Appendix

Accessible last-mile mobility support for children in Artis
a product-service proposal

Lotte Hoeksma
Master thesis
Integrated Product Design

Delft, August 2020

APPENDIX A

Reading guide

This appendix is grouped into three parts. Part 1 presents contains the general appendices. Appendices in part 2 elaborates on the design process. Part 3 presents literature reviews.

APPENDIX B

Cart capacity estimation

To give direction to the amount of carts needed in the future. The current amount and composition of visitors needs to be analyzed. The amount of visitors for 2030 is determined using predictions made earlier by Artis. An estimation of the amount of children in the target group (aged 1 up to and including 3) is made using available data.

B.0.1 Available data

- Amount visitors per day separated in day visitors and Artis members over 2019
- Total estimated visitors in 2030 per month (Factpack horeca en overige faciliteiten 2018)
- Amount of visitors per day tipping point for current amount of carts 2018
- Age distribution Artis members 2018

B.0.2 Visitor data

Artis aims for 2 million visitors in 2030, in 2019 they hosted 1.4 million visitors.Figure B.1 shows the amount of visitors on the peak day of every week over 2018 together with the capacity tipping point for facilities. This fact sheet assumes Artis will welcome 1.6 million visitors in 2030. Artis strategic plan aims at 2 million visitors for 2030.

There are 60 carts available. The tipping point for a shortage of carts is estimated around 3000 day visitors. Meaning, when over 3000 visitors have entered the park, there is a shortage of carts. Artis strives for a visitor experience above 8+, on a scale of 1 to 10. The shortage of carts influences the visitor experience negatively.

There is a sufficient capacity of carts on 44% of the days, resulting in a shortage of carts on 66% of the days.

The amount of carts stationed at the Papegaaienlaan were counted for two days (summer, 2018). section 7.1 on page <?> shows a high variety in need for the carts. The carousel can be empty with 1100 visitors in the park, however there can be carts left with 2800 visitors. This is dependent on the composition of the visitors. Furthermore, the front office only counts the amount of visitors entering the park and does not deduct the visitors that have already left, the amount of visitors inside the park is unknown. Most carts are taken between 10:30 am and 12:00 pm.

The age distribution of the day visitors is unknown. At the entrance the ticket type is checked, resulting in the following data: amount tickets for children ranging from 0 to 2 and tickets for children from 3 to 9 year old.

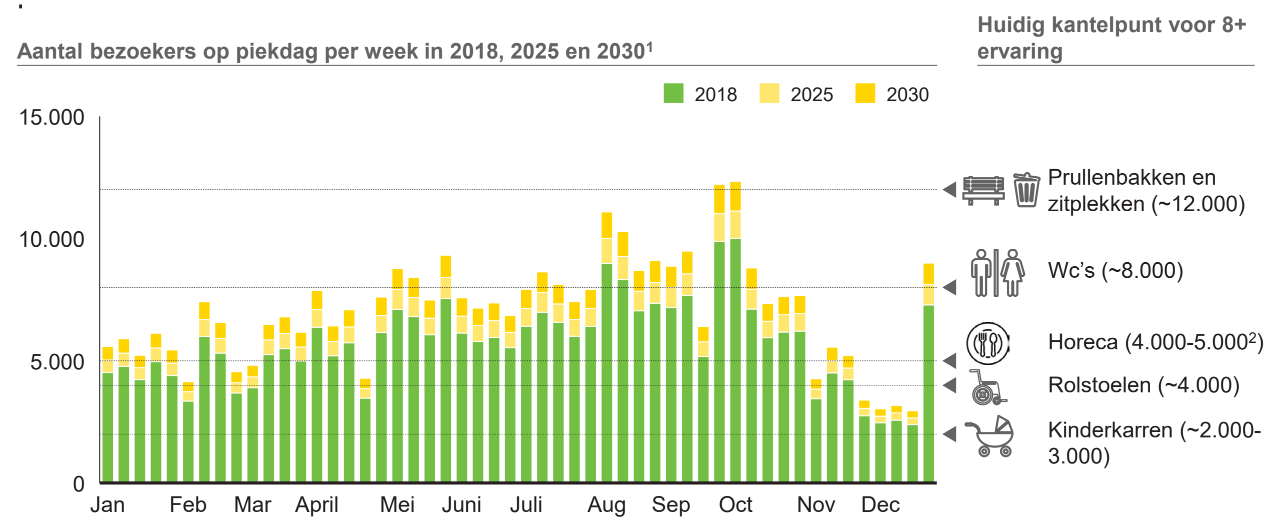


Figure B.1: Capacity tipping point for facilities in Artis

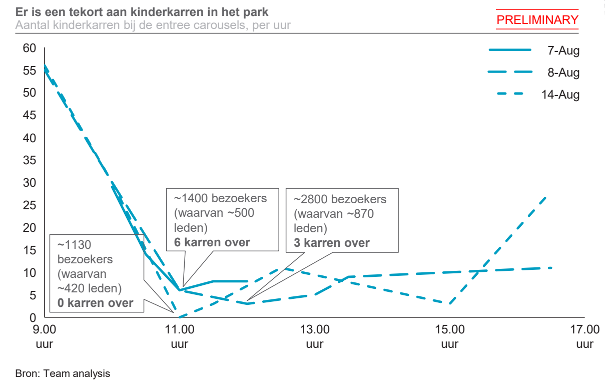


Figure B.2: Cart use peak hours

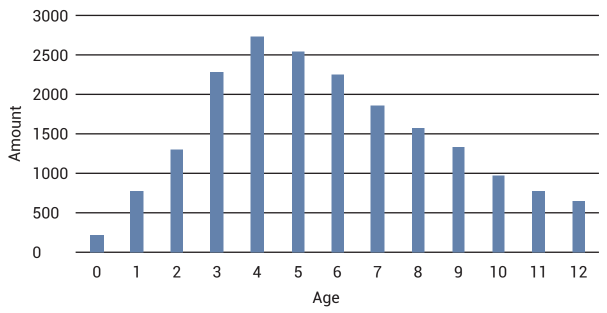


Figure B.3: Age distribution Artis members

The age distribution of the Artis members is known for the year 2018 (Figure B.3). 6% of the Artis members is aged 1 up to and including 3 years of age, assuming they all have at least one supervisor, 12% of the visitors could be involved with the children carts. Since only these data are available, the assumption following assumption was made: The age composition of visitors is distributed in the same way as the age distribution of the members. Resulting in a representation of the age distribution of all visitors.

B.0.3 Prediction cart capacity needed

With this data a prediction can be made for the amount of carts needed on the short term and the long term to be able to cope with the changes.

There are 180 children (aged between 1 up to and including 3) when there are 3000 visitors. With 60 carts, there is 1/3 cart per child. Resulting in the assumption there should be enough carts for 33% of the children.
To make a prediction of the amount of carts needed, the following assumptions were done.

- The amount of carts and the corresponding tipping point can be scaled with the same factor.
- The current tipping point for a shortage of carts is 3000 visitors (8+ visitor experience).
- The tipping point for 60 carts remains the same with an increase of visitors.
- The visitor composition and age distribution stays the same for the increase of visitors in the future.
- Amount of visitors in 2030 is estimated aroung 2 million.
- Rating of visitor experience remains the same with a linear increase of the amount of carts and visitors.

Table B.1 shows the amount of carts needed to increase the tipping point and the corresponding percentage of days the amount of carts available is sufficient.

Adding 40 carts will increase the capacity to 100. Hundred carts will be sufficient for 75% of the park days with the current amount of visitors. In 2030, having 100 carts will be sufficient for 55% of the days. Artis expects the amount of visitors to grow, to have a sufficient amount of carts for 75% of the days in 2030, 145 carts are needed.

Artis is concerned about the amount of carts in the park on busy days and does not want to overload the park with carts. A compromise needs to be made. Furthermore, resulting from interviews with other zoos, the demand for carts can be endless since visitors will use them for other purposes.

After discussion with Artis, 100 carts will be made intially. Thereafter the amount can be scaled in small batches when needed. This way the amount of carts can be increased easily to the demand.

B.0.4 Conclusion

The previous paragraphs result in the following conclusion:

- There should be at least 100 carts available in the park (sufficient for 75% of the days in 2020 and 55% of the days in 2030).
- The carts should be scalable in batches of 10 carts.
- Increasing the amount of carts will influence the infrastructure and accecibility for other visitors in the park. A balance needs to be found to make sure the park is not covered with carts.
- More carts could result in more occasional storage points.
- Increasing the amount of carts might imly visitors counting on the availability of the carts more.

Amount carts	Tipping point 2019 visitors	sufficient capacity	2030 (1.6) sufficient capacity	2030 (2 mln) sufficient capacity
60	3000	44%	35%	25%
65	3250	49%	41%	28%
70	3500	55%	45%	31%
75	3750	59%	50%	35%
80	4000	62%	55%	39%
85	4250	66%	58%	43%
90	4500	69%	62%	47%
95	4750	71%	65%	50%
100	5000	75%	68%	55%
105	5250	76%	70%	57%
110	5500	78%	72%	61%
115	5750	82%	75%	63%
120	6000	86%	76%	65%
125	6250	88%	78%	68%
130	6500	92%	81%	69%
135	6750	94%	84%	71%
140	7000	95%	87%	72%
145	7250	96%	90%	75%
150	7500	97%	93%	76%
155	7750	97%	94%	78%
160	8000	98%	95%	79%
165	8250	98%	96%	82%
170	8500	98%	96%	84%
175	8750	98%	97%	87%
180	9000	98%	97%	90%

Table B.1: Capacity sufficiency for amount of carts

APPENDIX C

Competitor mobility support services

C.0.1 Goal

To get insight in how other public places deal with mobility support, especially other zoo's since they have similar contexts.

C.0.2 Method

Compare mobility services of the zoo's in the Netherlands, as well as other city zoo's in Europe. Amusement parks in the Netherlands, Disneyland Paris and universal studios were also taken into account. Information about the services is gathered by desk research, websites.

Five zoo's with similar business or service models were interviewed (phone interview) to get extra information about their service and identify touchpoints. Zoo Antwerpen is comparable with Artis, therefore, more information was asked about the service via email.

C.0.3 Results

All results are gahtered in the table below. For the different parks, the type of mobility support (personalised/standard/unique), costs of the service and reservation possibilities are described.

Results from the phone interviews are written down per park. Questions asked during the phone interviews were: how does the service work? Which steps does the visitor go through? Do visitors pay for the service?

Gaia zoo

Gaia zoo provides visitors with pulling-carts for children. There are 20 carts available at the entrance stored underneath a canopy. They can be picked up at the entrance after paying a 20 euro deposit. All carts used to have a coin return lock, but when all tokens were lost, the locks were removed from the carts.

Dierenrijk

There are 20 wooden carts (bolderkarren) available at the entrance with coin return locks. Visitors can take one themselves from the wooden shelter. They are always outside under a canopy and can be recognized by the Dierenrijk logo.

Efteling

Carts and wheelchairs can be rented at the rental area at the beginning of the park. The carts are outside except for bad weather. Together with the cart you receive a payment confirmation in case someone else takes your cart when you left it at an attraction. When a cart is stolen, visitors can get a new one at the station.

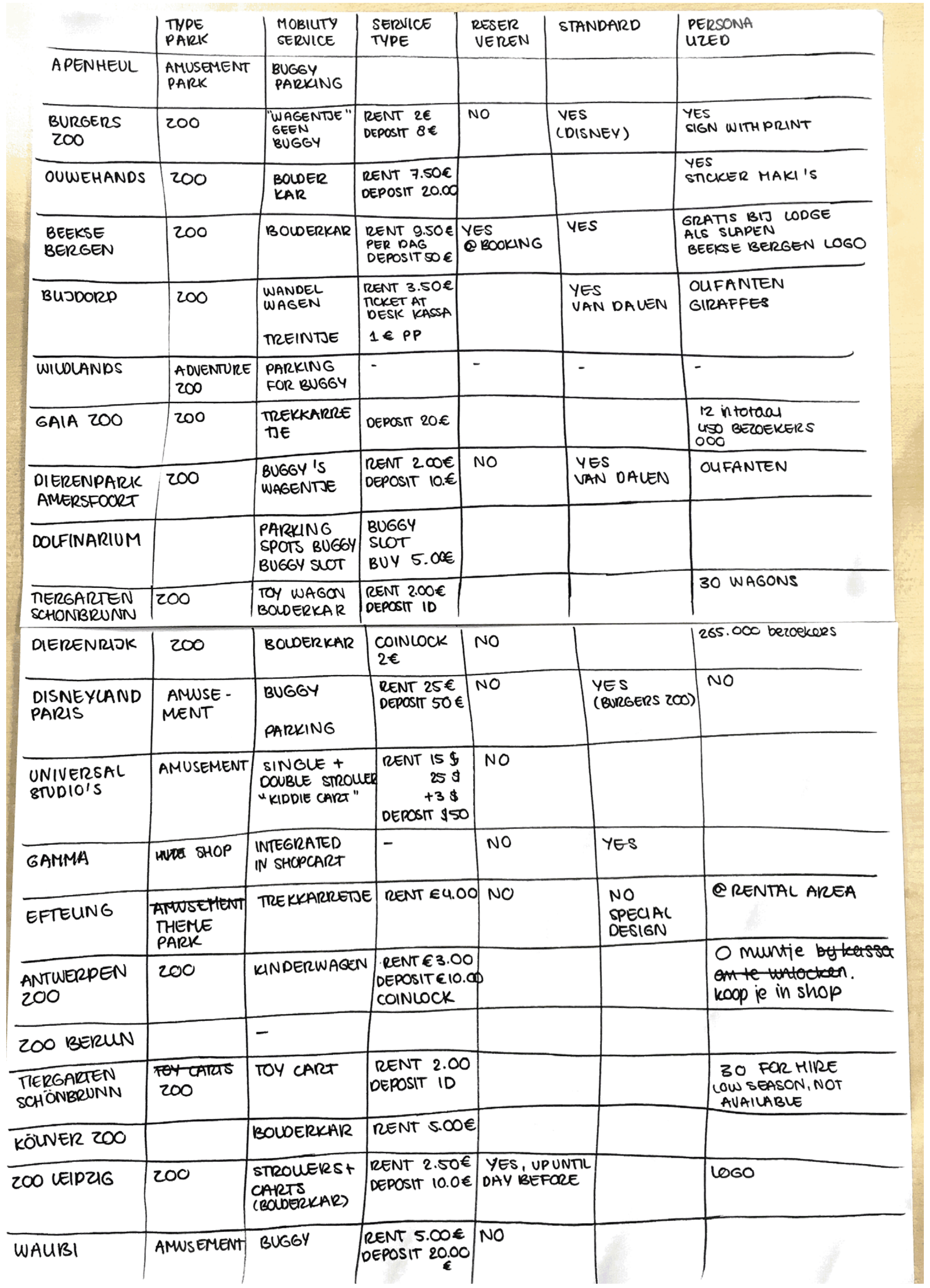
Diergaarde blijdorp

A ticket to rent a cart for a day can be bought at the shop or the cash desk, when entering the park you show your ticket to the ticket inspector and a cart will be assigned. The cart checkers keep an eye on the carts during the day. The carts are returned at the same point and stored under a canopy.

Antwerpen zoo

Antwerpen zoo has 75 carts and 30 strollers available. To rent a stroller or cart, the visitors pay for a token or key (3 or 6 euros) at the shop close to the entrance to then unlock the stroller or cart with the token or key. A 10 euro deposit is payed and returned when the token and stroller are returned to the shop together with their proof of payment. The carts are stored under a canopy.

In high season, all carts are rented out before noon, logistically there is too little space to place more carts at the station. At the end of the day, visitors bringing back their cart need to queue at the shop to get back their deposit and hand in the coin. This is experienced by the visitors as annoying. The process can be automized by investing in a coin machine, this is however too



	TYPE PARK	MOBILITY SERVICE	SERVICE TYPE	RESERVEREN	STANDARD	PERSONA UZED
APENHEUL	AMUSEMENT PARK	BUGGY PARKING				
BURGERS ZOO	ZOO	"WAGENTJE" GEEN BUGGY	RENT 2€ DEPOSIT 8€	NO	YES (DISNEY)	YES SIGN WITH PRINT
OUWEHANDS	ZOO	BOLDER KAR	RENT 7.50€ DEPOSIT 20.00			YES STICKER MAKI'S
BEEKSE BERGEN	ZOO	BOLDERKAR	RENT 9.50€ PER DAG DEPOSIT 50€	YES @ BOOKING	YES	GRATIS BIJ LODGE ALS SLAPEN BEEKSE BERGEN LOGO
BLIJDORP	ZOO	WANDEL WAGEN TREINTJE	RENT 3.50€ TICKET AT DESK KASSA 1€ PP		YES VAN DALEN	OLIFANTEN GIRAFFES
WILDLANDS	ADVENTURE ZOO	PARKING FOR BUGGY	-	-	-	-
GAIA ZOO	ZOO	TREKKARRE TJE	DEPOSIT 20€			12 in totaal 450 BEZOEKERS 000
DIERENPARK AMERSFOORT	ZOO	BUGGY'S WAGENTJE	RENT 2.00€ DEPOSIT 10.€	NO	YES VAN DALEN	OLIFANTEN
DOLFINARIUM		PARKING SPOTS BUGGY BUGGY SLOT	BUGGY SLOT BUY 5.00€			
TIERGARTEN SCHONBRUNN	ZOO	TOY WAGON BOLDERKAR	RENT 2.00€ DEPOSIT ID			30 WAGONS
DIERENRIJK	ZOO	BOLDERKAR	COINLOCK 2€	NO		265.000 bezoekers
DISNEYLAND PARIS	AMUSE-MENT	BUGGY PARKING	RENT 25€ DEPOSIT 50€	NO	YES (BURGERS ZOO)	NO
UNIVERSAL STUDIO'S	AMUSEMENT	SINGLE + DOUBLE STROLLER "KIDDIE CART"	RENT 15 $ 25 $ +3 $ DEPOSIT $50	NO		
GAMMA	~~HUIS~~ SHOP	INTEGRATED IN SHOPCART	-	NO	YES	
EFTELING	~~AMUSEMENT~~ THEME PARK	TREKKARRETJE	RENT €4.00	NO	NO SPECIAL DESIGN	@ RENTAL AREA
ANTWERPEN ZOO	ZOO	KINDERWAGEN	RENT €3.00 DEPOSIT €10.00 COINLOCK			O muntje ~~bij kassa om te unlocken~~. koop je in shop
ZOO BERLIN		-				
TIERGARTEN SCHÖNBRUNN	~~TOY CARTS~~ ZOO	TOY CART	RENT 2.00 DEPOSIT ID			30 FOR HIRE LOW SEASON, NOT AVAILABLE
KÖLNER ZOO		BOLDERKAR	RENT 5.00€			
ZOO LEIPZIG	ZOO	STROLLERS + CARTS (BOLDERKAR)	RENT 2.50€ DEPOSIT 10.0€	YES, UP UNTIL DAY BEFORE		LOGO
WALIBI	AMUSEMENT	BUGGY	RENT 5.00€ DEPOSIT 20.00 €	NO		

Figure C.1: Comparison mobility support parks

big of an investment and has no priority for now. (Personal communication, Antwerpen zoo, sara de bleser)

Carts are more popular than the elephant carts despite double amount of the costs. Strollers and carts are outside but covered by a canopy and locked to each other or the railing by a coin lock.

C.0.4 Conclusion

Most of the other zoo's and amusement parks who provide a mobility service for children have a revenue model, it is not known if any profit is made with the rental. Only Dierenrijk uses the same free self-service coin lock system.

Parks that do not offer extra mobility services in terms of carts, offer buggy parking spots and Dolfinarium Hardewijk sells buggy locks to keep your stroller safe.

Most parks have a manned location where visitors rent a cart, for example inside the shop, at the counter or at a separate rental area. Rent

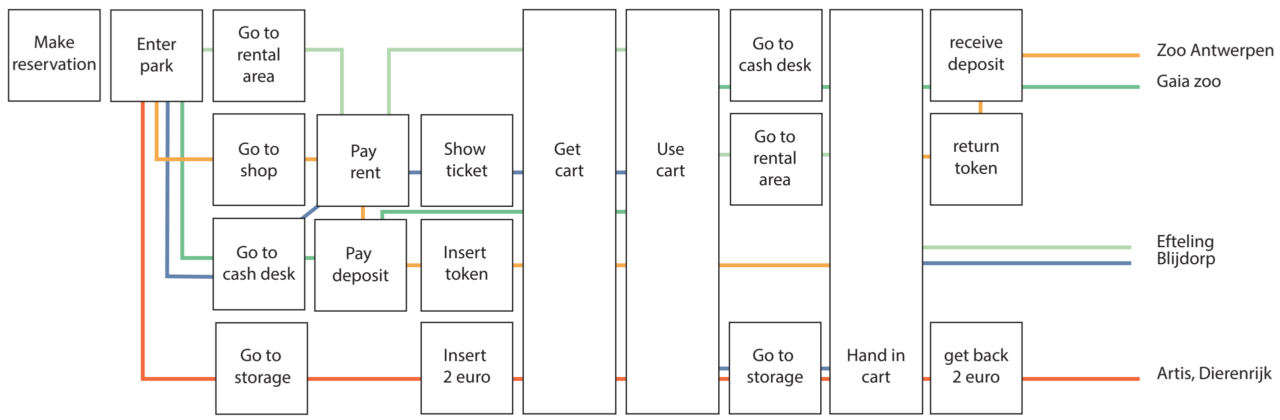


Figure C.2: Zoo comparison service steps for mobility support

prices range between 2 and 25 euro, deposits range from 8 to 50 euros. In some cases a cart can be booked beforehand or only a deposit has to be made. A manned location makes sure only visitors in real need of a cart will get one. A sense of responsibility is created by having to pay a deposit, assuming you will take care of your product when you have paid for it. Furthermore, this functions as a guarantee that visitors will bring back the cart to the entrance or stationing area.

Identified touchpoints that are used for the service: website, cash desk, ticket checker, shop, (manned) storage station. Figure Figure C.2 describes the different journey steps visitors go through when visiting other zoo's using mobility support.

Different mobility options

In general three different mobility options are provided by parks, strollers, pull carts, and carts. Most carts are standard and then personalized for the park with stickers. Parks that do not offer one, provide stroller parking spaces where visitors can stall their own stroller.

The Efteling, Artis and GaiaZoo use the same type cart (pull cart), but all have a different appearance. The first carts were introduced in the Efteling in the 60's. New versions have been made, keeping the original design in mind. Colors of the carts have changed over the years.

Burgers Zoo used to have the same type of cart but replaced them for strollers, the same as Disney Land Paris. Zoo's that provide carts use standard designs and are recognizable by their logo printed on the side. Carts have space for multiple kids, it is also easy to use them for storage.

The elephant and giraffe stroller are widely used (Antwerpen Zoo, Blijdorp). They can be nested to take less space when stalled. They are made the company Van Dalen, who also make carts and pull carts.

Figure C.3: Efteling carts (left: 2006, right: 2020)

C.0.5 Insights

- The coin return lock or deposit ensures the strollers/carts are returned to the gathering point again. Carts can be mostly taken depending on availability.
- Most of the other zoo's and amusement parks who provide a mobility service for children have a revenue model, implementing this in Artis can cover for example the maintenance costs.
- A sense of responsibility is created by having to pay a deposit, assuming visitors will take care of the product when they have paid for it.
- Service systems and corresponding touch points can be used as an inspiration for designing the different service steps. The current self-service system eliminates manned stations and extra steps for the visitor to go through.
- All other parks have one single gathering and distribution point near the entrance. All visitors that make use of the service have to return the cart at the same point.
- The carousel with coin lock eliminates intervention of an extra touchpoint where for example a coin needs to be collected to then unlock a cart (Antwerpen zoo).
- Most parks use a service based on availability without the possibility to reserve a cart/cart beforehand.

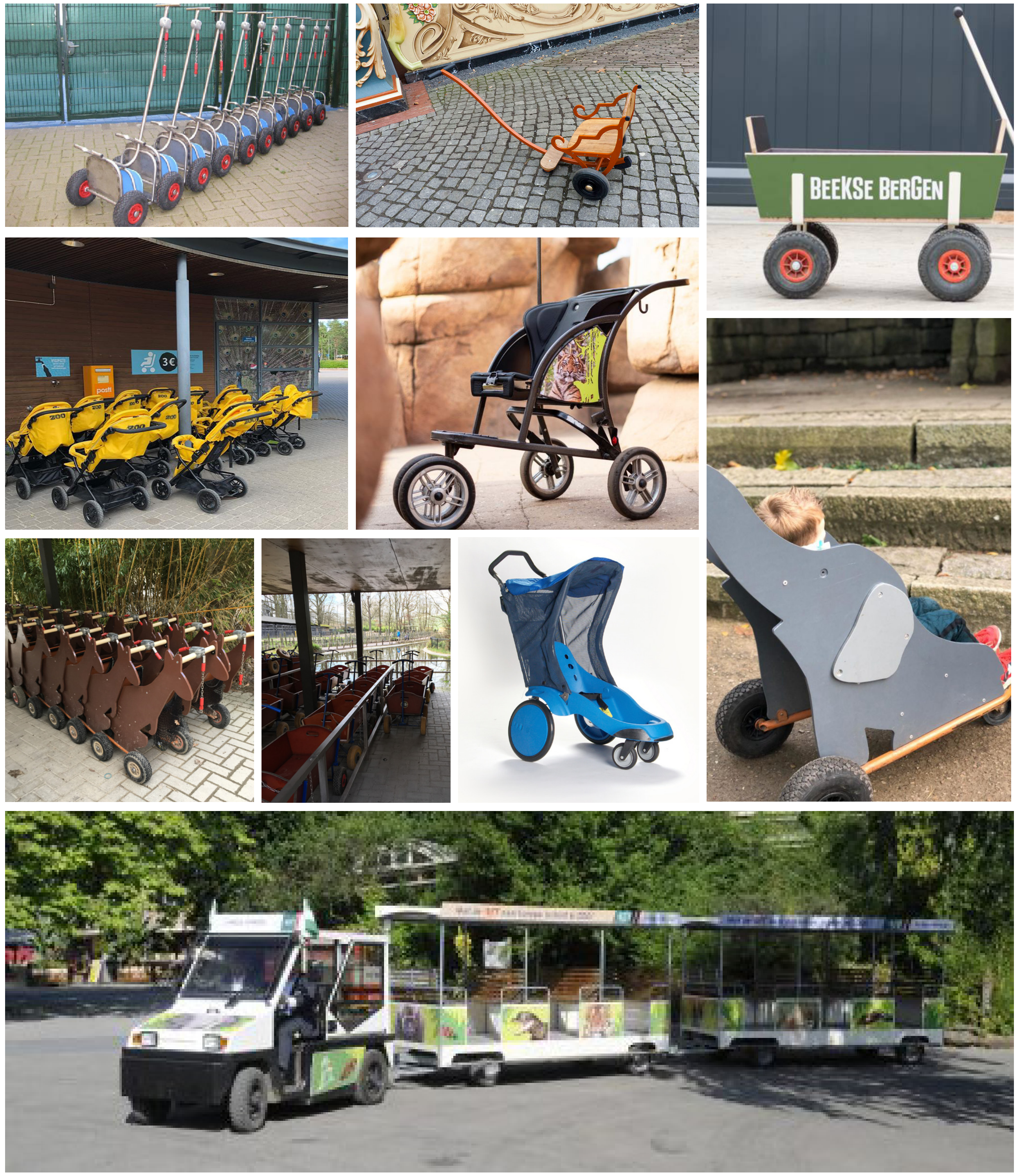


Figure C.4: Different types of mobility support for children in zoo's

APPENDIX D

Collage: facilities in Artis

D.0.1 Goal
Artis strong relation with her heritage and history was mentioned several times during interviews. Artis has a clear vision for her facilities, where and how they are situated their aesthetics. A collage was made, in the problem exploration phase, to make a visual representation of the context, the Artis park, in terms of the facilities.

D.0.2 Method
First the goal of the collage was determined; find and visualize the overarching theme of the facilities present in Artis.To then be able to then distill a visual framework in which the solution should fit. The Collage method from the Delft design guide was used.

The collage was made in Adobe Photoshop using own and stock photos provided by Artis.

D.0.3 Results
The complete collage is presented in Figure D.1. The background of the collage is filled with an old painting the Papegaaienlaan in Artis when there were still parrots along side the entrance lane. On the background, different facilities currently available in Artis are pasted.

In this collage, the green entrance poles and 'Het Groote Museum' on the right represent the still very much valued and present historical elements of Artis. On the right, the new entrance area with the ticket booth is visual.

On the right of the collage you see 'Het Artisplein', a meeting place for everyone.

All park facilities have neutral colours; green and grey, that make them blend in the enviroment and make them unobtrusive. Artis creates unity by using the same colours everywhere, Artis grey (RAL 7022) is preferred.

The classic Victor & Stanley litters fit in the historical city park. The park is authentic due to the entrance area, buildings and choice for decoration.

D.0.4 Insights
All facilities blend in the environment and form a strong aesthetic coherance. Artis does not use thematization throughout the zoo, but one could argue the overarching theme for the facilities is 'Authentic city park'. For example, the litters could also fit in the Vondelpark in Amsterdam as well as the lanters. This also shows the connection with Amsterdam. The facilities are all well maintained with a hint of nostalgia.

The 'bakfietsen', used for selling drinks and snacks are a recent addition to the catering facilities of Artis. They have an oldfashioned and traditional aesthetic.

This collage can be used as inspiration for aesthetic theme of the concept. By placing the future solution in the collage, the right balance can be found between modern and nostalgic.

Figure D.1: Facility aesthetics and theme collage

APPENDIX E

Service research methods

This appendix describes the methods used for both the internal stakeholder research and visitor research done.

E.0.1 Internal stakeholder interviews

In order to describe the role, values and capability of internal stakeholders with respect to the service, stakeholders were investigated by means of semi-structured interviews. Internal stakeholders were determined by means of snowballing. Starting from the management of 'Project beheer & onderhoud' stakeholders involved with the service were identified.

After identification, the internal stakeholders they were devided into three groups called; management, operational invisible and front stage channels to show their interrelationship and level of influence in the service.

E.0.2 Visitor observations

Caregiver combinations were observed specifically at carousels at the end of the Pappagaaienlaan, and more generally on the paths near the restaurant and walkthrough enclosures. Observations near the carrousel were coded, tallied and analysed quantitatively in order to get insight in the interaction between the visitors, carts and the carousel.

Next the observations at the carousels and other places were analysed qualitatively. After transcribing the main themes were distilled and summarized.

E.0.3 Visitor interviews

Semi structured interviews were done with 19 caretakers visiting the park. Interviewees were randomly chosen. Visitors using carts, strollers, other means of mobility support and not using mobility support were interviewed to get a broad overview of child mobility in Artis. The guiding question was, how is mobility support by means of the cart or other means of transport experienced? Several follow up questions were asked, depending on the answer of the visitor. Visitors who did not use the service were asked why not. Interviews were transcribed after writing down the answers. Visitors on maximum peak days in Artis could not be interviewed or observed due to the project planning.

E.0.4 Visitor online questionnaire

An online questionnaire was sent to several parents with children who visited Artis before. The questionnaire consisted of questions about preparation of the visit, whether strollers or carts were used and why, an how they influenced the day. The questionnaire was answered by nine respondents with children between one and six. Although the number of respondents is low, answers do give insight in the obstacles visitors encounter during a visit and when and how mobility support options are used.

E.0.5 Visitor Immersion

To immerse myself in the experience of visiting Artis with children, I walked through Artis together with a mother (age 29) and a child (age 3). Notes were taken during the visit. An in depth interview was done with a mother with a child to find out the different steps of going to Artis with children. During the interview the main questions were, what do you do next and why? Starting from the decision to go to Artis.

APPENDIX F

Evaluation design criteria

This appendix presents the evaluation of the design criteria. Most of the criteria are met, others need to be further developed or tested. A few criteria are not met and could be reconsidered.

🟢 Criteria met
🟠 Criteria to be tested or further developed
🔴 Criteria not met

Theme	Sub-theme	#	Req/whish	Description	Criteria met not met, to be tested , met
General		1	Reqw	Service is free of charge, deposit is payed before use and returned at the end of use	🟢
		1.1	Req	When stationed all carts are locked and cannot drive	🟢
User group			Req	Dutch p5 female and p95 male should be able to propell the vehicle, height of the handle bar should be variable between 65 and 95 cm	🟢
			Req	The vehicle should be suitable for children between 9 and 20 kilogram or up to 110 cm, whichever comes first	🟢
Service interaction	Take and return		Req	Unlocking/locking the vehicle should be easy to do by an adult with minimal instructions	🟢
			Req	The vehicle can be unlocked with means 90% of the visitors carries with them	🟠
			Req	Every cart can be locked and unlocked at any station without intervention of Artis employee	🟢
			Whish	Child can sit in vehicle while (un)locking the cart	🟢
			Whish	Two visitors can simultaniously take/return vehicle at one station	🟢
	Driving		Req	The vehicle is considered easy manouverable with one hand with child inside over all surfaces (cobblestones and pavement)	🟠
			Req	The design of the cart prevents the child from falling out of the vehicle to any direction when driving; any openings do not create entrapment, child cannot stand up	🟢
	Get in or out		Req	Any location/surface likely to cause the unit to tip over when climbing in must support the vertical force (200N) applied for 10 seconds	🟠
			Req	The unit is unable to drive when not propelled by the caregiver	🟢
	Park		Req	The vehicle cannot be tipped over or moved by the child when outside vehicle; The vehicle must not tip over when horizontal force of max 120N in a horizontal direction and 1500 mm above the horizontal surface or at the top edge is applied	🟠
Station	Location		Req	Stations are situated at obstruction points identified or major walking routes	🟢
			Req	At least one station is visible from the back exit	🟢
			Whish	Station including vehicles must not obstruct sight of animals in animal enclosures	🟠
	General			One station can host an unlimited amount of vehicles as long space allows	Visitor research, accessibility

Group	Subgroup	#	Req/whish	Description	Origin
			Whish	A station is considered recognisable by visitors with or without vehicles	
			Req	The station including carts should not have protruding parts that can hinder other visitors	
			Req	A station can be removed and resituated by Artis's maintenance team by only removing bricks	
Provide information			Whish	The number of carts available per station can be found in the Artis application	
			Whish	All stations are visible on the map and map in application	
			Req	Road signs indicate directions to stations	
			Req	Information on website and application is considered clear, visitor knows how to use the service, where stations are located before their visit	
			Whish	Every station provides information about; using the service, other stations	
Cart			Req	The product should be considered 'safe in use' by as many test subjects as possible	
			Req	The vehicle should not have protruding elements that can hinder other visitors when parked or driving.	
			Req	The vehicle should enable full sight for the child when seated	
			Req	The vehicles can be nested	
Space occupation			Req	The station at the papegaaienlaan should be able to host all vehicles on max 48 m²	
Aesthetics			Req	The vehicle and station are considered to fit in the classic park theme by main stakeholders	
			Whish	The vehicle is preceived as attractive and fun by children for as much tested people as possible	
Durability			Whish	Contact points with the ground are made of wear and impact resistant materials	
			Req	Vehicle must be able to stand outside and used for 5 years before repairment of frame and seat.	
			Req	Materials used are water,- mildew and dirtrepellent, shall not decolorate and remain stable in a range of temperatures from -10 to +40 °C.	
			Req	Parts shall be designed such that precipitation can drain off freely and water accumulation shall be avoided	
			Req	The vehicle shall support a static load of 800 N in the center of the area the child is seated.	
			Req	Materials used are recyclable in Artis' containers	
Safety test			Req	There shall be no protruding nails or pointed or sharp-edged components conform the edge test in the reach area of the child.	
			Req	When parked (facing up and down the slope) the vehicle shall remain static on a slope (10 degrees) for a minimum of 1 minute including weight child.	
Mainte-nance			Req	Parts that need common maintenance or replacement should be easily reachable and reparable by Artis' social workers with mostly generic tools	
Servicing			Whish	Multiple vehicles can be moved at the same time by one person manually	
Capacity			Req	Minimal 100 vehicles are always available for use in Artis	
			Whish	Quantity of vehicles is scalable in batches of 10 vehicles	
Costs			Req	The initial investment costs including installation of station and vehicles shall not exceed 100.000 euros	
			Whish	Repetative yearly maintenance of all vehicles does not exceed 120 manhours equal to 5000 euro	

APPENDIX G

User evaluation

G.0.1 Goal

To receive input on and evaluate the overall service concept, illustrating the end to end experience and to validate the interaction with the cart a user test was done with caregivers that have small children and have visited Artis before.

G.0.2 Method

Four participants, caregivers who have visited Artis with small children, participated in the user test. Qualitative data was gathered by asking open questions. No quantative data was gathered becasue of the low number of participants. Figure G.2 shows the test setup used. All models of the carts are presented open such that there is no spoiler about the pull bar that needs to be rotated.

The user test consisted of two parts; story board validation and a small interview. A prepared storyboard with main situations was discussed, one visual at the time. The situation on the visual was shortly described and then the participant was asked how he/she would react and what she/he would do next and why. Other questions asked were; How would you operate this? What do you expect to happen? What do you think you should do, what would be your next step?

Figure G.2: Scale models used during evaluation

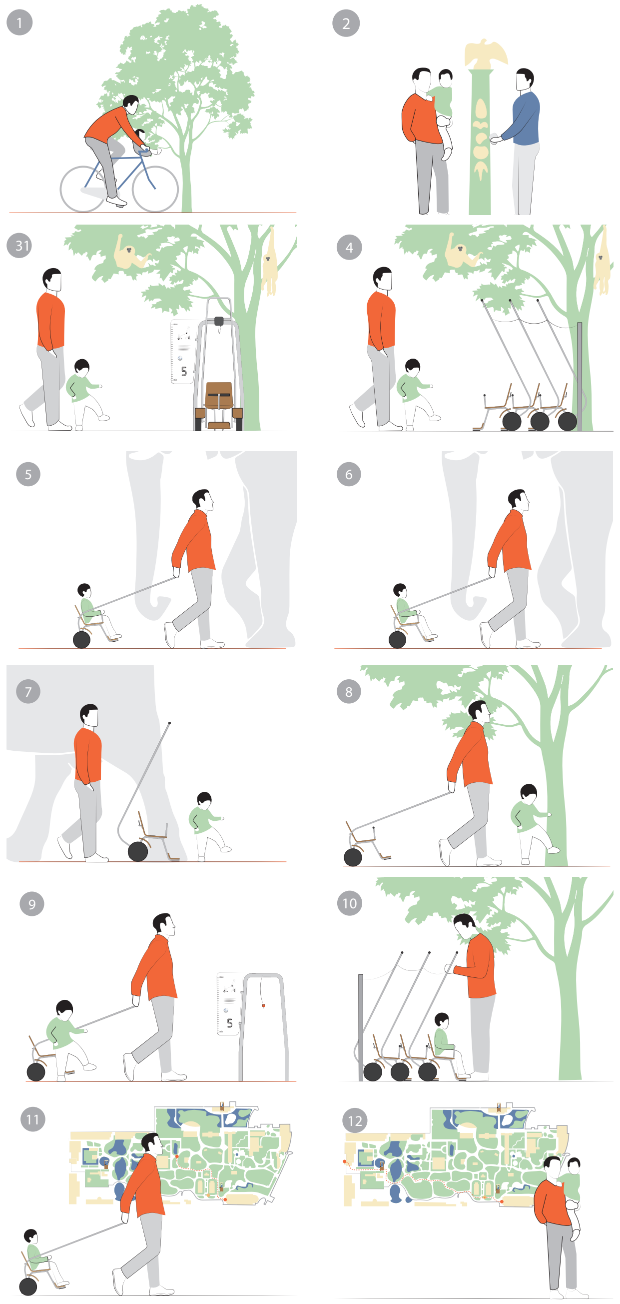


Figure G.1: Storyboard for user test

The interaction with the cart and station is integrated in the storyboard. Close up visuals were available to explain the shortcoming of the scale models and to show how it would look like in real life (Figure G.3).

Figure G.1 shows the storyboard used, the following descriptions were given. Follow up

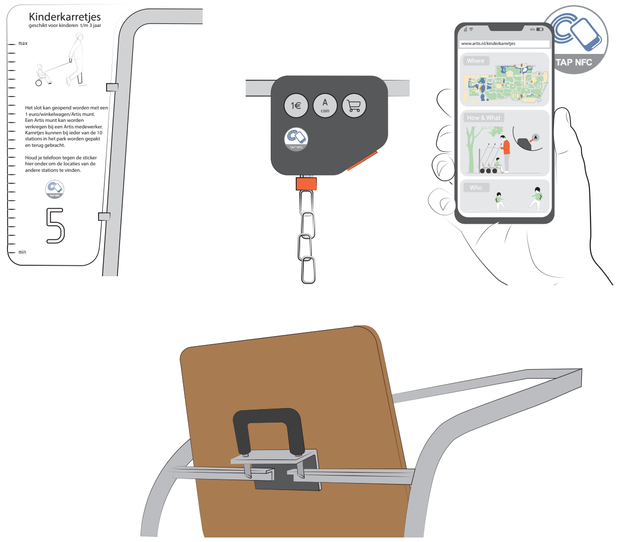


Figure G.3: Details for explaining storyboard

questions were asked depending on the answers.

1. You are preparing to go to Artis, what do you do?
2. Where do you go after you have entered?
3. You bump in to a station with carts, and want to have one, what do you do? How do you think it works? How do you interpret the sign at the station?
4. Taking a cart, how would you do this? Which steps are involved? How does the cart work?
5. Walking towards the elephants
6. Child wants to get out, what do you do? Describe the steps you need to take.
7. After opening, the child wants to walk further, what do you do with the cart?
8. Possibly walking a little
9. What would you do if you were walking past a station? What do you do when there are no carts left at the station?
10. How would you return the cart? How does it work?
11. You want to go to the aquarium, do you take a cart? What do you do with the cart when at the aquarium?
12. You want to go home, to the exit, how do you get there?

Available models were used for explaining the locations of the stations and Artis map. The scale models of the carts were used by the participant to show how they would interact with it. They also functioned as a visual representation of the carts and station (Figure G.2).

The service and cart were not introduced beforehand, the goal of discussing the storyboard was to get the participant familiar with the concept and get the first reaction and actions. The questions afterwards aimed at getting to know how and if the user would use the service when in Artis.

Questions asked in the second part were:

- Would you make use of the service?
- How would you make use of the service?
- Does the age of the child influence how you would use the service?
- Would you take and leave the cart multiple times a day?
- From which age do you concider the cart suitable?
- Would you consider the cart safe?
- Do you trust there will allways be a cart available at every station?
- Would your child be able to get in and out of the cart themselves?
- Which unsafe situations could occur?
- What do you think of the interaction with the cart? (easy, difficult, vague etc.)

Interviews were recorded and transcribed in Dutch, quotes were translated to english. Results were combined and gave insight in how visitors would use the service. All are described in the next paragraph.

G.0.3 Results

Results are catagorized in three groups; end to end experience, use of the cart and safety.

End to end experience

- None of the participants carry a euro coin. **Half of the participants carry a shopping cart token**, the other half does not carry any coins and mentioned they would go to the service desk to get a coin or euro.
- Three out of four participants mentioned they would first **try to unlock the cart before looking at the information board**. They would all open the website multiple times during the visit to find the nearest station. Three participants suggested placing a sign for the carts at the beginning of the park to inform caregivers about the use.
- None of the participants was familiar with NFC stickers. However, **3 out of four would tap their phone on the sticker** at the information sign or coin lock and open the website multiple times. One of the participants mentioned it takes too much effort to scan it. Additionally, one of the participants suggested to include a QR code.
- Half of the **participants would look for the nearest station (by opening the website)** if their child wants to walk instead of sit in the cart. After exploring Artis by foot, they are confident they will bump into another station with carts after a while. All participants would lock the cart to the station when visiting the aquarium, mainly because of the **risk of losing the cart if left unattended** in front of the aquarium.
- Taking and leaving a cart at one of the stations during the visit **dependents on the number of carts present at the station and previous experiences**. Opinions are divided on locking a cart at an empty station. Previous experiences influence the type of use, if visitors have the feeling there is a shortage, they suggest they will keep the cart with them for a longer period. One of the participants mentioned she would prefer to keep the cart the whole visit because she is never sure when she will need it again.
- **Taking and leaving a cart multiple times during the day is age-dependent**. All participants mentioned that with younger children, they would use the cart for longer periods and would depend more on the availability. Whereas, when children get older, more intermittent use was described.
- All participants mentioned they would **take a cart immediately at the front of the park** and would return it at another station dependent on how eager their child is to walk or sit in the cart. It is important to know the locations of the stations to adjust the visit. One of the participants mentioned it would be useful to know how many carts are present at every station.
- All participants mentioned that they would take a cart at one of the stations **at the end of the day** when their child is tired. Caregivers do not feel like carrying and the children do not want to walk. The carts are most useful at the end of the day.

Interaction with cart

- Three out of the four participants would rotate the pull bar downwards after unlocking to close the cart and then pull the cart to move forward. One of the participants mentioned she would probably try to push the cart, but that that does not look obvious.
- If the child wants to get out, half of the participants would try to **lift the child** out of the cart. The others would **open the pull bar**. The interaction with the lock was not immediately clear.
- One of the participants missed a hook to hang her bag onto.

Safety and suitability

- All participants **perceived the cart as safe in use** for the reason that their child cannot get out of the cart when driving because the movement to all directions is restricted. Furthermore, hands cannot get in the wheels because of the mudguards. One of the participants mentioned he would still need to pay attention to the child because he could drop something.
- All caregivers mentioned they would consider the cart suitable for their children from the point in time they can **sit up straight** independently and thought their child could climb in independently when the cart is open.

G.0.4 Discussion

Points for discussion about the conducted user test are desribed using bullet points.

- Scale models were used during the test, participants mentioned it was hard to imagine the real size of all elements. Therefore, the interactions described might be different when the cart is seen on full scale. For example, the height of the pull bar when stationed would then not invite to be pushed.
- Shortcomings of the scale models influence the reaction of the participant on the questions asked. The interaction with the lock was not immediately clear, one of the scale models had an improvised lock and the others did not have a visible lock. It could be, therefore, that the participants did not recognize what to do.

APPENDIX H

Parts, materials and production

Both the frame, pull bar and bended elements need to be made and produced. This appendix elaborates on the material choice and their corresponding production method. Since the carts are always outside, they have to endure all weather conditions. They should require low maintenance, costs should be as low as possible.

H.0.1 Bended plate parts

The seat, wheel covers and footrest need to be made from bended plates. Materials used in outdoor products should be suitable and are explored to find the right material.

The seat, wheels, and footrest are designed to be made from bended plate material. Both bamboo and treated beech wood were considered. HPL is not considered since a natural look is required and HPL does not create the right aesthetics.

Bamboo

Bamboo is sustainable and widely used outdoor for flooring or building panels. Planks are treated to make them weather proof. However, bamboo is hard to bend. Solid planks are used in for example street furniture. Bamboo veneer can be made but unfortunately cannot be treated to be weather proof (Personal contact, Rolf Bakker, MOSO Bamboo). Furthermore, it would be difficult to bend and the whole would become very costly. Concluding, bamboo is not suitable for bending, therefore it is not considered as a the right material.

Beech wood

Beech wood is flexible and strong, has dense structure, is dimensionally stable. It has a long lifespan making it durable. It is widely used in for example chairs with a bended seat. Contact with Van Drenth Buighout (Erwin Maton) gave insight in the opportunities for using laminated beech wood.

Production process

To make the wood weather proof every veneer layer is immersed in a type of melamine (process is called Thermoformal) before gluing and pressing in the mold. After bending, the contours of the seat is CNC milled together with holes for the bolts. RVS threaded tubes are pressed in the holes to enable screwing the seat to the frame.

Aesthetics

The treatment darkens the color of the beech, the wood structure will still be visible, Figure H.1 shows an example of the color. Painting the seat is discouraged due to discoloration of the paint and extra maintenance. Maintenance only entails cleaning the surfaces with water once a year. The wood will turn a little grey after a year.

Part evaluation

The design of all parts was discussed to ensure feasibility. The thickness 12 mm is sufficient, the center bend radius of 40 mm is possible. Standard existing molds can be used, reducing the costs. The 2D shape and single bend reduces the costs since the mold is very simple. Laminating the different layers makes the seat stiff. Connecting the seat with four bolts to the frame will give enough support.

Figure H.1: Beech wood color after treatment

'You can jump on the backrest, it will spring back'

Costs and batch size

The minimal batch size is 100 pieces. Costs per seat are around 50 euro's, costs are higher due to the treatment of the veneer layers. The wheel caps and footrest would be around 40 euros per piece.

Development costs for the CNC molds are 600 euros per element including programming costs, molds and test model. This results in 1800 euros for seat, wheel covers and footrest.

If molds should be made, mold costs of the seat would be between 2500 and 5000 euros. will result in a lot of material waste.

General insights

- Costs can be reduced by changing the footrest into a flat plank, programming costs will be 250 euros and costs per item around 20 euros.
- Engraving the seat is possible, this will however weaken the structure of the wood. Engraving is only possible at the backside of the seat since the other side is sucked in by the mold. The engraving is CNC milled together with the shape.
- Drilling a hole in the footrest will make sure no water can gather in the bend radius. This is not necessary for the seat since it slopes down when in neutral position.
- Melamine is stored in a vessel which needs to be used at once. Depending on the size of the components the batch size is determined. The minimal batch size is 100 pieces. Spare components could be ordered together with the initial batch. These could function as spare parts but also makes it easier to scale up the amount of carts when needed.

H.0.2 Steel frame

The frame and the pull bar need to be stiff to support the weight of the child. The caregiver should be able to lift up the seat by pulling up the pull bar. It should be suitable to always stay outside.

Steel tubes

Tubes of aluminium and steel were considered. Aluminium tubes need to be galvanized or coated to make them suitable all weather conditions. Aluminium has a 3 times less E-modulus compared to steel, it will bend earlier. The pull bar should be stiff enough to be lifted up. Aluminium will bend, stainless steel would be more suitable. Furthermore, steel is easy to weld, maintenance could be done by Artis' own workshop. A combination of both materials is not possible due to risk of galvanic corrosion.

Powder coated steel tubes will be used for all parts of the frame.

Manufacturing

The tubes are bended. The diameter of all main tubes is 20 mm, with a wall thickness of 3 mm. To decrease costs, similar radii and as few bends as possible were used. All bends of the main frame have a center radius of 40 mm. Distance between two bends is at least 40 mm (2 times the initial diameter). The two main tubes are identical.

For the T-bar, a tube with diameter of 18 mm is used. A L -profile is used for the horizontal stops.

The horizontal stops as well as the T-bar and wheel cover supports need to be welded to the main frame. The T-bar gives extra support to the frame. Holes need to be drilled in the main frame for the wheel axis, holes for adjusting the seat and footrest can should also be drilled.

To make the pull bar, bends of different radii are needed. The main bend has radius of 280 mm. The other 4 bends have a radius of 40 mm. The pull bar is made out of one tube. A piece of tube needs to be welded to the pull bar to connect it with the wheel axis.

The weight of the cart can be reduced by optimizing the wall thickness and shape of the tubes.

Costs

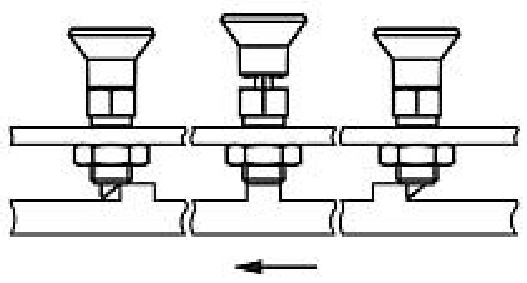
Two quotations were requested and integrated in the costs overview. Assembly and bending the tubes could be done by the same company. This needs to be figured out to get the best price as possible. All parts were considered manufacturable by all contacted companies.

Important cosiderations

- Using common tube diameters and wall thicknesses will reduce costs. For example, a 21,6 mm tube is five times cheaper than a 20 mm tube (Personal contact, Thermcontrol). This will slightly change the design but could be considered in further development.
- The possible heart radius for all bends is dependent on the available bending blocks, using standard blocks will reduce costs and can be considered.
- The big radius in the pull bar needs to be manufactured by rolling. This adds to the costs because and extra machine needs to be prepared (100 euros).

H.0.3 Mechanical lock

Indexing pins are integrated in the mechanical lock. The following pins; 'K1300 Arreteerbout met verdraaibeveiliging en schuine aanloop' are suitable since they will automatically



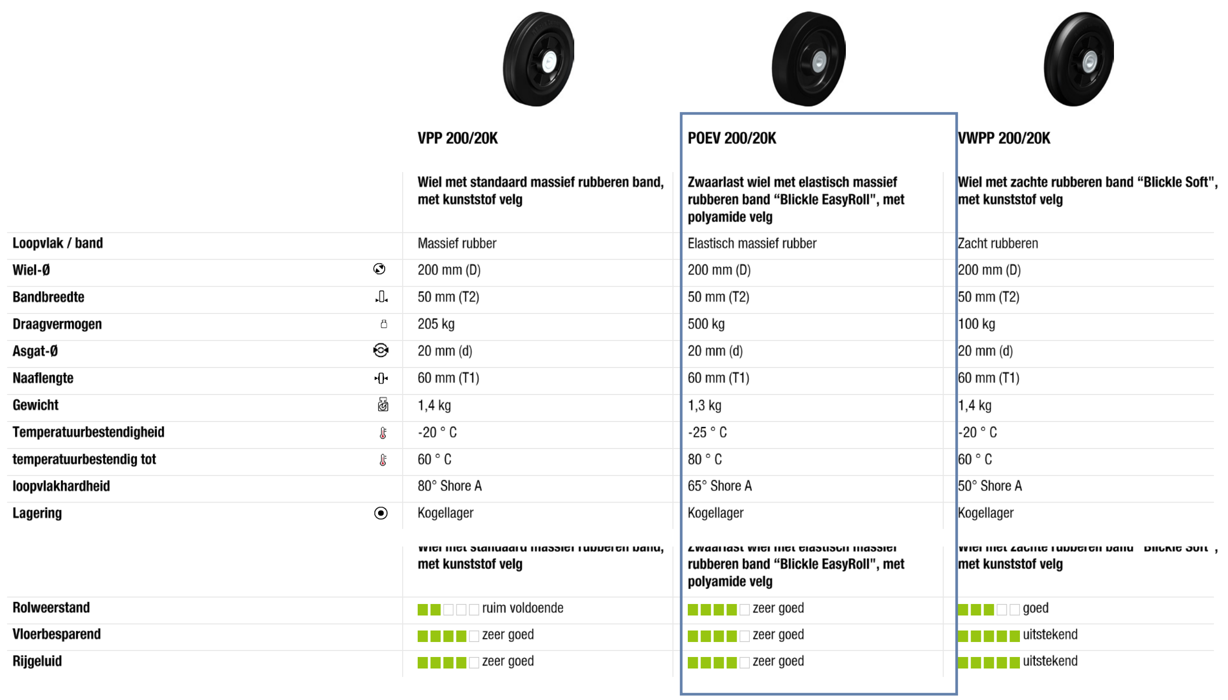
lock after opening. The bevel of the pin makes sure it opens when the mechanical stops hit the pins when the cart is closed. The stainless steel version is suggested to make sure it will last long.

The pins could be bought at Kipp: *https://www.kippcom.nl/nl/nl/Producten/Bediendelen-Normelementen/Verende-drukstukken-borgpennen-vergrendelpennen/Arreteerbout-met-verdraaibeveiliging-en-schuine-aanloop.html?search_keywords=k1300*

H.0.4 Wheels

The wheels enable the cart to drive. The ideal wheel will provide the cart with low roll resistance for easy driving, softness for suspension.

Personal contact with Blickle, a well known wheel supplier for companies among others other zoo's in the Netherlands provided in depth information



	VPP 200/20K	POEV 200/20K	VWPP 200/20K
	Wiel met standaard massief rubberen band, met kunststof velg	Zwaarlast wiel met elastisch massief rubberen band "Blickle EasyRoll", met polyamide velg	Wiel met zachte rubberen band "Blickle Soft", met kunststof velg
Loopvlak / band	Massief rubber	Elastisch massief rubber	Zacht rubberen
Wiel-Ø	200 mm (D)	200 mm (D)	200 mm (D)
Bandbreedte	50 mm (T2)	50 mm (T2)	50 mm (T2)
Draagvermogen	205 kg	500 kg	100 kg
Asgat-Ø	20 mm (d)	20 mm (d)	20 mm (d)
Naaflengte	60 mm (T1)	60 mm (T1)	60 mm (T1)
Gewicht	1,4 kg	1,3 kg	1,4 kg
Temperatuurbestendigheid	-20 ° C	-25 ° C	-20 ° C
temperatuurbestendig tot	60 ° C	80 ° C	60 ° C
loopvlakhardheid	80° Shore A	65° Shore A	50° Shore A
Lagering	Kogellager	Kogellager	Kogellager
	Wiel met standaard massief rubberen band, met kunststof velg	Zwaarlast wiel met elastisch massief rubberen band "Blickle EasyRoll", met polyamide velg	Wiel met zachte rubberen band "Blickle Soft", met kunststof velg
Rolweerstand	ruim voldoende	zeer goed	goed
Vloerbesparend	zeer goed	zeer goed	uitstekend
Rijgeluid	zeer goed	zeer goed	uitstekend

Figure H.2: Wheel characteristics comparison

APPENDIX I

Measurements

This appendix describes the steps taken to get to the right measurements of the cart to realize suitability for the target group. Several iterations resulted in the measurements used at the end of the appendix. This is a separate appendix since the main measurements of the concepts were the same.

I.0.1 Measurements seat

First version of measurements was made to get an idea of measurements needed of the seat which will guide the measurements of the cart in during the process.

Method

Measurements from existing strollers, bike seats are summarized in Table I.1. Together with measurements of the current cart (Figure I.1) and anthropometric data (Table I.2) the first version of the measurements of the seat were made by combining measurements and looking at proportions.

	Dutch child female 12-14 months p3	Dutch child female 12-14 months p50	Dutch child male 3 years P95
Standing Length	709 mm	773 mm	1093 mm
Crown to rump sit height	455 mm	501 mm	619 mm
Sitting popliteal height	138 mm	156 mm	285 mm
Sitting buttock popliteal depth	155 mm	185 mm	293 mm
Weight	7,1 kg	9,6 kg	20 kg
Hip breadth sitting	unknown	unknown	222 mm
Thigh clearance sitting	unknown	unknown	92 mm

Table I.2: Anthropometric measurements target group

Backrest height	40 cm
Seat to footrest distance	24 cm
Seat width	30 cm
Angle backrest	110 degrees
Seat depth	24 cm

Table I.1: Summary stroller measurements

Results

The results of the combined measurements for the seat are visible in Figure I.2 The abdominal depth is unknown, estimations about the size of the lapbar were done.

These measurements were used to built the wooden mock-up. The back rest angle is copied incorrectly and because of this used incorrectly in the mock up. With the wooden mock up, the measurements can be tested and iterated on. Measurements will change due to aesthetics or mechanical integration of parts.

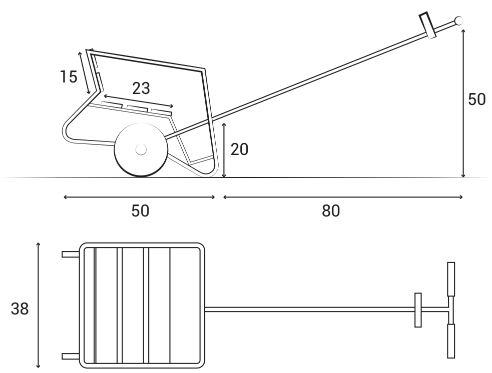


Figure I.1: Measurements current cart [cm]

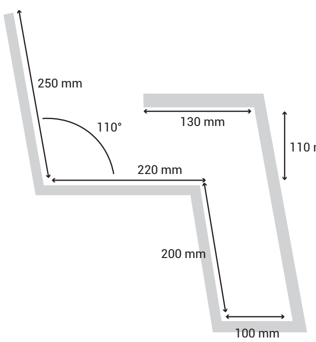


Figure I.2: Measurements seat [mm]

I.0.2 Measurements seat and lap bar in relation to child cart interaction getting in and out

Goal

The main goal of this research is to find out if all ages within the target group can get in and out and fit safely in the cart (measurements). Making sure a three year old child still fits in the cart and a one year old is safe all the time. Another goal is to find which configuration of the pull bar makes sure the child cannot get out when driving.

Research questions to be answered are:
How does the child fit in the cart?
Can he/she get in and out easily when the cart is open? If any, which elements of the cart block getting in and out?
Can he/she get out or fall out when the cart is closed for every pull bar configuration?
How does the child interact with the cart, how does he/she get in or out?
How does the shape of the cart influence getting in or out of the cart?

Method

Parents were asked for permission to take photos and videos during the test. Faces were blurred or are not filmed. Three tests were done, with children aged one two and three.

The following questions were asked to the caregiver prior to the experiment: How old is he/she?
How tall is he/she and how much does he/she weigh? Is he/she tall or small for his/her age?

Procedure

The child was asked to climb in and out of the wooden mockup. The caregiver was asked to assist when the child was not able to climb in independently. The child is asked to get in again, the different pull bars are attached to the cart and the child is asked to try to get out for every configuration. If the child cannot react on the question, the caregiver is asked to predict the capabilities of the child and is asked about the safety of the cart when closed. After testing the different tool bars, the child is asked to get out again. This concludes the experiment.
All interactions were filmed and thereafter analyzed, notable observations were written down per participant.

Results

Julia 3 ½ years of age, 100 cm, 17 kg, average height and weight

Julia gets in the cart independently, snap shots of the video show how she gets in and out of the cart, see Figure I.5. She gets in from the side, holding on to the leg bar and backrest to get in feet first. When seated she can still wiggle with her legs. Her feet stick out of the footrest. When seated, she holds on to the lap bar. Top of her thigh almost touch the lap bar. She cannot get out when the pull bar is closed, the lap bar restricts her movement upwards and the pull bar the sideward movement. When getting out, her foot gets stuck a little between the lap bar and seat. Caregiver considers safety as important and finds the cart safe.

Maya, 1 year of age
Maya did not get in the cart herself. Grandma tried to lift her in but she refused to get in. Grandma mentioned that the bar was unpleasant when lifting in the child. Maya climbed in once and left the cart at the opposite side immediately after.

Since she did not want to stay seated, the bar was not attached and it was nog tested if she could get out wehn closed or not. After 45 minutes of trying, the experiment was stopped.

Insights

- Pull bar should leave the complete side of the cart open, because all the space is needed to get in and out for a three year old.
- The lap bar invites to hold on to when seated, the space between the pull bar and lap bar should be reconsidered leaving enough space for hands to hold on to the bar.
- The lap bar should end above the seat to restrain movement when seated, this way they child cannot get up without the effort of getting out of the cart.
- Children look for support, holding on to different parts when getting in and out as well when seated. The pull bar should not lock at the lap bar since fingers will get trapped. The pullbar for concept B should lock behind the backseat such that no fingers or hands can get stuck. This influences the choice for the configuration of the pull bar (appendix FIMXE).
- For a P95 three year old to fit in, the measurements of the lap bar should be adjusted. The vertical space between the seat and lab bar as well as the length of the footrest needs to be enlarged.
- The current shape of the leg bar makes getting in and out difficult for a three year old, the construction of the lap bar should be reconsidered.
- A one year old is able to get in and out the cart independently
- For a one year old, the sides of the cart need to be closed when driving such that they cannot fall out sideways.
- Lifting a child into the cart is a hassle, since the lap bar blocks the acces from the front.

I.0.3 Handle bar height in closed position, before lifting and pulling

The caregiver lifts up the cart with the handle bar to start driving from the closed neutral position. Both the smallest and tallest adults should be able to lift up the handle bar. When walking (lifting up and pulling the cart) the arm swings backwards influencing the height of the handle bar. The height is not the same as when standing. When a tall person is lifting up the handle bar, the center of mass of the cart and the child should be in front of the wheel axis.

Figure I.4: Attaching pull bar mock up to sides

Figure I.3: Trying to get out when closed

Figure I.5: Three year old getting in and out of the cart

Figure I.6: One year old interaction with cart

Goal Find the optimal height of the handle bar in closed neutral position such that the tallest and smallest adults can lift up the cart and drive.

Method First, the P5 female and P99 male stature length as well as fist height (standing) were determined using DINED. Second, to estimate the height difference of the fist when pulling and lifting and normal fist height on person measurements were done, the procedure is described below.

Procedure For every participant (n=4), the stature, fist height standing and fist height when pulling a broom with T piece at the end were measured. The height difference between the second and third measurement resulted in delta fist height.
Results Table I.3 shows the measures important for determining the height of the handle bar (DINED, Dutch adults 2004). Table I.4 presents the measures resulting from the experiment.

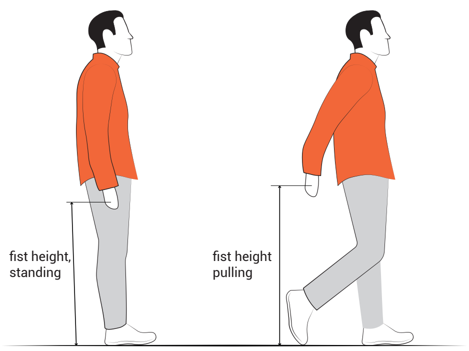


Figure I.7: Measurements location

The lowest fist height is 68,3 cm, the highest is 90.2 cm. The maximum delta fist height measured is 6 cm.

Conclusion The handle bar height in neutral position should be lower than 68.3 cm, this way the smallest person is be able to lift the handle bar. The maximum height of the handle bar when driving is 96 cm (Fist height max + max delta fist height), the center of mass should then be in front of the wheel axis.

	P5 female	P99 male
Stature [mm]	1558 mm	1895 mm
Fist height standing [mm]	683 mm	871 mm

Table I.3: Dutch adults measurements

	P1	P2	P3	P4
Sature [cm]	193	171	160	183
Fist height [cm]	87	82	74	82
Pull fist height [cm]	89	88	76	88
Delta fist height [cm]	2	6	2	6

Table I.4: Results measurement fist height

Discussion All measures were measured once, this influenced the precision of the measurements. However, results were used for making an assumption.

Insights

- The maximal handle bar height when in neutral closed position is 60 cm. The maximal handle bar height when driving can result in 95 cm. The center of mass of the cart should then be in front of the wheel axis.
- The relationship between the maximal height of the handle bar and the angle of the seat of the child is influenced by the horizontal distance between the seat and the handle bar.
- The handle bar height influences the shape of the pull bar, the height of the bar next to the child when it is seated.

I.0.4 Final measurements cart

Final measurements of the cart were determined by using all previous insights and iterating by means of adjusting the 3D model. Most important decisions and considerations are described in several categories below.

General measurements

- Basic seat (height backrest, length and width seat, angle between seat and backrest) dimensions were kept the same.
- The width of the seat is 300 mm and tapers to the front with an angle of 4 degrees. The footrest tapers to the front as well to enable nesting.
- The total width of the cart is 490 mm.
- When closed, the length of the cart is 1350 mm, when open, the length of the cart is 640 mm.

Footrest

- A vertical part was added to the footrest to enable smaller children to reach to the top and rest their feet on it.
- The horizontal length of the footrest was not increased since it is not necessary to support the whole foot.

T-bar

- The vertical space between the seat and lab bar was adjusted, resulting in a vertical space of 120 mm between the top of the seat and bottom of the bar.
- The vertical pilars of the lap bar obstructed getting in and out easily. They were removed during the different concept iterations, it was replaced by the T-bar.
- The T-bar makes it more difficult to get in and out, climbing is required. Therefore, it is placed to the front of the seat and the arms of the T are shorter than the width of the seat, making sure the child cannot get out when driving but makes it easier to get in and out when open.

Handle bar and pull bar

- The height of the handle bar when closed in 600 mm. The tallest and smallest caregiver are able to lift the cart keeping the seat angle within limits. The different positions are visualized in Figure I.8
- The horizontal distance between the handle bar and wheelaxis is 1250 mm. This contributes to the ease of lifting.
- The pull bar should end at least 2.5 cm above

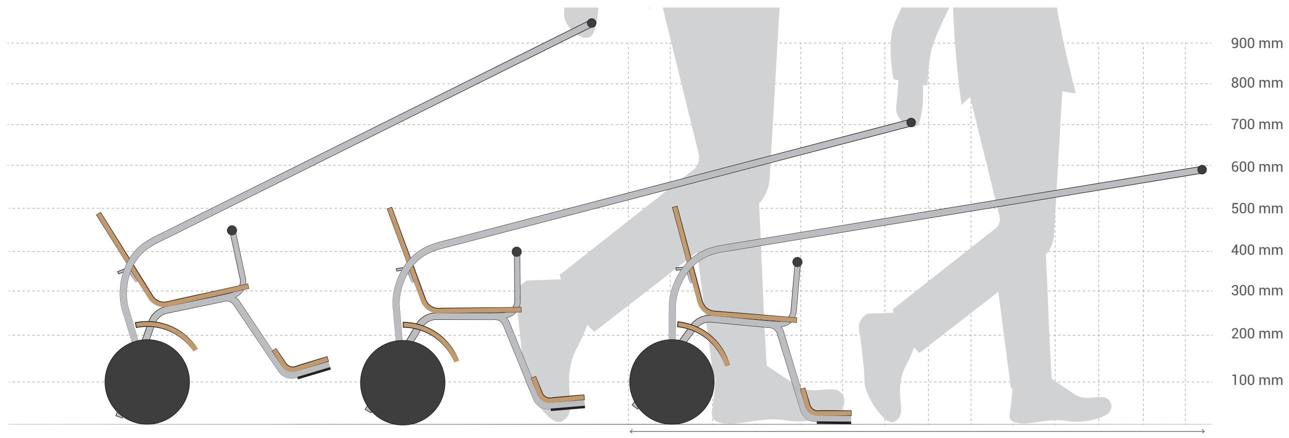


Figure I.8: Positions cart lifted by the smallest and tallest caregiver

the top of the lap bar. The pull bar is now located 6 cm above the T-bar, this makes sure no fingers can get trapped.
- The pull bar does not hinder sight of the children in the cart. Shoulder height of a girl (2 years old, p1) is 281 mm. The maximal vertical distance between the seat and pull bar is 180 mm. Shoulders are always above the pull bar.

Seat
- The slope of the seat is 5 degrees to make sure the child can stay seated when lifted. This makes sure rainfall can easily slip off.
- The height of the seat followed from the needed distance between footrest and seating, the outer tube diameter and rubber support were added.
- The center of mass should always be in front of the wheel axis, to make sure it cannot tip over backwards easily. Therefore, the seat is placed more to the front. The heighest point of the backrest ends perpendicular to the wheel axis.

Points of attention when testing with a 1:1 scale model.
Most measurements were taken using DINED and finding proportions by modelling. Therefore, if a 1:1 model is build, the following elements should be looked at.

The vertical distance between the pull bar above the seat should be decreased if the children attend to rest their arms on the sides. To achieve this, the handle bar height can be lowered and the slope of the seat should be increased to make sure it will work when a tall caregiver picks up the cart.
The width of the handle bar is 180 mm, enabling the caregiver to comfortably drive the cart.

The caregiver needs to bend over to unlock the pull bar. The height of the handle can be increased, this will change the shape of the pull bar. Further engineering is necessary find the ideal relationship between measurements.

APPENDIX J

Building scale models

1.1.1 1:10 scale model to test general design carts and station
To test how the carts slide into each other for nesting and how they interact with each other, 3D printed 1:10 scale models of both the carts and stations were made. Wooden mannequins of both the caregiver and child were installed next to the carts to give a sense of the scale.

Method
A simplified 3D computer model was made to be able to print the cart with the commong Ultimaker printers, preserving the functional elements. The pull bar can rotate around the axis and the carts can nest because of the negative space used in the model. The pull bars are able to lock behind the backrest enabling the model to drive, this way the movement of the cart can be simulated. One of the models was painted grey to give contrast when the carts are nested, this way it is clear what moves and slides along each other.

Major changes in model
- Pull bar has a square profile, placement of horizontal parts possible because of integrated holes.
- Pull bar does not taper to the front
- Main frame and seat are printed as one
- Wheel axis are connected to the main frame

After assembling the carts and station, several interactions with the carts were simulated to mimic the behaviour. Questions asked to judge the interaction:
- How do the carst nest?
- If you drive into the station diagonally, do the carts still nest and can the pull bar be opened?
- Does the pull bar have enough space to rotate backwards and slide along the other cart when nesting?
- How does the station guide the movement of the first cart that is stalled?

Results are discussed in the main report in the design evaluation section.

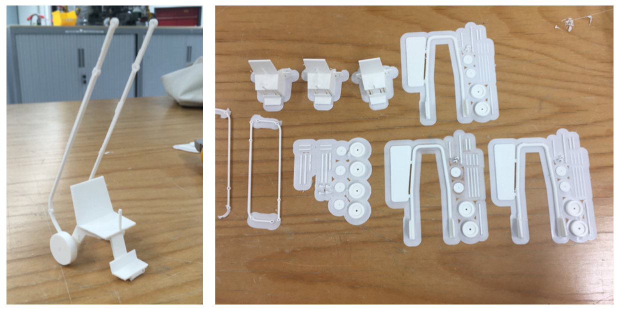


Figure J.1: 3D printed 1:10 scale model

Figure J.2: Process aesthetic 1:4 scale model

1.1.2 Aesthetics model 1:4

To be able to evaluate the cart with the user and to show all stakeholders how the concept design would look like, a 1:4 scale model was made. Copper rod were bended around molds in different planes to get the shape of the frame and pull bar. The frame was then spray painted to mimic the stainless steel color. Veneer layers were sawn and then glued together and bended. The mechanical lock on the back of the backrest is simulated with 3D printed clamps where the horizontal stops can clamp onto the backrest. This way the cart can drive with the pull bar locked at the back. A black wire was used to simulate the handle of the lock. Figure Figure J.2 shows pictures of the process.

J.0.1 Artis map with animals

To illustrate where the stations would be situated in the park during the validation and discussion, a map of Artis was lasercut. The animal enclosures were darkened for contrast giving the viewer more clarity. Little animals were put in their animal enclosures for orientation. White circles represent the stations.The map was used to explain the concept within the context of Artis.

Figure J.4: Final results of scale models; Back of 1:4 scale model (top), Wooden doll interaction with station (middle), Artis map with animals and locations of stations (bottom)

Figure J.3: Result aesthetic 1:4 scale model

APPENDIX K

Ideation to service themes

This part will describe ideation and steps taken towards defining service themes.

Method: Ideation started from the beginning of the project with writing down quick ideas that popped up during research. Few days of ideating, brainwriting and drawing everything down resulted in different idea clusters solving parts of the challenges. Most clusters focus on the type of cart or transportation.

However, first determining a service direction is important to create a framework to design for. **Personal goal** for finding directions: Think about the story of the visitor and how this influences all layers of the service blueprint. Which challenges does it focus on?

After finding directions these can be validated and discussed with Artis to decide on the most valuable one. This will be the starting point for further specific ideation on the elements of the service tangible and intengible. This can be read in the next chapter.

1.1.3 Ideation starters

To start the ideation, one of the starting points was to look at how capacity vs demand problems are solved in other sectors. Figure 1.1 shows four ways of solving capacity vs demand problems in aviation. Secondly I started thinking about the traffic jam problem and how this could be solved, representing the capacity problem in Artis but then reversed, see Figure 1.2. Child mobility was another inspiration source, how children can move themselves, see Figure 1.3, and how they are moved by their caregivers in for example different types of strollers. Competitor research resulted in inspiration for service steps and touchpoints (Appendix A).

1.1.4 How to's and theme ideation

During a free ideation session all ideas and solutions for questions that popped up were

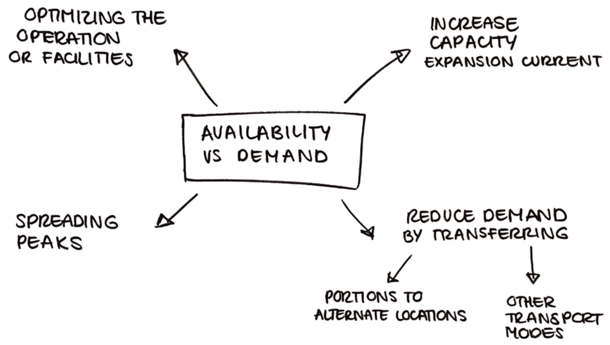


Figure 1.1: Availability vs demand

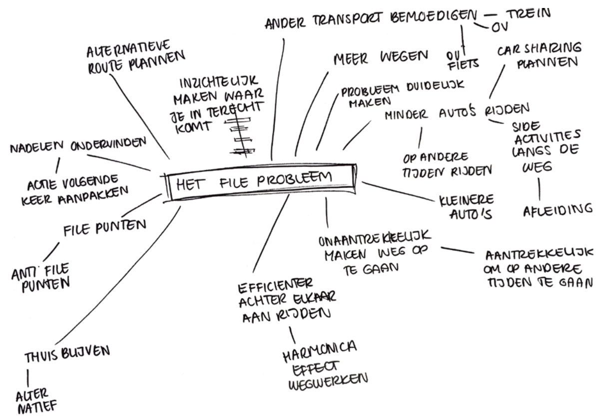


Figure 1.2: Solving the traffic jam problem

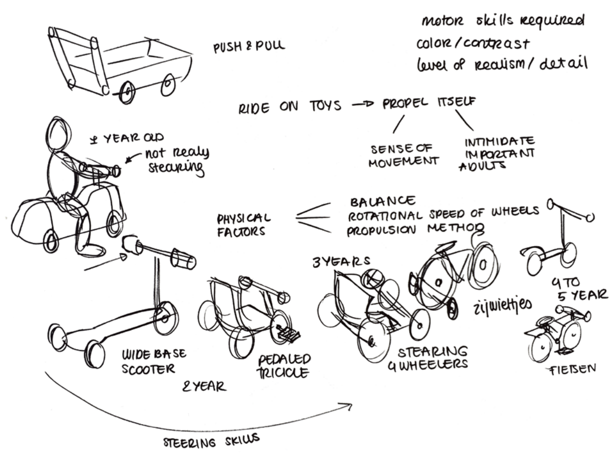
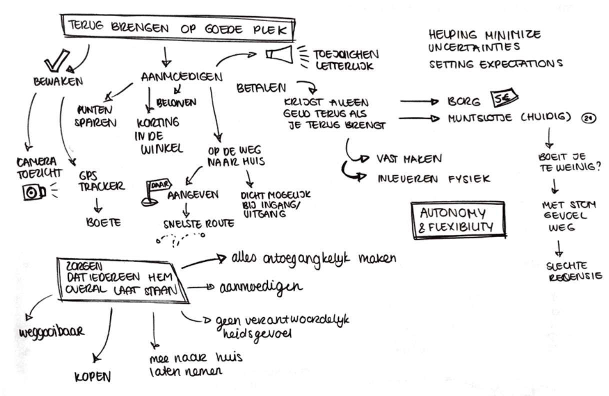
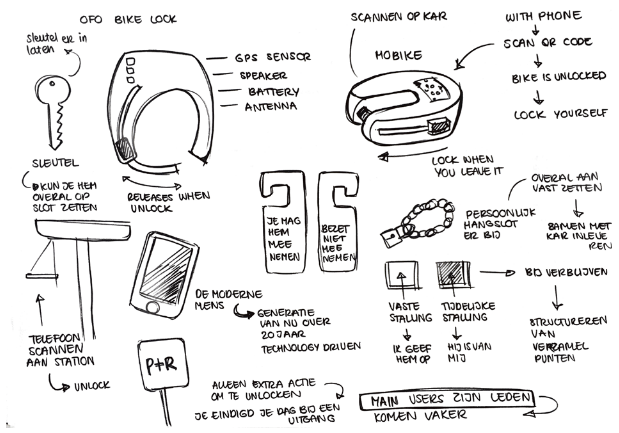
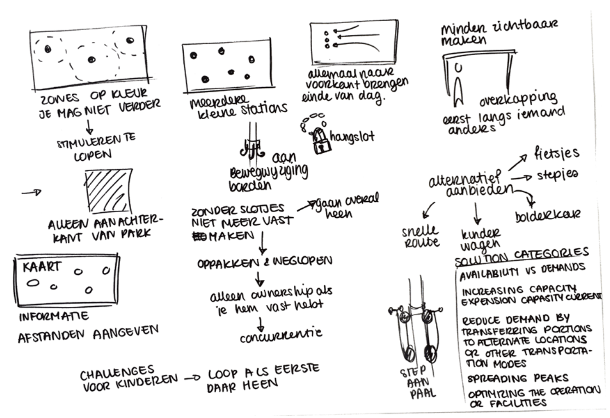


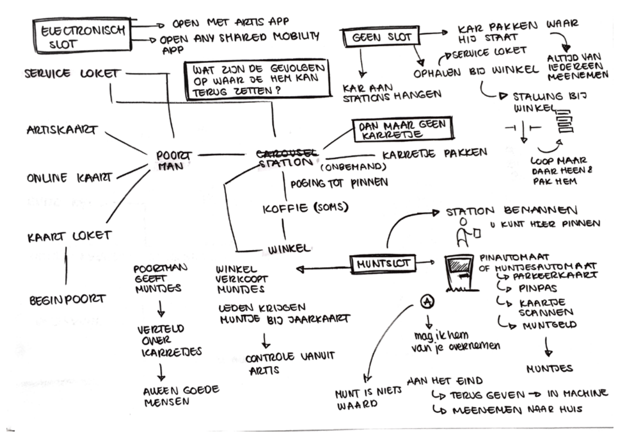
Figure 1.3: Ride on child mobility

written or drawn, see following figures. This resulted in a lot of random ideas that are clustered in the next part, no conclusions or ideas were excluded yet.



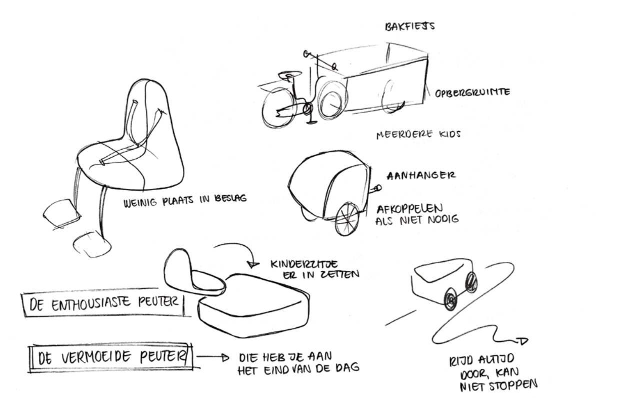


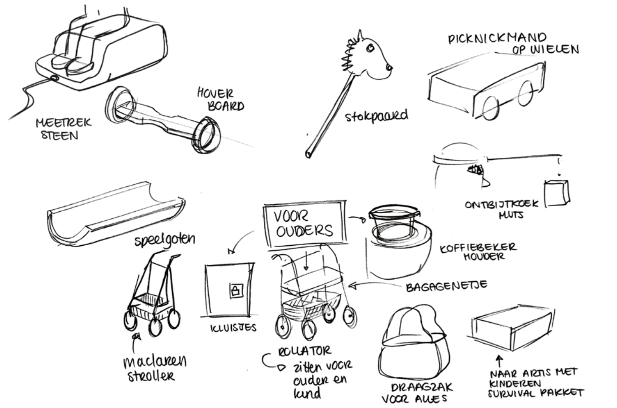


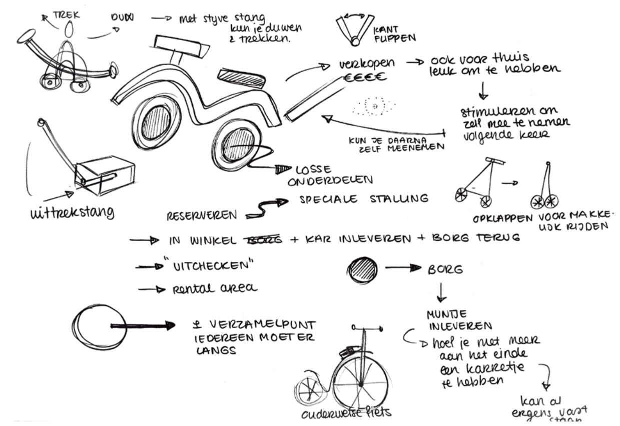


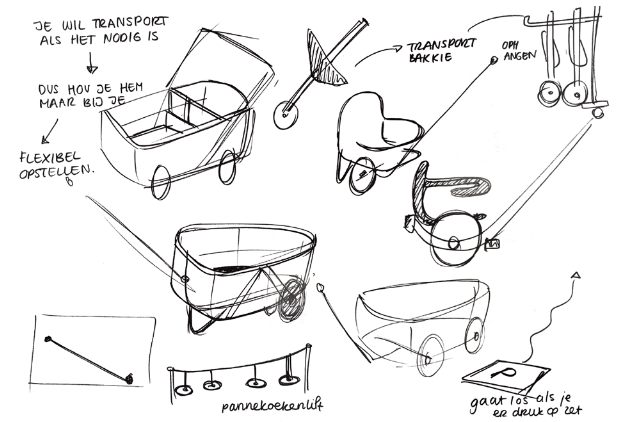
1.1.5 Clustering ideas

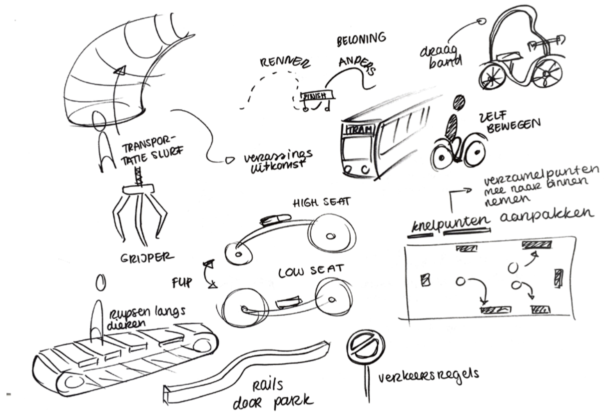
All different ideas were cut out and clustered into different themes representing parts of possible

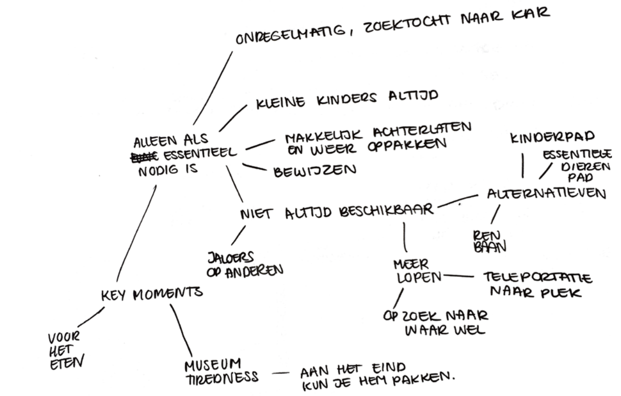


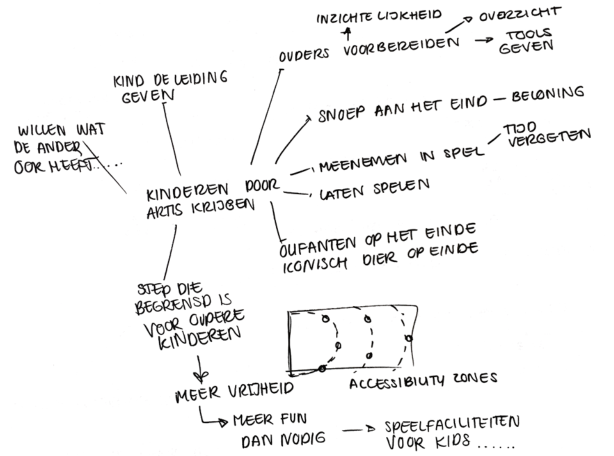


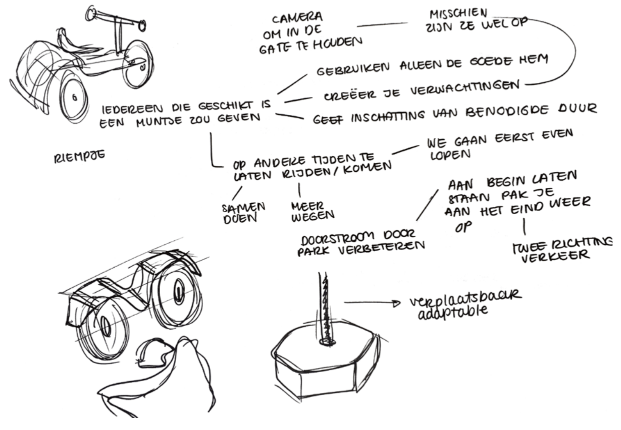


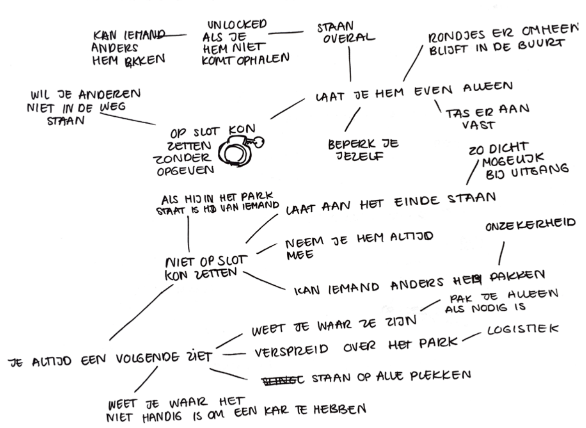


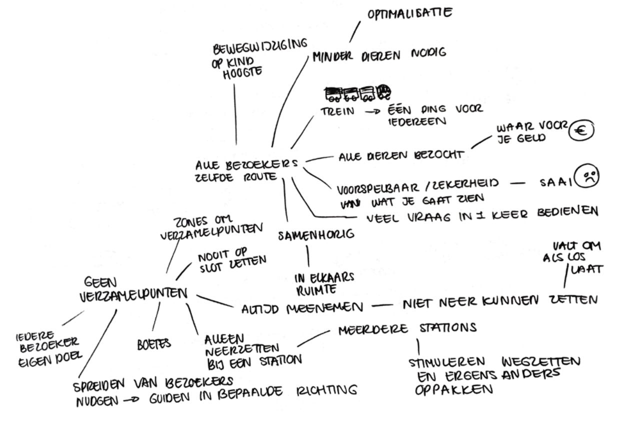


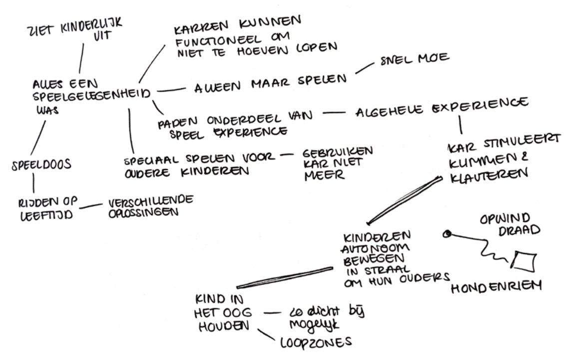


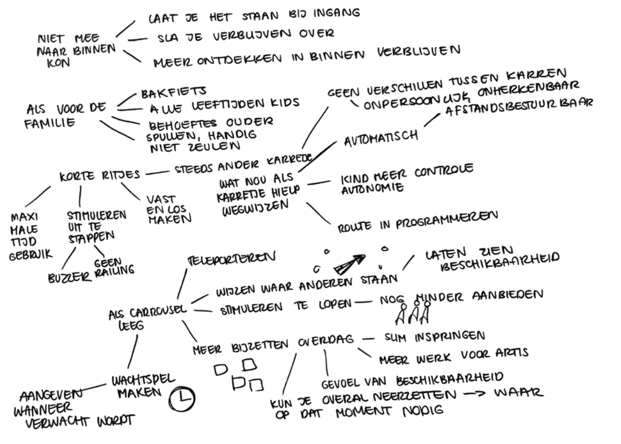




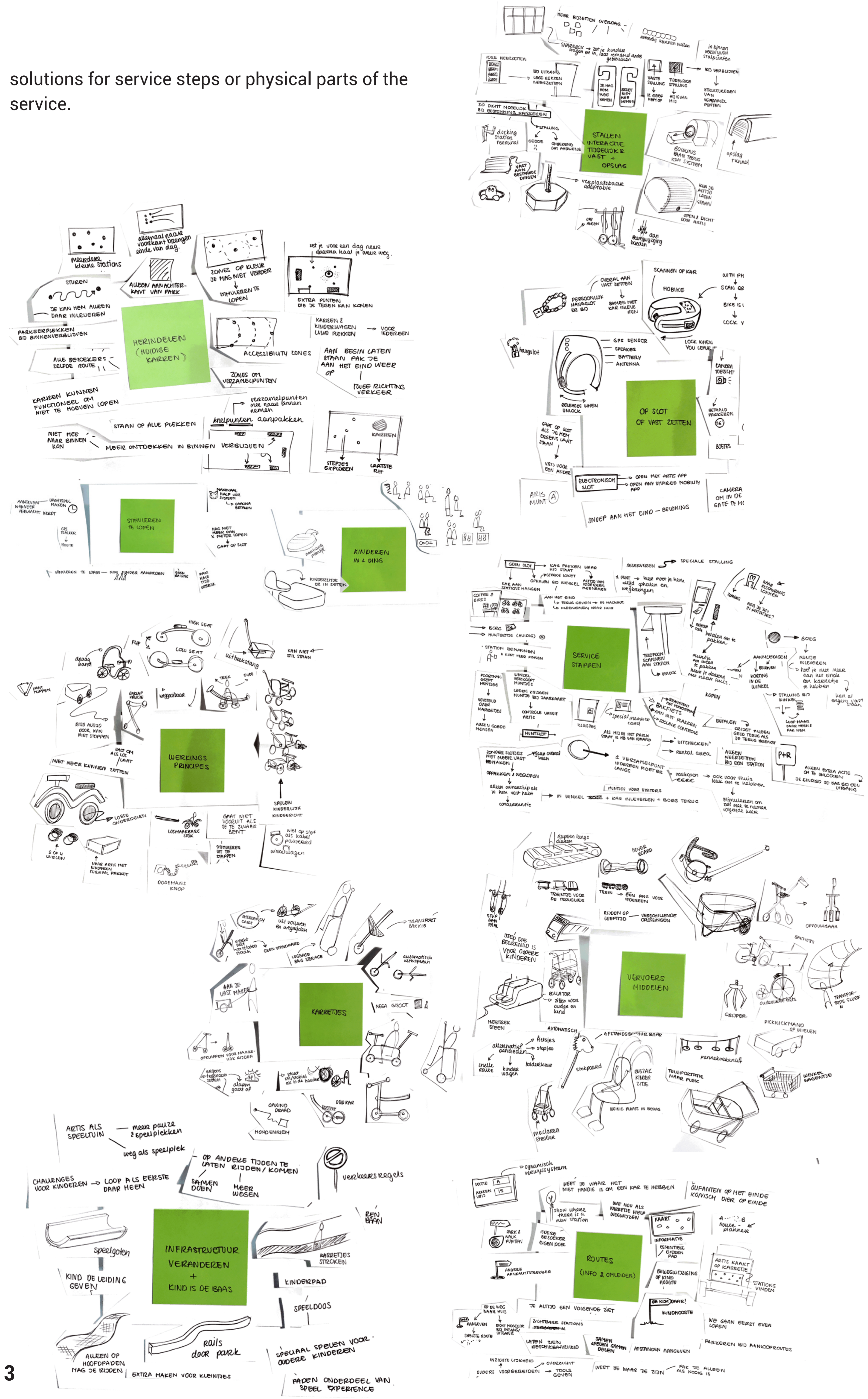








solutions for service steps or physical parts of the service.



1.1.6 Service themes

Method

Ideas from several clusters (previous section) were taken and combined to scenarios consisting of different elements. These scenario's are inconsistent in terms of completeness, they can not be equally compared and merely focus on the type of transport instead of the goal of the service.

To approach the ideation more from a service perspective the scenario's were clustered resulting in three different service themes all with plus, minus and interesting points. Scenarios that focussed more on specific solutions or had interesting elements that can be used later on were separated (Figure 1.8).

Assumptions and preliminary criteria

While clustering, several criteria arose for the service directions which should be taken into account for every direction.

- All visitor groups should be able to walk and explore their own route following Artis' park vision.
- The cart provides mobility support for the child, caregivers walk.
- There are clear stations/gathering points for the carts/carts etc. to make sure not all carts are lying around the park, causing chaos during the day, forming obstructions.
- Carts need to be locked at stations to prevent everyone (schoolchildren) taking them.

It is assumed that when there is a possibility to return/lock the cart, visitors will, a trust based return and stalling system could work in this way.

Keeping the current carts and adding the same or a different type or replacing all carts is considered as a possibility for every direction and can be taken into account when creating concepts.

All ideas for services which would make all visitors go the same route were excluded following from the previous criterium.

Results

Service themes that followed from ideation for mobility support services in Artis; last-mile transport, discover and play and companion for

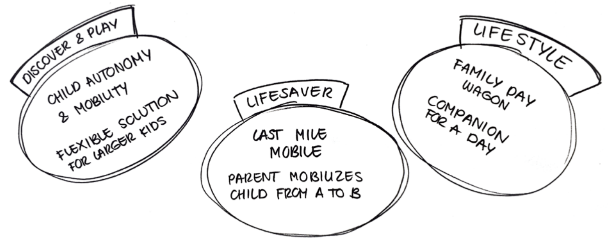


Figure 1.7: Service themes

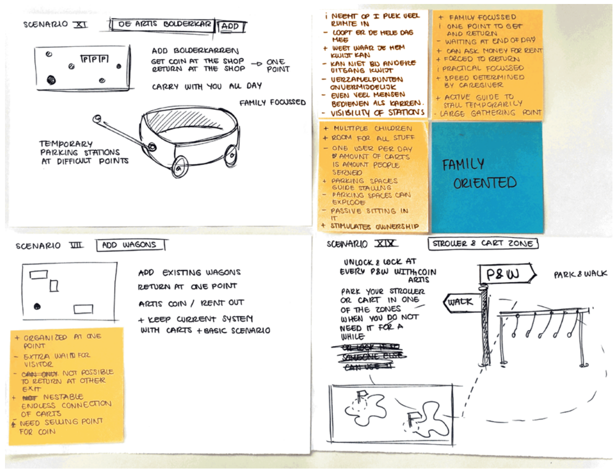


Figure 1.4: Service theme Family oriented

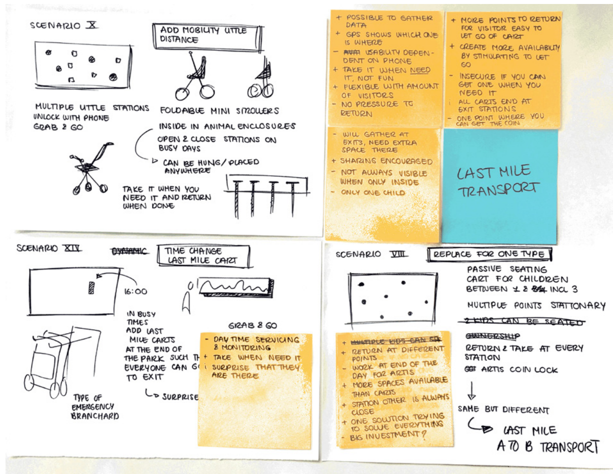


Figure 1.5: Service theme Last-mile

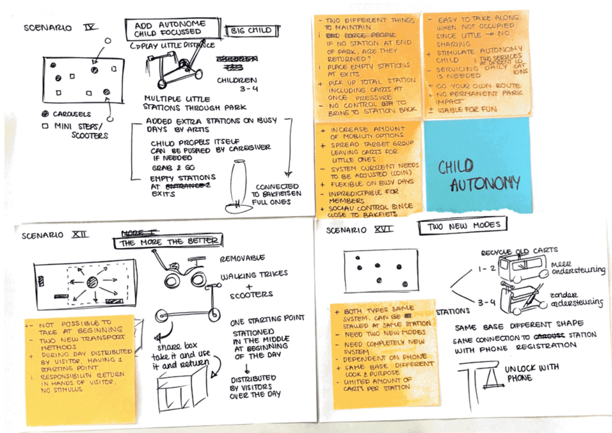


Figure 1.6: Child autonomy

a day (Figure 1.7 on page 33). All themes are looking for different opportunities to improve the visitor experience.

Last-mile transport

Provide a service which helps you to cover the last-mile when your child is tired and does not want to walk anymore. Multiple stations through the park make carts accessible everywhere, a sharing system can be considered. (Figure 1.5)

Discover and play

This service would focus on supporting children to move through Artis independently. Scooters and walk bikes are widely used in Artis, children can spread their energy by using a scooter instead of walking, exploring Artis in a different way. (Figure 1.8)

Companion for a day

Providing mobility support with a more family oriented focus results in theme two, where a buddy for a day accompanies visitors for a whole day. This theme follows from the observation of visitors having multiple children and the more classic mobility service approach of other zoos. One main station and reservation possibilities could make this service predictable.

Conclusion

All three themes can be used to further develop into service directions, all have elements that can meet challenges formulated. These themes need to be further defined, combined and equally elaborated on such that they can be compared as service directions.

Interesting points and plusses and minusses from the different small proposals can be taken into account when working towards three elaborated service directions.

Per service direction an outline of the service needs to be made with implications on the organisation of Artis and the different steps the visitor takes, see next chapter.

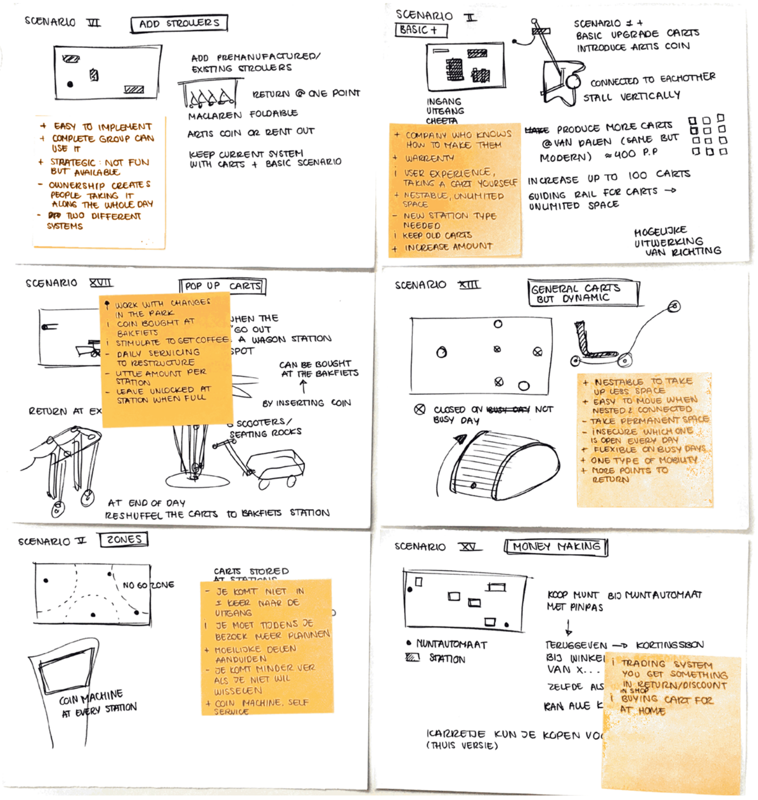


Figure 1.8: Ideas worth saving

APPENDIX L

Service directions

Directions followed from combining different aspects of the service themes focusing on the goal of the service and its corresponding elements. All directions are compared, focussing on different challenges. The directions are discussed with Artis, together a focus direction was chosen for the remaining project.

All directions resulted in a possible user journey and actions for internal stakeholders to provide the service. These were combined in preliminary two layered journeys. Improvements, neutral points and negative points are mapped comparing the possible new scenario with the current pain points in the service.

1.1.7 Service directions

Method

To transform themes into directions, different elements were derived and combined from Table 1.1 which resulted from idea clustering in paragraph 1.F.2. The overview mindmap in Figure 1.9 was used as inspiration.

Aspects determined for each scenario

- Goal of mobility support
- Focus challenges
- Visitor journey (how to take and return cart, where are stations)
- Impact demands on different internal stakeholders for Artis.
- How and if it solves pain points presented in

Theme	Idea 1	Idea 2	Idea 3	Idea 4	Idea 5	Idea 6	Idea 7
Current cart	Keep	Refurbish	Replace	Adjust			
Add type	Existing	Similar	New design				
Current station	Optimize locations	Add similar	Replace	Add other			
Station amount	None	One	Two	Three	Four	Five	Six
Station types	None	Zones	Physical	Portable	Fixed		
Take cart at	Manned point	every station	selected station				
Leave cart	Manned point	Every station	selected staton				
Amount carts available	Fixed	Add on busy days	Flexible during day				
Temporary stationing	Parking spaces	Free to take if left alone	Cart has owner	Impossible to leave	Parking card	Lock to lantern	
Type lock	None	Artis token lock	Euro coin lock	Electronic lock	Code lock	Scanner	
Service cost	Free	Deposit	Charge				
Service	Reservation possible	Claim cart at F2F counter	Self-service				
Possible touchpoints	Ticket office	Gate control	Service desk	Shop	Restaurants	Bakfietsen	Coin/ticket machine
Information touchpoints	Website	Application	Email	Push message	Physical signage	Map	Online map
Service for	All visitors	Members	Day visitors				
Suitability age	1	2	3	4	5	6	

Table 1.1: Table with service element options

the current service blueprint.

All aspects were determined and combined based on logical combinations and gut feeling.

Service proposals were kept simple not including advanced technology. Types of technology can be later integrated or mapped in a technology roadmap. What happens with the current cart is not determined yet in these directions to not focus on the physical aspects but more on the story and goal of the service.

Results
All service directions are described in the infographics on the next pages. For all directions a service outline is made. Figure 1.10 represents the Lifestyle direction, Figure 1.11 the Lifesaver and Figure 1.12 the discover direction. Every infographic displays the goal and challenges the direction focuses on (top left). A schematic overview of the service and physical elements in the park is given together with the route of the visitor (top right). The visitor journey steps together with the involvement of different stakeholders is mapped (middle). Coloured bullets indicate if the painpoints identified in the current service blueprint are improved (green), the same (yellow) or aggravated (orange). Positive (+), negative (-), interesting (i) and opportunities (o) for every direction are described (bottom).

All scenarios have one thing in common, an information strategy needs to be designed. Providing the visitor with the right information on the right channel before entering Artis will reduce the amount of questions at the front office and uncertainty for the visitor.

1.1.8 Comparison

Method and goal
The three directions focus on different challenges. To be able to compare and determine the best direction a comparison table was made to start the discussion, scoring the different directions for how they meet the challenges. An extra challenge was added; minimal demand on front office and security since this is a differentiation point for all directions.

Results
Table 1.2 on page 39 shows the result of the comparison. Challenges; minimal space and maintenance were not yet taken into account, these will be taken into account when creating concepts.

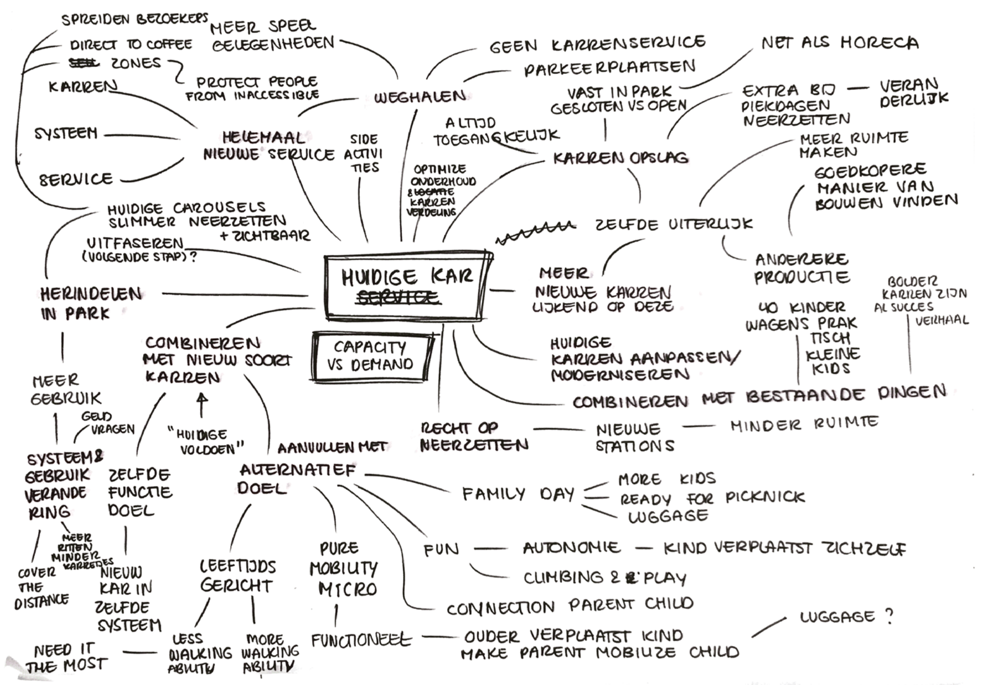


Figure 1.9: Mindmap: what can be done with the current cart?

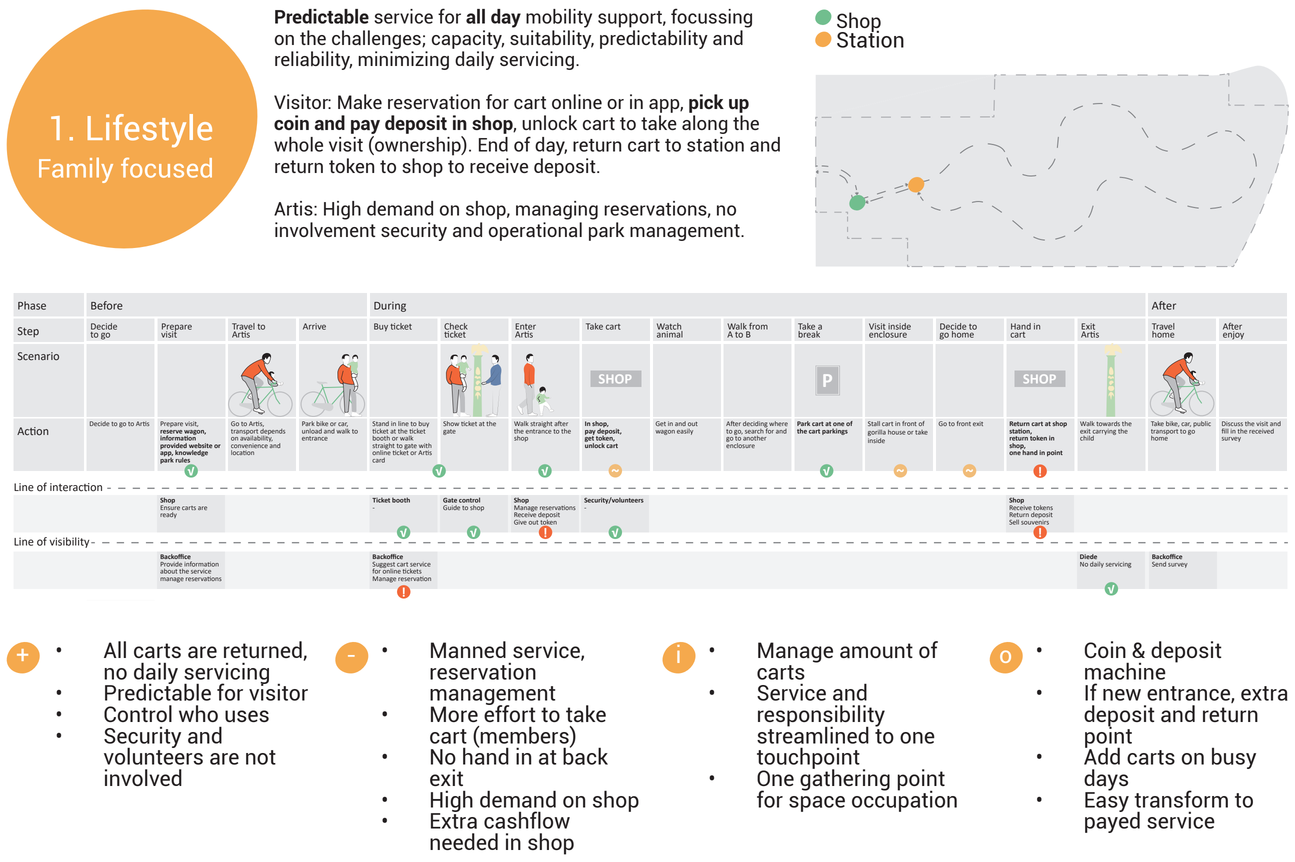


Figure 1.10: Lifestyle service direction infographic

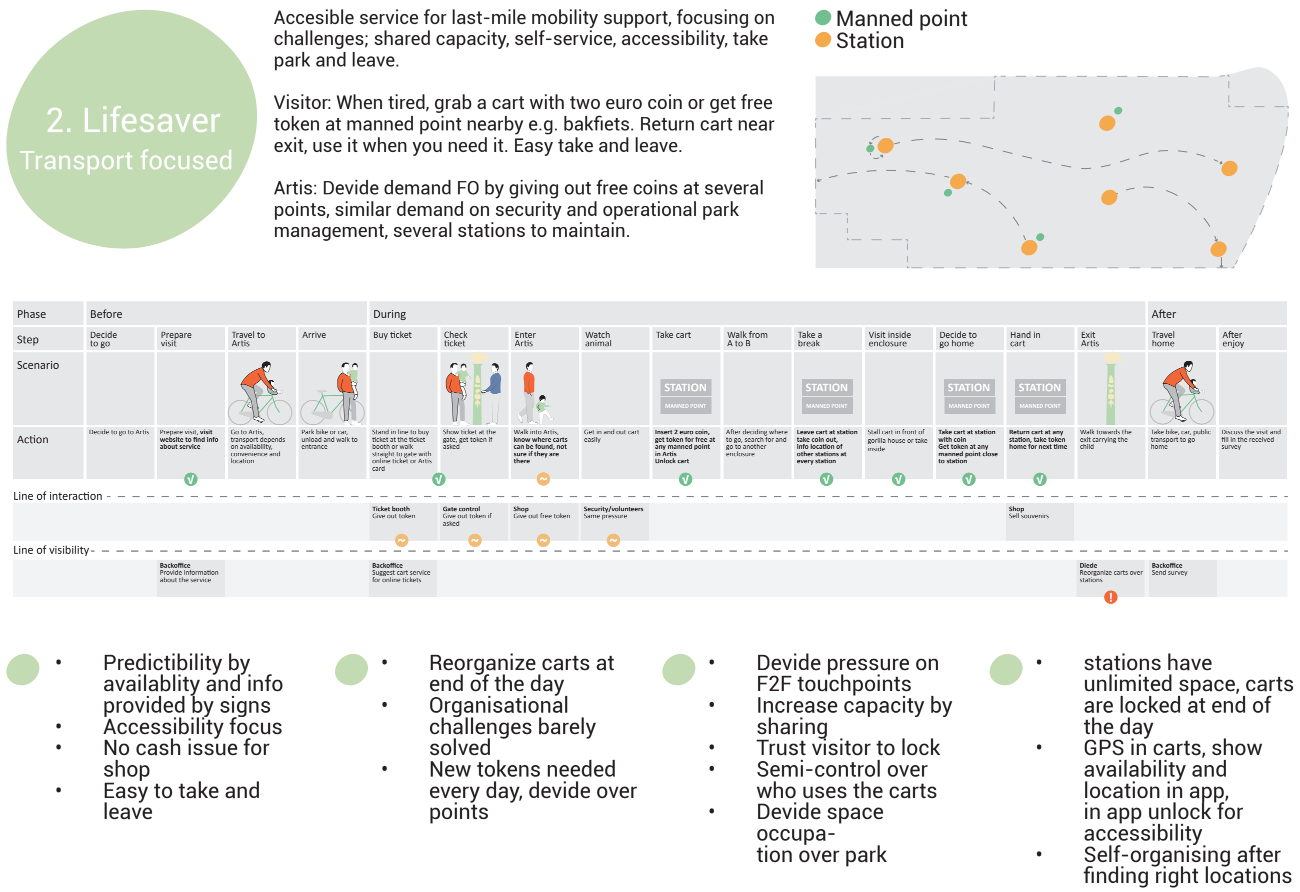


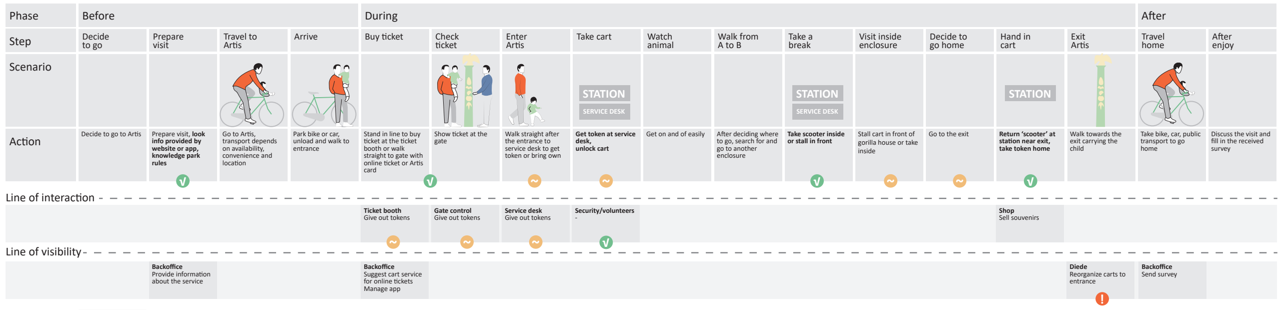
Figure 1.11: Lifesaver service direction infographic

3. Discover
Child focused

Service focussing on **exploring** and **child autonomy**. Focusing on the challenges; Capacity, Suitability, Fun

Visitor: Get Artis token at point (members bring own) unlock 'scooter' at station, use and devide energy to explore park bring back at other station, take token home.

Artis: Devide demand on FO by free tokens, no demand on security, reorganise carts to front, demand operational park management



- Little treshold to take cart, control over users
- Support child development

- Bring carts at end of the day to entrance
- Endless amount tokens needed (+- 15.000 year), send tokens to members

- Devide pressure on F2F touchpoints
- Trust visitor to lock and return
- Control over who uses the carts
- Members have coin, priviledge
- Focus on fun

- If stations have unlimited space, all carts are locked at end of the day
- Integrate GPS in carts, show availability and location in app
- Add stations on busy days
- Split target group

Figure 1.12: Discover service direction infographic

		1 Lifestyle	2 Lifesaver	3 Discover
FOR ARTIS	Provide service fitting park vision	+	+	+
	Provide sufficient capacity	+	++	+
	Use minimal space in the park	does not apply now	does not apply now	does not apply now
	Service with minimal maintenance	does not apply now	does not apply now	does not apply now
	Minimal daily servicing	++	--	-
	Minimal demand FO + security	-	+-	+-
FOR VISITOR	Suitable & safe for children 1-4	++	+	+
	Self service	--	+	+-
	Predictable, accessible and reliable	++	+	+
	Picked up, left and parked any time	-	++	+

Table 1.2: Comparison service directions to meeting and focussing on challenges

The **lifestyle** direction shows clear pluses for minimal daily servicing, due to the single station and deposit system where visitors are obliged to bring back the cart. There is more focus on suitability since it is family focused. Direction one focuses on availability and predictability with for example the reservation possibility. It scores however, negative for the pick up, leave and park anywhere. Since there is only one take and return point pick up and leave scores low. Visitors that want to exit at the back need to go to the entrance first to hand in. There is a high pressure on the shop, and self-service is not focused on.

Direction two, **lifesaver,** scores high on capacity since the multiple pick up and return points will stimulate a sharing system. This direction focuses on picking up and leaving any time, showing in the scoring. It will probably ask for rearrangement of the carts, daily servicing scores low. When designing this can be eased. Security is still involved in the same way as now and the demand on the front office is spread out. No reservation system is in place scoring less on reliability than direction one.

Direction two and three, **discover**, do not differ much in terms of what elements the service entails, however the goal of the service is completely different. Direction three scores less on self-service since every visitor (except for members) needs to go past a token point. The security is however less involved in direction three since there is complete control over who can use the service.

Conclusion

Pluses and minuses give indications for which challenges are focused on. Adding up all pluses and minuses will not automatically result in the best option since the directions focus on different challenges. All three have potential. Chosing the direction to focus on will be guided by gut feeling and discussion with stakeholders.

1.1.9 Stakeholder meeting Artis

Goal

The goal of the meeting was to find out which of the directions appealed the most to Artis and which of the directions or parts would be most feasible and suitable. Three directions were presented separately similar to figure 1.24 and the comparison table was presented to start a discussion.

Stakeholders involved during this meeting; Frist Hogen Esch (Department manager Project Management & Maintenance) and Suzanne Brinkman (Department manager Public & Experience)

Summary discussion

All directions were discussed separately and compared to each other. The **discover** direction fits in the vision in terms of moving and exploring Artis. However, in summer there are a lot of scooters and walking bikes lying around the park on busy days, they fly around everywhere. Unsafe situations are foreseen. Walking and climbing on the rocks should be considered as child autonomy in Artis. The service should support the caregivers to move their children. Therefor, this service direction was not considered suitable for Artis.

The **lifestyle** direction is attractive due to its large plusses (Table 1.2 on page 39), it shows clear benefits where the lifestyle looks more medioker in the scoring. The disadvantage for the members is clear, not being able to return it everywhere and enlarging the treshold to use mobility support, especially for the members. Clear benefit of this type of service is that it is focused on one point in the park, reducing pressure on operational park management. Reservation management by the backoffice is not considered as a disadvantage. This service would be more focussed on the day visitors.

For now, only using the deposit system will cost Artis more money since the cashier needs to be available at all times. A payed service could in the end close the business case and make it profitable. Practical problems with using the shop as the main point; it is very small and the layout is impractical for the amount of people which should then enter the shop. The possibility of reserving a cart is valuable.

The **lifesaver** direction is interpretated to score more average than the life style direction. Daily servicing is inevitable with a system like this, and is considered acceptible. Some logistic challenges are mentioned; reorganisation of carts. How can you make sure there are always carts everywhere? Do people get rid of the cart at the beginning of inside enclosures and get a new one at the end? How can you guarantee this?

Accumulation of carts at stations and shortages at others is seen as tricky. This needs to be thought of when designing the system.

Artis is charmed by the fact that people can pick up and leave somewhere else, the system would be something all visitors with children can use together. It is applicable for several locations in the park which makes it dynamic.

Providing other manned stations with Artis tokens that fit inside the lock will decrease the pressure on the shop, no extra money is needed. This is seen as an easy implementable improvement.

If some of the +- points can be changed to big plusses this would improve it a lot. Reservation of the carts could still be considered. If multiple carts could be moved at once this will already improve the amount of work when reshuffling.

This type of direction will focus more on the visitors that that get to Artis by bike, that cannot take a stroller, accessibility is key. Now, the members are the most frequent users of the service. You want to provide them with something. The lifesaver carts can still be used for the whole day for the smaller children, but it will support sharing for the ones who do not need support all day.

Conclusion

The lifesaver direction is preferred and considered as most valuable for Artis. It fits Artis' values about sharing and the idea of being able to pick up and leave the cart easily is appealing. Organisational problems are less focused on for now. This should be taken into account during the next project phase. The idea of always being able to take one and use one is most valuable especially for the visitors who mostly use it, the members. Visitors are still able to take a cart and use it all day, for the smaller legs. This service is flexible and can be used by all types of visitors.

General insights from meeting

- For now a manned station is not feasible due to the costs of the employee. Therefore the service should be unmanned and remain free as long as possible.
- Lockers will be placed at Micropia and 'Het Groote Museum'. For locking and unlocking the lockers a system is considered with payment by phone. Opportunity: using same in app payment system for taking a cart or making a reservation.
- If electronic locks and in app payment can be used, a payed service can be considered. Closing the business case is then important, covering costs of both application, maintenance and effort. For now, the business case is out of scope for this project.
- Artis has large interest in exploring the possibilities for use of electronic locks and involvement of the Artis application.
- Artis values the elaboration of the service steps and implications on the organisation. For the remaining project, a service - product combination is most valuable as end result.

Evaluation comparison table as discussion tool

The comparison table functioned as a good starting point to discuss the different directions. However, scoring the directions this way automatically results in adding pluses and minuses showing good and bad options which was not the goal since the service ideas are preliminary. The goal was to show the different focus points. Next time it might be better to make a table in which the focus challenges are indicated with a description of how they are achieved. This will leave more room for discussion and later adjustments.

1.1.10 Conclusion

Defining the directions resulted in a clear overview of all directions and their focus points. Together with Artis all directions were discussed, the Lifesaver direction is chosen. Preference for the lifesaver direction was expressed, several points of attention for further development of concepts were mentioned. Integrating possibilities of the Artis application and possibly electronic locks were ideas mentioned. Concerns were expressed about the distribution and ensuring availability of carts at the different stations. Choosing the lifesaver direction will result in a service with the main goal of providing mobility support for short distances that can be used anytime during the day, picked up and leave when you do not need it. The service focuses on accessibility and can increase capacity in a playful way.

APPENDIX M

Ideation braindrawing

After choosing a service direction, other challenges can be met by redesigning the current cart. To start a broad ideation was done.

Method

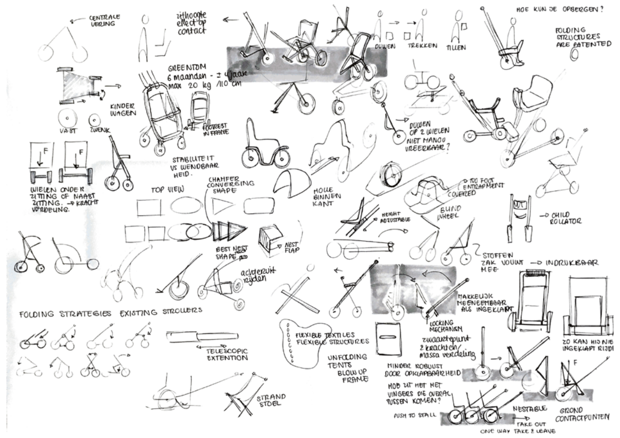
Brain sketching was used to explore and get ideas out. Then small idea generation sessions were done per element. This appendix gives insight in the ideas generated. Ideas were presented and discussed during a brainstorm which resulted in directions, this is described the next appendix.

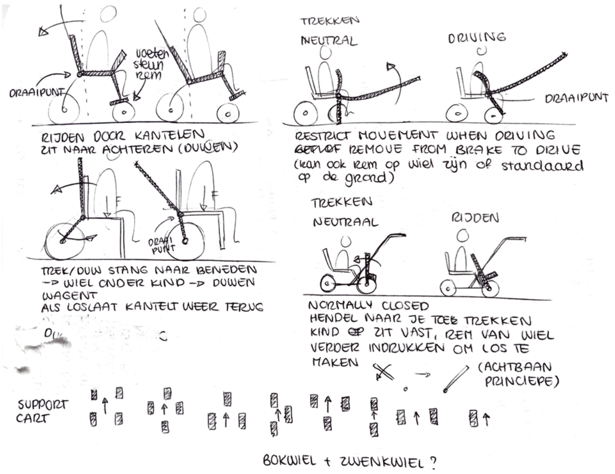
Results

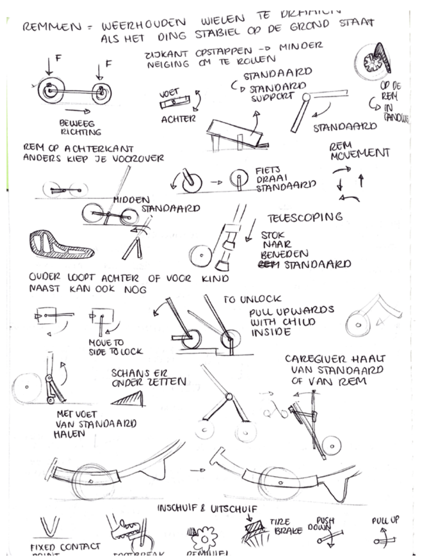
The following figures give insight in the sketch process. Requirements were used for the mini ideation per element.

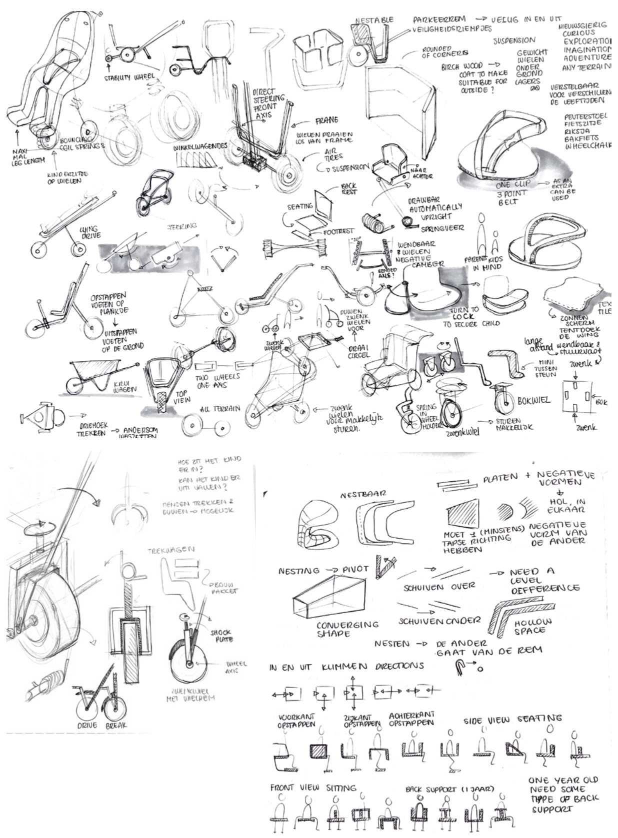
Conclusion

The ideation resulted in a lot of ideas, which created a lot of chaos. The next step is to combine and derive valuable concept directions.









APPENDIX N

Brainstorm to directions

N.0.1 Goal

To experience a brainstorm session with multiple designers to build on existing and each other's ideas. To get insight and combine all ideas to concept directions that can be further developed.

1.1.11 Method

Brainstorm session with Jos Oberdorf and Jan de Boer. Spread out all ideas on the table, discussing the main focus points and challenges for the design of a new cart and strong points of the current ideas. Build on the existing ideas by drawing resulting in concept directions and new guidelines/requirements for the design.

1.1.12 Results

The brainstorm resulted in three different directions and decisions made that are turned into requirements or nice to haves for the cart design.

Nesting

For a product to be nestable, no big volumes can be used. Forms suitable for nesting are made of tubes and plates. Materials suitable for this application are for example wood, bamboo and steel, or other outdoor materials. A nesting direction needs to be chosen to enable the carts to nest properly; converging or diverging, Figure N.1. Plates need to be under an angle to be able to slid over one another. Negative shapes, or removing materials can be used to enable nesting. Springs or hinges can be used to make space for nesting. The lap bar to restrain the child while driving can be replaced by a belt, this is a trade-off between maintenance (durability of parts) and space occupation.

Plate material can be shaped by wood molding or steam curving. Everything one can fold out of paper can be molded. The concept has to have the right mold releasing properties to keep the mold as simple as possible. The plate can be bended in two directions. Using a mold is an investment, but will result in lower production costs when the amount of carts needs to be increased.

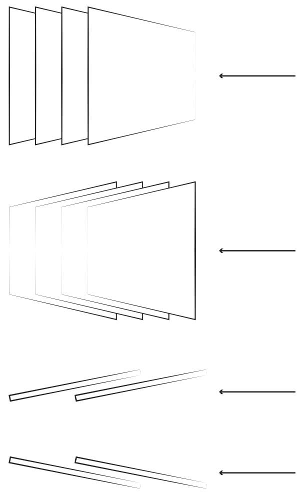


Figure N.1: Nesting guidelines

Pull cart

The concept of a pull cart is chosen to keep the fun and playful character of the carts in Artis. This way it is automatically different from any stroller. Ideas for pull carts were built upon.

Lift and pull

When pulling a cart, the most pleasant way to do this is to lift up the handle and walk instead of pushing down the handle and then walk. Therefor, the following requirement is added; to start the movement of the cart, the pull bar is lifted and then pulled to be moved.

Position wheels

For both directions the wheels are behind the center of mass of the child when seated to make

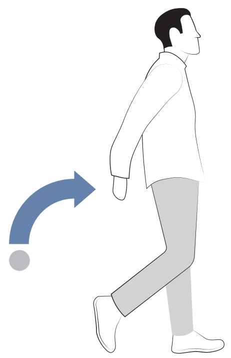


Figure N.2: Lift and pull movement

sure the cart cannot tip over backwards and will always tip over to the front resulting in a stable position. When driving the center of mass should still be in front of the wheels to prevent tipping over backwards. With the wheels more to the back, the cart will become heavier to lift because of the momentum, this needs to be taken into account.

Concept directions

Three main directions followed from the

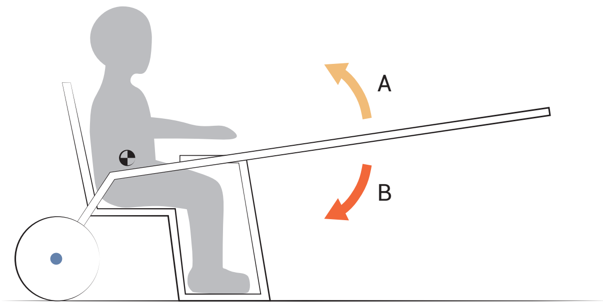


Figure N.3: Positioning wheels behind center of mass

brainstorm recap. All work with the pull bar 'locking up' the child to make sure it cannot fall out when driving. When standing still, the pull bar drops down or can be pushed upwards, opening the side of the cart so the child can get out or in.

A lap bar is integrated in frame of the cart to make sure the child cannot stand up when driving (Figure N.5). The lap bar should be designed to accommodate all statures of the target group. During the brainstorm this shape was determined. An alternative for the lap bar is a belt to be fastened by the caregiver, the caregiver can choose whether to fasten the seatbelt or not.

The caregiver needs to 'lock up' the child before driving away, this makes sure the child cannot get out, resulting in the feeling of safety and control for the caregiver.

All concepts require a hinge point, mechanical stop or wedge to enable and stop moving parts. No hazardous situations may occur where feet or fingers get trapped. By making sure the pivot point is behind the child and out of reach this is solved. The right size and shape of the pull bar and location of pivot point need to be determined. To make sure no fingers can get trapped, a 2.5 centimeters needs to be between the different bars.

For concept A the pull bar moves from the top

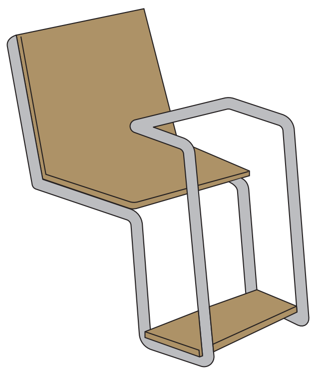


Figure N.5: Basic frame with lap bar

to the neutral positionm, see Figure N.4 for the user scenario. It needs a wedge to make sure the pull bar can be lifted to drive after pushing down to 'lock up' the child and get in driving mode. For concept direction B, the pull bar is lifted from the ground to drive, see Figure N.4 for the scenario. This one needs a mechanical stop to prevent the pull bar from getting to high and not lifting the cart to drive. Both of these elements are crucial to enable the cart to drive.

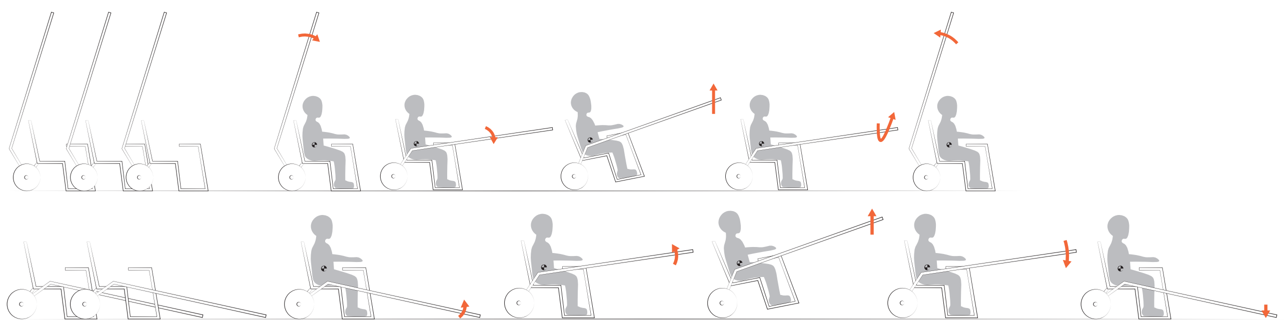


Figure N.4: Concept direction A and B movement scenario

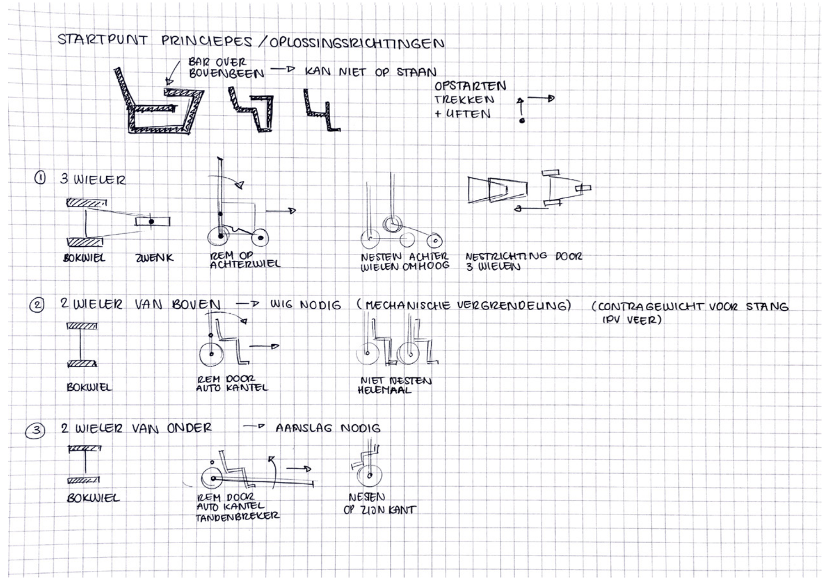


Figure N.6: Recap brainstorm session (1/2)

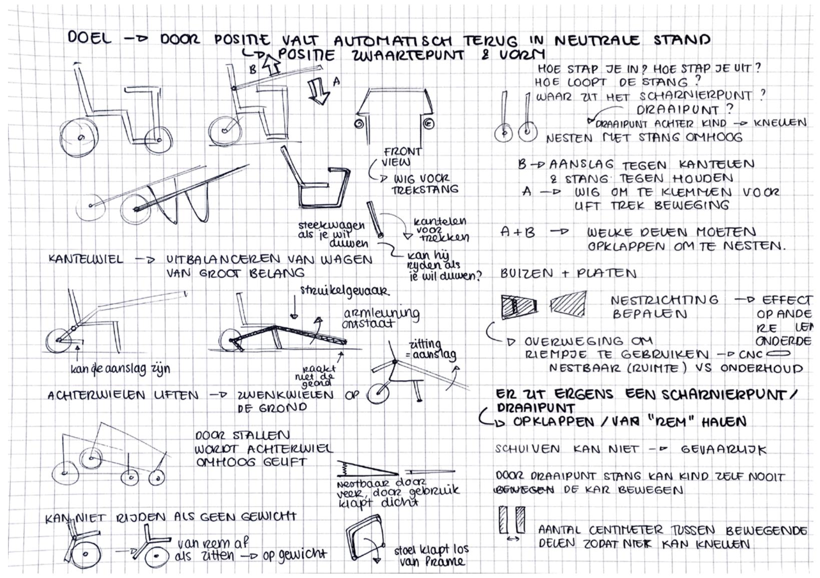


Figure N.7: Recap brainstorm session (2/2)

Thoughts to take along

The child may not be able to lift or push down the bar to unlock when seated in the cart
With the top bar down – visitors can also push the cart, this can be fun but can also cause dangerous situations.

If the cart cannot drive when not occupied the cart cannot be taken along the whole day. This can for example be done by releasing the brake when seated on the chair.

N.0.2 Conclusion

All directions need to be further elaborated on to make sure they all meet the main requirements. Thereafter a concept can be chosen to further develop. The directions are developed into concepts in the next appendix.

APPENDIX O

Pull bar configurations, shape and rotation point

O.0.1 2D exploration and first selection

This section describes the first part of the process towards the right configuration of the pull bar, the configuration is mostly focused on.

Goal

Find the right configuration of the pull bar that will enable the child to get in easily when standing still and will prevent the child from getting out when driving.

Method

Exploring different 2D configurations of the pull bar for two pull bar concepts (pull bar moves from top (open) to center (closed) and pull bar moves from bottom (open) to center (closed). Figure O.1 shows the positions of both concepts. From now on, the closed position is referred to as position B and the open position to A.

First, the basis dimensions (2D) of the cart was sketched and the endpoint of the bar in position B (after closing the cart) was determined. For now, the same position of the endpoint was taken as the current cart, 50 cm above the ground, see Figure O.1. The wheel position is not known yet. For now the axis of the wheel is situated behind the center of gravity of the cart including child when standing on the ground.

22 options for pull bars were drawn for both concepts; from top to center and from bottom to center. Every configuration was looked at, plus and minuses were written on the sheet. The most suitable configurations per dir   ection were marked in orange.

Three best options for both directions were chosen looking at the requirements described below.

Guidelines

- The pivot point of the pull bar should be in the orange area in Figure O.1. The pivot point of the pull bar should be out of reach of the child sitting in the cart.
- When in position B, the pull bar should prevent falling out sideward. It should block the light orange area in Figure O.1 as much as possible.
- When in position A, the pull bar should enable to get in the cart. It should leave the light orange and green area in Figure O.1 open as much as possible.
- The pull bar has an U shape and goes around both sides of the cart to block both sides when driving as well as for the stiffness of the pullbar.
- The height of the pull bar handle in position B should enable a caregiver (L = 155 cm) to pick up the cart.
- The pull bar is symmetrical on both sides, looking from the side of the cart.
- The bar should not obstruct nesting

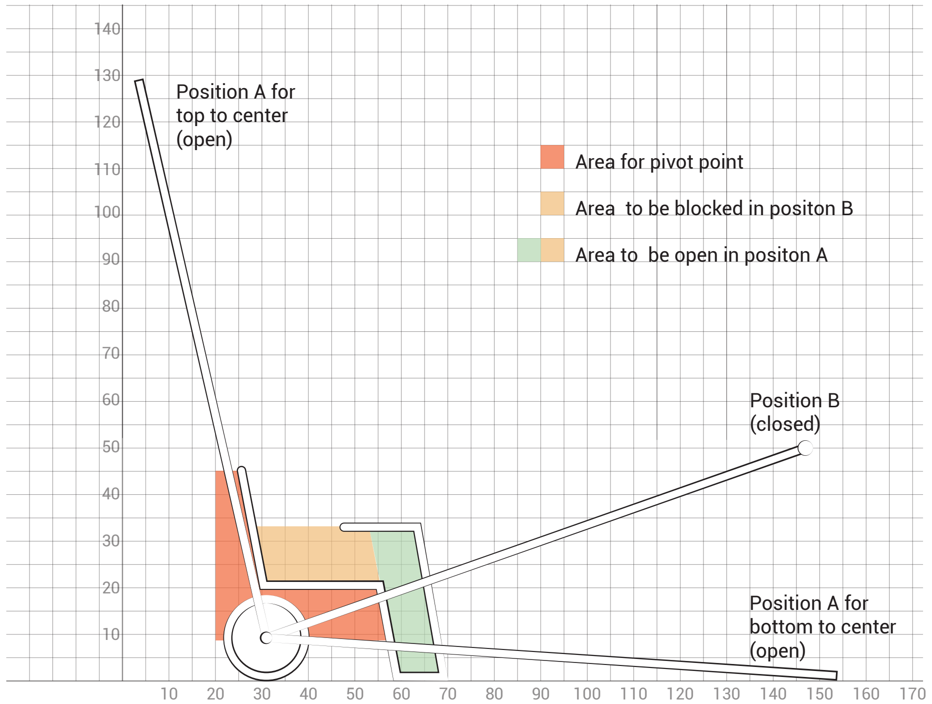


Figure O.1: Positions and areas for attachement, to be blocked or open when seated

Results

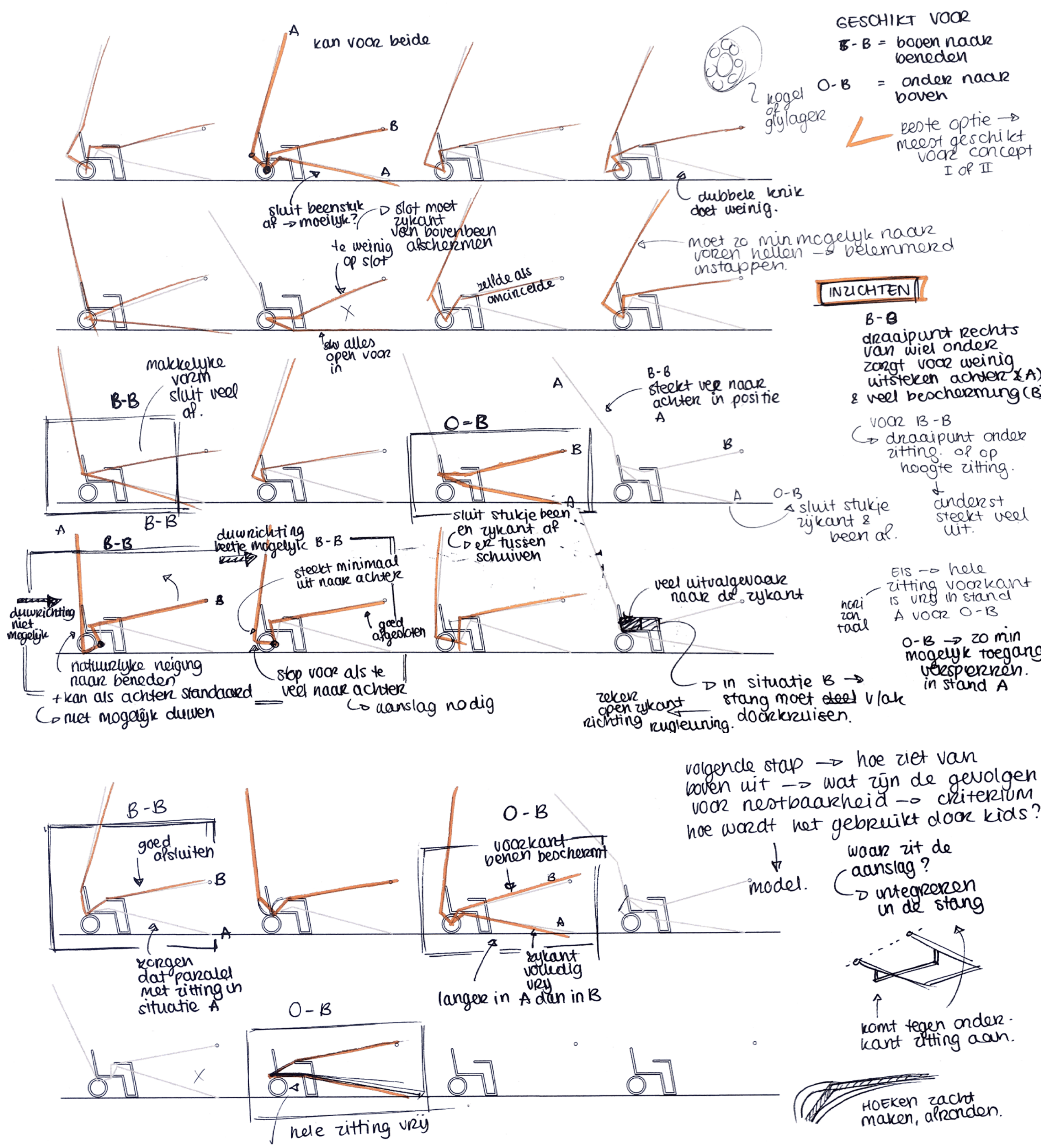


Figure O.2: Pull bar configurations

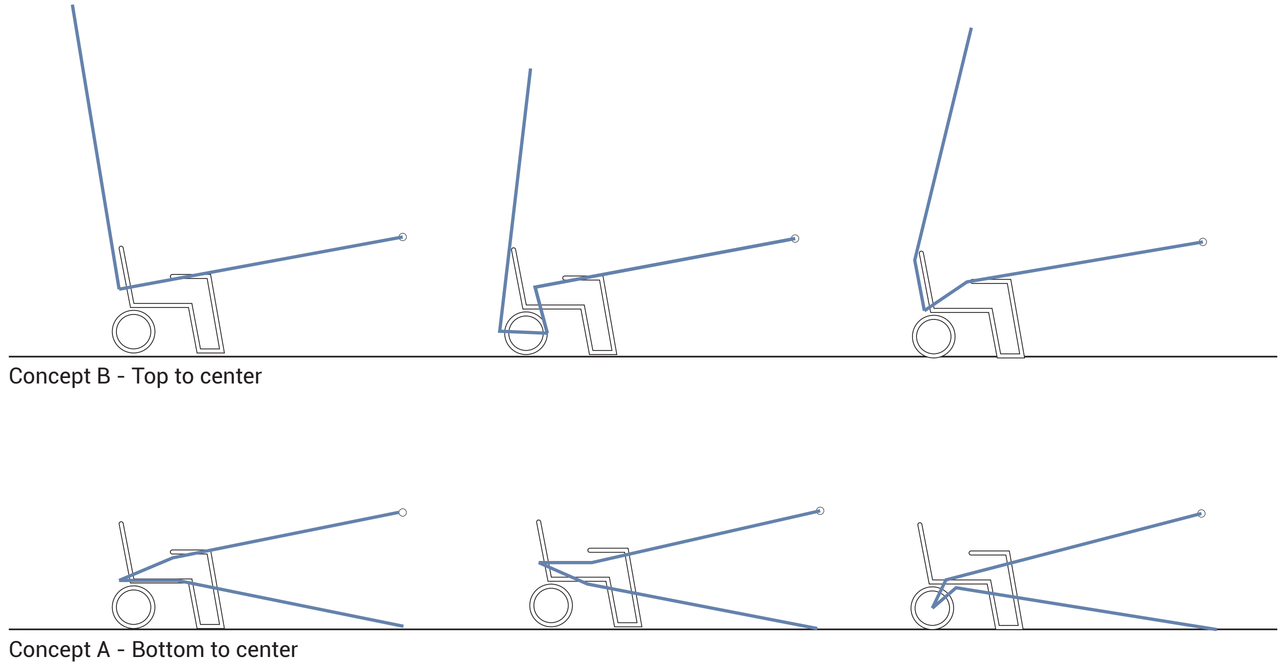


Figure O.3: Final selection configuration pull bar for both concept directions

Figure Figure O.2 shows the different configurations of the pull bars together with comments on suitability for either on one or two of the concept bars. The selection to continue with is visible in Figure O.3, all differ in the amount of space to get in the cart in position A and the amount of closure in position B. They are selected taking into account the requirements.

Insights

- For the top to center concept: pivot point to the right of the wheel makes sure it does not protrude in position A and protects the child in position B.
- For the top to center pull bar: the pull bar in position A should not invite to be pulled down by the child, this should not be possible.
- For the bottom to center pull bar: In position A, the area next to the seat should be completely free to get in easily.
- The length of the pull bar influences the momentum, the amount of force needed to lift up the cart. Optimizing the length of the pull bar will result in the minimal force needed to lift.

Next steps

These configurations can be built on the wooden model and interaction can be tested with children and caregivers. How children get in and out and safety are important to take into account when choosing the optimal configuration.

How the pull bar is integrated in the frame and the relative position to the wheels needs to be verified in the 3D model as well as the position of the required wedges or stops.

Measurements need to be further defined. This should be done after choosing the concept to continue with. The shape of the pull bar can be refined, rounding the corners and finding the optimal frienly shape.

O.0.2 Iteration shape pull bar

Concept A

For all chosen configurations of the pull bar in concept B, the side of the cart is blocked partly. Illustrator was used to find a shape of the pull bar which does not cover the side when it is down. The most right pull bar configuration in figure Figure O.3 (bottom left) was chosen since this shape worked best when adjusting the shape of the pull bar. The results of the shape can be seen in Figure O.4. The pull bar was modeled in FUSION360 to make sure the dimensions were right. The shape of the bar makes sure the handle does not touch the ground when down. The pullbar is symetrical on both sides of the cart.

Concept B

Using the results of the experiment with the wooden mock up, there is only one pull bar configuration left which is suitable. The most right configuration inFigure O.3 is the only option for a pull bar that can be locked behind the backrest. This option is chosen to elaborate on for the concept, see Figure O.5.

O.0.3 Conclusion

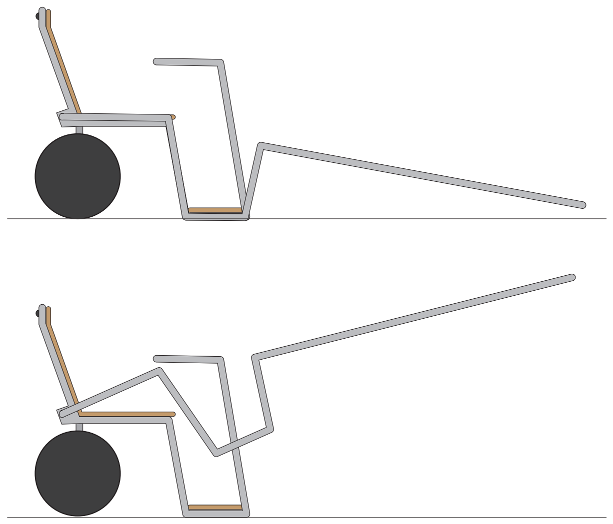


Figure O.4: Pull bar iteration concept A

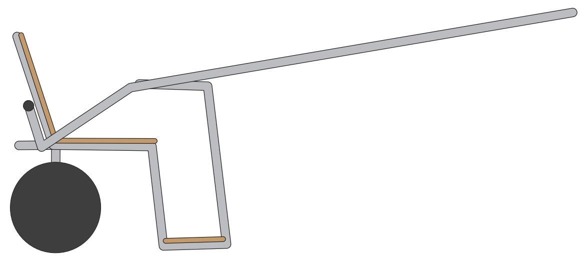


Figure O.5: Pull bar choice concept B

This research concludes with a starting point for the shape and rotation point of the pull bar for both concepts resulting from ideation and selection with requirements. Both are integrated into the first version of the concepts. Next steps for the design of the pull bar are described in the concept specific apendices.

APPENDIX P

Directions to cart concepts

This appendix describes the process from directions towards equal concepts. Concepts are discussed seperately in the different paragraphs. This appendix concludes with the decision for a concept to continue with.

P.0.1 Method

After the brainstorm several focus points were written down to start working with resulting in concepts. The elements functioned as ingredients that were taken one at the time. For almost every element a mini-sprint was done to come up with solutions which could then be integrated. This part mostly focused on finding the right mechanisms that could be combined to create concepts.

Two concepts were elaborated on and are presented in this appendix. Concepts were compared, and one final concept is chosen to continue with. Measurements of the concepts are discussed in Appendix FIMXE.

P.0.2 Three to two directions

One of the concept directions was eliminated af a short evaluation of the basic principles. The three weeled concept would be hard to steer with the pull bar connected to the rear wheels with a castor wheel in the front. This was concluded after builging a very low fidelity mock-up (Figure P.2). The orientation of the wheel would also make it difficult to move multiple carts at the same time since giving direction to the train would be impossible.

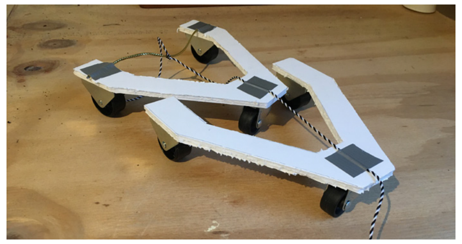


Figure P.2: Steering mock up

P.0.3 Concept A: The Giraffe

Basic concept principle

The cart can be lifted and pulled by a caregiver after lifting up the pull bar to 'close' the cart. When lifted, it can be propelled and drives on two wheels. Once the caregiver lets go of the pull bar, it drops down opening the side of the cart enabling the child to climb out. The user scenario describing the process of taking, using and leaving the cart is visualized in figure Figure P.1. Below,

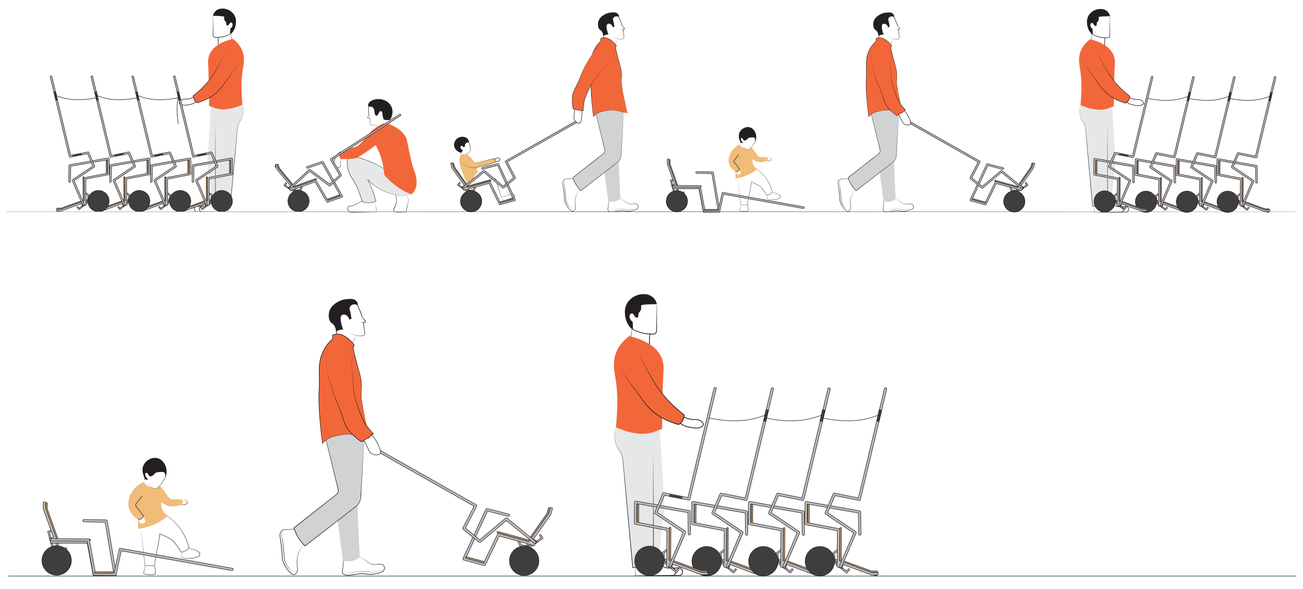


Figure P.1: User scenario the Giraffe concept

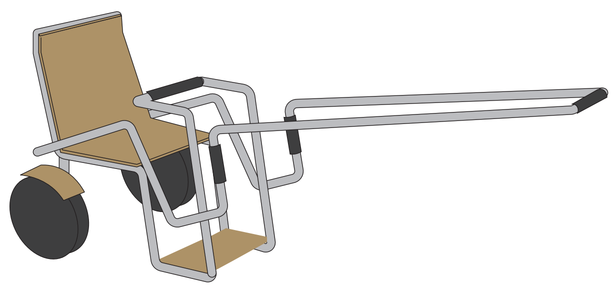


Figure P.5: Drawing concept the Giraffe

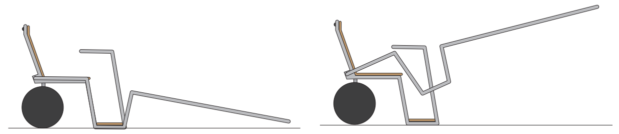


Figure P.3: The Giraffe open (left) and closed (right)

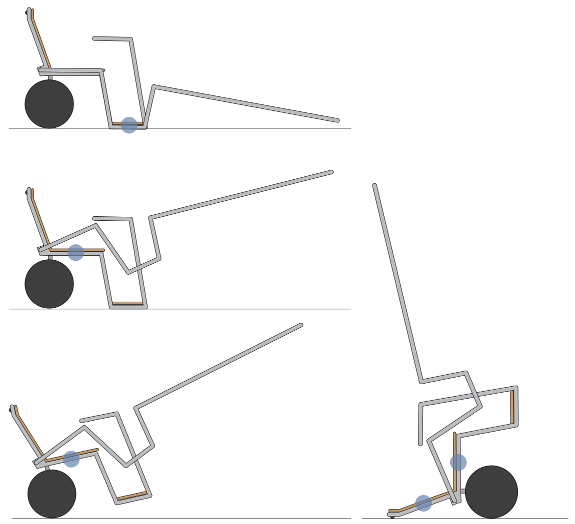


Figure P.6: Movement cart positions

the main process towards deciding on the main components is described.

Nesting and moving several carts at a time

All carts need to be stored at several stations in Artis taking as little space as possible. The Giraffe's length is 120 cm in closed position. Storing the carts in this way will result in the same space occupation as the current carts.

Goal Make carts occupy as little space as possible when parked at a station. Find way to move carts when nested.

Method Exporation nesting principles (appendix nesting) of exisiting products together with ideation on paper for both goals.

Conclusion

- The backrest tapers upwards. This way, when the cart is turned for nesting, the backrest can slide in between the wheels of the cart behind.
- A ball wheel is integrated in the frame on the back rest touching the ground when the cart is turned for nesting. In this position, three wheels touch the ground, the ball wheel enabling driving.
- The chain (part of the lock) connecting the carts and the ball wheels enable Artis to move several carts at the time by pulling the front cart.
- Wheels at the back of the cart is the widest point for stability.

Mechanical Stop

When the pull bar is lifted from the ground, the seat needs to be lifted to be able to drive. A mechanical stop needs to be integrated to enable the caregiver to lift the seat of the ground to start driving.

Goal Design mechanical stop that guides

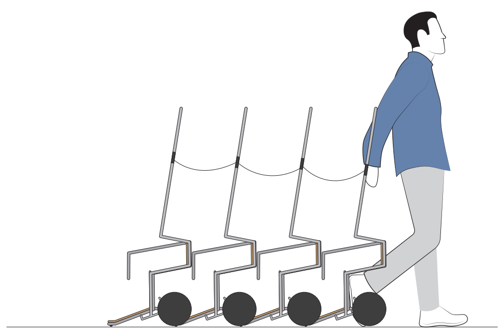


Figure P.4: Move several at the same time

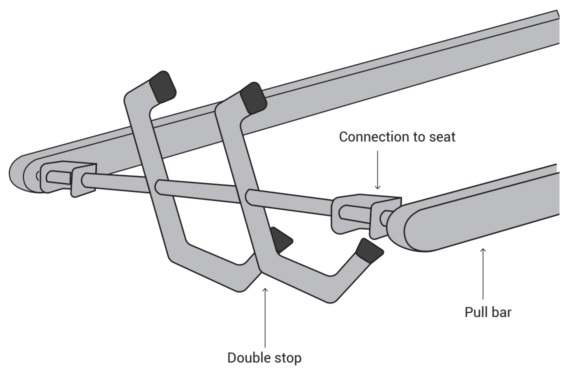


Figure P.7: Two sided mechanical stop

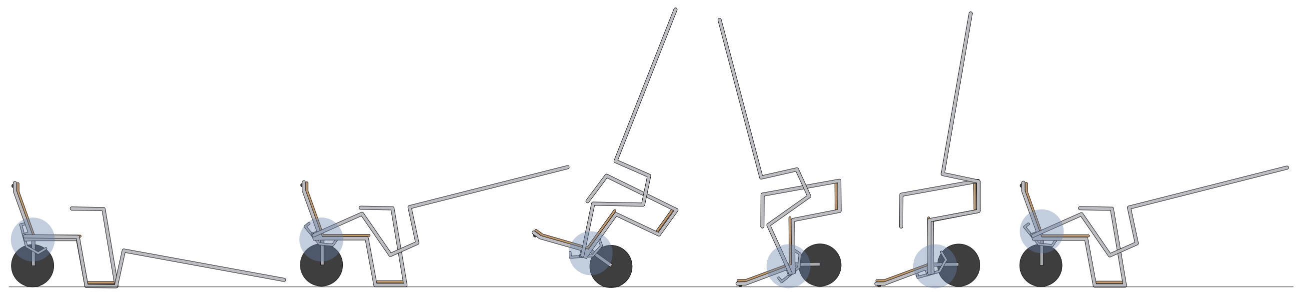


Figure P.8: Movement seat due to movement pull bar and double mechanical stop

movement of the seat and pull bar when lifting for driving and turning over for nesting.

Method Analyzing movement of cart in combination with pull bar. Determine points to support the seat to lift or restrict movement.

Results Figure P.6 shows the different positions of Giraffe and what needs to be done to make sure it can take this position.

Position 1 (top left): Shape of pull bar makes sure the handle does not touch the ground.
Position 2 (middle left): Mechanical stop should enable lifting front of the cart of the ground to get in position 3 (low left). Stop should lift bottom of seat.
Position 4 (right): Mechanical stop should guide tilting backwards for nesting by lifting the bottom of the seat. Stop should push backrest to tilt seat back for driving.

The movement of the seat follows the movement of the pull bar. Therefor, the mechanical stop is attached to the pull bar. A double stop (Figure P.7) makes sure all movements of the pull bar result in the right movement of the seat (Figure P.8).

Conclusion
A two sided mechanical stop attached to the pull bar makes sure the seat rotates together with the pull bar enabling every position needed.

Rubber handles
Rubber sleeves around the frame make the frame more comfortable to touch. They indicate the parts of the cart to be touched, at the handle bar and the lap bar. Extra rubber sleeves are positioned on the curve of the pull bar to assist the caregiver when lifting the cart for nesting.

Space occupation
The cart was modeled in FUSION 360 with the measurements determined in Appendix (measurements). Exact measurements can be drawn from the model. Using the current dimentions, 36 carts can be stalled on 16 m^2 (4 rows x 9 carts including 60 cm walkways). When stationed, this concept uses 3 times less space than the current station and carts.

Because of the nesting, rows are formed, adding a cart to the row will add 37 cm per cart (48 cm + 37 cm per cart). When in use, the length of the cart is 127 cm and the width is 45 cm.

The cart occupies the same space when in use as the current cart. Stationed the carts take up three times less space as the current stations including carts.

P.0.4 Concept B: The ring-tailed lemur
Basic concept principle
The cart can be lifted and pulled by a caregiver after pulling down the pull bar to 'close' the cart. The pull bar needs to be locked when down to enable the lifting and pulling movement. When lifted, it can be propelled and drives on two wheels. When the cart is in neutral position, the caregiver opens the cart by unlocking and lifting up the pull bar, the child can climb out. The user scenario describing the process of taking, using and leaving the cart is visualized in figure Figure P.1. This figure shows the parking direction of the carts which determines the nesting shape of the cart. Below, the main process towards deciding on the main components is described.

Locking pull bar
The pull bar should be able to be pulled down by the caregiver. When down, rotation or movement

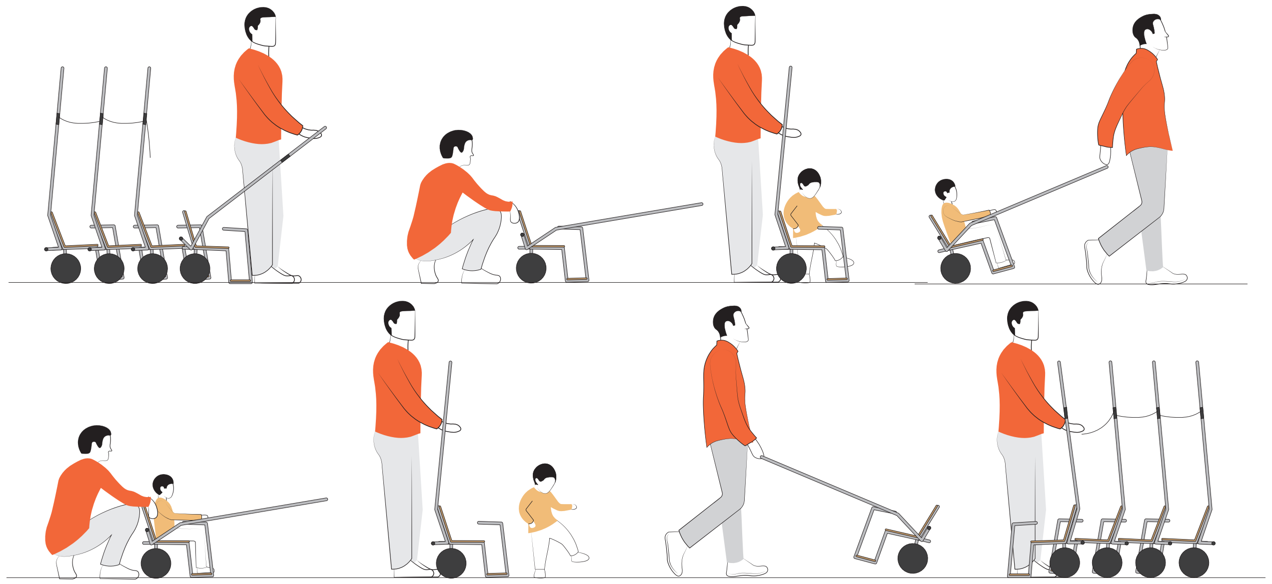


Figure P.9: User scenario the Ring-tailed maki concept

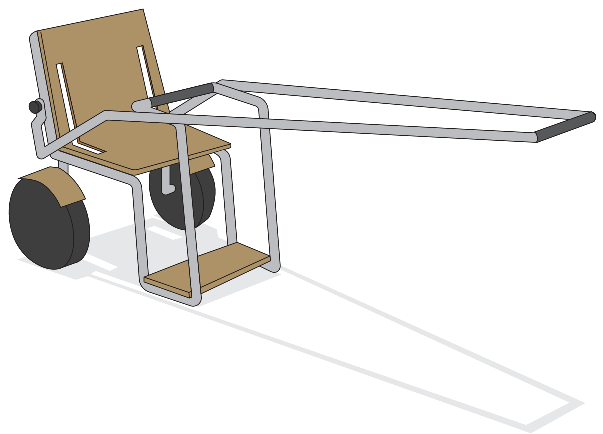


Figure P.10: 3D drawing concept B

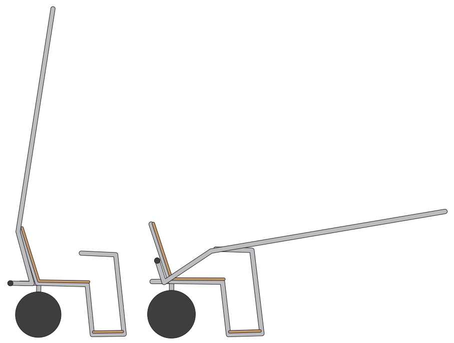


Figure P.11: The ring-tailed lemur open (left) and closed (right)

up and downwards of the pull bar should be blocked to enable the user to lift up and pull the cart to move forward. To open the cart the caregiver should be able lift up the pull bar.

Goal To find the right type of 'locking mechanism' which restrains movement of the pull bar when driving but enables the caregiver to open and close before and after driving. The locking mechanism is crucial, if it does not work the whole cart fails and is unserviceable.

Method The first step was an exploration of existing locking mechanisms. Thereafter interesting ideas were selected using the criteria resulting in a collection of, push to open mechanisms as well as manual locks and buttons. The remaining ideas were further explored and possible applications were drawn. A Harris profile (Boeijen et al, 2020) was used to make a decision for one of the ideas.

The locking mechanism should meet the following criteria.
- The child should be unable to open the pull bar when seated and driving
- The cart should close easily by pulling down the pull bar
- The cart should open after maximal one action by the caregiver
- It should be possible to integrate the locking mechanism behind the backrest of the seat
- There should be no risk of failure of the mechanism
- The mechanism should be easily replaceable (preferably with standard parts)
- Mechanism should be as simple as possible (no moving or loose parts)
- Locking mechanism should be able to carry the weight of the child and cart
- Action to unlock the pull bar can be done with one hand

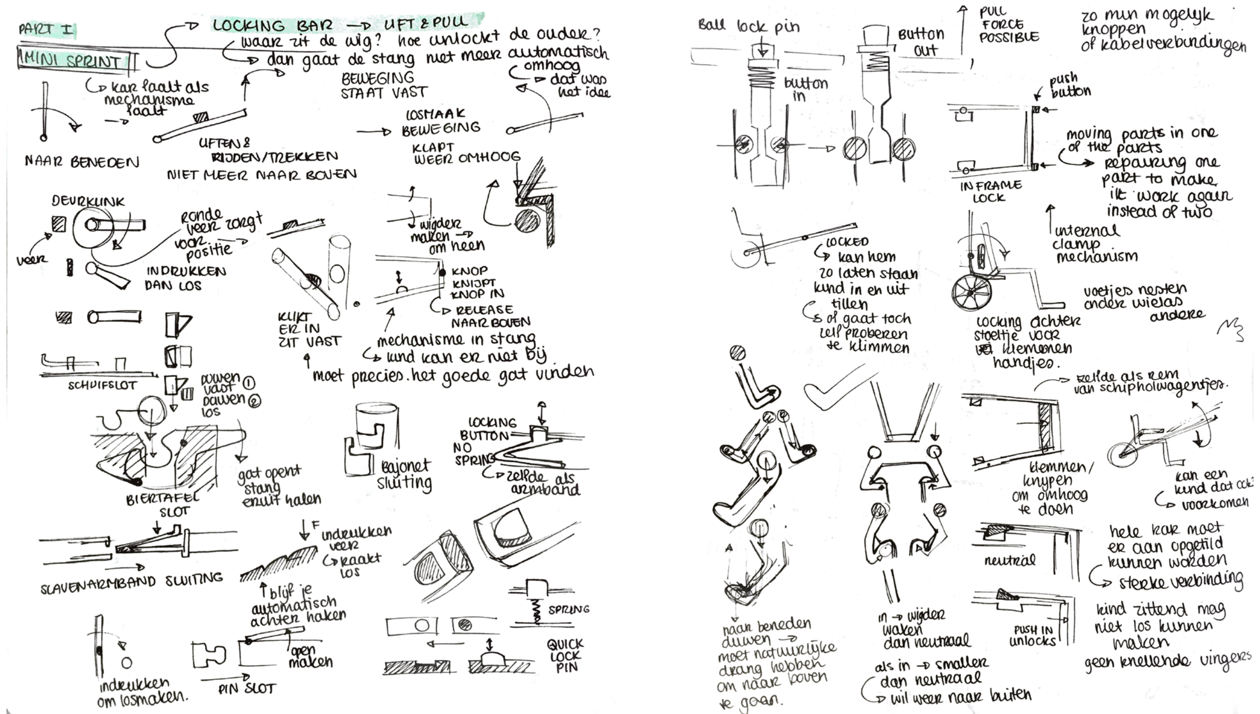


Figure P.12: Exploration locking mechanisms

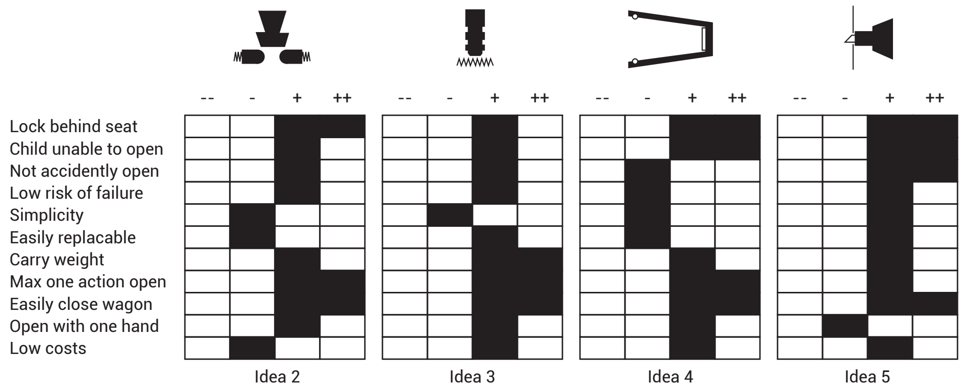


Figure P.13: Harris profile comparing ideas

- It should not be possible to accidently open the cart when driving
- The costs should be as low as possible

Results Figure P.12 shows the exploration of locking mechanisms that could be applied in the cart. Figure P.13 shows the Harris Profile used to visualize the differences between the ideas, the requirements were arranged from most to least important. All compared ideas do not unlock when the pull bar is pulled upwards. The ideas are described below.

Idea 1: push to open mechanism bar
Standard part used in for example ball points. By pushing down the pull bar, it is released and can be lifted up. When pulling down the pull bar locks underneath. The pull bar is used as a spring.

Idea 2: push to open mechanism bar
Simplified version of idea one, the J shape guides the pull bar and functions as a wedge. To open the cart, the pull bar is pressed downwards releasing the pull bar opening the cart. The pull bar is used as a spring.

Idea 3: Docking pin push to open
A docking pin is attached to the pull bar, when the pin approaches the target, the latches open and close after the pin, locking the pin. The pin does not release when pulled at. To release the pin including the pull bar, it is pushed inwards. The latches open and the pin is ejected. This mechanism is used to dock space shuttles.

Idea: 4 LQR

This is an existing mechanism made by BallSeal, a company in Amsterdam. It works in the same way as idea 3 where the bar needs to be pushed down to open. Due to the special circular spring, the pin is locked when pulled and opens when pushed down.

Idea 5: stroller button
The button at the handle of the pull bar needs to be pushed to release the pull bar. Two pins slide in the frame when closing the pull bar. This is the same principle as used in strollers to fold and unfold them.

Idea 6: indexing pin
The indexing pin is attached to the pull bar, when it comes in contact with the seat it locks, the pin slides in the hole. The knob needs to be pulled to release the pin and the pull bar. Indexing pins are made to endure high shear forces.

Idea one and two were immediately eliminated after testing with the wooden mock up. One of the conclusions was that the locking mechanism should be attached behind the backrest. This is not possible for both ideas because of the size of the parts needed.

Idea 3 and 4 both have a possibility to accidently open when for example the child pushes down the pull bar when seated in the cart. This is a big disadvantage. The indexing pin scores best on the most important requirements. It is a standard part which is easy to replace and has no loose parts. The parent is in control when opening the bar and close to the child to help getting in or out. Therefor, the indexing pin is chosen.

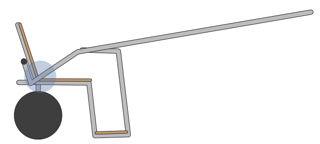


Figure P.14: Rotation point of pull bar

Conclusion An indexing pin connected to the pull bar will be used to lock and unlock the pull bar. Next steps are integrating it in the shape of the pull bar. The right spot for the pin to connect with the frame needs to be found. Furthermore, the position of the pin needs to be carefully chosen to make sure it will withstand all the forces on the pull bar.

Shape and rotation point pull bar

The pull bar needs to lock behind the backrest of the seat. Therefore, the pivot rotation point of the pull bar is chosen to be behind the back rest on

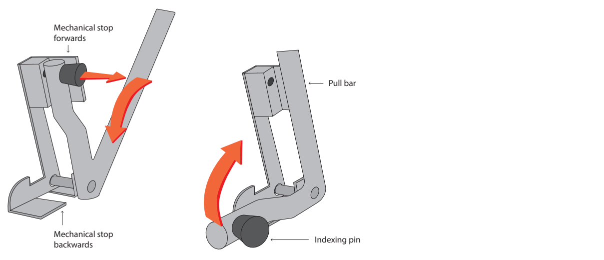


Figure P.16: Indexing pin and pull bar working principle model, open (left), closed (right)

the height of the seat. This was the only suitable one remaining form the conclusion of the rotation point exploration.

The shape of the pull bar was optimized by drawing lines between the begin and end point of the pull bar in closed position to make sure the sides of the cart would be as blocked as possible when closed.

Integrating indexing pin

When nesting, the pullbar of the cart rotates to the back and needs to slide along the seat of the other cart behind, along the lap bar of the other. To achieve this, the indexing pin is integrated in the pull bar. The pull bar makes another angle to make sure the pin can lock behind the back rest. When rotating backwards the pull bar is stopped by the stop which is attached to the backrest of the seat, resulting in a maximal rotation backwards. When locked the indexing pin slides in the block and and the pull bar is stopped by a mechanical stop.

One indexing pin is integrated at one side. The caregiver releases the pull bar by pulling the indexing pin with one hand and pulling the pull bar

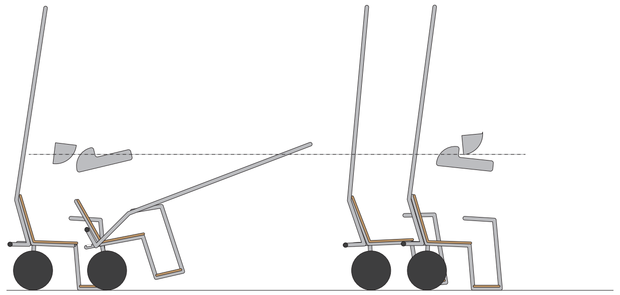


Figure P.17: Hooks lifting up footrest during nesting

upwards with the other.

The cart can only be opened from one side and all forces react on the singe indexing pin, this needs to be looked at again.

Nesting

The carts could be parked in front of each other with the pull bar up. This would however mean every cart would take up 50 cm and does not save enough space. For nesting, the lap bar is an obstruction since for nesting negative space is needed.

Slots in the backrest and seat make sure the lap bar including frame can slide in the cart in front. When nesting, the slots slide over the lap bar of the cart behind resulting in minor space occupation.

The seat together with the frame of the lap bar are tapered to the front such that the slots can be placed in the wooden part of the seat and carts can nest. Since the footrest is less wide than the wheel base, it can slide in between the wheels when nesting.

The two slots together with the tapered seat allow the carts to nest.

Move multiple carts

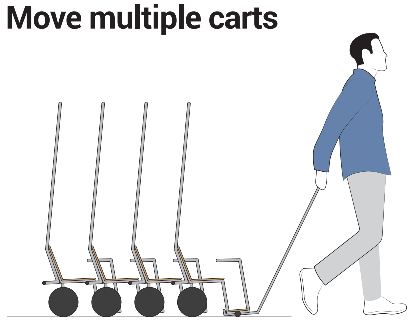


Figure P.18: Move multiple at same time tool

When parked in a row, all carts touch the ground with their wheels and footrest. To be able to move multiple carts at the time, the footrest of every cart needs to be lifted, only the wheels remain in contact with the ground.

By sloping the seat downwards, a level difference is create between the front and back of the seat. The front of the cart could be lifted by the next cart approaching the station. Figure P.17 shows the positions of two carts. Two hooks are integrated in the frame at the back of the cart. The hooks lift up the cart behind when approaching the station. When the front cart is dropped, the footrest touches the ground, lifting up the footrest of the one in the back.

Multiple carts can be displaced by using a tool designed for the cart caretaker with one rotating wheel and a long bar which can be placed below the footrest of the cart in front. This way all footrests are lifted from the ground and multiple carts can be displaced.

Space occupation

The cart was modeled in FUSION 360. Exact measurements can be drawn from the model. Using the current dimentions, 36 carts can be stalled on 16 m^2 (3 rows x 12 carts including 60 cm walkways). When stationed, this concept uses 3 times less space than the current station and carts.

Because of the nesting, rows are formed, adding a cart to the row will add 27 cm per cart (53 cm + 37 cm per cart). When in use, the length of the cart is 127 cm and the width is 45 cm.

Open and in use the cart occupies half of the space of the current cart since the pull bar is pointing upwards. When stationed one third of the space is occupied compared to the current stations.

P.0.5 Evaluating concepts

A meeting with both project coaches from the TU Delft resulted in an evaluation of the two concepts. This paragraph describes the evaluation points of both concepts.

Both concepts exist mostly of steel frames. This is overtaking the design and does not make the carts look friendly. The frame needs to be reconsidered using a minimal amount of tubes. They both look too complicated and need to be simplified. This will be tackeled in the next chapter.
The lap bar in both concepts obstructs getting in and out easily, this followed from the test with the wooden mock up. The shape and connection point of the lap bar need to be reconsidered.

Concept A: The mechanical stop does not prevent the cart from tilting backwards. If the child is moving a lot when driving there is a risk of tipping over. The mechanical stops need more attention.

The extra bends in the frame cause the metal frames to slide next to each other inviting fingers to get stuck. Scissor parts need to be prevented.

Concept B: Fingers can get trapped easily when the carts are nested. When taking a cart from the station, arms get trapped between the lap bar and the backrest.

The choice for a second rotationpoint of the pull bar needs reconsideration. It would be more logical to have the pull bar rotate around the wheel axis. Fingers can get trapped in the current hinge point. Furthermore it makes the construction unnecessarily complicated.

P.0.6 Concept choice

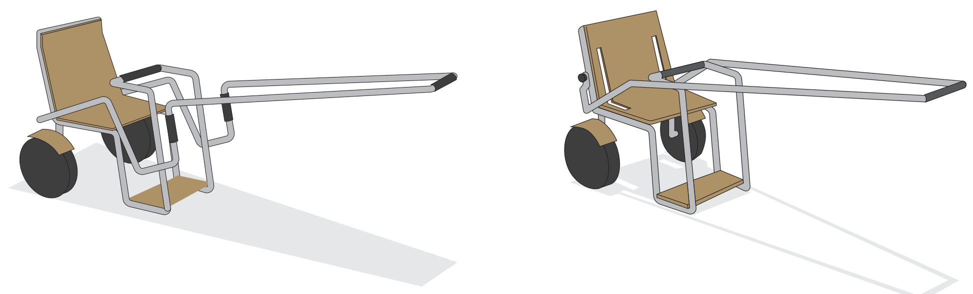
There is a lot of work to be done before both concepts can be eaqually compared. For now, they do not meet all requirements as a concept should. However, due to time constraints a choice needs to be made between both concepts. The concept with the most potential was chosen, the Ring-tailed lemur concept.

Figure Figure P.19 shows the prositive and negative elements of both the concepts. They are not compared on whishes and requirements.

The Ring-tailed lemur concept was chosen mainly because of the inviting character of the cart. When the pull bar is up it invites the child to climb in. Furthermore, the space occupation of the carts in the park will decrease since the cart is small when opened.

P.0.7 Conclusion

The design process with different sub-elements led to two concepts. Both concepts still had their flaws and could not be compared on fullfilled requirements. Due to time constraints the most interesting concept was chosen to continue with; the Ring-tailed lemur. Another iteration needs to be done to make the cart more simple and to



Concept A - The Giraffe

- Space per nested wagon 37 cm
- Easy to trip over when open
- Long when open in use
- No feeling of control, automatically opens
- Caregiver far from child when opening
- Tilt wagon to nest
- No extra tool to move multiple wagons

Concept B - The Ring-tailed lemur

- Space per nested wagon 27 cm
- Inviting to climb in when open
- Small when open in use
- Feeling of control, open with concious action
- Caregiver close to child when opening
- Unlock pull bar to nest
- Extra tool to move multiple wagons

Positive · Neutral · Negative

Figure P.19: Concept comparison

remove the superfluous. This will be done in the next appendix.

APPENDIX Q

Concept elaboration iteration 1

This appendix elaborates on the iteration process of the ring-tailed lemur concept cart. The thought process and relationship between elements are explained. The goal of this iteration is to end with a feasible simplified version of the concept meeting all requirements.

Q.0.1 Relationship nesting and lap bar

To park the cart in the station the pull bar needs to be unlocked and rotated upwards. The rotation of the pull bar should not interfere with the lap bar of the cart behind it. Changing the shape and connection point of the lap bar influences the shape of the pull bar including the location and attachment of the locking mechanism, as well as the other way around. All paragraphs of this appendix aim at finding the best solution.

1.1.13 Lap bar shape and configuration

Goal

To design a lap bar that makes sure the child cannot stand while the cart is closed, enables getting in and out without obstructions, is connected with the seat, backrest or footrest, does not interfere with nesting and is rigid. The rotation of the pull bar past the lap bar should not cause situations where fingers or hands can get trapped.

Method

Exploration of 3D shapes of bended tubes by sketching on paper. Promising proposals were chosen looking at the goal described above. Four options were chosen and prototyped on the wooden mock up to evaluate the potential interaction of the child and caregiver as well as other pro's and con's. One of the configurations was chosen to continue with.

Results

Figure Q.1 shows the results of the exploration on paper, the different configurations are marked orange. Figure Q.2 shows the selection of four possible lap bars quickly prototyped. All of the configurations are rigid, no extra hinge points are needed. The lap bars are described below and compared in Figure Q.3.

Idea 1 (top left) L shape backrest to lap

The bar enables the horizontal bar of the pull bar to be continuous since it can move underneath. This improves the rigidity and the reliability of the pull bar and the locking mechanism. However the bar is connected to the backrest and not stiff if force is applied to the bar. It will deflect. The configuration eases nesting since only the footrest of the cart needs to be pushed underneath the next cart. Children can get in at one side, this limits the child when getting in however, gives

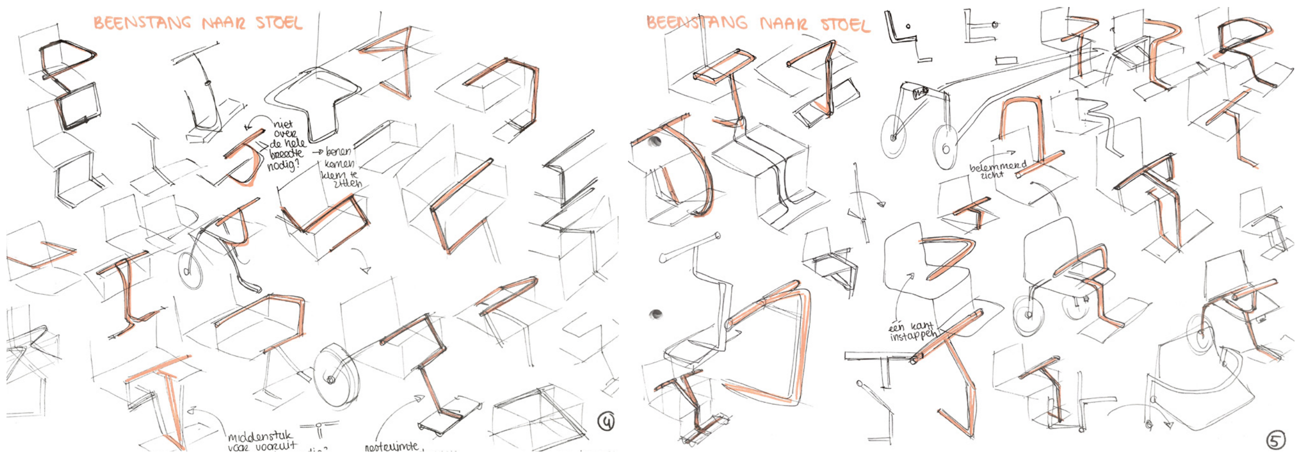


Figure Q.1: Sketch ideation connection lap bar to seat or footrest

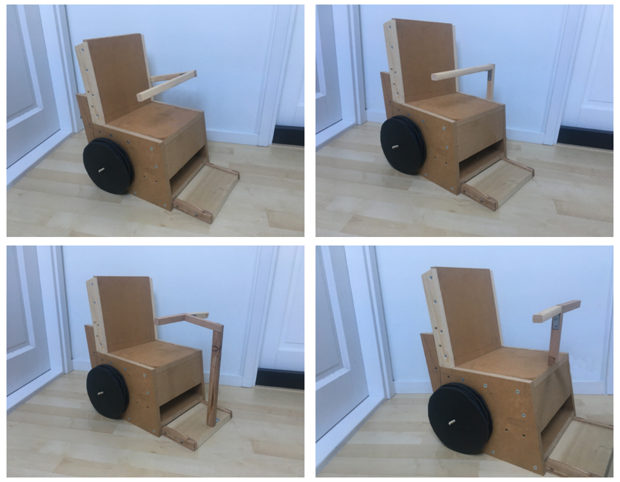


Figure Q.2: Lap bar configurations

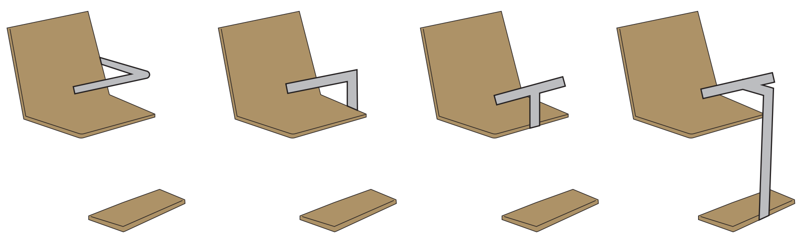
caregivers the security of knowing where their child will get in and the opportunity to respond. The pull bar will scissor along the bar risking cutting of hands.

Idea 2 (top right) L shape seat to lap
The bar does not allow the horizontal bar of the pull bar to be continuous since it needs to pass along the vertical part of the bar. This negatively influences the rigidity and the reliability of the pull bar and the locking mechanism. The bar is connected to the seat and is stiff when force is applied to the bar. It can be connected to the frame easily. The configuration eases nesting since only the footrest of the cart needs to be pushed underneath the next cart. Children can get in at one side, this limits the child when getting in however, gives caregivers the security of knowing where their child will get in and the opportunity to respond.

Idea 3: T shape from seat
The bar does not allow the horizontal bar of the pull bar to be continuous since it is blocked by the vertical part of the bar. This negatively influences the rigidity and the reliability of the pull bar and the locking mechanism. The bar is connected to the seat and is stiff when force is applied to the bar. The configuration makes nesting difficult since the horizontal part interferes with the backrest. The carts will take up more space if no nesting slots are used. Getting in and out is difficult, children need to climb in and out around the T shape.

Idea 4: T shape from footrest
The bar does not allow the horizontal bar of the pull bar to be continuous since it is blocked by the vertical part of the bar. This negatively influences the rigidity and the reliability of the pull bar and the locking mechanism. The bar is connected to the footrest and is less stiff when force is applied to the bar. The configuration makes nesting difficult since the vertical bar interferes with the backrest. The carts will take up more space if no nesting slots are used. Nesting slots will increase the risk of getting trapped when nested. Getting in and out is difficult since feet can still get trapped in the middle at the vertical bar.

Idea 2 was chosen. It makes sure no fingers can get trapped. Furthermore it is stiff and makes nesting easy eliminating the need for nesting slots. Children can get in at one side which influences the interaction with the cart but getting in is easy since no feet can get trapped.



Stiffness	Insufficient	Sufficient	Sufficient	Insufficient
Interferes nesting	No	No	Yes	Yes
Get in/out easy	Yes	Yes	No	No
Get in both sides	No	No	Yes	Yes
Risk trapping fingers	Yes	No	No	Yes
Block rotating pull bar	Yes	No	Yes	Yes

Figure Q.3: Comparision lab bar

Conclusion
The lap bar will have an L-shape starting from the side of seat ending above the seat. It will be connected to the rest of the main frame. The pull bar should end 2.5 cm above the lap bar when closed, no hands or fingers can get trapped. This type of leg bar influences the configuration of the horizontal bar in the pull bar with the locking mechanism. This will be further explored in paragraph pull bar shape.

Q.0.2 Pull bar unlocking and locking
When pulled down, the pull bar locks behind the backrest of the seat. The indexing pin makes sure the pull bar cannot rotate back up, the backrest functions as stop for the pull bar rotating more to the ground.

Ideally the indexing pin should be positioned and lock in the middle of the back rest to enable the caregiver to open the cart from two sides, furthermore, the child cannot reach it when seated. When in the center it eliminates an extra torsion moment resulting from pulling and lifting the bar when driving. Both forces will be on the same line of action (Figure Q.4).
A horizontal bar connected to the pull bar functions as part of mechanical stop needed to block the movement of the bar, the indexing pin on the backrest locks in the hole in the bar when they cross. The bar cannot connect both sides of the pull bar due to the shape of the lap bar which

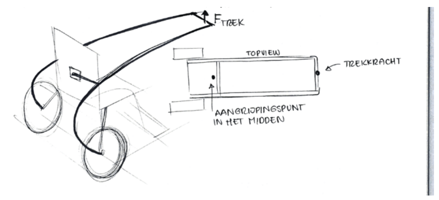


Figure Q.4: Position indexing pin

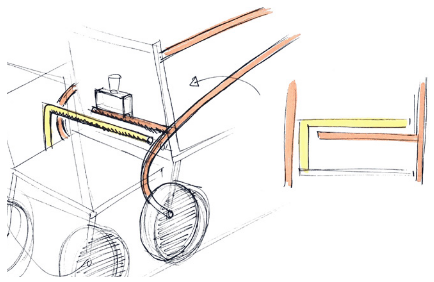


Figure Q.5: Mechanical stop in pull bar

interferes with the horizontal bar when nesting (Figure Q.5).

Caregivers open the cart by pulling the indexing pin and rotating the pull bar. This action should be as easy as possible the position of the pin and orientation influences this. Two options were compared, pulling side wards and upwards to unlock the pin. It is easiest to pull up the pin in the same direction as the pull bar is pulled with the other hand. The shape of the pin needs to be determined to make sure it can be pulled up in the limited space behind the backrest (Figure Q.7).
An extra mechanical stop perpendicular to the backrest is needed to make sure the pull bar cannot be lifted upwards when locked.
The indexing pin and mechanical stop block need to endure all forces. The wooden seat is not strong enough to withstand this. Therefore, the indexing pin including block are connected to a metal L shaped plate which is screwed onto the seat (Figure Q.6). This way the metal frame will take in

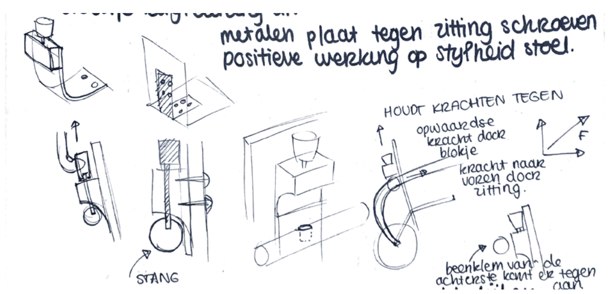


Figure Q.6: Indexing pin and metal plate

the forces instead of the wooden seat.

1.1.14 Pull bar shape
The pull bar will be symmetrical and be on both sides of the seat, the horizontal stop must be connected at both sides of the cart to be stiff enough. The rotation point of the pull bar is translated form the height of the seat to the same

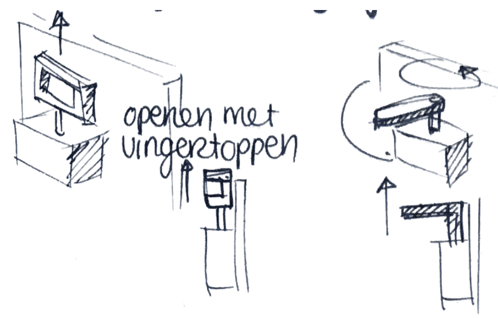


Figure Q.7: Shape handle pin

axle as the wheels to simplify the design and ease the production.

Goal
Find the optimal shape of the pull bar in the XZ plane. Feasible with a minimal amount of bends in the tube used for making the pull bar.

Method
The optimal shape of the pull bar was determined by first determining the points that the pull bar should go through. Thereafter, all points were connected by an line through the four points it must go through. The shape was further defined by experimenting with circle radii that would connect the different points.

Results
There are four points the pull bar must go through, see Figure Q.8.

1. The pull bar rotates around the same axle as the wheels, this is the starting point.
2. The connection point of the horizontal bar for the locking mechanism should be just a little lower than the height of the lap bar and touch the backrest when closed. This way, the most vertical position of the pull bar can achieved when nested and the pull bar will protrude least to the front. When nested the horizontal bar is stopped by the backrest of the cart behind stopping the pull bar from getting vertical. Figure Q.11 shows what happens if the horizontal bar would be higher or lower than the lap bar and the influence of the movement of the pull bar when stationed.
3. The pull bar should stop 2.5 cm above the lap bar when closed, this way no hands can get trapped.
4. When closed. the pull bar must end at least 50 cm from the ground and 1250 cm from the wheel axle when closed.

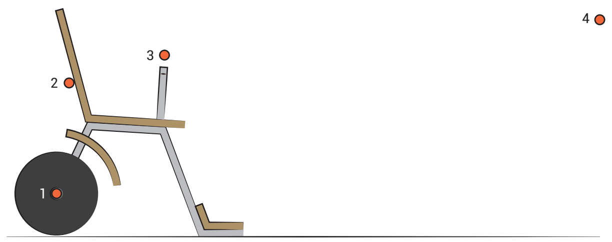


Figure Q.8: Connect points pull bar

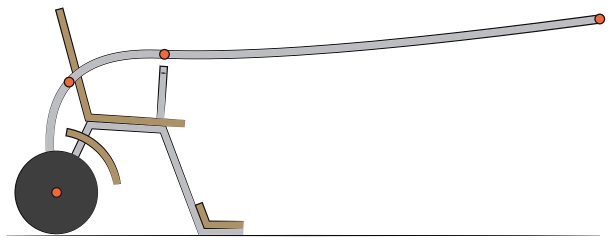


Figure Q.9: Fluent line through points

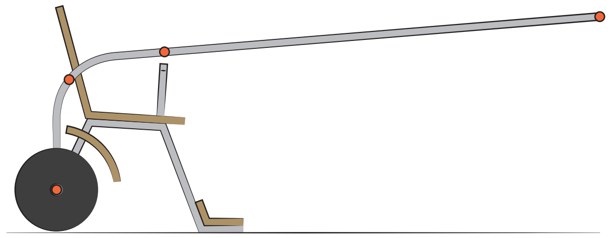


Figure Q.10: Ideal shape pull bar

Figure Q.9 shows how the fluent line through the different points. Figure Q.10 shows the ideal shape with one bend (radius of 150 mm), the other parts of the bar are tangent to this curve.

When parked, the cart is open. Because of the large radius of the curve it protrudes at the back of the cart. Raising the rotation point of the pull bar will decrease this, however will make the construction more complicated and therefore, was not seen as a better solution.

When open, the rotation of the pull bar needs to be stopped to make sure it does not touch the ground and does not take up more space. The next paragraph aims to find a solution for stopping the pull bar and keeping it in the right position.

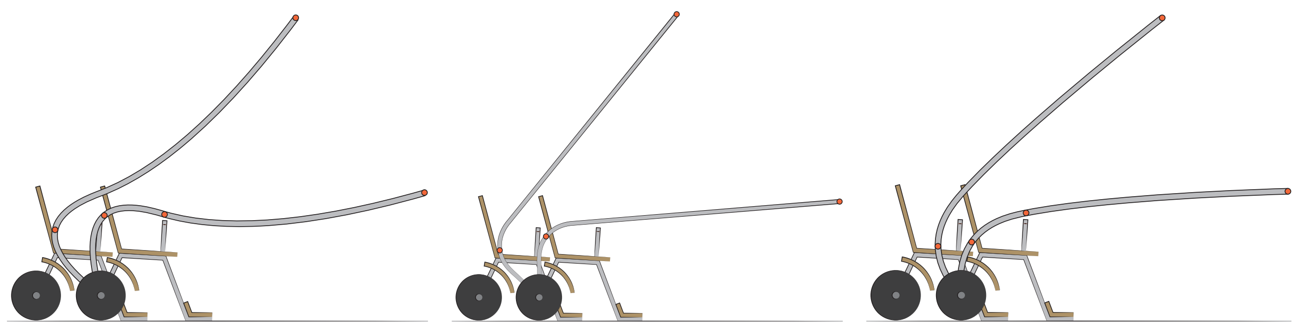


Figure Q.11: Positioning bar relative to lap bar height, heigher (left), underneath (middle), lower (right)

Conclusion
The pull bar can go through all four required points with one bend (radius 150 mm), it rotates around the wheel axle. This way no fingers can get trapped and the pull bar opens maximally when nested. A mechanical stop needs to be integrated to make sure it will not rotate further backwards, this needs to be done in the next iteration.

Q.0.3 Wheel basis
The cart has two wheels, the wheel base is raised to enable nesting (footrest slides in between the wheels). The frame has a double wheel suspension to make sure the wheels will stay perpendicular on the wheel axis. The raised wheel base ends at the intersection point of the back rest and seat (Figure Q.13). This will provide the cart with stiffness. The frame needed for the wheels is U shaped with welded L shaped tubes to create the double suspension. This extra bar gives support and is the attachment point for the wheelcaps.
The pull bar and wheels can rotate independently around the same axle using separate bearings.

There needs to be 2.5 cm between the seat and pull bar to make sure no fingers can get trapped. Positioning the pull bar and vertical part of the wheel base next to each other would make the

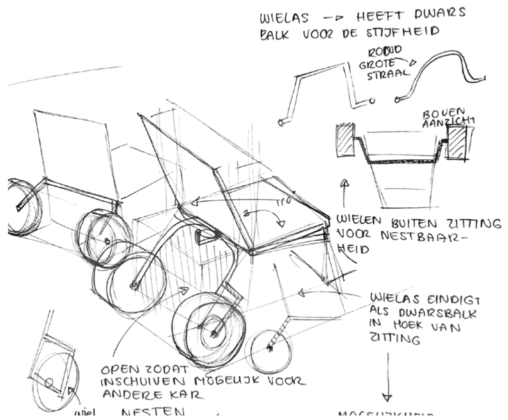


Figure Q.13: Wheel basis

width of the cart out of proportion. To find the right configuration of the wheels and pull bar a study was done. The wheels should be as far apart as possible to make sure the cart is stable and cannot tip over when driving in a bend. Figure Figure Q.12 shows the different options considered. Three iterations were made on the most linear configuration (left) resulting in the most suitable one (right).

By positioning the pull bar on the inside, no fingers

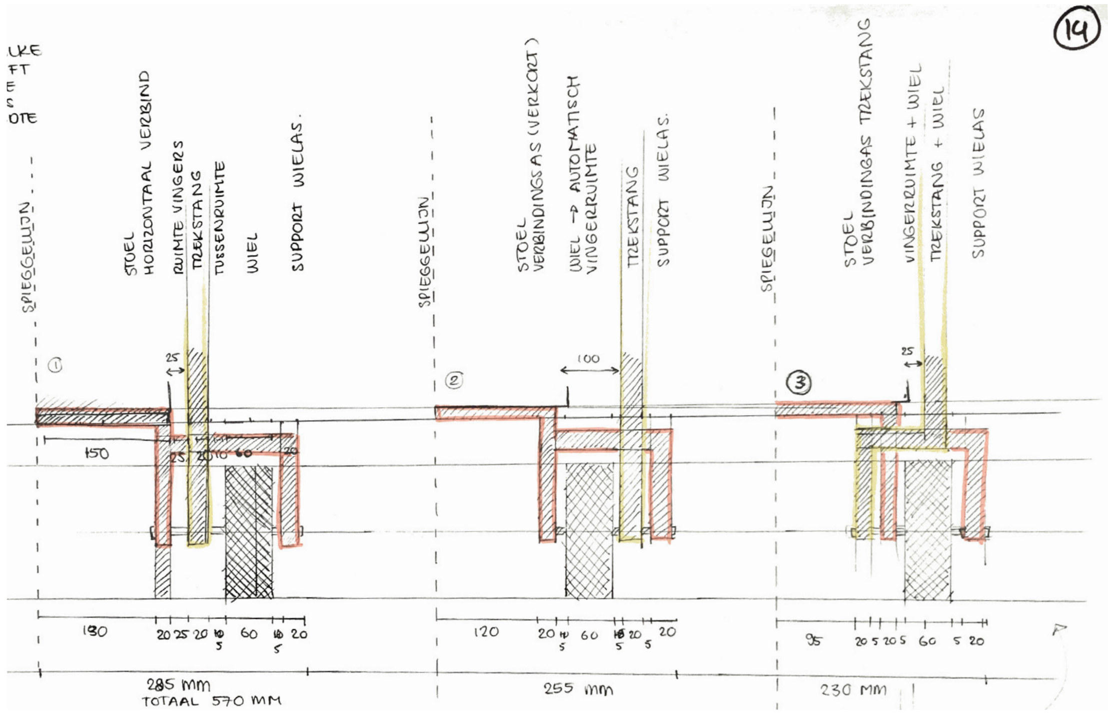


Figure Q.12: Configuration wheels, wheel suspension and pull bar can get trapped between the wheels and pull bar. Furthermore, the extra bend makes sure the 2.5 cm between the seat and pull bar can be achieved.

This configuration has consequences for the shape of the footrest. The footrest should be narrower than the horizontal distance between the two sides of the pull bar. It can be wider below the wheel axle but should then still be narrower than the distance between the wheels.

Q.0.4 Footrest

The footrest is connected with one bar to the bottom of the seat and is attached in the middle of the raised wheel base. Only one bar is used to keep the design as simple as possible. The footrest is supported with a metal plate with rubber studs which touch the ground when the cart is in neutral position. The frame will not wear this way.

Q.0.5 Conclusion

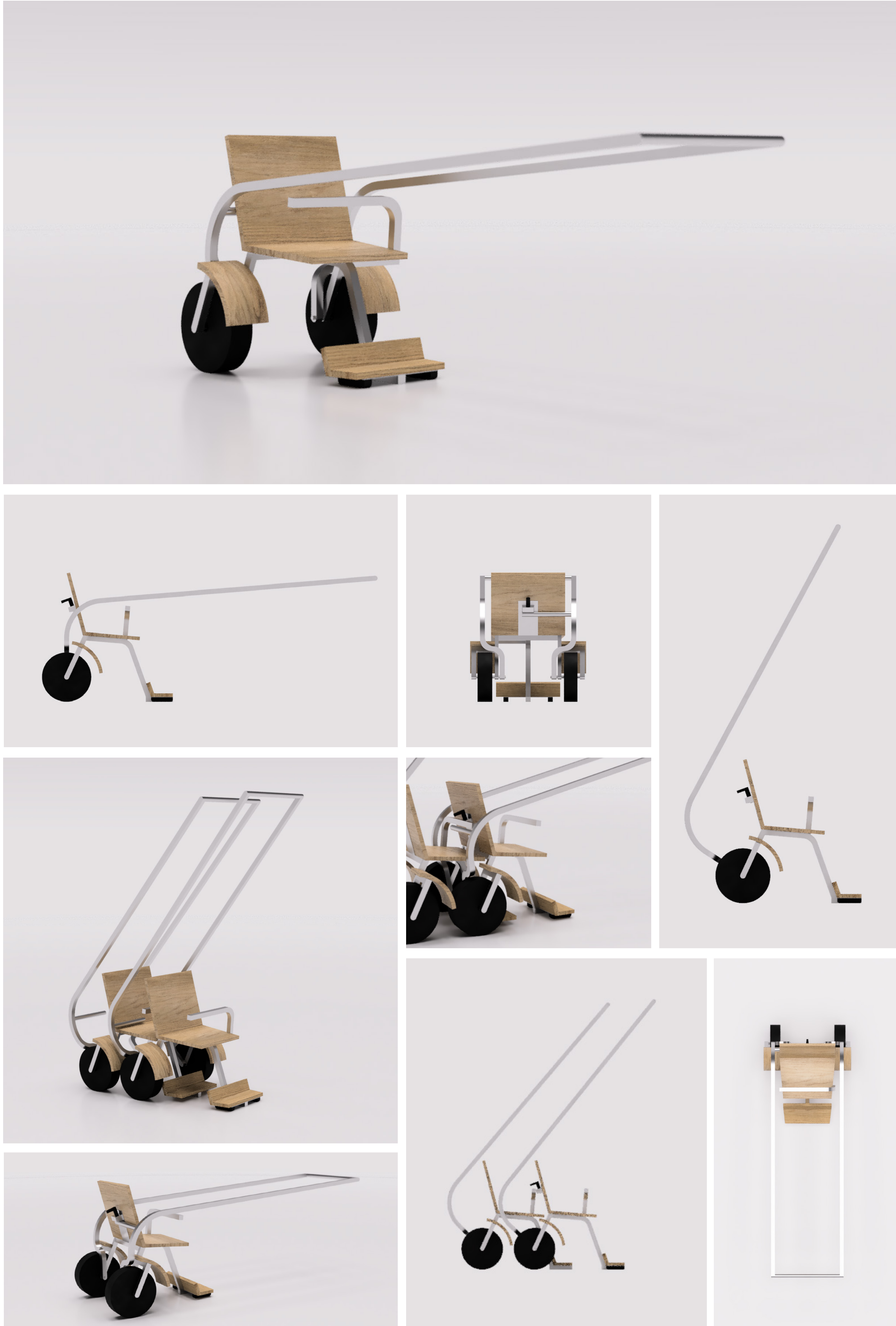
All elements decided on in this appendix are combined into a 3D model which meets all focus points described before. This model was also used as an iteration tool to see how changes would influence the design and functionalities. The render collage on the next page shows the end result of this iteration.

Q.0.6 Evaluation design

A meeting with both project coaches from the TU Delft resulted in an evaluation of the concept. The design can be more simple an extra iteration round could make this happen. Since all elements influence each other, concessions need to be done to get to the best design.

The following elements need more attention:

- Relationship nesting and lap bar, because of the shape of the lap bar, the horizontal bar can't be connected with both sides of the pull bar. Hesitant if the indexing pin connected to the horizontal bar will be able to withstand the forces when lifting and pulling the pull bar. The hole in the horizontal bar makes is less stiff and since it is not continuous from one side to the other it can deflect or break. If the horizontal bar would be continuous there would be no risk. No hole is needed in the bar since the pin can end behind the bar to lock it in its place.
- The wheels are supported by a double wheel suspension. This needs to be reconsidered and depends on the type of wheels used. If a single suspension is sufficient this could make the design more simple. Then a solution needs to be found to attach the wheel covers.
- The character of the cart appears because of the form that follows the function. More emphasis on the shape of the seat, footrest and wheel covers could strengthen the appearance of the cart.



APPENDIX R

Concept elaboration iteration 2

R.0.1 Increase stiffness of horizontal stop

The relationship between the horizontal stop and the lap bar was explained in the previous chapter. The horizontal stop of the last iteration was considered not stiff enough after the evaluation. It would bend or deform permanently since it should withstand all forces when lifting.

Goal

to get to a horizontal stop that is stiff enough and will not deform considering the relationship between the pull bar and lap bar.

Method

Find elements that can influence the relationship between the horizontal stop and leg bar. An ideation was done for each element using the how to question: How can this element be influenced to ensure a stiff construction and remain the qualities of the cart?

Five valuable ideas were selected and then compared using the Datum method (Boeijen et al, 2020), separately comparing every idea for all relevant criteria.

Results

Elements that influence the relationship between the horizontal stop and lap bar were; nesting (direction), shape of lap bar and the configuration of the pull bar and horizontal stop. The five selected ideas are visualized in Figure R.1 and are shortly described below.

Nest less

Leaving more space between the carts when nested makes sure the cart can stay the same and the horizontal stop can be continuous. This way the carts will take up twice the space of the original concept and will protrude more to the front.

T shaped lap bar and double stop

By changing the lap bar into a T-shape, the horizontal stop can be split in half. When nesting, and pulling the pull bar upwards, the horizontal stops will slide along the vertical part of the T shape.

Rotating lap bar

The rotating lap bar would rotate towards the backrest of the seat when nested. The continuous stop of the pull bar would push back the lap bar.

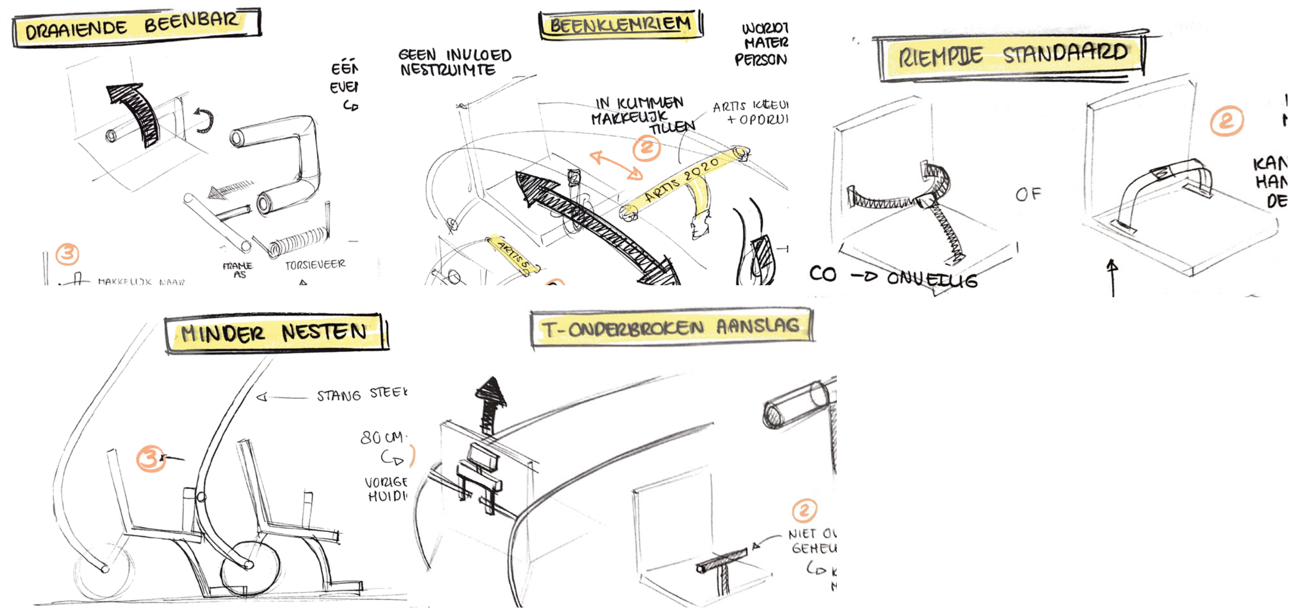


Figure R.1: Ideas for increasing stiffness horizontal bar

Lap bar belt

The lap bar is integrated in the pull bar, consisting of a wide strap that can be pulled towards the child when seated. It needs to be pulled away to release the child and to be able to pull up the pull bar.

Belt

A standard belt could be integrated in the seat. The caregiver is responsible for closing the belt making sure their child is safe.

One of the Datum comparisons is shown in Figure R.2. This was done for all elements being the datum once. The datum method gave insight in the differences between the five ideas and which of the criteria they would influence. The belt and rotating lap bar were eliminated since they would not improve the design. 'Nest less' scored best, since only the space occupation was doubled. This is however one of the most important requirements and therefor was eliminated from the options. The T shaped lap bar scored second best. It does not have a continuous horizontal stop but does give the child autonomy and there is no responsibility for the caregiver, the user scenario is not changed. Since the 'lap bar belt' resulted in extra hassle for the caregiver and less autonomy for the child this idea scored low. The T shaped bar was chosen since this is a compromise without changing too much.

Conclusion

The T shaped lap bar changes nothing to the user scenario. It enables the child to get in from both sides but he/she needs to put in more effort to climb in and out. The two stops are stiff enough and slide along the T bar. The cart still automatically blocks the way in and out when closed which was the original purpose of the design. This idea makes sure the size of the child that can sit in the cart is maximized. The locking mechanism needs a double pin to block the movement of both stops in the pull bar.

1.1.15 Simplification of the frame

Single suspension leaves room for pull bar

The wheels do not need a double suspension reducing the width of the cart with four centimeter. The configuration and order on the wheel axis

Datum method selection	Minder nesten	Riempje	Beenklemriem	T splitsing	Draaiende beenbar
Potential risks during use	0	-1	-1	0	0
Space occupation parked	0	0	0	0	0
Space occupation nested	-1	0	0	0	-1
Stiffness aanslag horizontaal	1	1	1	0	1
Frequency and amount actions caregiver	0	-1	-1	0	0
Smooth scenario (clear in one go)	0	0	-1	0	-1
Autonomy getting in and out (use)	1	1	1	0	1
Ability getting in and out (nest)	1	1	1	0	1
Responsibility parent locking	0	-1	-1	0	0
Beperkt tot doelgroep (moet)	0	-1	-1	0	0
Durability (weather proof)	0	-1	-1	0	-1
Costs	0	-1	-1	0	-1
Looks	1	-1	1	0	1
Complexity design	-1	-1	-1	0	0
TOTAL	**2**	**-5**	**-4**	**0**	**0**

Figure R.2: Datum method comparison ideas

of the pull bar, main frame and wheels was reconsidered. Using the order of the most right option in Figure Q.12 on page 63 resulted in an appropriate proportion between the seat width and wheel covers. Since this was the most simple option, limiting the amount of bends needed in the pull bar this was implemented.

Footrest supported with double tubes simplifying the base frame

The footrest was considered not stable since it was supported with only one tube. The ideation done for connecting the footrest with the seat resulted in several options. Now, two tubes stabilize the footrest allowing the wheel base to be connected with the tubes going to the front. Changing this simplified the base frame resulting in two tubes connecting the front with the wheel axis of the cart, visible in Figure R.3. Rubber parts

Figure R.3: Double tubes to footrest, single suspension

need to be integrated to make sure the steel tubes will not touch the ground, limiting wear of the frame.

R.0.2 Stop for rotating pull bar

Criterium

The pull bar should have a stop that prevents the pull bar from tilting backwards when open and should prevent it tilting forward when nested.

When nested, the center off mass of the pull bar is in front of the rotation axis causing it to tilt to the front if not blocked.

Goal: To enable the pull bar to rotate and stop when in vertical position making sure it does not tilt over forwards due to the center of mass.

Method: Use a how might we to answer the following question; how to stop a rotating bar temporarily.

Results: Figure R.4 shows the results of the How to. The torsion spring and gas spring were most suitable, both should be combined with a mechanical stop to make sure they will not break when someone pulls the cart backwards.
Conclusion The gas spring will make sure the pull bar will have a maximal rotation angle and it will stay up when the carts are nested. It will also provide suspension for the pull bar when opening and closing, making sure the pull bar cannot accidently close or fast. The spring should be able to lift 5 kg (weight of the pull bar), the exact measurements need to be determined when the concept is further defined.

R.0.3 Making sure the cart cannot tip over

A mechanical stop needs to be integrated, to make sure the cart cannot tip over.

Goal Making sure the cart cannot tip over backwards when driving and when parked (pull bar open). Integrate this in the most simple way in the design.

Method First the movement of the cart was analyzed to determine the part of the frame the mechanical stop should be connected to. Then the requirements of the shape of the stop were determined and the stop was integrated in the design.

Results The stops could be connected to the base frame or the pull bar. If connected to the pull bar, this could also function as a stop for the rotation of the pull bar. It would however not prevent the seat from tipping over when the pull bar is open. Therefor, the stop should be attached to the base frame.

The stop will block the following movements;

- When driving, the cart cannot tilt over backwards when lifted up to high.
- When open and the pull bar is pulled backwards, the pull bar does not rotate further because of the gas spring, the base frame will rotate and the stops will touch the ground before tilting. Since the center of mass of the base frame and seat will stay in front of the rotation axis of the wheels it will always tilt forward.

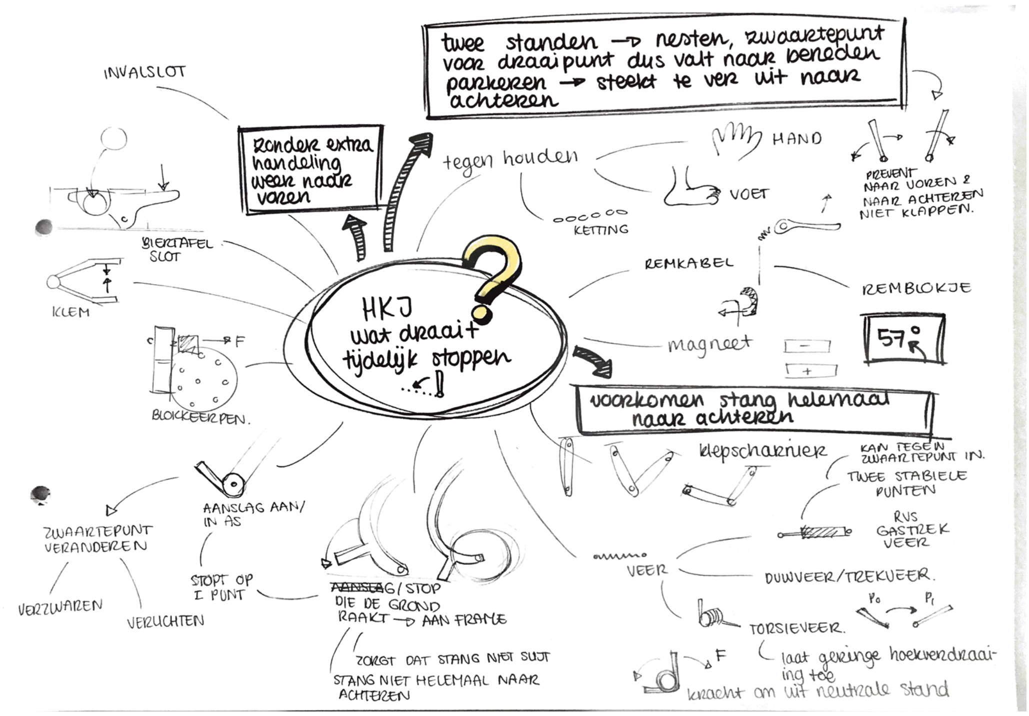


Figure R.4: Result H2 stop what is rotating

The maximal rotation angle is determined by the fist height of the caregiver when pulling. The stops should not obstruct driving. The maximal height of the handle is 95 cm (p95 Dutch male). The height of the handle is 60 cm. Max rotation angle is 17 degrees (rotation frame around wheel axis), the minimal rotation angle is 5 degrees. Meaning, the stops should block movement in the angle is greater than 17 degrees. The stop should protrude a little from the wheel, otherwise it will never touch the ground to stop.

By using trial and error, the angle between a vertical line intersecting the wheel axis and the center line (construction line) for the stop, starting from the center of the wheel axis is 55 degrees, see Figure R.5. This figure shows how the stop rotates around the wheel axis and the position of the stop. A few degrees are added to tolerate a little more movement.

Conclusion

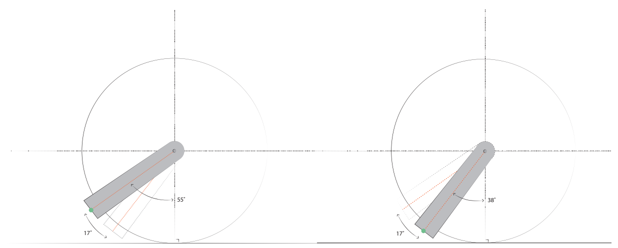


Figure R.5: Maximal rotation angle of stop following the base frame

The end point of the mechanical stop in neutral position of the cart is determined, length from center 110 mm and angle with vertical is 55 degrees. This point will rotate around the wheel axis the same way for every frame configuration since the relative position to the axis will stay the same. Now the stops needs to be integrated in the main frame.

R.0.4 Conclusion

The concept was evaluated during a coach meeting. The elaboration of the horizontal stops needs to continue to find a smarter, low weight option. The mechanical stops need to be integrated in the frame. Details need to be added, to do this, 3D modelling skills need to improve. The collage (Figure R.6) below shows the results of this iteration.

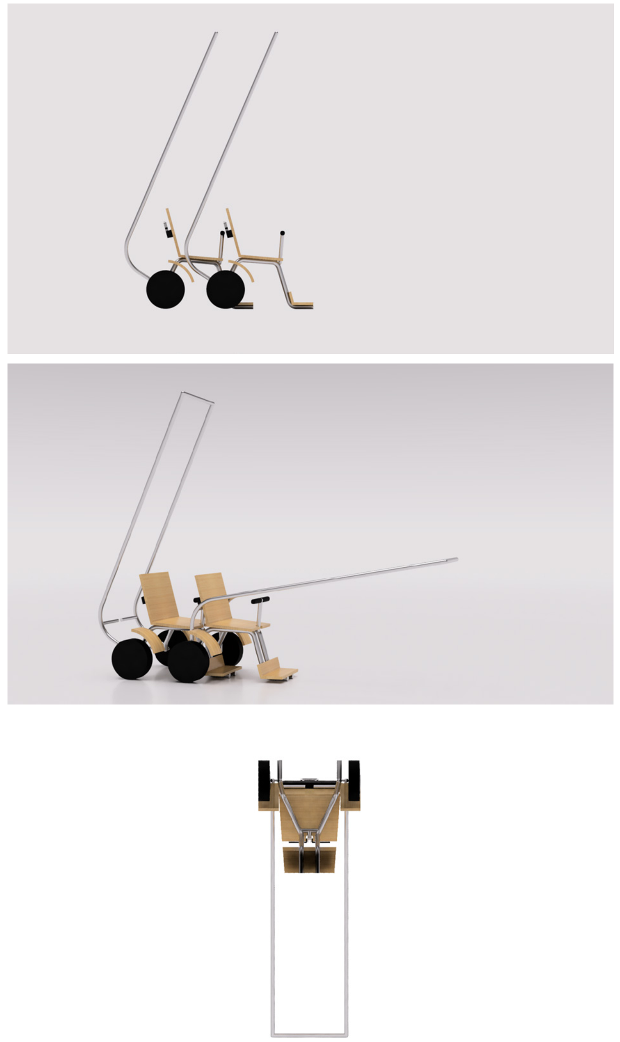


Figure R.6: Results iteration 2

APPENDIX S

Concept elaboration iteration 3

S.0.1 Integrating mechanical stops for tipping over

Stops need to be integrated, keeping the stiffness of the base frame and using as less bend as possible. Both parts of the base frame need a stop to make sure it is balanced.

One continuous tube (stop to main frame) is not considered as possible since then the wheel axis would be in the bend which would not be stiff enough. Two other options were considered, see Figure S.1. Both ask for an extra weld. However, the first option also requires an extra bend in the main frame. Therefore, the second option is chosen and integrated in the 3D model.

Since the stops are in between the wheels, the width of the footrest needs to be smaller than the distance between the stops. The stops are finished

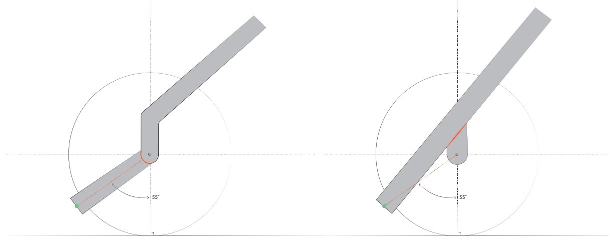


Figure S.1: Integration options mechanical stops

with rubber tubes to make sure the frame will not wear.

S.0.2 Shape of the pull bar

Up till now, the pull bar has changed a lot. The one big bend ensures the child is captured in the seat. However, it can be designed such that its weight is limited and it takes less space. Tapering the pull bar to the front will decrease the weight and will create a natural point for the handle bar. The width of the pull in the front is 260 mm, the widest point of the pull bar is 360 mm. Both sides of the pull bar are parallel at the seat. 140 mm after the main bend the bend is started to taper the pull bar to the front. This way, it can be manufactured but also makes sure the child does not have to squeeze her/himself when the pull bar is lifted. Rubber was added to all parts that touch the ground. Rubber was added to all parts that touch the ground.

S.0.3 Shape of seat

The seat is made out of one part, bended (30 mm radius) in one direction. The seat tapers to the front, the backrest tapers up to create a symmetric shape. The tapered front makes it easier for the child to get in. The thickness of the bended multiplex is 12 mm.

1.1.16 Connecting parts and assembly

The wooden elements are connected to the frame with bolts. The frame is made out of powder coates steel tubes welded together. Separate wheel axis will connect the pull bar, wheels and main frame.

APPENDIX T

Exploring measurements strollers and bike seats

A visit to the baby store resulted in insight in sizing and measurements of seating for children (strollers and bike seats).

Method

Measure different strollers and bike seats for children between 9 months and 4 year old. Measurements (Figure T.1) are taken on strollers in most up right posisiton Measurements are compared and translated into requirements in the main report.

Results

Table T.1 shows the different measurements for the different strollers and seats. Locations of measurements are indicated in Figure T.1 and correspond with numbers in the table.

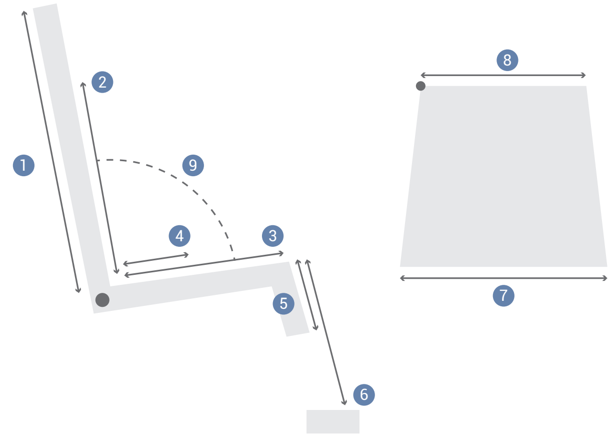


Figure T.1: Measurement indications seat

	Recaro easilife buggy	Prenatal basis buggy	Nuna pep next	Easywalker harvey 2	Joolz aer	Yepp nexxt mini (bike)	Yepp nexxt maxi (bike)
Minimal age	6 months	0	-	6 months	9 months	9 months	9 months
Maximal age [years]	3,5	-	-	-	-	2	6
Maximal weight [kg]	18	15	15	20	18	15	22
Backrest total height [cm] (1)	43	44	44	41	47	32	46
Backrest belt attachement height [cm] (2)	25	26	27	30-35	22-36	27	32-37
Seat depth [cm] (3)	20	24	20	22	26	15	18
Belt attachement depth [cm] (4)	13	12	8	19	10	15	18
Support leg length [cm] (5)	12	-	17	12	-	-	-
Seat to footrest distance [cm] (6)	27	24	22	22	22	30	30
Seat width front [cm] (7)	32	32	32	29	38	24	32
Seat width pivot point (8)	28	26	27	28	25	13	17
Angle seat backrest [degrees] (9)	110	111	134	113	106	-	-
Handle height push bar [cm]	105	103	95-103	110	105	-	-

Table T.1: Stroller measurement results

APPENDIX U

Seat mock-up

Goal
Build a mock up to get a feeling for the size and the basic shape, to use for exploring and testing. To test different configurations, the size of the cart with the target group.

Method
Measurements were determined using the first measurement iteration.This was the main guideline to start builing a wooden frame. The mock-up was constructed with wood then glued and screwed together.

The mock-up needed to be strong enough to be able to test with children, therefore a bottom plate was integrated as well as bars between plates ensuring a strong connection.

Two side plates close the sides of the seat. Holes are drilled in the sides to attach a pull bar in different configurations and test different configurations. The model is not nestable.

Insights
- The lap bar is a vulnerable part of the seat, when getting in it probably needs to withstand the bodyweight of the child, length pendant part need to be determined.
- The angle backrest angle was copied incorrectly, it should be 110 degrees. This needs to be taken into account when testing.
- Wheels are reachable when the child is seated and they are wider than the seat.
- Starting with a complete drawing of all parts will structure the building process and leave less unneccesary mistakes.
- Making a 1:1 size mock-up gives an tangible indication of the size and proportions.
- The model can be easily adapted due to the material used.

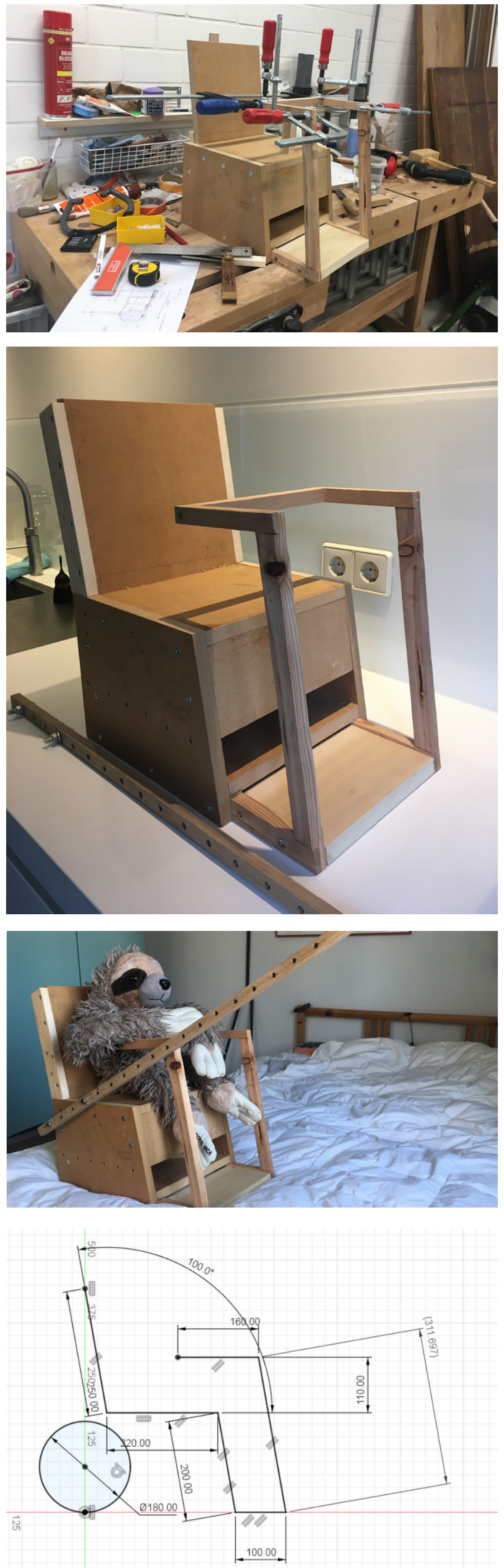


Figure U.1: Process and result of mock up >

APPENDIX V

Safety standards review

To ensure the cart is safe for the target group amongst others, research was done about standards. The standards the cart needs to meet are investigated. This Appendix will result in several requirements concerning different themes.

V.0.1 Goal
Research if should be designed conform standards, distill criteria for the list of requirements.

1.1.17 Method
Inspiration for standards that could be useful resulted from analyzing strollers and carts designed for other zoo's and discussion with Herman van der Vegt (NPK design). Artis' own safety expert, Geert Pieter Grundmann, was consulted to check if the playground equipment standards should be apllied. Reading through different standard resulted in criteria that should be fulfilled.

1.1.18 Results
Competitor carts and standards
Strollers used in Disney and Ouwehands Dierenpark are tested following the norm for strollers. Quick phone call with the company (Bereford) revealed, their strollers are suitable for public sights. They are designed for children from the age of 9 months (when they can sit up right). Instructions say the maximal load is 15 kg but it can withstand 80 kg. They are designed as strollers for public spaces.

By ensuring the vehicle can bear 80 kg, it will not break when an adult sits in it. Communication target group is different from the test group.

Carts designed by Van Dalen, are designed following the EN-1177 norm for playground equipment. A phone call with the company revealed, the carts have this standard to make sure products from China cannot compete.

Standards
The NEN, Nederlands Normalisatie instituut, supports the normalization process in the Netherlands and publishes agreements made, most information about the norms is derived from their publications.

Since the to be designed product will only be used in the Netherlands, only European norms need to be taken into account.

Artis is in between a public sight and own property. Basically Artis is private property, however, because there are so many visitors, it can be seen as a public sight by outsiders. Rules and requirements for private property can be used.

A summary of the norms that could be useful is listed below.

CE-mark
The CE mark is defined as the European Unions mandatory conformity marking for regulating the goods sold within the European Economic Area (EEA). It represents the manufacturers, importers, distributors responsibilities when placing a product on the market. The manufacturer is responsible for checking that their products meet EU safety, health, and environmental protection requirements (Manufacturers, 2017). The cart should be conform to the CE regulations.

CE marking for the toy industry
Minimising the risk of injuries to children playing with toys is an essential element of EU, the CE marking is an indication that it meets the essential safety requirements. The directive defines a toy as any product or material designed or intended, whether or not exclusively, for use in play by children under 14 years of age (Bureau van publicaties an de europese uni, 2013). The cart is not a toy in itself but however can be played with. For later stages of the development process, this should be consulted.

Safety of toys – EN71
Toys are things that are used by children to play with. The norm describes safety directives for toys. It specifies mechanical and physical properties for example, it determines which requirements need to be met to make sure a child cannot swallow or trap her fingers (Veiligheid van Speelgoed, z.d.). The carts in basis are not toys, however should be safe for children to interact with. This norm can be used to distill criteria from to determine safety criteria the cart needs to fulfill.

Child care articles - Wheeled child conveyances – EN1888
NEN-EN 1888 describes safety requirements for strollers and buggies that are used for one or multiple children (Norm voor kinderwagens, z.d.). It includes for example requirements for the backrest in terms of comfort and safety (inclination of the backrest such that the spine is relieved). Carts in Artis do not need to be conform standards for strollers since they are not used on public ground. However, this norm can be used to derive safety standers from.

Playground equipment – EN 1176 and 1177
Following the authorities, all playground equipment in public space should be safe. They should be designed to minimize and show the risk of playing. Definition of play equipment (speeltoestel): an establishment intended for entertainment or relaxation using only gravity or physical strength of people. After consulting Geert Pieter Grundmann, safety specialist in Artis, it was concluded that this standard is not applicable for the carts in Artis. It was mentioned that the carts merely focus on transport and not on fun or relaxation. However, since playground equipment is most of the time outside, regulations for materials can be useful.

V.0.2 Conclusion
Both the standard for strollers (EN-1888) and toys (EN-71) can be used to derive requirements from as well as the playground standard. In the end, the product should meet the CE standard before production and meet all safety standards for toys. For now, deriving requirements from the standards is the first step to design a product that can be produced and meets the criteria. In a later stadium of the process a discussion with a standard-expert should be arranged to discuss the design with.

V.0.3 Requirements
Requirements for the carts are distilled by reading through the different selected standards. Criteria of all standards are combined and clustered in themes. Standards used; playground equipment EN 1176-7:1997, Safety of toys NEN-EN 71-1 2009.

Safety standards for strollers, EN-1888 is not available, therefore, information about this norm was gathered by online desk research. A test report of an existing stroller which failed the EN-1888 2003 norm was used to derive requirements. Requirements are when applicable literally transcribed from the different norms or are adjusted to suit the context. Final products are tested to make sure they are conform the standard, this part concludes with an overview of tests.

Criteria's formulated need to be adjusted to become measurable and achievable. Combining the test requirements with the criteria below is don ein the main report.

Below, the criteria clustered in themes:

Materials
- The selection of materials and their use should be in accordance with appropriate European standards. Special attention should be given to potential toxic hazards of surface coatings.
- Timber parts shall be designed in such way that precipitation can drain off freely and water accumulation shall be avoided
- Wooden equipment shall be made of wood with a low susceptibility to splintering. The surface finishing shall be non-splintering. Any exposed wood parts shall be smooth and free of splinters.
- Material used shall be visually clean and free from infestation. The material shall be assessed visually by the unaided eye rather than under magnification.
- Celluloid (cellulose nitrate) shall not be used in the manufacture, except when used in varnish, paint or glue, or in balls of the type used for table tennis or similar games. As well as materials with a piled surface which produce surface flash on the approach of a flame and highly flammable solids.

Structural components
- Structural parts shall resist the worst case loading condition. Worst case load condition is 80 kg. The cart shall support a static load of 800 N in the center of the area the child is seated.

Safety
- There shall be no protruding nails or pointed or sharp-edged components. There may be no burrs and sharp edges within the access zone. Edges, points and corners outside access zone shall be rounded and free from burrs.
- There shall be no open-ended tubes, projections, holes, loose washers, speed fixings, nuts or crevices in which the child's finger or flesh can become trapped within the access zone. (entrapment = Hazard presented by the situation in which a body, or part of a body, or clothing can become trapped.)
- Equipment shall be constructed so that any openings do not create neck and head entrapment hazards either by head first or feet first passage.
- The space in, on or around the equipment that can be occupied by the user should not contain any obstacles that the user is not likely to expect and which could cause injuries if hit by the use (Figure V.1).

Figure V.1: Prevent 'invisible' obstacles

- Accessible edges shall not present an unreasonable risk of injury.
- Edges of metal or glass are considered as potentially hazardous sharp edges if they are sharp as determined according to the sharpness test (Figure V.3). If the edges fail the test, they shall be assessed to determine whether they present an unreasonable risk of injury taking into account the foreseeable use of the toy.
- Edges of metal including fastenings (e.g. screw heads) and of rigid polymeric material shall be free from burr capable of causing wounds or abrasion.
- If there is a handle or other structural member which can fold down over a child, it shall have at least one main locking device and at least one secondary locking device, both of which shall act directly on the folding mechanism.
- Toys with folding or sliding mechanisms intended to bear or capable of bearing the mass of a child and capable of injuring fingers, shall be so constructed that the space between moving elements shall also allow a 12 mm diameter rod to be inserted if it allows a 5 mm diameter rod to be inserted.
- Driving mechanisms shall be enclosed in such a way that they do not expose accessible hazardous sharp edges or accessible hazardous sharp points or otherwise present a hazard of crushing the fingers or other parts of the body.
- The cart, intended to bear the mass of a child shall not tip over when tested on stability.
- When parked the vehicle, facing up and down the slope, shall remain static on the slope for a minimum of 1 minute including weight child. Any attachment device shall not become detached during the test.
- Removable or detachable components of the vehicle shall not, whatever their position, fit entirely in the cylinder when tested according to the test: small parts cylinder (Figure V.2).
- Mechanical parts that is essential for its safe operations shall be attached such that it cannot be displaced from a normal operating position or broken.

Product information
- The potential dangers of using the vehicle and

precautions to be taken shall be brought to the attention of the parents or caregivers.

- Toys that due to their construction, strength, design or other factors are not suitable for children of 36months and over shall carry the following warning on the toy and its packaging:. "Warning! Not to be used by children over 36 months." together with a brief indication of the specific reason for this restriction (e.g. insufficient strength). The age warning shall be clearly legible at the point of sale of the product.
- Product information shall be provided to reduce the possible consequences of foreseeable hazards connected with the use of the vehicle
- Product information about the user group should be provided in the following way: This vehicle is intended for children from (minimum age, in months or years) and up to (maximum weight 15 kg)
- A statement that the vehicle shall be used only for up to the number of children for which it has been designed.

Maintenance

- In order to prevent accidents, an appropriate inspection schedule should be established and maintained. The schedule should list the components to be inspected at the inspections and the methods of carrying out the inspection. Such measures should include: tightening of fastenings, repainting and retreating of surfaces, maintenance of any impact absorbing surfaces, lubrication of bearings, cleaning, corrective maintenance (replacement parts).

Seating

- The angle between the backrest and the seat shall be at least 100 degrees
- The height of the backrest shall be at least 380 mm

Breaks (if applicable)

- If the vehicle has a breaking device then the user shall be able to activate the braking device when he/she is walking.

Restraint system (if applicable)

- Seat shall be fitted with a restraint system, incorporating a crotch restraint for each position a child can occupy.
- When straps are included in the restraint system they should have a minimum width of 20 mm.
- The attachment of the restraint system shall not break, deform, work loose or become torn/ displaced and the seat unit shall remain in place without permanent damage.
- The buckle shall have a single action release mechanism that does not release at a force less than 40 N.

When the vehicle needs to be folded or unfolded for use, additional requirements should be added.

V.0.4 Tests

Strollers and toys need to survive several tests to be approved conform the standard. Those tests can be used to confirm if requirements are met.

Stroller tests

The vehicle should survive the following tests; dynamic strength test, durability test, irregular surface test, inclinable test, bite test. the vehicle shall not have suffered any damage which impairs its safety.

Inclinable test (hellingproef)

The vehicle should not tip over when on a surface under 10 degrees. A stop can be placed on the plane against the wheels in a manner it will not prevent the vehicle from tipping over. This test is similar to the stability test for toys.

Front stability test (child climbing in)

Place the vehicle on a horizontal plane, apply a force vertically downward to any part of the front edge of the seat or on any location likely to cause the unit to tip over. The surface must support the vertical force applied for 10 seconds without tipping over.

Kerb mounting test

This test is used to determine the complete structure stiffness of the stroller while mounting a kerb or stair step. Climbing and descending a kerb is simulated 3000 times with a full load in the stroller.

Irregular surface test

The vehicle drives with 5 km/h over a roller band with bumps. The stroller should be able to withstand this for X kilometers without changes.

Test methods for toys

There are several tests described in the standards which can be done to test products on their safety e.g. tension tests and torque tests. Some of them are described below.

Small parts cylinder

Place the toy or component without compressing it and in any orientation in a cylinder having dimensions as indicated. Determine whether the toy or component fits entirely within the cylinder. If it fits, it is too small and does not fulfil the requirement.

Tip over test

Place the toy on a horizontal surface and attempt to tip it over by pushing the toy slowly past its centre of balance three times, one of which shall be in its most onerous position, by gradually applying a force, which is not to exceed 120 N, in a horizontal direction and 1500 mm above the horizontal surface or at the top edge of the toy for toys less than 1500 mm in height.

The original point of application relative to the toy shall be maintained, and the force shall remain horizontal, throughout the test. The vertical position of the point of application relative to the horizontal surface is permitted to increase during the test. If a force greater than 120 N is required to bring the toy beyond its center of balance, or if the vertical position of the point of application, relative to the horizontal surface, exceeds 1 800 mm, the tip-over test shall be stopped.

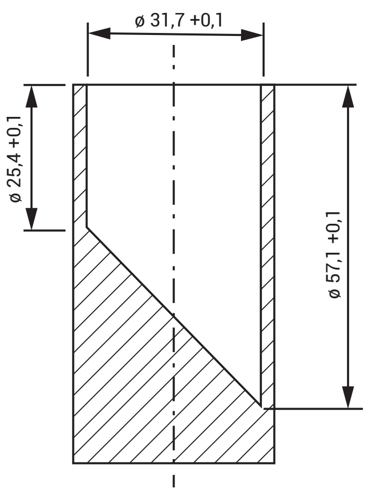


Figure V.2: Small part cylinder (mm)

Sharpness of edges

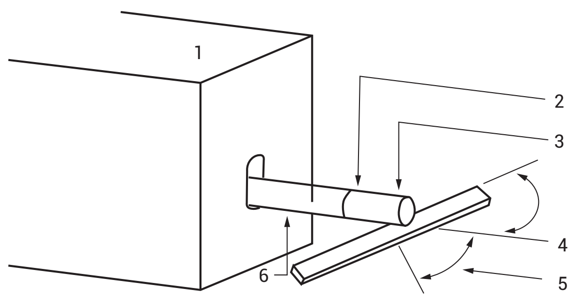
A self-adhesive tape is attached to a mandrel which is then rotated for a single 360° revolution along the accessible edge being tested (Figure V.3). The tape is then examined for the length of cut. Calculate the percentage of the length of tape which has been cut during the test. If this is more than 50 % of the contact length, the edge tested is considered to be a sharp edge. (applied force 6 +- 0,5 N)

Static strength

The strength of the toy is tested by static and dynamic strength tests by applying a load to the toy. Two loads are specified, 50 kg for toys intended for children of 36 months and over, and 25 kg for toys intended for children under 36 months. In case of doubt as to which age range the toy is intended for, the greater load should be used. The masses are based on anthropometric data and take into consideration the deterioration that toys are subject to during their lifetime.

If a toy which is designed to bear the weight of a child allows the child to use its feet to provide stability, the requirements do not apply. If the child is completely enclosed, the requirements should apply. It is a natural reaction for children to stabilize a toy with their feet when possible.

Load the toy in the most onerous position with



1 Any suitable device, portable or non-portable, to apply a know force and rotation to the mandrel
2 (6 ± 0,5) N applied to the mandrel axis
3 Single wrap of self-adhesive tape
4 (90 ± 5 degrees) (test edge relationship to mandrel)
5 Variable angle to seek worst case situation
6 During the test the mandrel rotates one full revolution

Figure V.3: Edge test aparatus

a mass of (50 ± 0,5) kg on its standing or sitting surface for 5 min (for toys labeled suitable for over 36 months). For toys labelled as not suitable for children of 36 months and over, load the toy with a mass of (25 ± 0,2) kg. Where the toy is intended to bear the mass of more than one child at a time, test every sitting or standing area simultaneously. For toys where the mass of the child, by design, is distributed over various positions on the toy, distribute the prescribed load consistent with the recommended use of the toy. In this case, apply other test loads where consideration of the number of distribution points has to be made.

Determine whether the toy continues to conform to relevant requirements of this European Standard.

Stability
Load the toy in the most onerous position with a mass of (50 ± 0,5) kg on its standing or sitting surface. Place the toy on a (10± 1)° slope in the most onerous position with respect to stability. Determine whether the toy tips over.

APPENDIX W

Literature: Anthropometric design

To ensure the optimal fit of products to the people using them, the anthropometric design approach should be used. This will help to make decisions on size, adjustability and shape throughout the design process (Boeijen et al., 2020). This appendix describes the anthropometric design methods and decisions made.

W.0.1 Anthropometric measurements

Goal
Determine important anthropometric measurements for the user group. Define the user group in terms of weight and length, excluding as less children as possible.

Method
Johan Molenbroek presents a model to understand which steps are important in the anthropometric design process. The Anthropometric design process was used as guideline for determining the design guidelines. The content of the different boxes is described in the paper 'Enhancing the use of anthropometric data'.

There are two main user groups, caregivers and children. The children in the target group are aged 1 up to and including 3. There is no data available in DINED for children below two years old. Therefore, the TNO Growth Table for girls 0-4 years old (SOURCE) and the data available from the book CHILDDATA were combined to determine the values of the variables needed. The growth table only shows the numbers of statures and no extra body measurements, therefore, data available from the book childdata was used for body part measurements.

Results
The target group is children aged 1 up to and including 3 years old. Research revealed, age is an unsuitable parameter to design for due to the

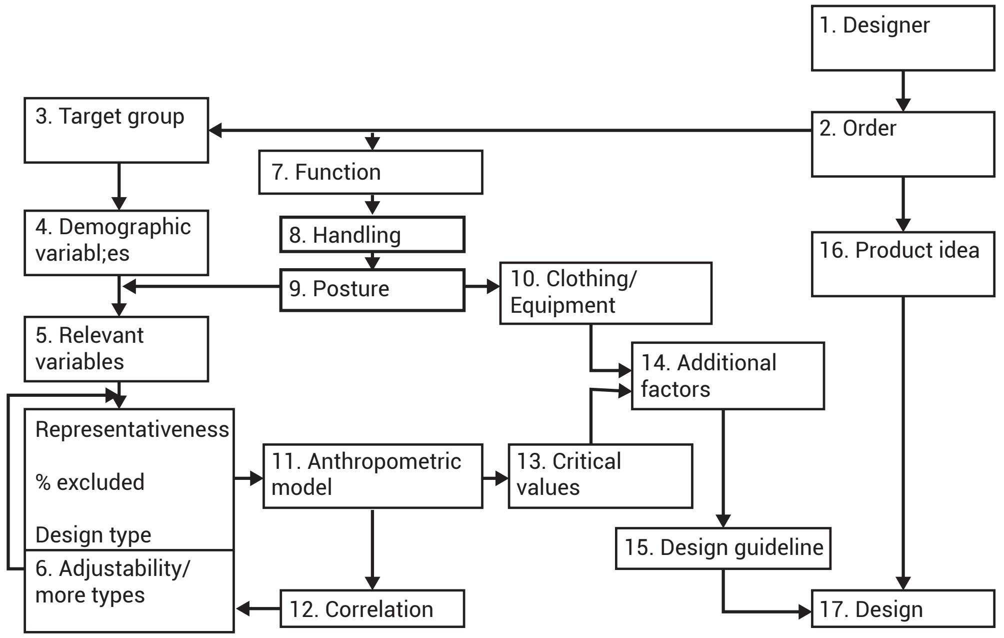


Figure W.1: The anthropometric design process [Molenbroek, 1993]

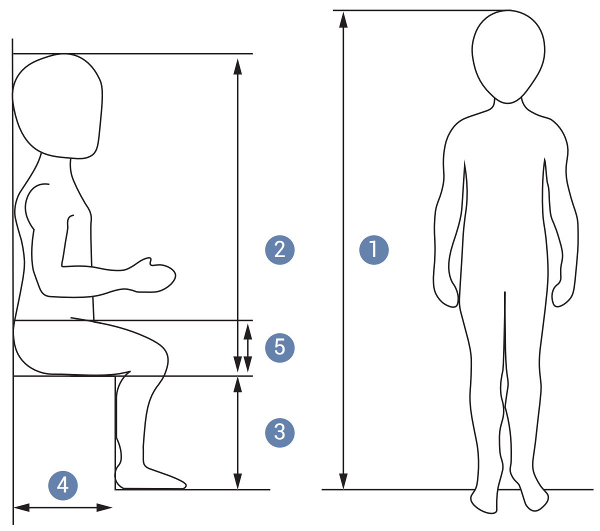


Figure W.2: Child body measurements (1 length, 2 crown to rump sitting height, 3 popliteal height, 4 buttock-popliteal depth)

large variation within age groups. Therefore, it is suggested to describe suitability requirements in length or weight, which have a strong positive correlation.

Stroller brands describe child's maximum weight and/or length the stroller is suitable for. Greentom (stroller company) mentions on their website; 'this stroller is suitable for children weighing up to 20 kg or 110 cm tall, whichever comes first.' They

	Dutch child female 12-14 months p3	Dutch child female 12-14 months p50	Dutch child male 3 years P95
Standing Length (1)	709 mm	773 mm	1093 mm
Crown to rump sit height (2)	455 mm	501 mm	619 mm
Sitting popliteal height (3)	138 mm	156 mm	285 mm
Sitting buttock popliteal depth (4)	155 mm	185 mm	293 mm
Weight	7,1 kg	9,6 kg	20 kg
Hip breadth sitting	unknown	unknown	222 mm
Thigh clearance sitting (5)	unknown	unknown	92 mm

Table W.1: Relevant measurements

mention this is approximately for children up to 4 years old. Comparing this to the growth diagram of TNO, this is in line with p95 weight and length of a three year old boy. This also corresponds to data from DINED; p95 body mass for male children aged three is 18 kg with corresponding stature of 1093 mm.

Concluding, by using p95 stature, five percent of the boys and 2 percent of the girls aged three is excluded (DINED). 110 cm stature corresponds with p64 of the mixed boys and girls population aged 4, meaning more than half of the four years old will fit in the vehicle. p95 body measurements and proportions are used. Figure X.3 (yellow) shows tallest possible child sitting.

The lower limit is determined combining data from CHILDDATA and the TNO datasheet. Girls are in general smaller than boys aged one, because of this, the growth table for girls is used. Looking at most strollers, they are suitable for children aged 6 months and up, from the point they can sit independently.

Table X.1 shows the data available from CHILDDATA for girls aged 1. Following the growth table, girls aged one: p2 weigh 7,75 kg and p2 are 69 cm, p50 weigh 9.5 kilograms and are 75 cm tall. p50 girls aged one is chosen as the lower limit. Figure X.3 (blue) shows the smallest child plotted as measured sitting straight up. The abdominal depth is unknown.

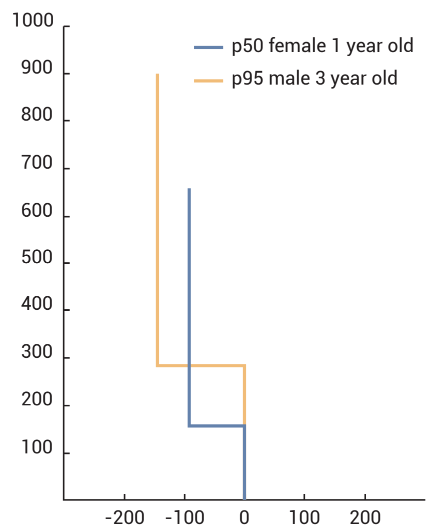


Figure W.3: Lower limit and upper limit measurements child sitting

By using p50 stature for one year old children, no two year old children are excluded according to data from DINED.

Conclusion

The cart should be designed such that children between 75 cm and 110 cm will fit in it, up to 20 kg, whichever comes first. The measurements in table Table X.1, together with Figure X.3 can be used as guidelines for designing the seat dimensions giving the upper and lower limit. Data for shoulder height when sitting is not available for children aged one. Figure X.4 shows the statures of the upper and lower limit of both children and adults that the cart should be designed for.

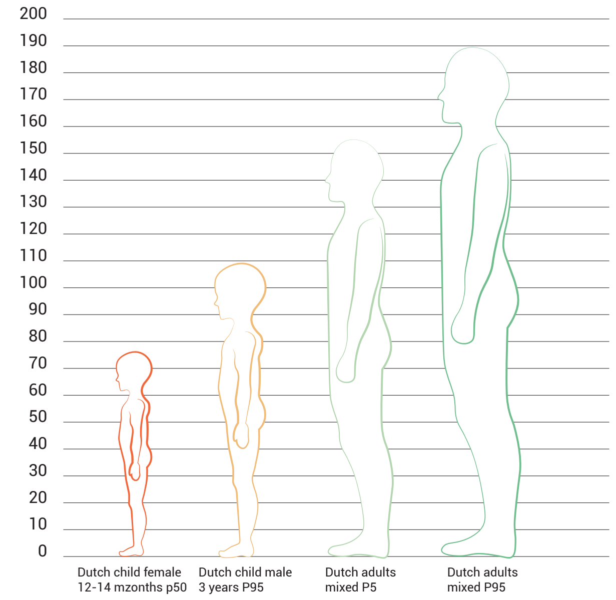


Figure W.4: Stature target group children and