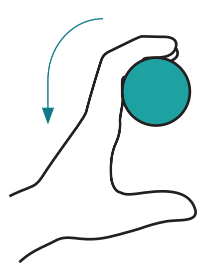
HAND STRAP

To develop a concept for the hand, I first started making some sketches. In these ones, the hand was hold by a strap that would go over it.



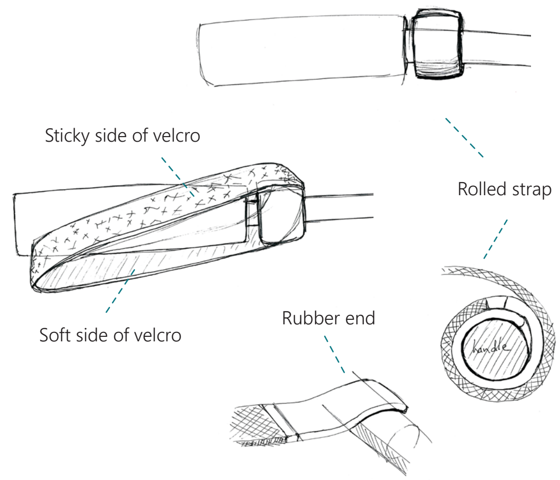


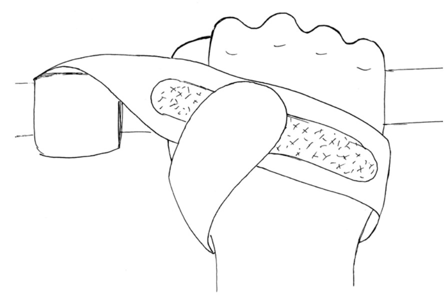
While trying on myself this way of putting the strap, I realised that it did not really hold the hand in place. The way the hand usually falls is like shown in the adjacent illustration.



So I tried other ways, and found one that worked quite well. The strap goes over and then underneath the hand as well.

I continued to develope that idea, and I got to a very simple concept that would be cheap to manufacture. A strap with velcro on both sides is attached on the end to a piece of rubber. To use the strap it needs to be rolled on the handlebar, starting with the rubber. The rubber makes it stay in place. When not in use, the velcro keeps it rolled. To use it, one can un-roll it the needed length, pass it around the hand, and stick it again to itself.

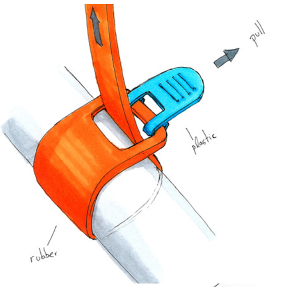




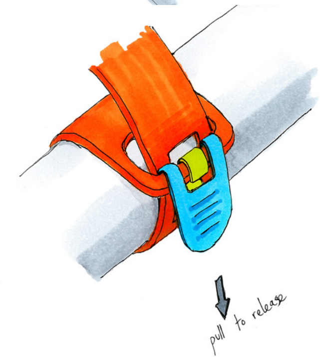
I made a mockup of this concept, which proved to work. But the strap was quite stiff due to the velcro on both sides and maybe because of the way the mockup was done. If there was a layer of textile between the two sides of velcro, then it would problably be more malleable.

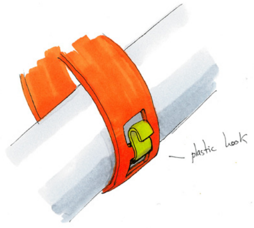
One problem with this concept was if the strap was rolled the other way around, it would not work. To solve this some indications could be added, maybe a painted sign on the rubber, that shows which direction to roll it.

After trying it on myself I was not happy about the way to attach the strap to the handlebar. It did not feel like it was firm enough. For that reason, I kept working on it to try to find another way of fastening it. I developed a concept inspired by the bicycle light shown on the picture. Two pieces of rubber are joined through a rigid plastic hook. When put on a tube, the rubber gets stretched, making it harder to get the rubber out of the hook.



The concept then uses the same mechanism, but adding a part - shown in blue in the drawings - that facilitates the action of inserting and taking off the rubber off the hook.





COLOURS

When thinking about how to colour the product, I had in mind that it was small scale production, so adding a great variety of colours would raise the price. I first thought about four different options. This number allows for some customization, while not increasing much the cost.

Therefore, most of the parts have only one colour, and only the top part of the casing, which is the most visible, have four colour choices. The colours where chosen based on the most common bike colours on the market. There is one option that is neutral, so it could go with all colours, and then 3 more.

NEXT STEPS

There are still many things that could be done in order to develop this product further.

The main step that needs to be taken is to test a working prototype of the whole assembly. That would give me the a great amount of feedback, and highlight the issues I should focus on if I made another iteration in the future.

REFLECTION

The process of doing this concept has been very productive but very difficult. It was not easy to try to put so many parts together and still try to give it some common styling to show that they all have the same purpose.

There is also some more work to do to ensure that the mechanism functions properly when used just with one hand.

I feel the concept is not finished, it needs more testing and design iterations. I would have also liked to spend more time on styling, trying to integrate more all the parts.

PEDALS

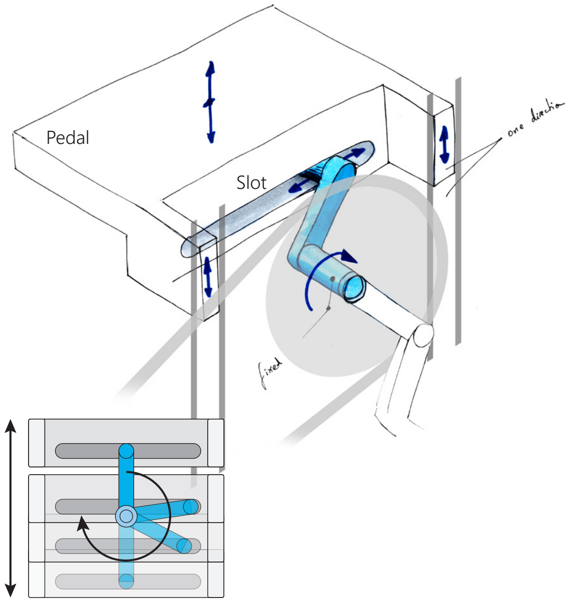
MAIN REQUIREMENTS
Should need less effort to pedal
Should have something to hold the feet, but still be able to take it out quickly and without needing help
Should fit into a regular bike

While talking with the specialists during my research, it was mentioned that it could be interesting to have a pedaling system that was in a linear, up and down movement.

I first spent quite some time trying to satisfy that suggestion. To do so, I started by looking at existing products that could have a similar system. I found what are called "street steppers". A model of those is shown in the picture.

This idea had to be dismissed because it would be very difficult to implement it so it can fit a regular bike. The main issues would be how to make it so the crank is in the same position as a regular bike, and how to make it small enough so it does not interfere with the front wheel.

I moved on to looking at classic mechanisms that translate linear into rotatory movement. The most interesting one that I found to be worth investigating was a scotch yoke. The concept applied to the pedals is illustrated in the following picture.

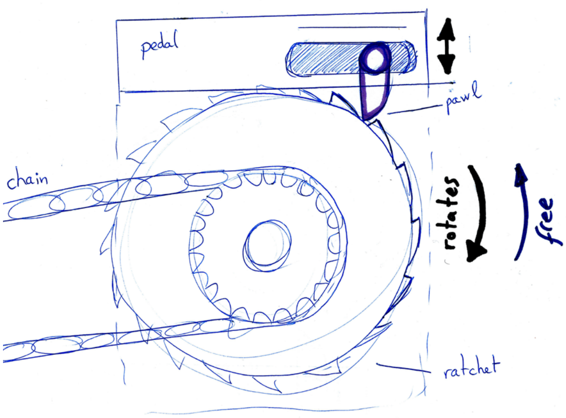


The blue arm would be attached to the wheel that transmits the movement to the chain. The end of that arm is inside a slot in the pedals. By moving up and down the pedals, the arm rotates.

There were two big problems with this system. The first one was that when the pedals were in the extreme positions - up and down - it was really hard to start moving the pedals. The second problem was that there was not a way to ensure that the mechanism would always move in the forward direction.

Not being able to find a solution to those problems I had to dismiss this concept and move on to another solution.

The next concept I thought about is shown in the next illustration.



In this system the pedal would have a pawl that would engage a cogwheel - a wheel with teeth - on its way down, but it would go freely on its way up.

This concept was later ruled out because it would be difficult to make it run smoothly and it would be very inefficient.

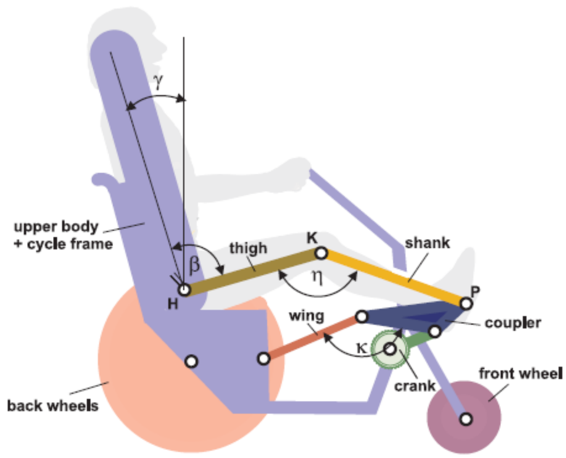
CHANGING DIRECTION

At the end, I was not able to find a system that could effectively and simply enough convert linear into circular movement, so I started looking for another way to facilitate pedaling that did not necessarily involve linear movement . That is when I came across a paper called "Design optimization of a pedaling mechanism for paraplegics" (Rasmussen et al. 2003).

In it, the authors present a mechanism, that combined with electrical estimulation of the muscles, could make a paraplegic able to cycle.

What interested me about this paper was the mechanism itself. It is a four bar mechanism, that removes the dead points that a regular bike has. A dead point is the position of a mechanism where the external force applied can't really do anything to move it. In the case of a bike, those positions are when the pedals are vertical. It means a considerable effort to start pedaling if the pedals are in that position. People usually avoid this by pushing the bike forward at the same time they start pedaling.

The mechanism shown in this paper is quite complex, but I tried to adapt it in size and orientation to use it in the bike.

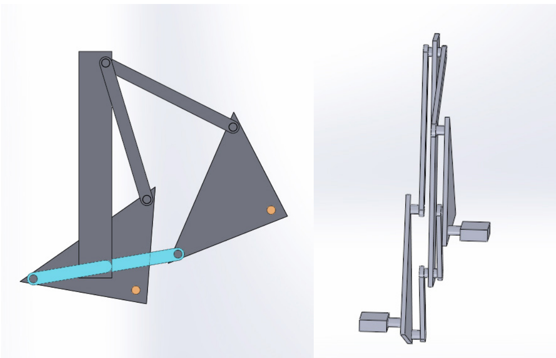


In the paper the authors state that "The ratio between maximum and minimum muscle activity has been reduced from 5.1 in the conventional pedaling mechanism to 2.2."

Even though this is most certainly not the case in the mechanism I have adapted, it just shows the purpose of this mechanism, which is decreasing the difference between the maximum and minimum effort of the muscles, making the movement more even and fluent. This is a great advantage for kids with CP, because it diminishes the amount of efforts made in a short period, resulting in an overall lesser muscle tension .

THE CONCEPT

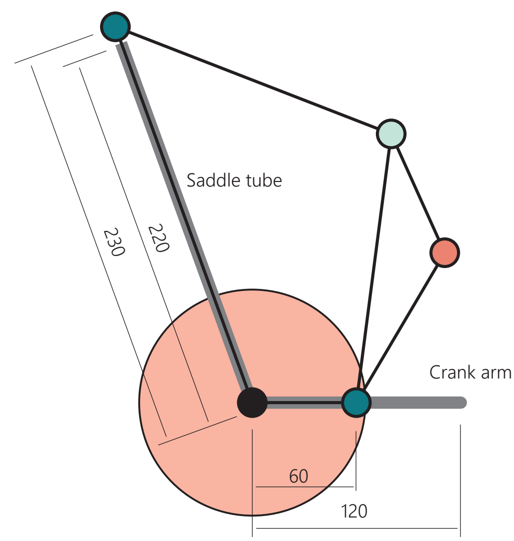
Once confirmed that this mechanism could actually fit my purpose, I made a rough CAD model, in order to figure out the size and position of the different bars.



By changing the bars sizes the movement the pedals make can be modified. But by modifying them too much, there is a risk the mechanism stops working. Consequently, in order to find the most appropiate measurements, I had to have a that in mind, plus a few more considerations. The first one was that the pedals movement could not go too forward, because then they would interfere with the front wheel. Secondly, the movement of the pedals could not be too high, because then the child would need to bend too much his knees. And lastly, the overall dimensions and positions of the bars had to be in such a way that it would not be too hard to attach them to a bike.

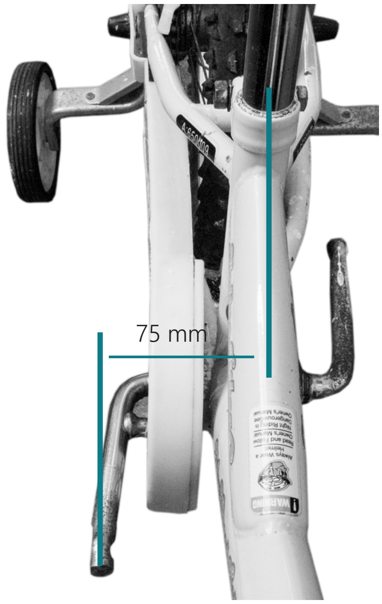
Once I found the right measurements, I made a quick cardboard model to prove the principle, and to attach it to a bike and check if it actually had the proper size.

Even with the rough model I made, I was able to confirm that it worked, so I started thinking about a way to attach it.

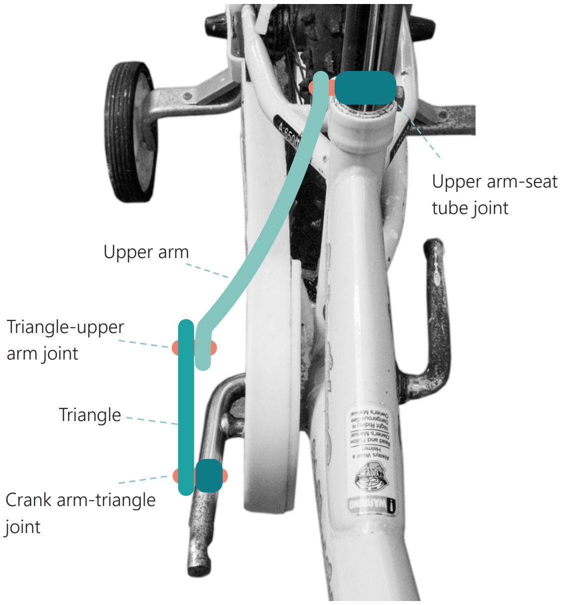


The dark green circles above, show where the mechanism would be attached to the bike. The top joint would have to be fitted on the beginning of the saddle tube. The lowest joint would have to be fitted to the middle of the crank arm.

Another obstacle present when trying to fix the system to the bike is the distance between the seat tube and the crank arm, which makes the system not to be so flat, but a width of approximately 75 mm.



That could be solved by bending the upper arm, so it attaches to the saddle tube, and then opens up to reach the triangle of the pedal.



POSTPONEMENT

At this point I was quite close to the hand-in date of the project, so I decided to prioritise finishing the other two concepts, which I had in a much more advanced stage.

REFLECTION

I was not able to finish this concept and document it, but I certainly plan on keep working on it later on.

It was not easy to make the decision. By leaving this concept out of the accesories group, the overall concept is not as strong.

Maybe I should have quit on finding a linear movement mechanism earlier in the process, but I did not want to desist until I was sure I had run out of options.

Nevertheless, the system found has some potential, and it is going to be interesting to see if it can actually be implemented into something practical and user-friendly.

SADDLE

MAIN REQUIREMENTS

Shouldn't be less comfortable than a regular saddle

Should have some system to hold the kid in position

Should have a shape that prevents adduction

Should be possible to use the same common manufacturing process as the other seats, to keep it cheap

To start developing this product, I started out by sketching general ideas about how it could be. As inspiration I used some of the products that I was shown in one of my visits to a center.

The product on the left is used for babies, to help them sit properly and not slide out. The one on the right is made specially for the kid, with his size. It has a protrusion in the middle, to help the legs stay a bit separated. The straps help the pelvis stay in the right position, making it easier for the child to stay upright.

HOW IT IS MADE[7]

I quickly realised that the shape possibilities depended heavily on the manufacturing process. For that reason, I reasearched on how the saddle is made, and I disassembled one to have a look at the different parts.

There are usually three main parts in every saddle: a rigid structure, a foam layer and a cover. The part that gives the shape of the seat is a rigid plastic shell, made by injection moulding. It is commonly made out of a nylon based plastic.

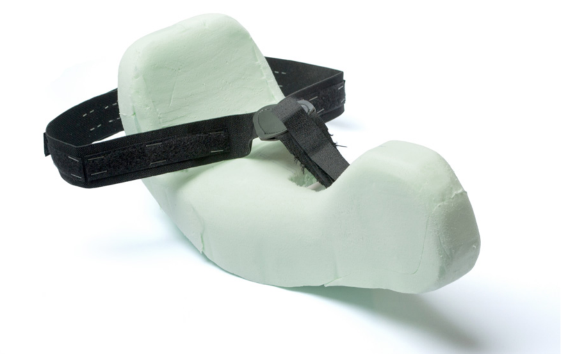
The foam layer covers the top of the rigid plastic. It is also injection moulded, sometimes directly overmoulded on top of the plastic, and sometimes moulded separately and then glued on top. Manufacturers often use closed-cell foams, which means that every bubble formed by the gas is completely surrounded by material. This makes the foam non-absorbent and durable.

The most visible part is the cover. It can be made out of different kinds of materials: vinyl, leather, fabric, kevlar, rubber, nylon, or heavy fabric such as canvas. The cover is glued to the foam using spray adhesives. Then the edges are bent underneath the plastic and glued or stapled to the plastic structure.

FIRST TESTS

The next step was making a foam model. It was based on the ideas that I sketched at the beginning. This mockup was going to be tested with kids. The main purpose was to get the dimensions right, both on the saddle and the straps. Consequently, the style of it was not important, but the proportions and sizes of the different parts.

The model had a back rest and a protrusion to prevent adduction of the legs. It also had straps to test how long they needed to be, and the best position for them.



The mockup was tried on Gabriel, who is 6 years old, and Raúl, who is 9 years old. The last one is actually out of my target group age, but it was interesting to learn that the seat could still fit him.

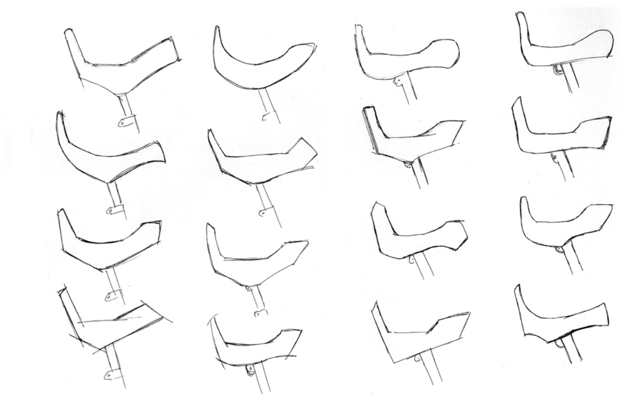
The main important aspect that I learned from this test, shape-wise, was that I should make it longer, because it was uncomfortable where the protrusion was placed. It was interesting to learn that the back rest helped them maintain a proper posture.

The width and height of the model was fine, and so was the length of the straps.

Gabriel's mom commented that she would be very glad if she could actually find something like this on the market. The specialists from the Hospital were pleased as well about the concept and made positive comments about it.

FINDING A SHAPE

The following step was to work on the shape of the seat. For doing that I started by sketching many possible profiles, that could still fit in the main shape and proportions that it had to have. The sketches were made on top of bike pictures, to try with different forms and see how they would fit into the bike style.



While the sketches were a good place to start, because they give an overall idea of a style, it was very hard to get a spatial feeling of the design. That is the reason why I started making mockups of those that seemed more interesting.

The way I did it was putting clay on top of the regular saddle I already had. This allowed me to play with the shape as much as I wanted. To keep track of the different shapes I made, I created a cast out of every iteration.

While doing this, I had both the comfort and styling side of the design in mind.

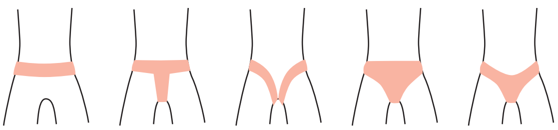
The last one shown here has the main shape and size chosen to develop in CAD. I took it with me to a meeting I had with physiotherapists in Vester Mariendals Skole, in Aalborg. They had positive comments about it, which I implemented in the final design of the concept. They also confirmed that the concept was going in the right direction. Furthermore, they insisted on the importance of the straps being easy to put on/off, because otherwise the kid would be annoyed and would not want to use them after all.

The physiotherapists had some interesting comments that, due to the tight timeframe, I was not able to consider. However, it would certainly be interesting to consider them for further development in the future.

They have agreed on letting me test my mockups with the kids in that school. I hope to get valuable feedback out of it.

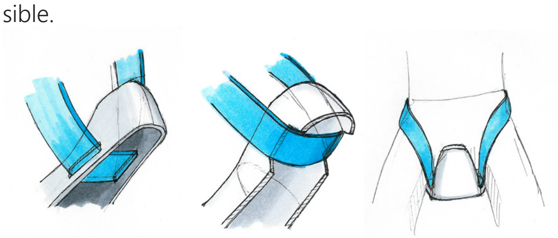
THE STRAP

Once I had an idea of the shape the saddle could have, I started having some thoughts about the straps.
There are different ways the straps could go.



The final concept is something in between the second and the last options. It provides the needed fastening while being comfortable. The straps are adjustable in length, to fit a wider range of children.

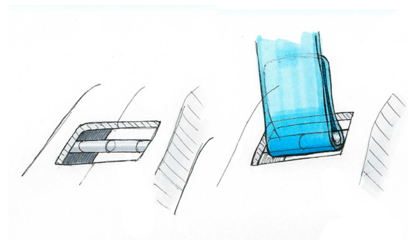
Next, I started detailing how would the straps attach to the seat. The most complicated part would be the attachment on the front, due to the lack of space. The main idea was to make something that would require the least number of parts and processes added as possible.



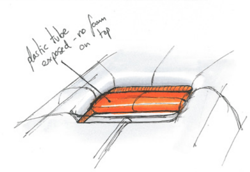
In this case, I was trying to make it really simple, and use the shape to hold the strap. This was less comfortable, and I was not sure about the durability of the edge of the plastic.

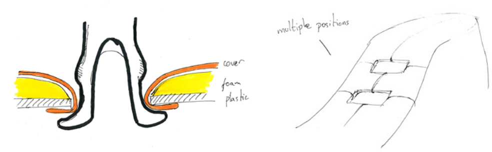
Some saddles have some holes in the structure, to allow for some air flow. I tried to use this to create some concepts.

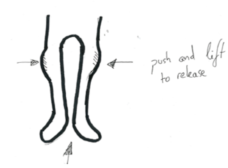
I had to have in mind that the cover of the saddle goes inside the hole, to be attached underneath, so there should be some space left around the edges.



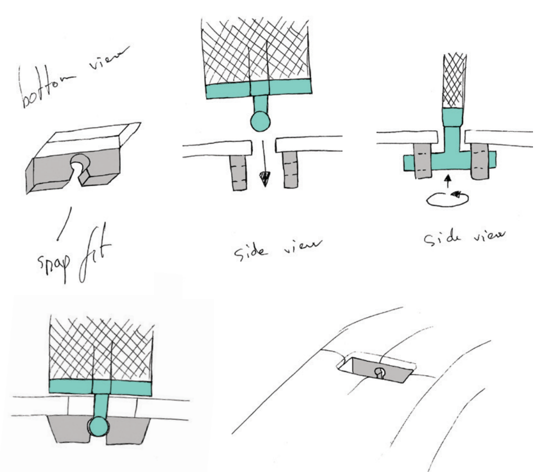
This concept was the one used for the mockup. It has a tube added beneath the hole, or the plastic itself used to make the tube. It was ruled out because it was not easy to roll the strap around the tube.







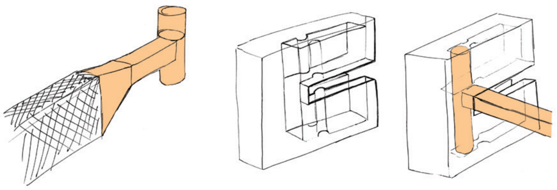
With this concept I was trying to make a clipping system, where the strap was attached to a plastic piece that would clip inside the hole. It was dismissed because of doubts on the durability of the clip.

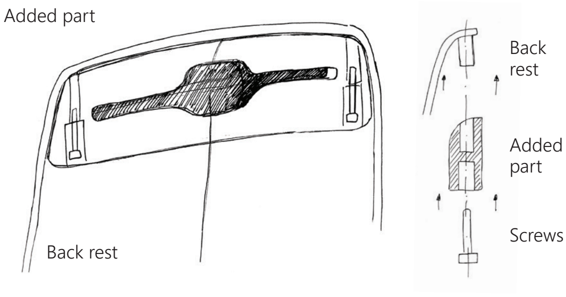


The concept chosen was this last one. It has two “walls” coming out of the plastic structure, close to the hole.

There is a metal T-shaped piece attached to the end of the strap, that is introduced in the hole, and then turned and pulled back up to snap-fit it into the walls. It is easy to use and durable.

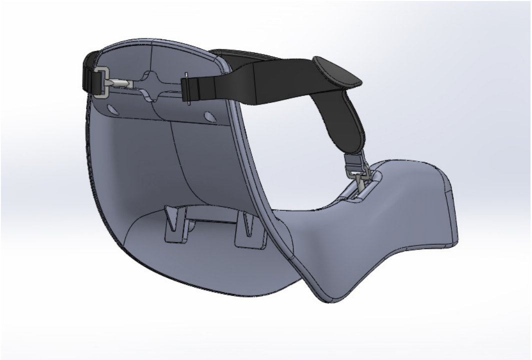
For fastening the strap on the back, I wanted to use the same part as in the front, to reduce the amount of different parts. Therefore I used a system that would work with that piece as well.





An additional plastic part is screwed onto the back of the saddle. The strap is then fixed by sliding the metal piece from the middle to the end of the slot, where there is a small feature that stops it from coming out again.

Finally, the last step was drawing up the saddle in CAD, making some minor adjustments to the shape, and detailing the way the straps fasten.



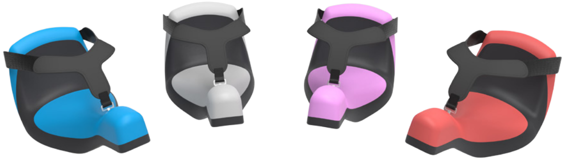
COLOURS

For the colouring of the saddle, I had in mind that it was a rather large part, so it would not look nice if it was in just one colour.

The colours are added by painting the cover. This gives some freedom in patterns and colours, but I still did not want to use more than two colours in one design, to keep the price down.

I tried different ways of dividing those two colours. The main thought behind it was to look for a way to visually reduce or disguise the size of the saddle.

All of the options share one colour, the dark grey. It is because it is a neutral colour, that fit with all or most of the bikes. Then there is an option where is combined with light grey, so it is completely neutral. The other three colours where chosen because most of the bikes have those colours -the same ones as the handlebar.



REFLECTION

The final concept fulfils the requirements set at the beginning of the process. I am quite satisfied with the main idea, but I would have liked to have more time to improve the shape and the details.

The strap shape is very basic. I would have liked to spend more time developing the shape of the strap itself, but also the locking mechanism. I think the principle is good, but it needs some development.

The test of the saddle was a very positive thing to do, because apart from finding out about the shape changes needed, it was the first time that the users where put in contact with the concept, getting a positive feedback. Since the children were in Spain, I could not make the test myself. I would have probably gotten even more feedback if I was present. But I still received some interesting comments.

I could have been good to test the saddle again with kids, to get a better idea of how the shape adapts to the body, and then be able to improve it.

SALES & PRODUCTION

This section briefly describes the materials and the manufacturing methods used to produce the parts, and presents the economical and logistical aspects that surround this proposal.

SMALL SCALE PRODUCTION

In denmark 180 babies are born with CP every year. That means 180 potential new costumers a year in this country. That is not a big enough market to be able to make affordable products. Therefore, it would make sense to expand the market to European scale.

In Europe (EU 28), around 5 million babies are born every year[8]. Looking at the statistics, two out of one thousand are going to have Cerebral Palsy, which is 10 thousand babies. Of those, 70% are going to have the Spastic variant, which is what I am focused on. That leaves a potential new market of 7000 every year.

MARKET EXPANSION OPPORTUNITY

There are other disorders that cause similar effects on the body. It is the case of the Down Syndrome, which 1 out of 600-1000 babies are born with every year[9]. Cranioencephalic Trauma (Head Trauma) and some Degenerative deseases could beneficiate from these products as well.

This could be an opportunity to sell these products to a bigger number of people.

PRODUCTION QUANTITY

Even though there is an approximated market potential of 7000 new users a year, and could be more as explained in the previous section, it is not realistic to asume that these products will be sold to 100% of the market. Consequently, all the production costs shown in the manufacturing section have been calculated with a production of 5000 units a year for each of the products.

Therefore, this is not going to be a mass production, but rather a small scale production.

OTHER CONSIDERATIONS

When put on sale, the saddle should at least be sold in two different sizes, in order to reach to a bigger market. The handlebar would not need other sizes, since it is big enough to be used by older children.

Since the parts used to attach the products to the bikes are standard, and do not need special tools to be mounted, they can be easily integrated in the current market. That means that as soon as it is put in the market, it could be adopted by the users, without having to wait for an adaptation period.

BUSINESS PLAN

There are a few different ways in which these products could be sold. I have listed the four that seemed most possible and discussed what advantages and disadvantages they could have.

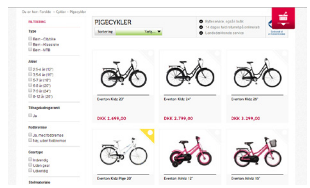
Supermarkets

+ Close to where you live.
- They are not international.

Bike stores

A sub-brand of an international company could be done, and sell the parts through the same distributors.

+ Personal attention.
- There are maybe only a few stores in each country. It is not very accesible.



Web shop

+ It is more accesible. People can buy from anywhere and send it with the post.
- Not personal.

Therapeutic products vendors

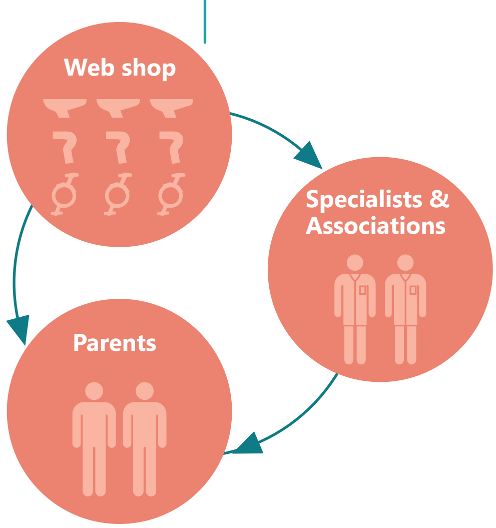
+ Use the channels through the specialists.
- They are not specialised in bikes, so it would make the products more expensive.

Any of these two options could work, but since everybody is getting used to buying products on the Internet, the best option might be the **webshop**.

It would be good to use the specialists or associations to make people aware of the product.

In this system, the products are sold through a website, that should be available in different countries. There should be some sales representatives in each country, that could visit the patients or specialists associations to make them aware of the product.

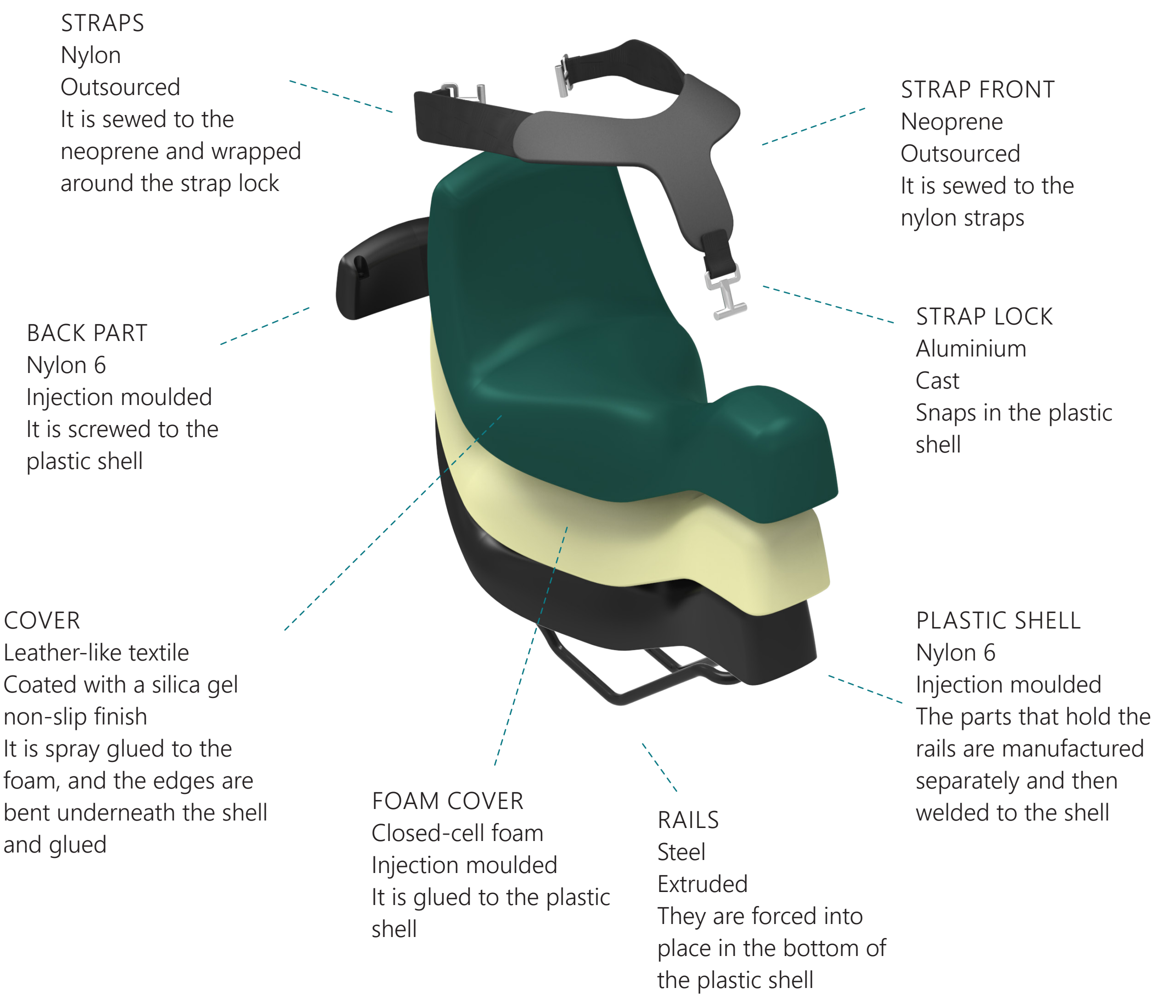
Then people could buy the products online and they would be sent through mail.



MATERIALS, ASSEMBLY & MANUFACTURING

As mentioned earlier in the report, all the parts should be manufactured in the same way they are made nowadays, because it will probably be the cheapest way.

SADDLE



The manufacturing and assembling process of this saddle is basically the same as any other saddle. There are a few additions that will make the cost higher.

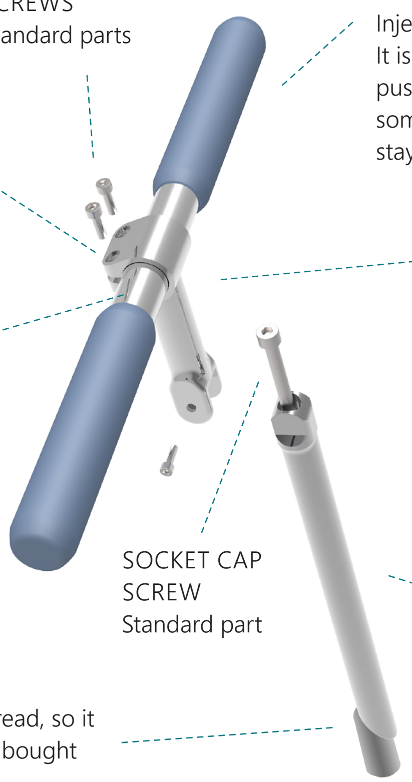
The first one is the material of the saddle itself. The protrusion on the front and the back rest add around 40% of material. It has to be taken into account that the material itself is not the overall cost of the part. If we asume that the material is the 50% of the cost, an increment of the 40% in the material would mean and increment of the 20% in the total cost.

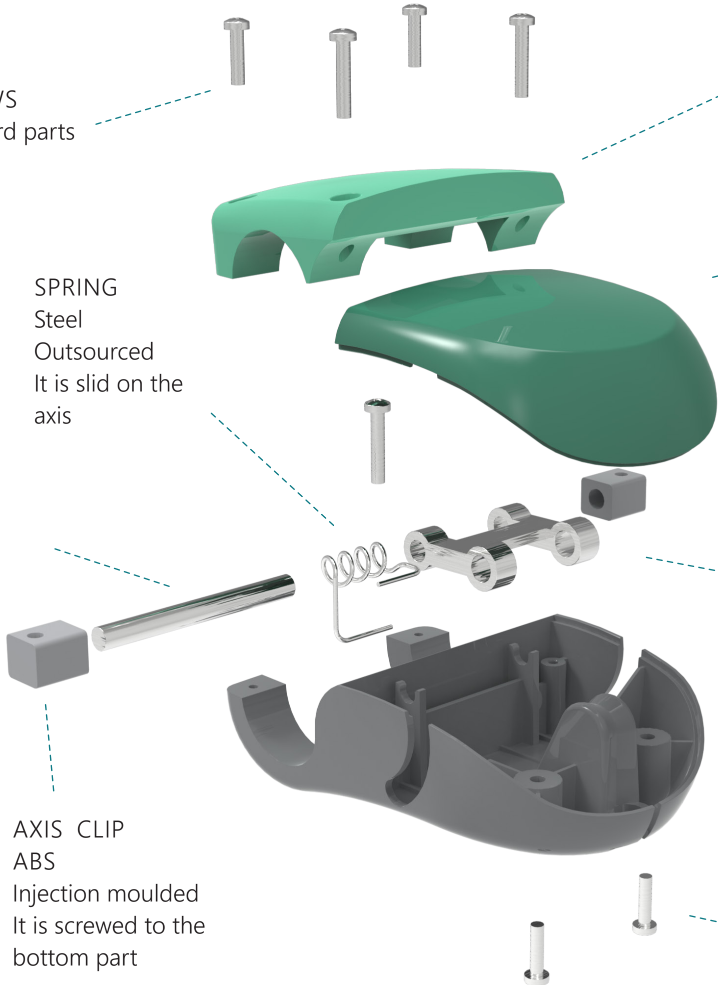
The second one is the strap, that has three differenciated parts. The strap fasteners have a very simple shape, so they could probably be made out of standard parts welded together, or the whole part cast. In the second case, an estimation gives a price of 8 DKK. To make this estimation, I have used a program developed by a company that manufactures parts and have a cost estimator online (see Appendix D).
The neoprene and the nylon for the strap are not commonly found on bikes, so these are elements that would probably be outsourced. These sorts of straps can be bought in the market for around 50 DKK, so its production cost is probably half of that.

The last one is the part for the back. It is made in two injection moulded parts, and then glued or welded together. Then the part is joined to the back with screws, which are standard parts. Using the cost estimator, the part could cost around 40 DKK.

The price of the saddle in page 19 was 419 DKK. That is a medium range price. If we add the 20% of the cost of the material, plus 150 DKK for the rest of the parts - asuming they are doubled the price for sale - it is a total of 653 DKK.

HANDLEBAR




SCREWS
Standard parts
CLIP
ABS
Injection moulded
It is screwed to the bottom part
TOP PART
ABS
Injection moulded
It is screwed to the bottom part
SPRING
Steel
Outsourced
It is slid on the axis
AXIS
Steel
Extruded
It is a standard profile, so it could be bought
It is hold in place by the two axis clips
AXIS ARM
Steel
Cast
It is slid on the steel axis
BOTTOM PART
ABS
Injection moulded
AXIS CLIP
ABS
Injection moulded
It is screwed to the bottom part
SCREWS
Standard parts


BRAKE BAR GRIP
ABS
Injection moulded
It is glued to the bar
BRAKE BAR
Steel
Extruded
It is a standard profile, so it could be bought
It is welded to the axis arm

The material chosen for all the plastic parts is ABS. These parts are going to suffer blows and they need to withstand the force applied on them when in use. ABS is a plastic with a high impact resistance and toughness.

The manufacturing costs of this concept is something very difficult to estimate due to the amount of different parts it has, made with different materials and processes.

The handlebar itself and the pole are pretty easy to manufacture. Compared to the one in page 19, the new handlebar has the same functionality of adjusting the angle, and it seems like it might be simpler and use less material in its manufacturing. But still, let's assume they have the same price of 793 DKK. To this amount, the price of the whole braking system would have to be added.

The brake bar is a simple part. The metal part is a standard profile that just needs to be cut, and then the two grips are glued to it. Using the cost estimator, the two grips would cost around 13 DKK each. A 1 m long steel tube with same characteristics as the brake bar costs around 30 DKK in a regular store. Then we could assume a price for the 400 mm of 7 DKK. That is a total of 33 DKK for the brake bar.

The brake mechanism have many parts. Some of them can be bought, like the screws, the axis, and the spring, and the others would have to be made. Using the cost estimator, I have found an approximated cost for those parts:

Bottom part	43 DKK
Top part	24 DKK
Clip	19 DKK
Axis clip	6 DKK
Arm	9 DKK

The total amount of screws will cost approximately 1 DKK (price based on pts-uk.com). For the axis, based on what was said for the brake bar, it could be estimated a price of 2 DKK. And for the spring also around 2 DKK.

The total amount then for all the parts would be 106 DKK. The assembly is an important part of the cost. It should not take more than a couple of minutes to put it all together, but to be safe, let's assume it increases the cost by 50 DKK.

If that final figure is doubled to reach the sales price, the total amount of the whole assembly would be 156*2 + 33*2 + 793 = 1171 DKK.

CONCLUSION

The final price for the different parts is more expensive than mid-range regular products, which was expected. It has to be emphasised that most of the prices have been estimated choosing a safe figure, meaning that is possible that they are cheaper. It is also important to stress that there are other things that I might have overlooked.

However, if we stick with these figures, even though they are more expensive, they are inside an affordable price range, and a much lower price when compared to the purchase of a therapeutic bike.

REFLECTION

The business side of a product has always been the hardest thing for me to think about, and I do not feel very comfortable doing it. This is because I do not have enough data to make an informed decision, so it is all about guessing and making approximations, which makes me feel unsure about the results.

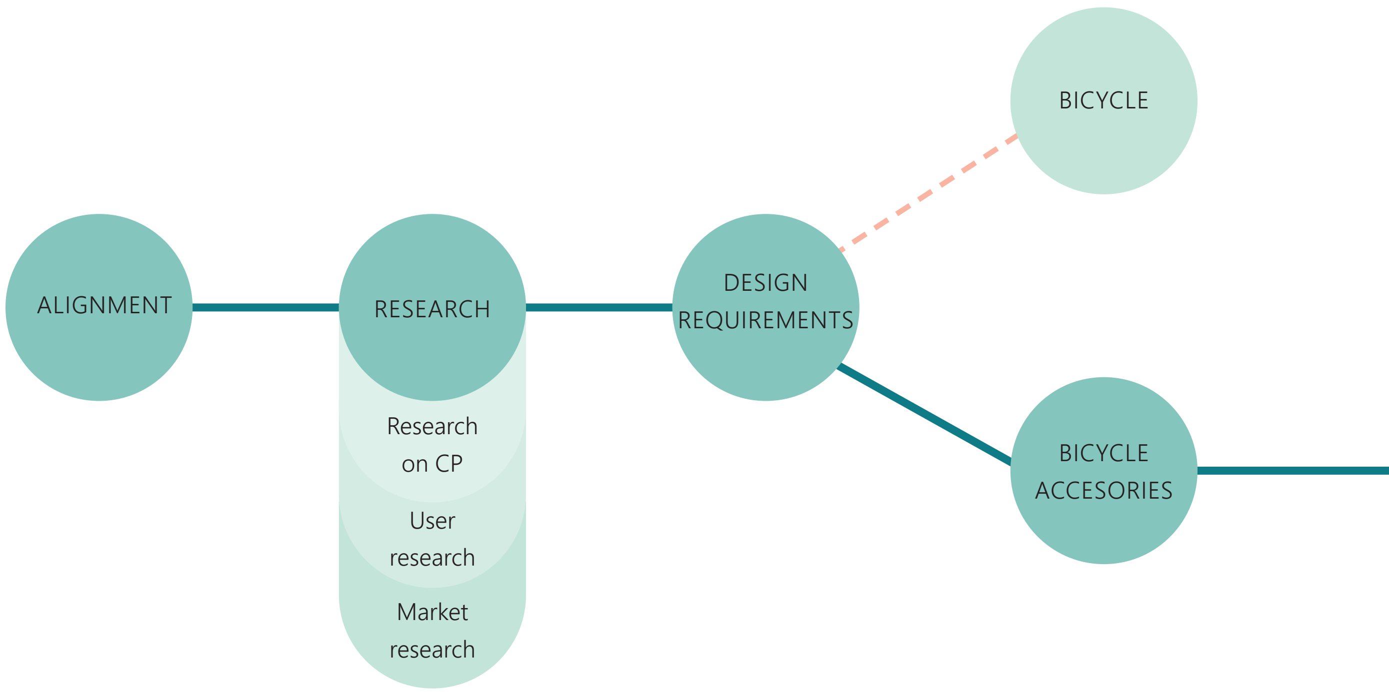
Even not being sure about numbers, I still think there is a market opportunity based on the people that I have talked to, which are potential buyers, and have shown much interest about the product.

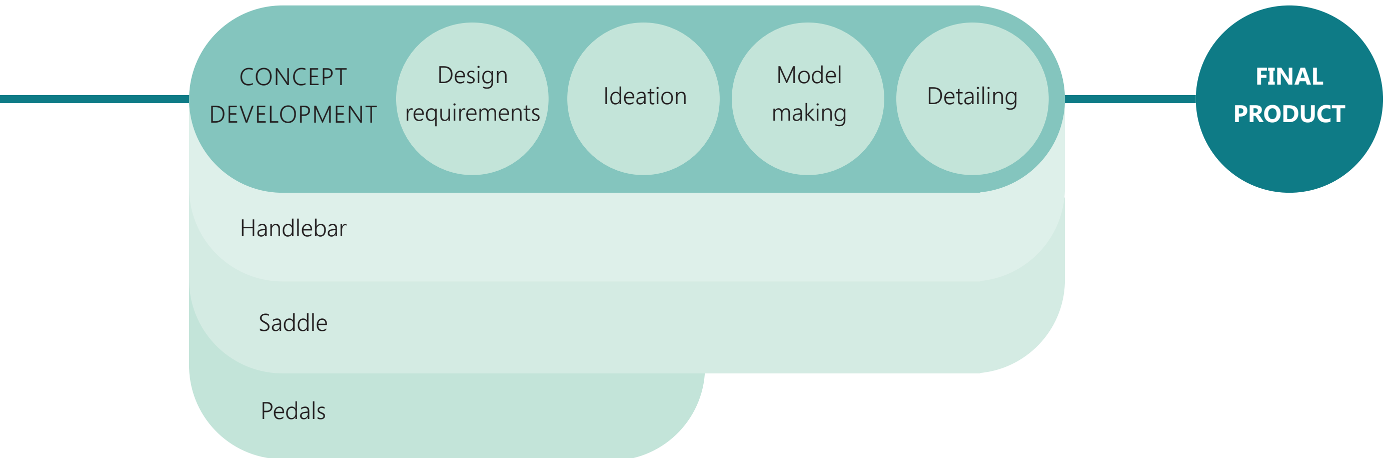
Making cost estimations is very difficult to do, because I do not have the knowledge that is most usually adquired through experience. It was even harder because of the amount of different parts, and because I have not previously worked with metals so I do not have an idea of how much things cost.

In relation to the exact processes used to manufacture the parts, I haven't been able to find out about it. It is not easy to find that kind of information. I contacted a few manufacturing companies in Denmark, trying to find out more about this, but I only received a very succint reply. It would have been better to know about this to make a more accurate estimation of the price.

OUTRO

OVERVIEW OF THE PROCESS




CONCEPT DEVELOPMENT
Design requirements
Ideation
Model making
Detailing
FINAL PRODUCT
Handlebar
Saddle
Pedals

CONCLUSION

The initial goal of making it easier to access a bike for children with CP has been achieved. It has not been done by re-designing a bike, which was the initial idea, but with a different concept that makes it more affordable to get an adapted bike.

The price of the final solution does not suppose a big investment, and it has the advantage of customization, which means that only the wanted parts need to be bought.

The concept fulfils both the technical and ergonomic requirements set during the research phase.

Although the styling of the parts have been limited by the cost, it certainly is an improvement from the existing solutions, and the parts are much closer to look like regular bike parts than therapeutic equipment.

The final design has already been shown to several people involved on the project, both professionals and parents, receiving very positive feedback. This indicates that the concept is going in the right direction.

FINAL REFLECTION

The overall process has been a very positive experience. Since it was a subject that I chose because I was really interested in it, I have been enthusiastic about it during the whole process.

Working with children and with this kind of problem made the process a bit harder in different ways. While talking with people, the words used have to be carefully chosen, and there are some aspects that parents may not be so willing to talk about. I was lucky that the parents of the children I tested the model on were kind enough to let me take pictures, but it could have been a problem.
Another issue that I had to deal with was the scale. I am not used to design for children, so I was not sure about the proper proportions. That is one of the reasons why user testing was important in this project. I would have liked to test more often the design.

Regarding the process, I feel I could have use more time to be able to develop the concepts further. Being alone in the project made it difficult to start a working routine, which made me loose much time at the beginning, and then have a lot of work load towards the end. In that sense, I need to be more organized, and make some deadlines and try to actually meet them.
The Appendix E shows the calendar that I planned at the beginning. It was too far optimistic with the time used for concept developing and detailing. I also did not make a differentiation in my process between the two stages, because I kept working on many different things at the same time, using the requirements as a tool to drive the process.

The fact that I was actually working on three different products, which should relate somehow, was also a difficult aspect of this project. They all came from the same initial problem, but I developed them separately, and unfortunately I did not have enough time to bring them closer again, and make a better integration of the

whole line of products with the bicycle.
The not completion of the pedals also supposed a weakening of the concept, but it seemed more important to finish the other concepts.

Nonetheless, working on three products was also interesting and productive. If something was not going well, I could choose to put it aside for a while and keep developing another one. That way I did not feel worn-out at any time.

It was a positive experience to work alone. Even though it was a lot of work, I had to make all the decisions, and I was responsible for them, which was quite challenging. It has also given me the opportunity to find out or confirm what my weaknesses and strengths are, helping me to improve.

The subject that I chose has been very fruitful. It allowed me to work with user-centred design, which is something I am interested in. It has also brought up different aspects to be considered, making it more challenging but enjoyable at the same time.

FURTHER DEVELOPMENT

The development of the pedals is not finished, so that will be one of the main aspects to focus in the future. It needs to be designed and then tested with a functional model to check that it works as expected.

Also the saddle and the handlebar need to be tested. They will probably undergo modifications based on the data gathered from these tests.

At the same time, the style of some of the parts will be revised, in order to integrate them better as a whole.

Further away in the future, it could be interesting to develop other features that have come up in the process. It is the case of the light for the brake casing, or the suggestions made by the physiotherapists from the school in Aalborg.

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ILLUSTRATION SOURCES

Page 8 Bicycles	http://www.metrobicycles.com/images/library/large/ral_lil_honey_purple_12_m.jpg http://ecx.images-amazon.com/images/I/51Yrq9RaXkL._SY300_.jpg http://thebikerack.com/images/library/large/trek_jet20_09_m.jpg http://www.westernbikeworks.com/productimages/images450/ccg161-1.jpg http://archive.raleighusa.com/wp-content/uploads/post-images/RB_2011_Retro-16_Purple_LG.jpg http://ecx.images-amazon.com/images/I/415m8hmBfNL._SX300_.jpg http://www.bikemastertool.com/media/bikes/1106/xlarge/DB_MiniDellaCruz_Pink.jpg?1313622142 http://images.the-house.com/se-bronco-16-bike-yllw-kids-11-zoom.jpg
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P. 20 haverich	http://www.haverich-reha.de/images/artikel/small/2.jpg
P. 20 everton	http://www.fribikeshop.dk/Files/Billeder/Produkter/700x478/YJE4302602.jpg
P. 20 sister bike	http://www.norco.com/img/bikes/121685-01-1.jpg
P. 20 saddle	http://static.jensonusa.com/images/Default-Image/Zoom/640/SA299A39.jpg
P. 20 handlebar	http://www.rifton.com/~/media/images/rifton/products/features-tab/rifton-adaptive-tricycles/rifton-tricycle-handlebars.jpg?mw=340
P. 20 crank	http://findbilligt.dk/wp-content/uploads/2014/05/04FCM785E08X.jpg
P. 20 pedal	http://findbilligt.dk/wp-content/uploads/2014/05/EPDT400LR_A.jpg
P. 20 wheels	http://fdynmedia.thg.dk/img/230211003_0_m_400_700.jpg
P. 25 swing	http://www.goodhousekeeping.com/cm/goodhousekeeping/images/Jf/ghk-boy-swing-lgn.jpg
P. 25 walkie talkie	http://mco-s1-p.mlstatic.com/walkie-talkie-radio-motorola-mj270r-alcance-43km-recarga-ble-1319-MCO3447721540_112012-F.jpg
P. 25 scooter	http://www.bestchristmastoysonline.com/wp-content/themes/shopperpress/thumbs//razor-a2-kick-scooter-blue.jpg
P. 25 trunki	http://4.bp.blogspot.com/-QsVg7E53wT4/ToASPWVNYnI/AAAAAAAAFHo/TgjgcNdioso/s1600/5402-TrunkiCase-Sunny.jpg
P. 25 shoes	http://www.aroundforce.com/upload/products/700x700/Nike-AJ-Shoes-Collection-air-jordan-3.5-retro-kids-shoes-009-01.jpg
P. 25 boys	http://www.4tunate.net/wp-content/uploads/2012/08/5yearoldquadrupletboysplayingoutside.jpg
P. 25 boy in yamaha	http://www.kidswheels.com/components/com_virtuemart/shop_image/product/00f3139351f51569b13f0cbb4f8de26b.jpg
P. 25 girl barbie	http://topnews.in/law/files/childhood-dream-jobs.jpg
P. 25 hop ball	http://www.growingtreetoys.com/img/cache/product/005558__.jpg
P. 25 girl with guitar	http://cdn.novafm.com.au/sites/default/files/styles/nova_grid_full_video/public/media-youtube/X4Kjtp4sA9E.jpg?itok=Ju_qWRBs
P. 25 girl chairs	http://www.kidsomania.com/photos/cool-bright-kids-chair-sono-kid-from-Dieter-Paul-2.jpg

P. 25 kids pogo	http://d1jqecz1iy566e.cloudfront.net/large/di050.jpg http://www.digginactive.com/images/gogopogo01.png
P. 25 kids ipad	http://uk.eonline.com/eol_images/Entire_Site/201391/rs_560x415-131001144752-1024.kids.cm.10113_copy.jpg
P. 25 boy with board	http://2.bp.blogspot.com/-P7bW6gWPCac/TqGa6iTY0QI/AAAAAAAAAKc/dBX4WV-l3X8/s1600/spooner.jpg
P. 25 kids with bikes	http://media.utsandiego.com/img/photos/2013/03/09/UTI1695862_r620x349.jpg?75d51d0aea2efce5189afce216053cbc530c46a8
P. 25 kid virtual	http://thumbs.dreamstime.com/x/juegos-futuristas-1360279.jpg
P. 25 girls	http://www.miniroos.com.au/media/43392/miniroos-for-girls-image-32_600x337.jpg
P. 27 quill stem	http://www.culturecycles.com/wp-content/uploads/2013/01/8365718467_4e41b54fb6_c.jpg
P. 27 threadless	http://cdn.media.cyclingnews.com/2010/10/05/1/katie_compton_stevens_stem_600.jpg
P.28 faceplate	http://media.performancebike.com/images/performance/products/1500/50-0271-NCL-ANGLE.jpg
P.28 welded	http://www.universalcycles.com/images//products/large/50890.jpg
P.35 stepper	http://www.igreentech.it/store/image/cache/data/PIMPGARAGE/STREETSTEPPER/786x500-1253284417-www.panzenberger.com_streetstepper-5-500x500.jpg
P.36 mechanism drawing	J. Rasmussen, S.T. Christensen, M. Gföhler, M. Damsgaard, T. Angeli . 2003. "Design optimization of a pedaling mechanism for paraplegics"
P. 42 saddle	http://www.slanecycles.com/images/selle-italia-c2-gel-flow-saddle-black.jpg
P.47 EU map	http://upload.wikimedia.org/wikipedia/commons/f/ff/EU28_Single-Euro-Payment-Area_-2013-.svg
P.48 kvickly	http://faxenyt.dk/nonsec/npix/2014/2/2201422495427.jpg
P.48 bike store	http://www.vestbyens-cykelhandel.dk/files/gallery/71/600/600/
P.48 rehab centre	http://www.sanatorioallende.com/files/Contenidos/339/dosfkt_655x492.png

The rest of the illustrations are self made or self taken.

APPENDIX

APPENDIX A

Relation of visited centres and contacts established.

SAN JUAN DE DIOS
Situated in Las Palmas, Gran Canaria. Spain

Contacts there:
Romina Pestana Miranda. Physiotherapist
Patricia Gómez Corral. Occupational therapist

UNIVERSITY HOSPITAL OF CANARIAS
Situated in La Laguna, Tenerife. Spain

Contacts there:
Candelaria González Hernández. Physiotherapist
Ana Domínguez Suárez. Physiotherapist
Fernanda Hernández Gutiérrez. Physiotherapist
Patricia Martín Guillén. Physiotherapist

HEALTH CENTER DOCTOR GUIGOU
Situated in Santa Cruz, Tenerife. Spain

Contacts there:
María Isabel Armas Armas. Physiotherapist
Inmaculada Vinuesa Suárez. Physiotherapist
Lía Martín Rodríguez. Occupational therapist

VESTER MARIENDAL SKOLE
Situated in Aalborg. Denmark

Contacts there:
Lone Johns. Physiotherapist

APPENDIX B

Complete transcript of the interview to Raquel. The questions of the questionnaire in Appendix C were used to guide the conversation.

Gabriel is 6 years old and he has a spastic hemiparesis
He has a bike . He has had it for 2 years, but he doesn't use it anymore, because it is too small for him. He had a regular bike, but he couldn't pedal, so he would just push the bike, putting the feet on the floor. The problem is that he would get hurt on his knees.
Now he has one of those pedal-less bikes. But having the hemiparesis, his hand drops from the handlebar. We have tried to attach his hand with something, but then he is not able to let go his hand. There has to be something that holds his hand, but he should have the possibility to release it. Especially because he is conscious about being tied up.
We saw the bike without pedals in a Toys "R" Us catalogue.
He uses the bike with two small wheels on the sides of the back wheel, because he has problems with balance. He always pushes to the side he has problems with. Sometimes he loses his balance.
He is starting to walk now. He moves more easily with a bike than walking. He was happy with the bike because he could go wherever he wanted. The bike makes him feel safe. And he loves it.
The bike was really cheap. It was about 20€. And it's aluminium, it's very light. You can pick it up without effort. But of course it's too small now. There are only models without pedals for smaller kids.
Now he is not using any bikes, because it's too small so it's uncomfortable. But when it was his size, he used to cycle a few times a week.
We have been thinking about adapting a regular bike for him. But we don't really know how to do it, or if it's going to be too expensive.
Gabriel stares at bikes whenever he sees one.
The bike should fit in a car trunk. With the side wheels easy to take off.
He has to be comfortable on the bike. The seat it's very important, he has to seat very well.
Bikes are too expensive for the amount of years that a kid can use it.
He used to ride at home, in even surfaces. It is really hard for him to go uphill, but he loves going downhill. He is very adventurous and loves playing. I also took him sometimes to parks, but it was safer at home because he already knew the place, and they could leave him alone.
With the age that he has it may not seem logical to spend money on a bike, because he is going to outgrow it very soon, but we think it's the time when they most need it, because they need to play.
We would spend even 800€, if we saw that he is capable of moving the bike, that he is going to use it and he is happy with it. With other things that he can't use or are uncomfortable, he gets frustrated and angry pretty fast and stops using them. So if he is happy with the bike, then it would be a win, and it would be worth the money.
The most important thing of a bike is that fits the kid. Second, the aspect. Third, easy to transport. Fourth, durability. Fifth, price.
The bike has to be for him to play, not to work out. It has to be a toy like the other kids have. If it's a bike, it's a bike. Maybe with a bit more accessories, but it has to look like a bike. It is a bike for him to play with other kids in the park or wherever, but it's for him to enjoy. It is not a workout tool.
He doesn't have toys especially made for his disorder.
We have looked for bikes in big shopping centres like Toys R Us or Decathlon. We haven't thought about looking over the Internet.

APPENDIX C

Questionnaire

Masters' final thesis: Bicycle for a child with cerbral palsy.

Emma Díaz González | Master in Industrial Design - Aalborg University

✱ Please feel free to make any additional comments.

1 How old is your child?

2 Does your child have a bike? ☐ Sí ☐ No

If the answer is no, please continue in question 3. If yes, continue in question 4.

If the answer is no:

3 Why not?

Please continue in question 13.

If the answer was yes:

4 For how long has he/she had it?

5 How much was it?

6 Was it sold as a specific bike for children with motor disorders, or was it adapted from a regular bike in the market?

7 Did you buy it in a store or through the Internet? Which one?

8 How much does your child use it?

☐ Every day ☐ A couple of times a week ☐ A couple of times a month

☐ A couple of times a year ☐ Never

1/2

9 Where does he/she use it? (At home, in the yard, in a park, etc.)

10 Is it easy to transport? (Is it foldable, how much it weights, how many accesories, etc.)

11 Is it adjustable? (The saddle, the handlebar etc.)

Do you find it neccesary to be adjustable?

12 Is it easy to use? (if you had to read a manual to understand how it works, how long it takes to prepare it, etc.)

Continue in the next question.

13 How much would you pay for a bike?

☐ Up to 400€ ☐ Up to 700€ ☐ Up to 1000€ ☐ More than 1000€

14 Number 1 to 5 what you think it would matter the most when buying a bike (1 being the most, 5 being the less):

☐ Price ☐ Durability ☐ Aspect ☐ Adjustability ☐ Easy transport

15 Other comments or suggestions:

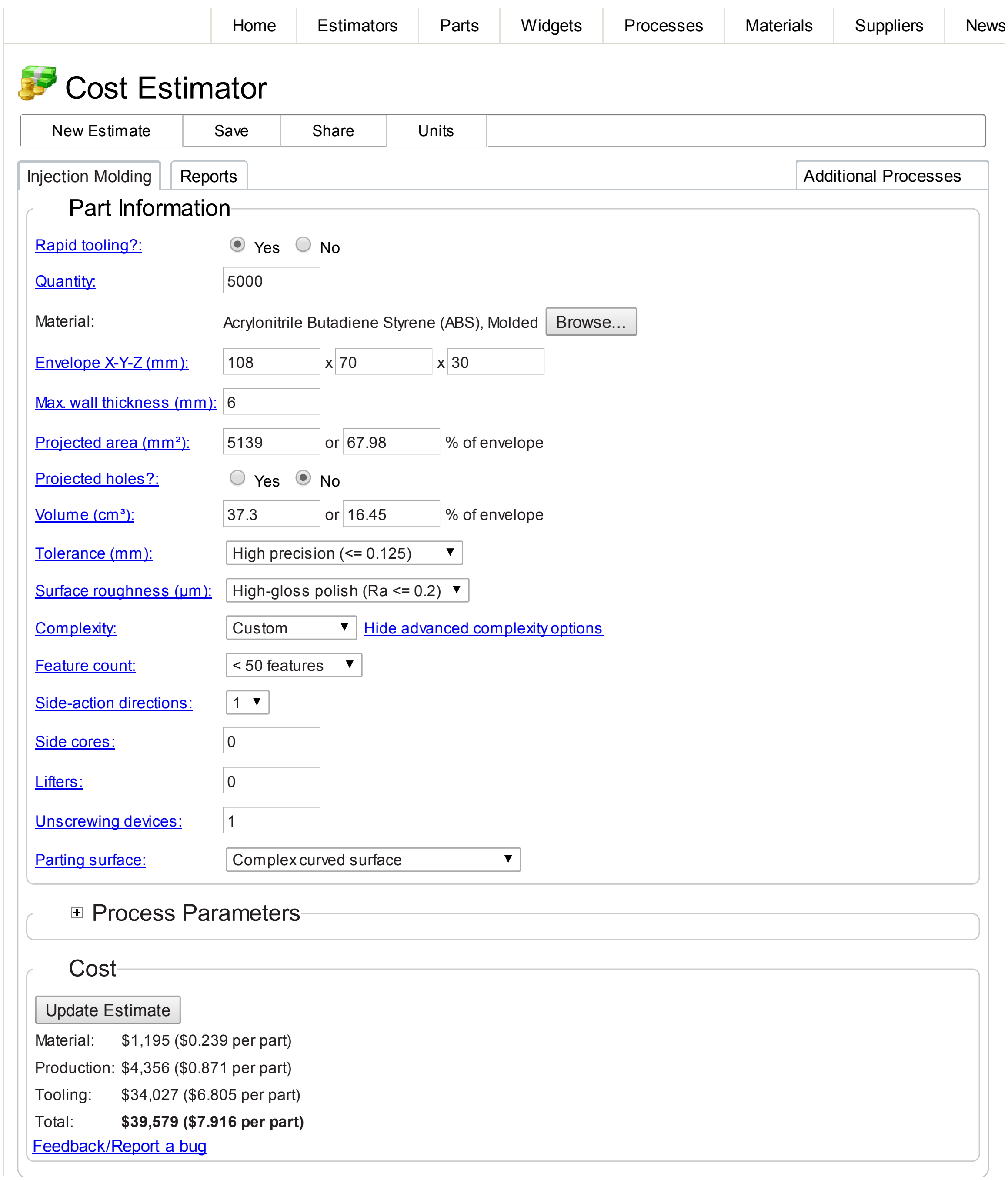
Thank you very much for your cooperation.

2/2

APPENDIX D

Examples of cost estimations made through www.custompartnet.com

Bottom part of the handlebar casing



Home | Estimators | Parts | Widgets | Processes | Materials | Suppliers | News

Cost Estimator

New Estimate | Save | Share | Units

Injection Molding | Reports | Additional Processes

Part Information

Rapid tooling?:	(•) Yes ( ) No
Quantity:	5000
Material:	Acrylonitrile Butadiene Styrene (ABS), Molded [Browse...]
Envelope X-Y-Z (mm):	108 x 70 x 30
Max. wall thickness (mm):	6
Projected area (mm²):	5139 or 67.98 % of envelope
Projected holes?:	( ) Yes (•) No
Volume (cm³):	37.3 or 16.45 % of envelope
Tolerance (mm):	High precision (<= 0.125)
Surface roughness (μm):	High-gloss polish (Ra <= 0.2)
Complexity:	Custom — Hide advanced complexity options
Feature count:	< 50 features
Side-action directions:	1
Side cores:	0
Lifters:	0
Unscrewing devices:	1
Parting surface:	Complex curved surface

⊞ Process Parameters

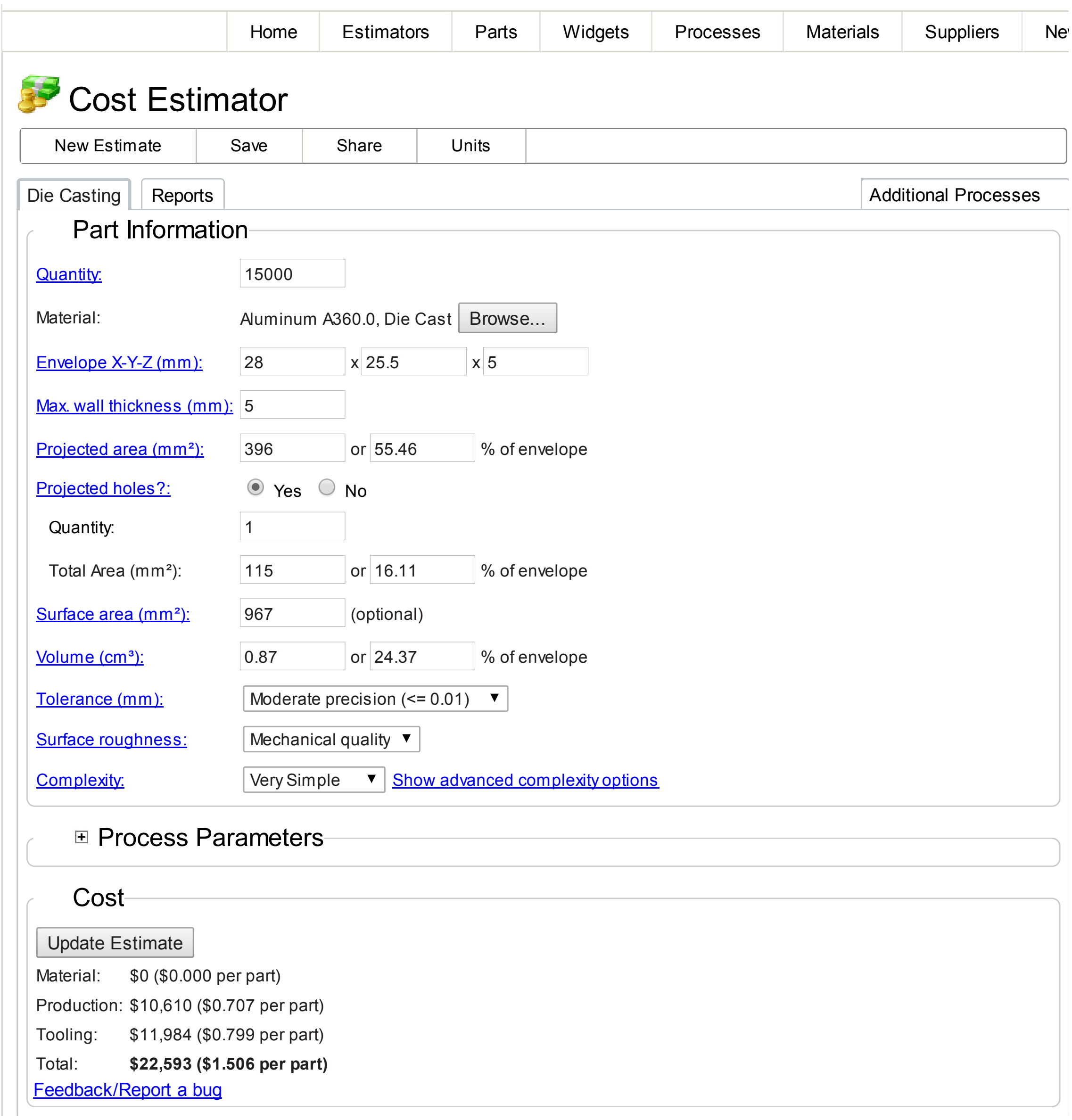
Cost

Update Estimate

Material:	$1,195 ($0.239 per part)
Production:	$4,356 ($0.871 per part)
Tooling:	$34,027 ($6.805 per part)
Total:	**$39,579 ($7.916 per part)**

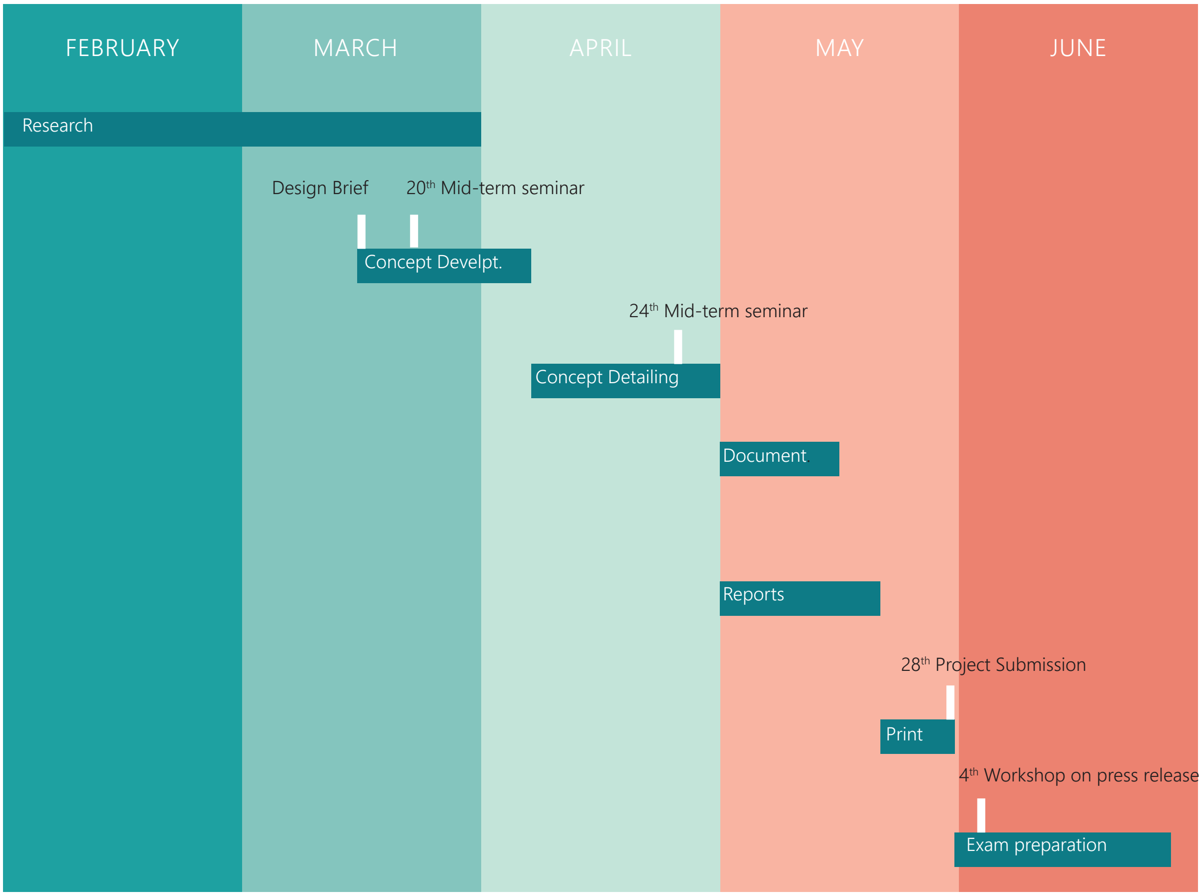
Feedback/Report a bug

Strap lock of the saddle



APPENDIX E

Calendar as planned at the beginning of the process.



RESEARCH
Cerebral Palsy
User research
Market research
Technical research

CONCEPT DEVELOPMENT
Sketching
Prototyping
Analysis-evaluation

CONCEPT DETAILING
Sketching
Prototyping
CAD modelling
Analysis-evaluation

DOCUMENTING THE PRODUCT
Renders
Technical drawings
Cost and price estimation

REPORTS
Text
Layout
Correction

APPENDIX F

Technical drawings. Please see attached folder.