GREENTOM GO

Designing a circular and sustainable hand cart

APPENDIX

Graduation Thesis
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APPENDIX

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A1 Key Stakeholders

People sometimes forget the network of directly or indirectly involved parties when producing and selling products. However, this network is important to keep in mind since some parties - also called stakeholders - can greatly influence the success of a product in the market. In this section, we identify all current Greentom stakeholders, their goals, and their influence on each other, to understand which key stakeholders especially to keep in mind when developing requirements for the Greentom Hand Cart.

A1.1 Identifying stakeholders

The stakeholders are identified by interviewing Greentom about their current product life cycle (see Section 2.3.2), further researching material sources from Greentom's material suppliers, and keeping in mind the European requirements for sustainable products.

According to Greentom's product life cycle, the Greentom classic is made out 97% recycled material (Red-dot-21, 2016) which mainly consists of recycled PP (rPP) in the form of structural beams and recycled PET (rPET) in the form of woven textile.

The use of recyclable materials and Greentom's aim to become a circular brand also fits the EU environment policy on moving more towards a circular economy and "protect the Union's natural capital, [...] [become a] resource-efficient, green, and competitive low-carbon economy, [and] [...] safeguard [...] citizens from environment-related pressures and risk to health and wellbeing" by 2020. (European Commission, 2014; European Commission, 2019)

The parts for Greentom products are produced by international manufacturers by means of (gas-aid) injection moulding, extrusion, foam moulding, knitting and weaving. The materials used by the manufacturers are provided by Greentom's material suppliers.

Repreve-branded rPET is provided as yarn to the textile manufacturers and made from post-consumer PET bottles. The rPP granulate is provided by recycled plastic granulate manufacturer and supplier Quality Circular Polymers (QCP) who are based in the Netherlands. QCP makes recycled PP and recycled (HD)PE granulate from pre-sorted post-consumer PP and (HD)PE plastic waste provided by waste recycling plant Suez.

Suez sorts Dutch household waste in the form of plastic packaging, but also metal packaging and drink cartons (PMD) (Greentom, 2017; SUEZ Nederland, 2016; Ketenakkoord Kusntstof Kringloop, 2016). Suez as well as other waste collecting companies also collects recyclable waste.

Avalex is one of the waste collecting companies in the Netherlands collecting waste for six municipalities in South-Holland, including Delft, and that provides PMD waste to Suez. (Avalex, 2019b)

A1.2 Defining key stakeholders

After identifying Greentom's stakeholders, the goals of these stakeholders and their influence on each other can be defined to understand how they would influence a future Greentom product on the market. Especially

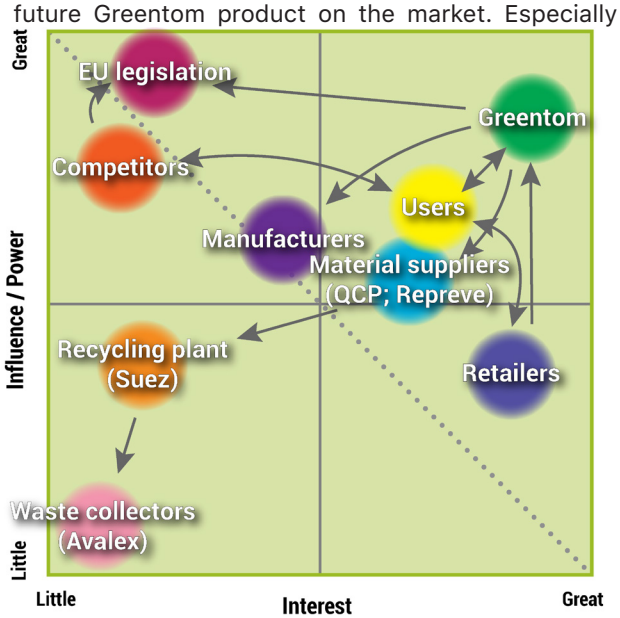


Figure 127 - Stakeholder diagram for selling a sustainable (circular), simple, easy to use, and affordably-priced hand cart which is suitable for young families with up to 3 small children.

key stakeholders may be kept in mind when developing requirements for the Greentom Hand cart.

By using the first two steps of Mike Ashby's five-step approach to "assessing a proposed articulation of a sustainable technological development", with the prime objective, based on the graduation project assignment for Greentom, being defined as "Selling a sustainable (circular), simple, easy to use, and affordably-priced hand cart which is suitable for young families with up to 3 small children", Table 6 and Figure 127 could be created. (Ashby, 2016)

Table 6 shows an inventory of the goals of all stakeholders and their concerns. From this list, an interest/influence diagram could be created as seen in Figure 127. The diagram shows to which extent all stakeholders are interested in Greentom trying to sell a sustainable, circular hand cart. Also, the extent of their influence on that prime objective is also indicated. The arrows point towards the stakeholder that the other stakeholder is dependent on.

As can be seen in Figure 127, the important stakeholders are the ones above the diagonal dotted line. The key stakeholders which have a great influence and great interest when Greentom will develop sustainable, circular hand carts are found in the upper-right quadrant. The important stakeholders, and especially the key stakeholders can be kept in mind when developing requirements for the Greentom Hand Cart. However, also similar products from competitors can be analysed to see where a market gap, a product market opportunity with few competitors but high user interest, might lie.

Table 6 - Identified stakeholders, their concerns, and their goals.

Stakeholder	*What do they want?*	*How will they try to get it?*
Greentom	Expand product portfolio; come up with game changer on the market; become a circular brand.	Design and produce great, new products, such as a sustainable Hand Cart, that users like to buy.
Users	Receive a good product.	Buy from Greentom or competitors.
Retailers (Retailers of mobility products for children)	Become popular and well visited by customers.	Have good products in store that customers want to buy.
Manufacturers ((gas-aid) injection moulding companies)	Interest from companies that need (gas-aid) injection moulded parts for their products.	Have a better or differentiating service from other (gas-aid) injection moulding companies.
Competitors	Beat competitors.	Have better or differentiating products.
EU legislation	Safety, consumer protection, sustainable future.	Set rules for producing and recycling products.
Recycling plant (Suez)	Provide separated post-consumer plastic per recyclable plastic type.	Collect easily recyclable plastic packaging materials.
Material suppliers (QCP, Repreve)	Provide rPP and r(HD)PE as granulate to specifications, and get interest and future collaboration from Design Studios.	Buy well recycled separated types of material. Being able to process and tweak the plastic material properties to specification.
Waste Collectors (Avalex)	A pure recyclable waste stream to provide to recycling plants	Find methods to well collect recyclable waste streams.

A2 List of Hand Carts

	Hand Cart	Price (€)	Wheels dimension (mm)	Weight (kg)	Inner Volume (cm)	Compactness (cm)	Aesthetics	Comfort	Load capacity (kg)	Comment
	10T - Foldy Trolley	149		12,85	104 x 54 x 62		3	3		*1
	Beach Wagon Lite	290	Ø290, w:	13,6	95 x 65 x 65	103 x 55 x 18	9	8		*2
	Beachtrekker Life	289	Ø260, w:85	16	78 x 50 x 32	66 x 63 x 34	7	2	100	*3
	Berg Toys - Berg L	239		26,8	87 x 44 x 23	94 x 60 x 37	4	1		*4
	Berger - Bollerwagen	100		13,3	129 litre	40 x 20 x 80	3	3		*5
	Bremermann - Out & Active	75		11,4	81,5 x 61 x 25		3	3	70	*6
	Coocarooc - Breeze	595		18			9	9		*7
	Deuba - Bollerwagen	63		16	84 x 44 x 27,5		6	4	100	*8
	Eckla - Express	299		16	82 x 45 x 25	60 x 57 x 23	6	2		*9
	Eurotrail - Beach Car Sunny	139		11,2	76 x 50 x 18		4	3	75	*10

	Fuxtec - Bollerwagen FX-CT800	199		13,4			6	7	75	*11
	Hauck - Eco Mobil	250		17			8	9	50	*12
	Hudora - Überländer Comfort	250		15,5	30 x 39 x 24		7	5	100	*13
	Hudora - Überländer Premium	400		13,1			7	8		*14
	Keenz - Stroller Wagon	332		14,5			9	7	100	*15
	Kyboka (Kickstarter)	500		12,5	135L		9	5	50	*16
	Leggero - GoGo	269		10	90x42x37		8	8		*17
	MacSports - Beach Wagon	110		10			6	4	70	*18
	MacSports - Mac Wagon	124	Ø236	10,2	81 x 43 x 25 cm	76 x 52 x 21	6	3		*19
	Micro - Wagon	109		10	85 x 42 x 29	40 x 20 x 80	4	2	50	*20
	NPK - Walking wagon	500					9	8		*21
	Pinolino - Bolderkar	150		16	74 x 41 x 25	92 x 61 x 34	4	3	100	*22

	Puky	230		9,6	34 x 33 x 60 cm	80 x 31 x 51	8	7		*23
	Rambler - Explorer 120	1799		36			8	8		*24
	Rambler - Explorer 80	1499		33			8	8		*25
	Samax - Offroad	90		11			4	6	100	*26
	Travel & Co - Bolderkar	79		9,3	95 x 47 x 34	90 x 37 x 18	4	3		*27
	UlfBo - UlfBo Comfort	495		10,8	90 x 40 x 25		7	7	80	*28
	Veer - Cruiser	530		15			9	10		*29
	Active-Outdoor	169		14	80 x 45 x 25	30 x 58 x 77			75	*30

Comments	
*1	https://www.camping-outdoor.eu/en/outdoor-equipment/trolleys-carts/collapsible-carts/10t-foldy-trolley-foldable-handcart-50-kg-lifting-capacity/a-1193763705/
*2	https://www.beachwagon.company/en/outdoor-wagons/art/beachwagon-lite-soft-red
*3	https://www.youtube.com/watch?v=_Gr_huq-7HE https://www.expertentesten.de/garten/bollerwagen-test/ https://www.beachtrekker.de/collections/beachtrekker-life
*4	https://www.anwb.nl/vrije-tijd/test/bolderkarren-2015/berg-l
*5	https://www.fritz-berger.de/artikel/berger-bollerwagen-811
*6	https://www.amazon.de/bremermann%C2%AE-Bollerwagen-Handwagen-Einkaufswagen-faltbar/dp/B00JEX54B4 https://www.expertentesten.de/garten/bollerwagen-test/
*7	http://www.coocarooc.com/breeze/ https://www.sparkdesign.nl/en/projects/coocarooc-breeze-bolderwagen-kids-cart
*8	https://www.deuba24online.de/bollerwagen-blau-faltbar-mit-abnehmbarem-dach.html https://www.idealo.de/preisvergleich/OffersOfProduct/5799456_-bollerwagen-faltbar-mit-abnehmbarem-dach-deuba.html https://www.falt-bollerwagen.de/deuba-bollerwagen-faltbar-mit-abnehmbarem-dach/
*9	https://www.bolderkar-shop.nl/eckla-eckla-express-luchtbanden.html
*10	https://www.obelink.nl/eurotrail-beach-car-robbie.html

*11	https://www.fuxtec.de/fuxtec-bollerwagen-fx-ct800-mit-uv-geschuetztem-sonnendach-schiebegriff-und-innenraumverlaengerung-gra https://www.expertentesten.de/garten/bollerwagen-test/
*12	https://www.amazon.de/Hauck-Eco-Mobil-Bollerwagen-Transportwagen/dp/B00WEN7IGU https://www.expertentesten.de/garten/bollerwagen-test/
*13	https://www.hudora.de/produkte/bollerwagen/hudora-ueberlaender-10-gruen
*14	https://www.hudora.de/produkte/bollerwagen/hudora-ueberlaender-alu-12
*15	https://auswandererguide.com/product/keenz-stroller-wagon/
*16	https://www.kyboka.com/
*17	https://www.bikebox-shop.de/kinderfahrzeuge/puky-kinderfahrzeuge/puky-bollerwagen-ab-1-5-jahr/leggero-gogo-bollerwagen/a-7202/ Leggero GoGo manual
*18	https://macsports.com/collections/for-beach/products/beach-wagon-with-side-table?variant=6969586122806
*19	https://www.bolderkar-shop.nl/opvouwbare-bolderkar/macwagon/ https://macsports.com/products/mac-wagon
*20	https://www.bolderkar-shop.nl/micro-wagon-opvouwbare-bolderkar.html https://www.micro-step.nl/en/micro-wagon-foldable.html
*21	https://npk.nl/project/walking-wagon/
*22	https://www.anwb.nl/vrije-tijd/test/bolderkarren-2015/pinolino-til
*23	https://www.trapautodealer.nl/bolderkar-puky-h25-ceety-rood.html https://www.anwb.nl/vrije-tijd/test/bolderkarren-2015/puky-h-25-ceety
*24	https://www.rambler.company/nl/bolderwagens https://docplayer.org/58154701-Rambler-user-guide-gebrauchsanweisung-de-rambler-daytrack-rambler-rambler-explorer-explorer-65-rambler-80-120-le.html
*25	https://www.rambler.company/nl/bolderwagens https://docplayer.org/58154701-Rambler-user-guide-gebrauchsanweisung-de-rambler-daytrack-rambler-rambler-explorer-explorer-65-rambler-80-120-le.htmld
*26	https://www.expertentesten.de/garten/bollerwagen-test/
*27	https://www.anwb.nl/vrije-tijd/test/bolderkarren-2015/travel--co-opvouwbare-bolderkar
*28	https://www.ulfbo.info/ulfBo-Comfort https://www.bolderkar-shop.nl/ulfbo-ulfbo-comfort.html
*29	https://www.goveer.com/cruisers/
*30	https://www.bolderkar-shop.nl/opvouwbare-bolderkar-blauw-met-huif-en-mand.html

A3 Hand cart norms

To find out whether the addition of a pushing bar would bring with the necessary introduction of norms, several hand carts and their norms are analysed, several hand cart producers are contacted if no indication of norms are shown on their website, and the Dutch Normalisation Institute NEN is contacted by e-mail.

Strollers should comply with the NEN-EN 1888, 1, 2 norms: Child use and care articles — Wheeled child conveyances (Intertek, n.d.). In addition to this, the Greentom stroller also complies with the NEN-EN 71 norms - Safety of toys, which concerns the allowed material types and sizes if the children can bite or nibble on it. To find out what norms current hand carts comply with, six hand carts are analysed on their norms:

Veer Cruiser

The Veer Cruiser (Figure 128) claims to be a "[combination of] a premium stroller and a rugged wagon" (Veer, n.d.), and can be both pushed and pulled. Interestingly, when pushed, the cart has fixed wheels in the front, which proves to be uncomfortable during my tests. It features a foot brake for the back wheels and children safety straps.

The Veer Cruiser complies to the following norms:

- ASTM F833 - Standard consumer safety performance specifications for carriages/buggies
- JPMA certified

Figure 128 - The Veer Cruiser

UlfBo

The UlfBo (Figure 129) is a foldable hand cart. It can only be pulled, but also features a foot brake for the back wheels.

No norms for UlfBo could be found, and email contact gave no response.

Figure 129 - The UlfBo Comfort

Leggero Gogo

The Leggero Gogo (Figure 130) is a versatile, everyday hand cart (Bike-Bep24, n.d.), which can only be pulled.

According to an email exchange with Leggero, the hand cart does not comply to any norms.

Figure 130 - The Leggero GoGo

Leggero Enso Surf

According to Leggero, the Leggero Enso Surf (Figure 131) is a bike attachment, stroller, and jogger (Leggero, n.d.), which can be pushed by hand or attached to the back of a bike. It features a hand brake for the back wheels, and safety straps for the child.

The Leggero Enso Surf complies to the following norms:

- TÜV certification (crash tests/stiffness tests)
- DIN 31000-2:1987 (towing hinges)
- EN-1888:2012 (Standard for pushchairs)
- Standard EK2/AK2,1/13-01-2013 (bike trailer)
- ISO 9001 (Social enterprise)

Figure 131 - The Leggero Enso Surf

Beach Wagon Lite

The Beach Wagon Lite (Figure 132) is a "lightweight walking wagon" that can be used for different environments including the beach (BeachWagonCompany, 2019). It can only be pulled.

No norms for the Beach Wagon Lite could be found, and email contact gave no response.

Figure 132 - The Beach Wagon Lite

Rambler Explorer

Rambler (n.d.) claims that the Rambler Explorer 65 (Figure 133) is the most compact hand cart of the Explorer series fitting a maximum of five children. Finally, it has a hand brake for the front wheels and children safety straps. The Rambler Explorer 65 can be pulled and optionally pushed with extra pushing beams.

The Rambler Explorer complies to the following norms:

- NEN-EN 1888 Child care articles - wheeled children conveyances - safety requirements and test methods.
- NEN-EN 71-1,2,3 Safety of toys.

Figure 133 - The Rambler Explorer 65

Looking at the different hand carts and their norms, it can be assumed that if a pushing bar is added to the hand cart, then the hand card are required to have children safety straps and at least one hand or foot brake. These may be the same regulations as stated in the NEN-EN 1888 norms.

Furthermore, normalisation consultant Mr Goeyens confirms this by e-mail, saying: "At first sight, there are no specific norms for hand carts. The norm for strollers (EN 1888-parts 1 and 2) could potentially be used as inpiration. The same counts for the EN 15918:2011+A2:2017 (Cycle trailers - Safety requirements and test methods)."

A4 Online users' experiences

A desk research is conducted in order to find what context users use the hand cart in, the current problems that users encounter when using their hand cart, and what they prefer or like in a hand cart.

Several online forums, blogs, and retailers' websites are consulted during the gathering of information.

Context

The hand cart is used on campings, the forest, at attraction parks, and on the beach (ANWB, 2015)

Some users mention using the hand cart only for short walks or at the attraction park, using the hand cart mostly twice a year. (Zwangerschapspagina, 2017abc)

It is mentioned that children like to stand in the hand cart which could lead to unhandy situations. Another user mentions that the children should be restrained in the hand cart in such a way that they can play, but cannot stand up. (Forum Viva, 2012; Forum Viva, 2018; Zwangerschapspagina, 2017abc; GrootGezin, n.d.)

Design challenges

Mentioned problems are that the hand cart is difficult to use in sand, on slopes (due to not having a hand brake), and riding onto or off of a sidewalk. (Forum Viva, 2012; Forum Viva, 2018; Zwangerschapspagina, 2017abc; GrootGezin, n.d.)

Users mention that it is difficult to use the hand cart for long walks, and that pulling the hand cart is more difficult than pushing the hand cart.(Forum Viva, 2012; Forum Viva, 2018; Zwangerschapspagina, 2017abc; GrootGezin, n.d.)

A user mentions that it is not pleasant to not be able to see the children when pulling them behind themselves, especially in the city. Alternatives are mentioned such as two strollers or one stroller and a textile baby carrier. (Forum Viva, 2012; Forum Viva, 2018; Zwangerschapspagina, 2017abc; GrootGezin, n.d.)

What is interesting, is that hand carts are not allowed onto a train. (Forum Viva, 2012; Forum Viva, 2018; Zwangerschapspagina, 2017abc; GrootGezin, n.d.)

Preferences

Some mention wanting to have a sturdy hand cart, one that can be made ready to be used fast, and which is compact to take along. Also, enough belongings have to fit the hand cart.(Forum Viva, 2012; Forum Viva, 2018; Zwangerschapspagina, 2017abc; GrootGezin, n.d.)

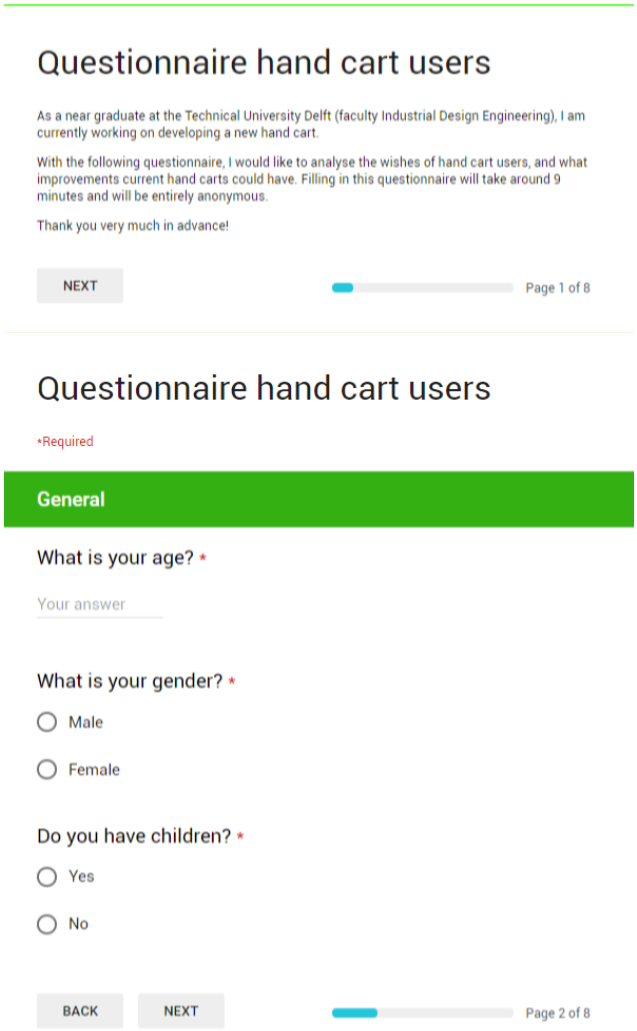
Some mention preferring air tyres, an umbrella or tent roof above the hand cart to prevent it from getting wet, or a lock to prevent it from getting stolen. (Forum Viva, 2012; Forum Viva, 2018; Zwangerschapspagina, 2017abc; GrootGezin, n.d.)

Furthermore, a user mentions wanting to have a baby car seat inside the hand cart. (Forum Viva, 2012; Forum Viva, 2018; Zwangerschapspagina, 2017abc; GrootGezin, n.d.)

Positive aspects

Some users mention feeling pity for parents with two strollers, apparently because one hand cart can serve the function of two strollers just as well. (Forum Viva, 2012)

A5 Questionnaire questions



Questionnaire hand cart users

As a near graduate at the Technical University Delft (faculty Industrial Design Engineering), I am currently working on developing a new hand cart.

With the following questionnaire, I would like to analyse the wishes of hand cart users, and what improvements current hand carts could have. Filling in this questionnaire will take around 9 minutes and will be entirely anonymous.

Thank you very much in advance!

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Questionnaire hand cart users

*Required

General

What is your age? *

Your answer

What is your gender? *

Male

Female

Do you have children? *

Yes

No

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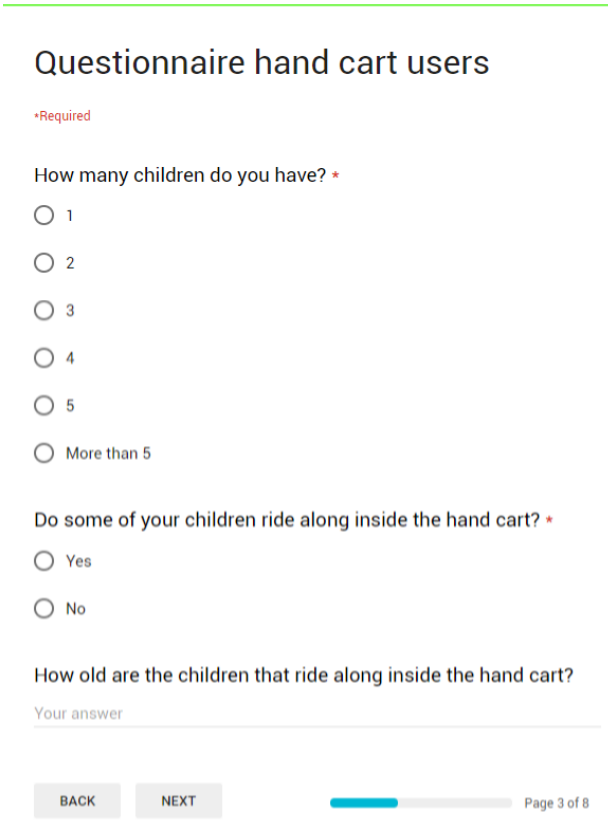

Questionnaire hand cart users

*Required

How many children do you have? *

1

2

3

4

5

More than 5

Do some of your children ride along inside the hand cart? *

Yes

No

How old are the children that ride along inside the hand cart?

Your answer

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Questionnaire hand cart users

*Required

Your hand cart

I would like to ask for you opinion on the hand cart(s) that you have used/use.

Which hand cart(s) do you use at the moment? *
(Multiple answers are possible)

☐ Deuba - Bollerwagen

☐ Puky

☐ Berg Toys - Berg L

☐ Micro - Wagon

☐ Hudora - Überländer Premium Complete

☐ Beach Wagon Lite

☐ Rambler - Explorer 120

☐ Bremermann - Out & Active

☐ Fuxtec - Bollerwagen

☐ Coocarooc - Breeze

☐ Travel & Co - Bolderkar

☐ MacSports - Mac Wagon

☐ Beachtrekker Life

☐ Samax - Offroad

☐ 10T - Foldy Trolley

☐ Leggero - GoGo

☐ UlfBo - UlfBo Comfort

☐ Keenz - Stroller Wagon

☐ MacSports - Beach Wagon

☐ Eurotrail - Beach Car Sunny

☐ Eckla - Express

☐ Berger - Bollerwagen

☐ Pinolino - Bolderkar

☐ Hudora - Überländer Comfort

☐ Veer - Cruiser

☐ Hauck - Eco Mobil

☐ Kyboka

☐ Rambler - Explorer 80

☐ Other:

What do you use your hand cart for? *
(Multiple answers are possible)

☐ For transporting children

☐ For transporting my pets

☐ For transporting things

☐ Other:

What are the reasons that you specifically chose this hand cart? *

Your answer

What are some of the problems that you experience with the current hand cart? *

Your answer

Which aspects in the current hand cart are you happy with? *

Your answer

For what distances do you use the hand cart? *

○ Short distances (for example, from the car to the camping/beach; doing groceries in the neighbourhood)

○ Long distances (for example, long walks in the forest)

○ Both short and long distances

Could you indicate how many kilometers per time? *
Please give two answers if you use the hand cart both for short and long distances.

	1	2	3	4	5	6	7	8	9	≥ 1
Distance in km:	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Where do you mostly use the hand cart? *
(Multiple answers are possible)

☐ At the camping

☐ At the amusement park

☐ On the beach

☐ In the town/village

☐ At a festival/event

☐ In the forest

☐ At the playground

☐ In the park

☐ At the zoo

☐ Other:

In which context do you use the hand cart? *
(Multiple answers are possible)

☐ During a holiday

☐ On a day out

☐ During a walk

☐ During events/festivals

☐ When doing chores/groceries

☐ Other:

How frequently do you use the hand cart per year? *

○ Seldom (At most, 2 times a year.)

○ From time to time (Multiple times a year.)

○ Often (Multiple times per month.)

How many times per year/per month is that? *

Your answer

On the next page, you will be asked about which aspects you find important in a hand cart.

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Questionnaire hand cart users

*Required

Aspects hand cart

Indicate to which degree you find the following aspects important.

Indicate to which degree you find each aspect important in relation to the other aspects.
(1 = least important, 8 = most important). You can use each number only once!

	1	2	3	4	5	6	7	8
Environmental friendliness	○	○	○	○	○	○	○	○
Weight	○	○	○	○	○	○	○	○
Compactness (folded)	○	○	○	○	○	○	○	○
Appearance (how attractive it looks)	○	○	○	○	○	○	○	○
Comfort for passengers (children/pets)	○	○	○	○	○	○	○	○
Manoeuvrability (how well it steers)	○	○	○	○	○	○	○	○
Personalisable (colour/patterns)	○	○	○	○	○	○	○	○
Volume	○	○	○	○	○	○	○	○

Which aspects are first priority when buying a hand cart? *
Choose a maximum of 4 aspects

- ☐ Compactness (folded)
- ☐ Comfort for passengers (children/pets)
- ☐ Personalisable (colour/patterns)
- ☐ Volume
- ☐ Manoeuvrability (how well it steers)
- ☐ Environmental friendliness
- ☐ Weight
- ☐ Appearance (how attractive it looks)
- ☐ Other:

Which previously unmentioned aspects do you also find important in a hand cart?
Which ranking in the list would they get?

Your answer

How much would you pay for the ideal hand cart? *

- ○ Tot 100 euros
- ○ 100 - 200 euros
- ○ 200 - 300 euros
- ○ 300 - 400 euros
- ○ 400 - 500 euros
- ○ 500 - 600 euros
- ○ 600 - 700 euros
- ○ 1000 - 1500 euros
- ○ 1500 - 2000 euros

On the next page, I would like to know your opinion on several current hand carts

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Current hand carts

Below, I would like to ask for your opinion about seven kinds of hand carts.

Hand cart #1

This hand cart has cushions for children, a strong frame, big wheels, and is foldable.
It costs 495 euros and weighs 11 kg.

How attractive do you think the above hand cart looks? (#1) *

	1	2	3	4	5	6	7	
Unattractive	○	○	○	○	○	○	○	Attractive

How likely would you consider buying the above hand cart? (#1) *

	1	2	3	4	5	6	7	
Unlikely	○	○	○	○	○	○	○	Most likely

Please explain your answers: (#1)

Your answer

Hand cart #2

This hand cart has a strong frame, big wheels, and can remain standing on its wheels when it is folded.
It costs 290 euros and weighs 16 kg.

How attractive do you think the above hand cart looks? (#2) *

	1	2	3	4	5	6	7	
Unattractive	○	○	○	○	○	○	○	Attractive

How likely would you consider buying the above hand cart? (#2) *

	1	2	3	4	5	6	7	
Unlikely	○	○	○	○	○	○	○	Most likely

Please explain your answers: (#2)

Your answer

Hand cart #3

This hand cart is made of wood, has a metal frame, big wheels, and a hand break.
It costs 150 euros en weighs 16 kg.

How attractive do you think the above hand cart looks? (#3) *

	1	2	3	4	5	6	7	
Unattractive	○	○	○	○	○	○	○	Attractive

How likely would you consider buying the above hand cart? (#3) *

	1	2	3	4	5	6	7	
Unlikely	○	○	○	○	○	○	○	Most likely

Please explain your answers: (#3)

Your answer

Hand cart #4

This hand cart is possible to push, is foldable, and has extra accessories such as a roof and extra baskets.
It costs 330 euros and weighs 15 kg.

How attractive do you think the above hand cart looks? (#4) *

	1	2	3	4	5	6	7	
Unattractive	○	○	○	○	○	○	○	Attractive

How likely would you consider buying the above hand cart? (#4) *

	1	2	3	4	5	6	7	
Unlikely	○	○	○	○	○	○	○	Most likely

Please explain your answers: (#4)

Your answer

Hand cart #5

This hand cart has small wheels, and can be folded compactly.
It costs 100 euros and weighs 13 kg.

How attractive do you think the above hand cart looks? (#5) *

	1	2	3	4	5	6	7	
Unattractive	○	○	○	○	○	○	○	Attractive

How likely would you consider buying the above hand cart? (#5) *

	1	2	3	4	5	6	7	
Unlikely	○	○	○	○	○	○	○	Most likely

Please explain your answers: (#5)

Your answer

Hand cart #6

This hand cart has big wheels and is designed to look like a fast, attractive race-car.
It costs 270 euro and weighs 10 kg.

How attractive do you think the above hand cart looks? (#6) *

	1	2	3	4	5	6	7	
Unattractive	○	○	○	○	○	○	○	Attractive

How likely would you consider buying the above hand cart? (#6) *

	1	2	3	4	5	6	7	
Unlikely	○	○	○	○	○	○	○	Most likely

Please explain your answers: (#6)

Your answer

Hand cart #7

This hand cart is suitable for 5 children to sit in, is strong, has big wheels and a hand break.
Next to this, there is a stair to easily step into the cart.
It costs 1500 euros and weighs 33 kg.

How attractive do you think the above hand cart looks? (#7) *

	1	2	3	4	5	6	7	
Unattractive	○	○	○	○	○	○	○	Attractive

How likely would you consider buying the above hand cart? (#7) *

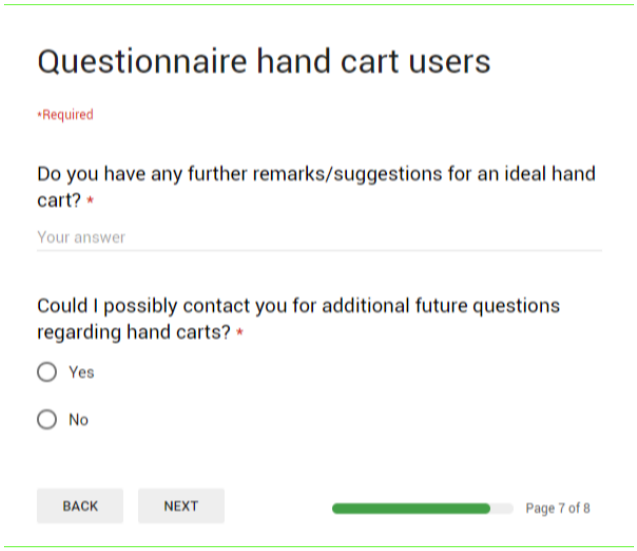
	1	2	3	4	5	6	7	
Unlikely	○	○	○	○	○	○	○	Most likely

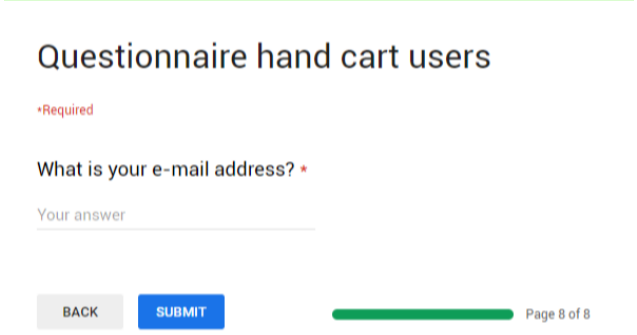
Please explain your answers: (#7)

Your answer

Almost done! On the next page, there will be one final question to this questionnaire.

BACK NEXT Page 6 of 8


Questionnaire hand cart users
*Required
Do you have any further remarks/suggestions for an ideal hand cart? *
Your answer
Could I possibly contact you for additional future questions regarding hand carts? *
Yes
No
BACK
NEXT
Page 7 of 8


Questionnaire hand cart users
*Required
What is your e-mail address? *
Your answer
BACK
SUBMIT
Page 8 of 8

A6 Questionnaire - Full results

In this section, the results of the questionnaire sent out to hand cart users of Dutch and German nationality are presented here. All graphs show the combined results of 16 people of Dutch nationality and 4 people of German nationality unless stated otherwise.

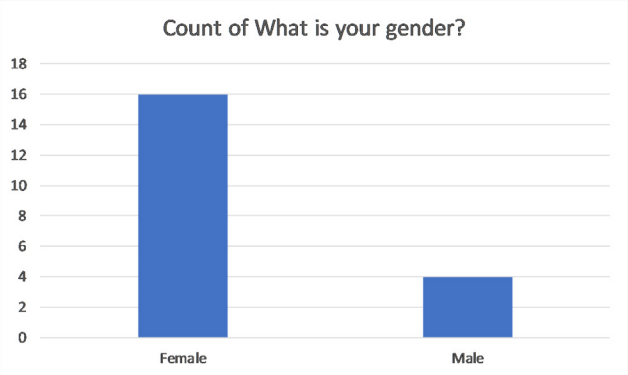


Figure 134 - User's gender

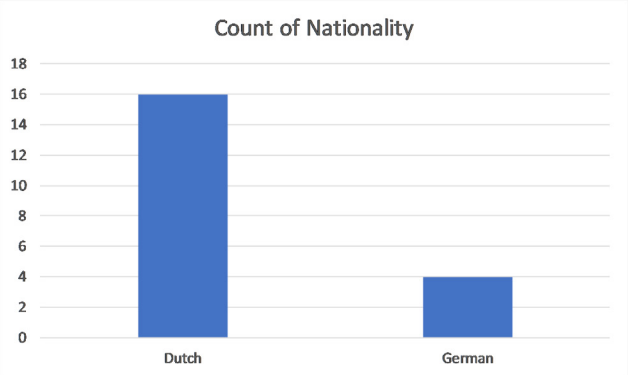


Figure 135 - User's nationality

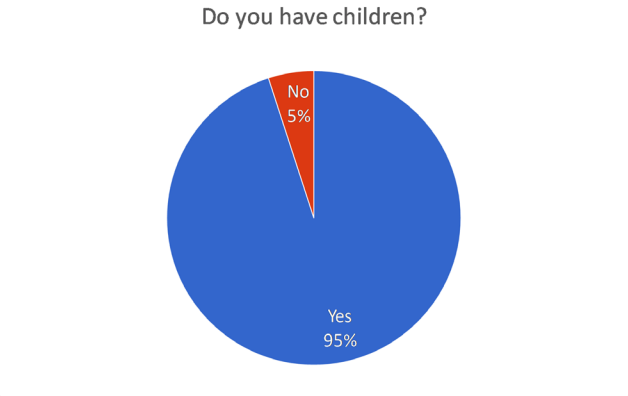


Figure 136 - Presence of children in the family

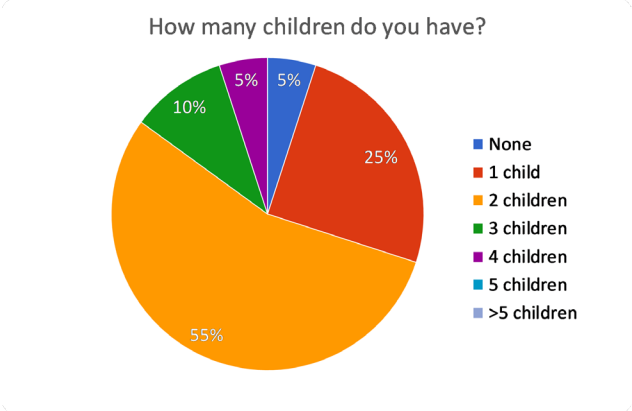


Figure 137 - Number of children per user

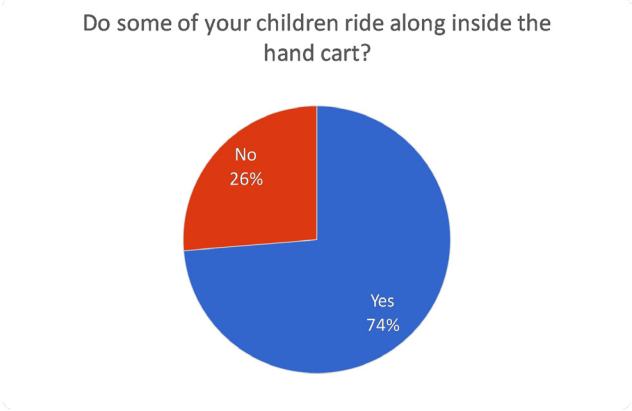


Figure 138 - Percentage of users whose children ride inside the cart

How old are the children that ride along inside the hand cart?
none
7, 4
2
1, 3
1
4
4, 5
3, 5
1.5
3
From the moment they can sit independently until their 5th/6th year.
3
3, 4
<8
2
3 and 5

Figure 139 - Passenger's age

Figure 140 - Type of context during use

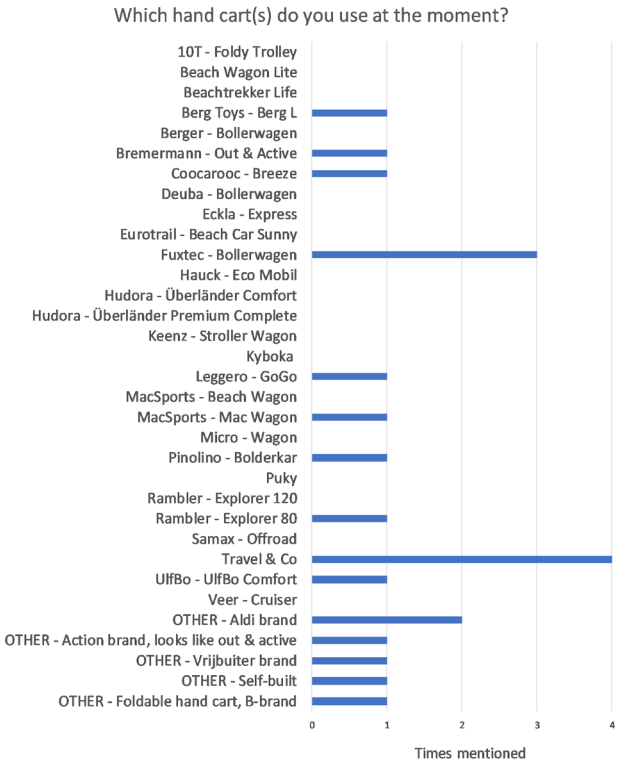


Figure 141 - Hand carts owned by users

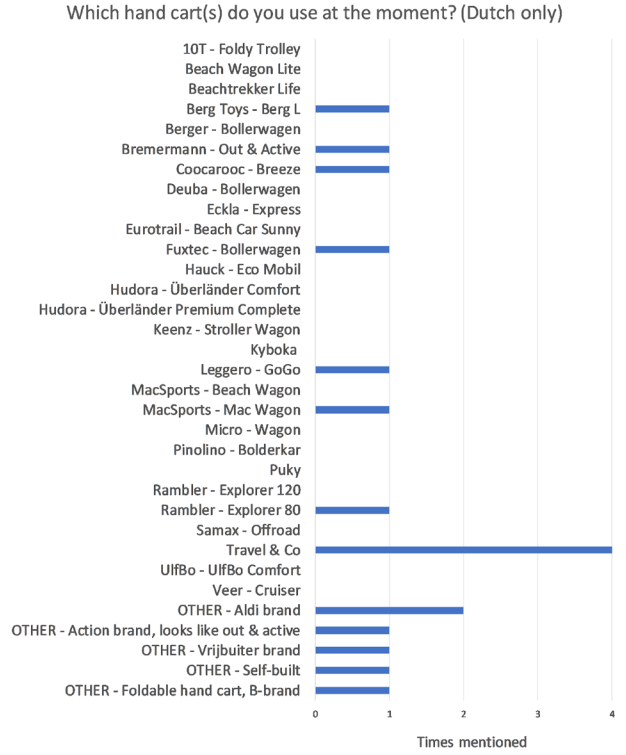


Figure 142 - Hand carts owned by users (Dutch users only)

What are the reasons that you specifically chose this hand cart?
Came across it
Affordable
Received as a gift
Affordable, Foldable
Foldable
We have had it.
Foldable
Foldable
.
For excursions where the kids have to rest in between or swimming pool etc where we bring a lot of stuff along.
Push bar
Affordable, to transport things
Sturdy, and good for the beach
Came across it, Affordable
Foldable: Easy to store and fits in the car.
Design, reviews of other users, (inner) dimensions
Sturdy, Big tyres, storage benches
Received as a gift
Received as a gift
Sturdy on rough terrain

Figure 143 - Reasons for choosing hand cart

What are some of the problems that you experience with the current hand cart?
Steering
Small handlebar grip, and small, hard wheels.
The pulling handlebar cannot be shoved more upwards, and we would have preferred a normal handlebar grip for the ergonomics and easy of pulling.
The nobs that hold the textile on the frame constantly jump off.
It folds very roughly, I would like the wheels to be a able to pivot, right now I cannot take all curves well.
A bit feeble sometimes.
Difficult to manouvre with.
Easily tips over when folded
.
Not accepted in all public transports.
I prefer air tyres.
-
The zippers and push-buttons can break.
-
Not enough things fit inside.
Not as easy to deconstruct as was expected.
-
Wheels are solid and are causing a lot of vibrations.
Too heavy, too little space.
The axes of the wheels poke out, mounting the front wheel is difficult sometimes.

Figure 144 - Problems with current hand cart

Which aspects in the current hand cart are you happy with?
Most of it.
Light, easily foldable, compact
Enough space for 2 toddlers and some things.
Foldability
When it is finally folded, then it is very compact to take along. Unfolded, it is ideal to transport things.
Foldable
Foldeability
Light to pull
.
Easy to pull, foldable
It folds well, you can push it, and it has a tent top.
Handlebar works well, pulls easily, easy to fold and unfold.
Sturdy, and drives though sand.
Easy to fold, rides fine (pivoting wheels in front), handlebar adjustable in height.
Functions as expected.
Possible to pull without too much force.
Stable, drives lightly.
Well foldable
Good tires
Stability and use on terrain

Figure 145 - Positive aspects of current hand cart

How many times per year/per month is that?
1
3
4
4
5
5
5
8
10
10
15
18
25
48
36
36
144
1
2
5

Figure 146 - Use frequency per year

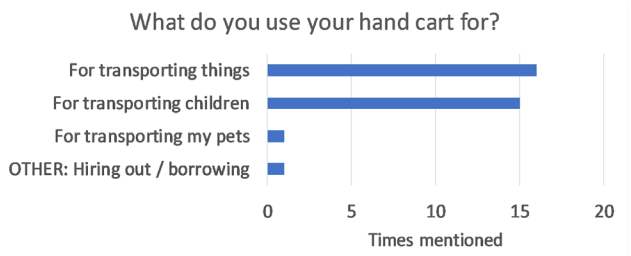


Figure 147 - Type of use per hand cart

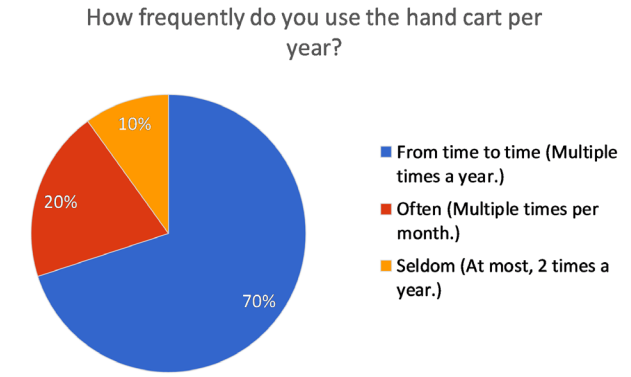


Figure 148 - Frequency of use per year

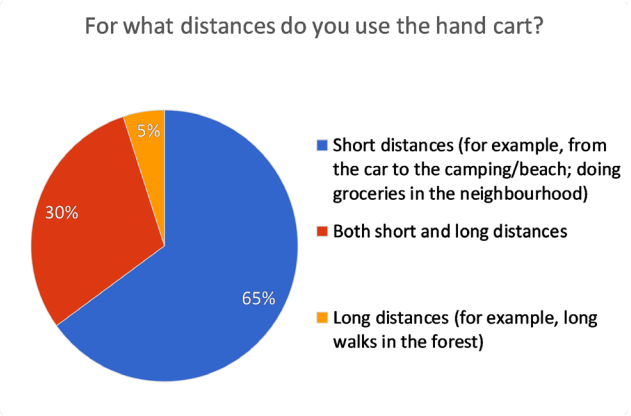


Figure 149 - Type of distance per use

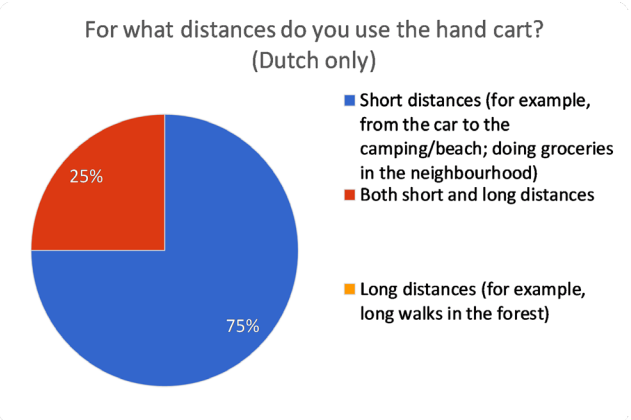


Figure 150 - Type of distance per use (Dutch only)

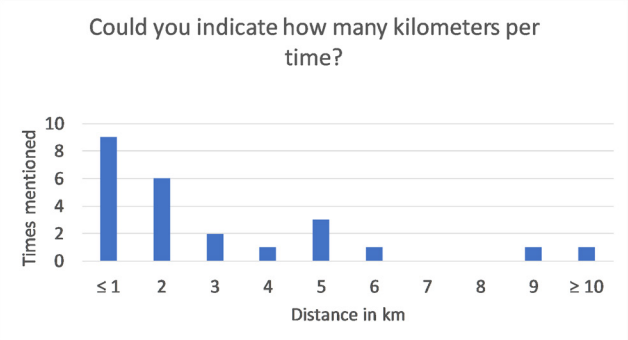


Figure 151 - Kilometers travelled per use

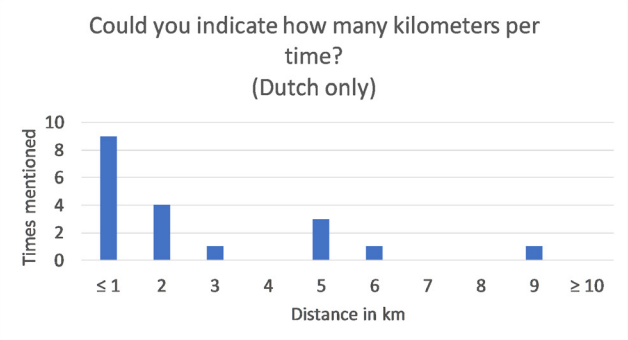


Figure 152 - Kilometers travelled per use (Dutch only)

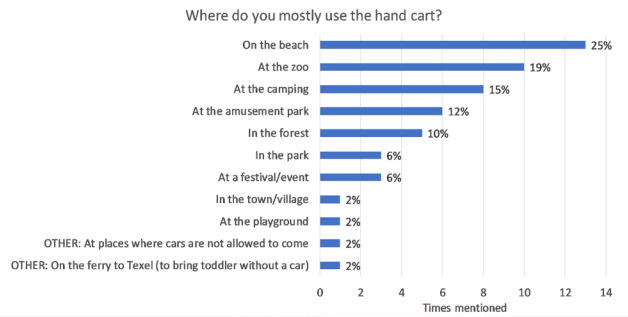


Figure 153 - Locations of use

Figure 154 - Type of context during use

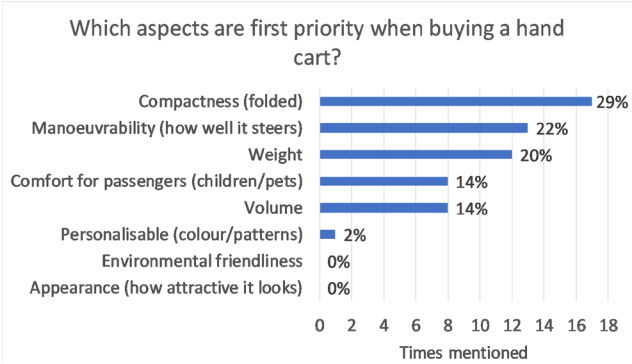


Figure 155 - Users' most valued attributes

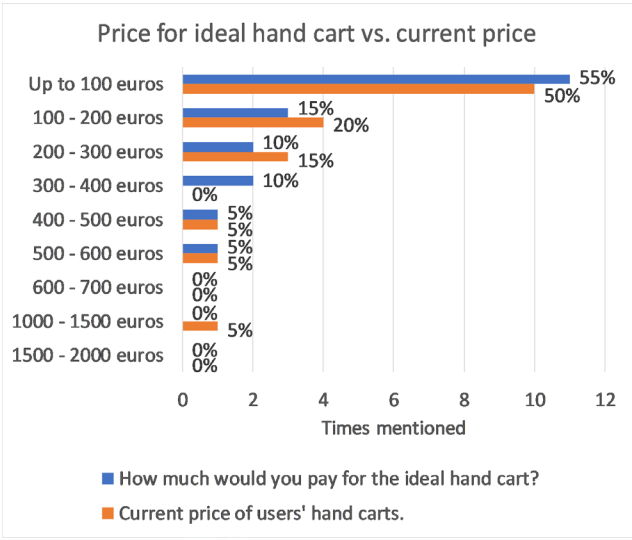


Figure 156 - Users' price for an ideal hand cart vs their current price

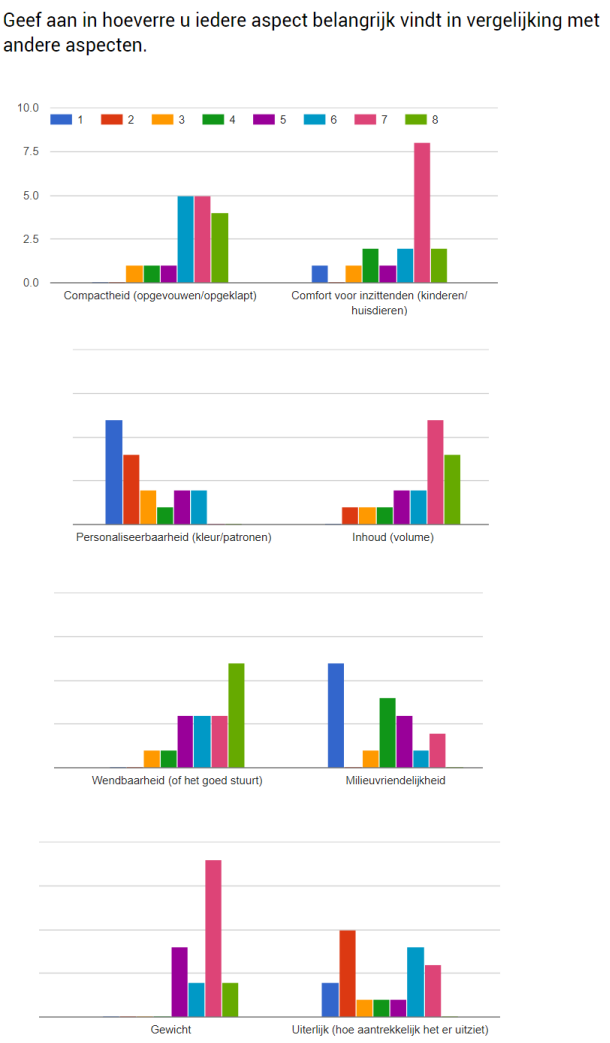
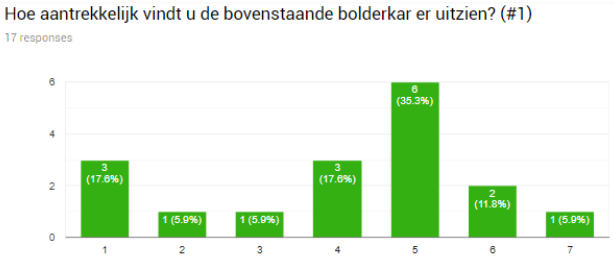


Figure 157 - Importance per aspect (Dutch only)



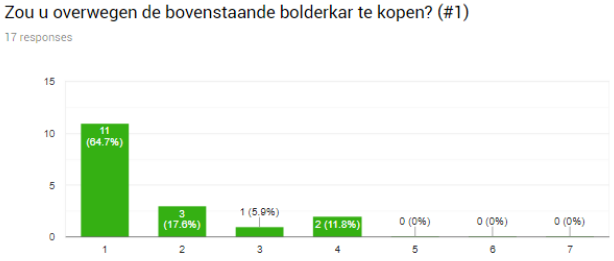
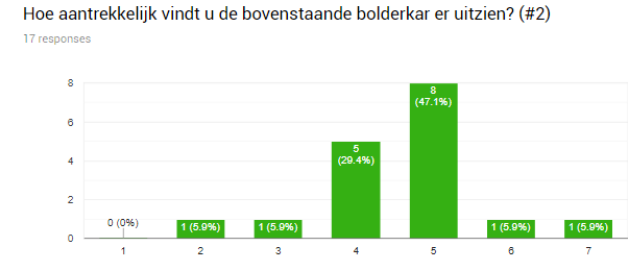


Figure 158 - Evaluation first hand cart (Dutch only)



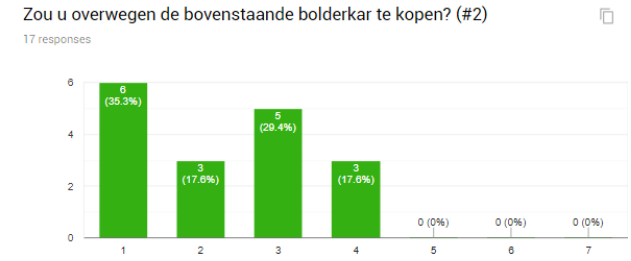
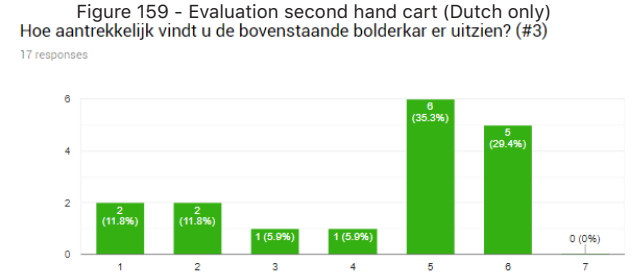


Figure 159 - Evaluation second hand cart (Dutch only)



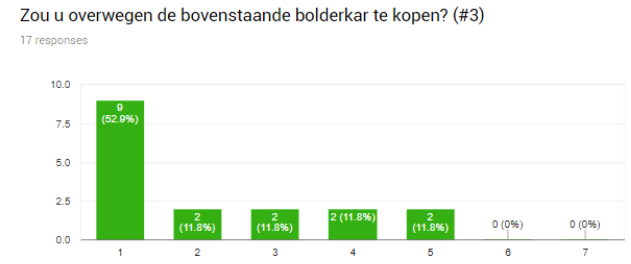
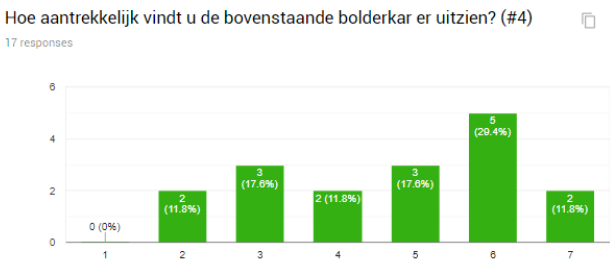


Figure 160 - Evaluation third hand cart (Dutch only)



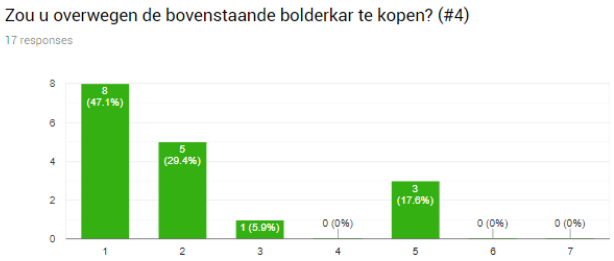
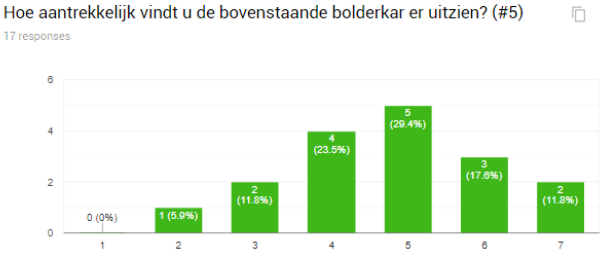


Figure 161 - Evaluation fourth hand cart (Dutch only)



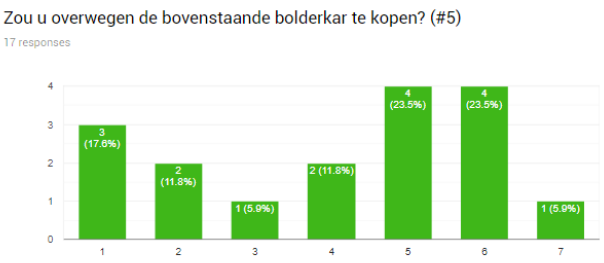
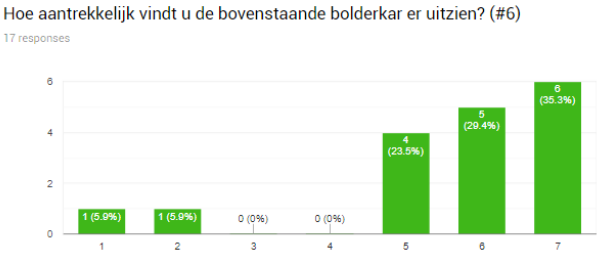


Figure 162 - Evaluation fifth hand cart (Dutch only)



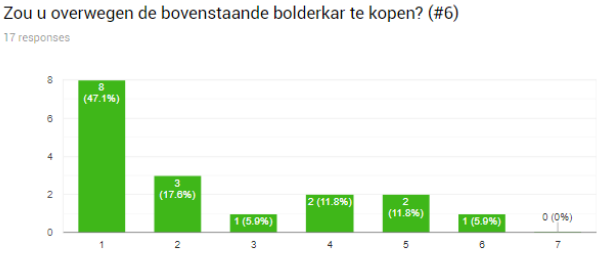
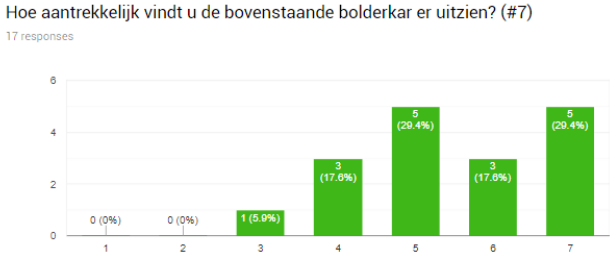


Figure 163 - Evaluation sixth hand cart (Dutch only)



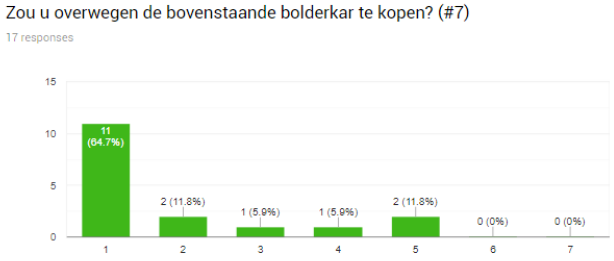


Figure 164 - Evaluation seventh hand cart (Dutch only)

A7 CC for alternative scenario

This section shows the value capture of a refurbishment end-of-life scenario for the Greentom Classic in which the product is 90% collected, and 80% refurbished, as a best-case scenario.

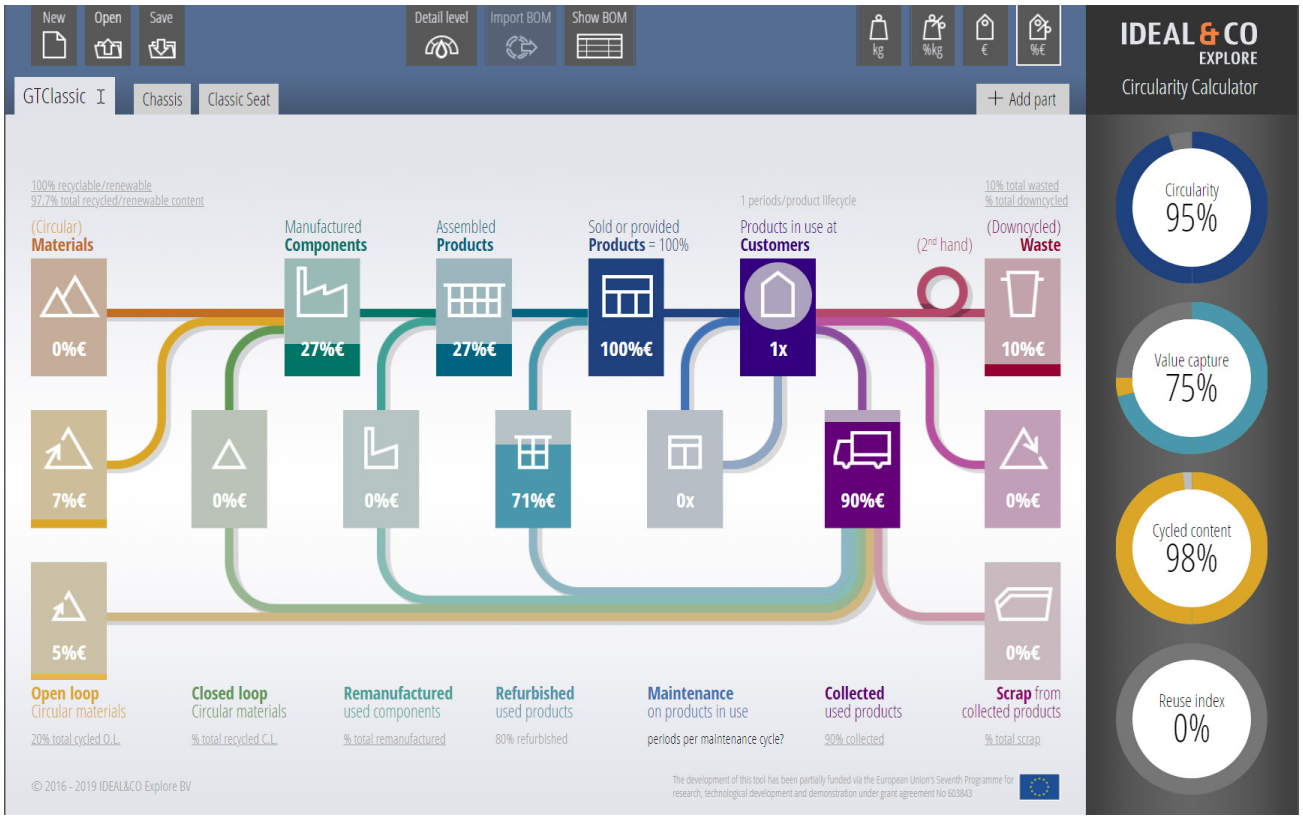


Figure 165 - Circularity Calculation (in euro percentage) of the Greentom Classic in its future product life cycle

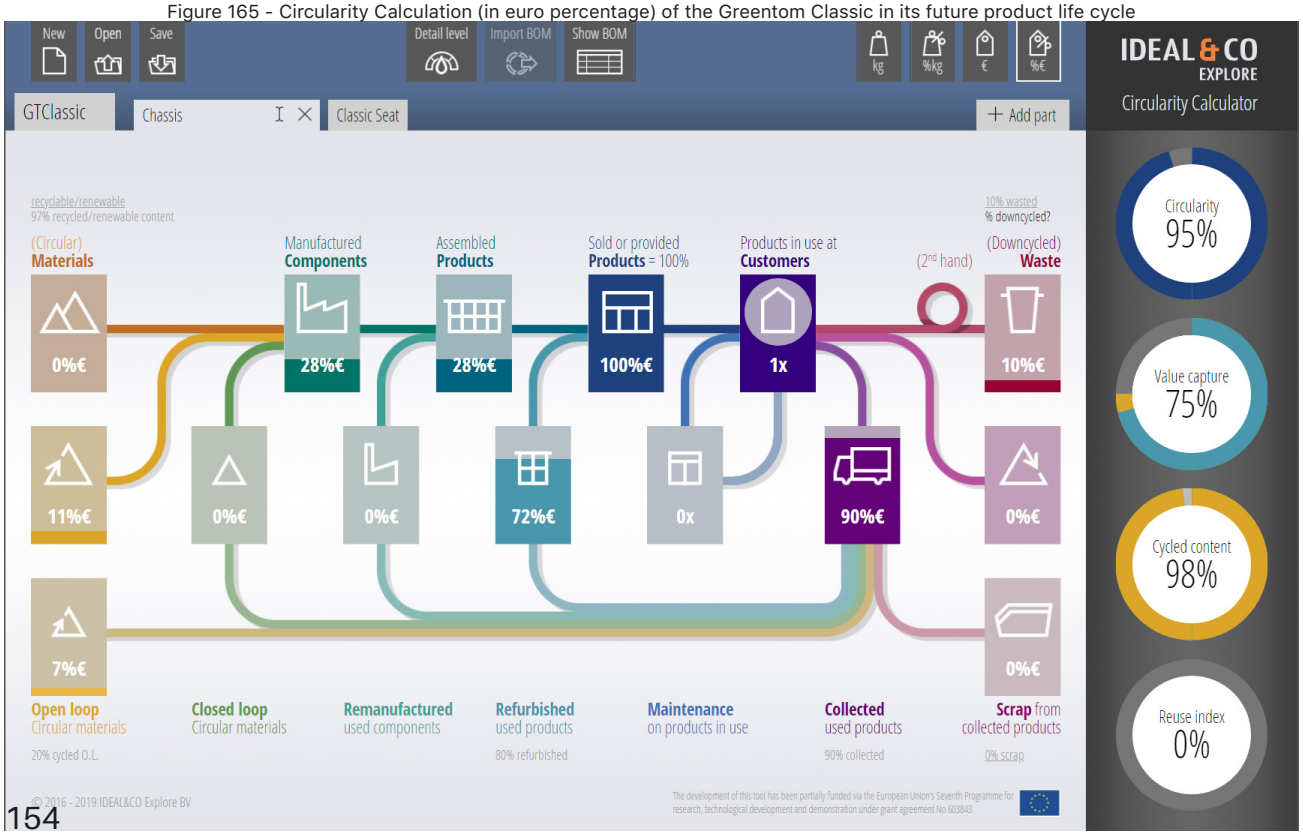


Figure 166 - Circularity Calculation (in euro percentage) of the Chassis in its future product life cycle

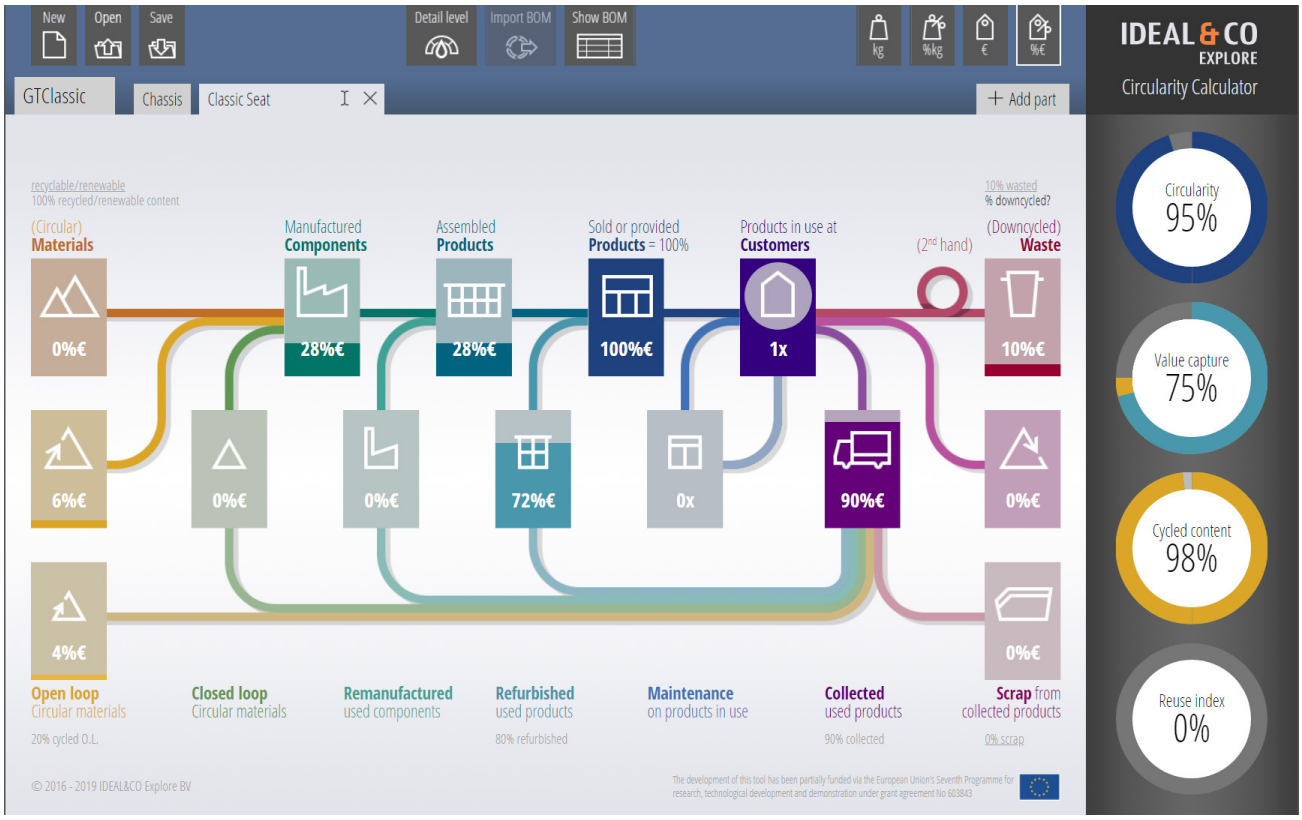


Figure 167 - Circularity Calculation (in euro percentage) of the Classic Seat in its future product life cycle

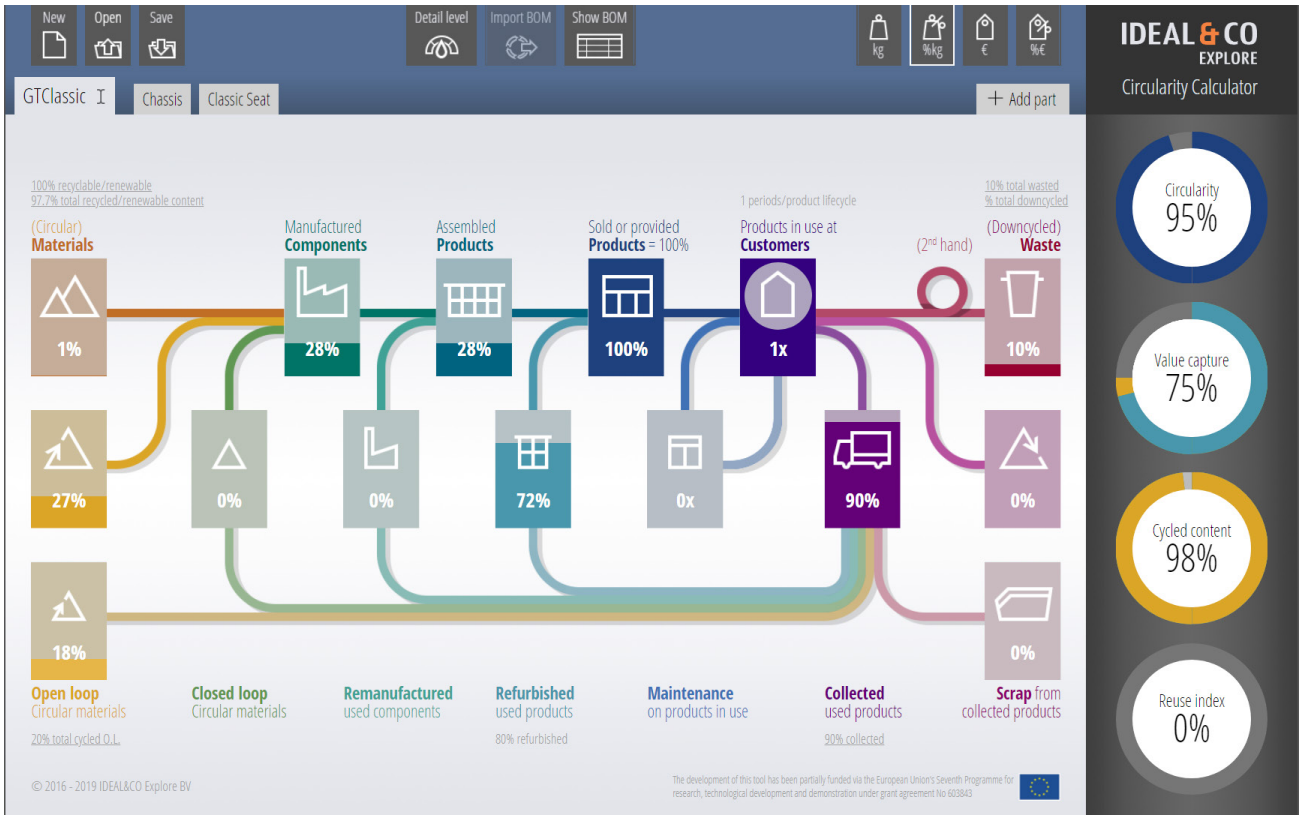


Figure 168 - Circularity Calculation (in kg percentage) of the Greentom Classic in its future product life cycle

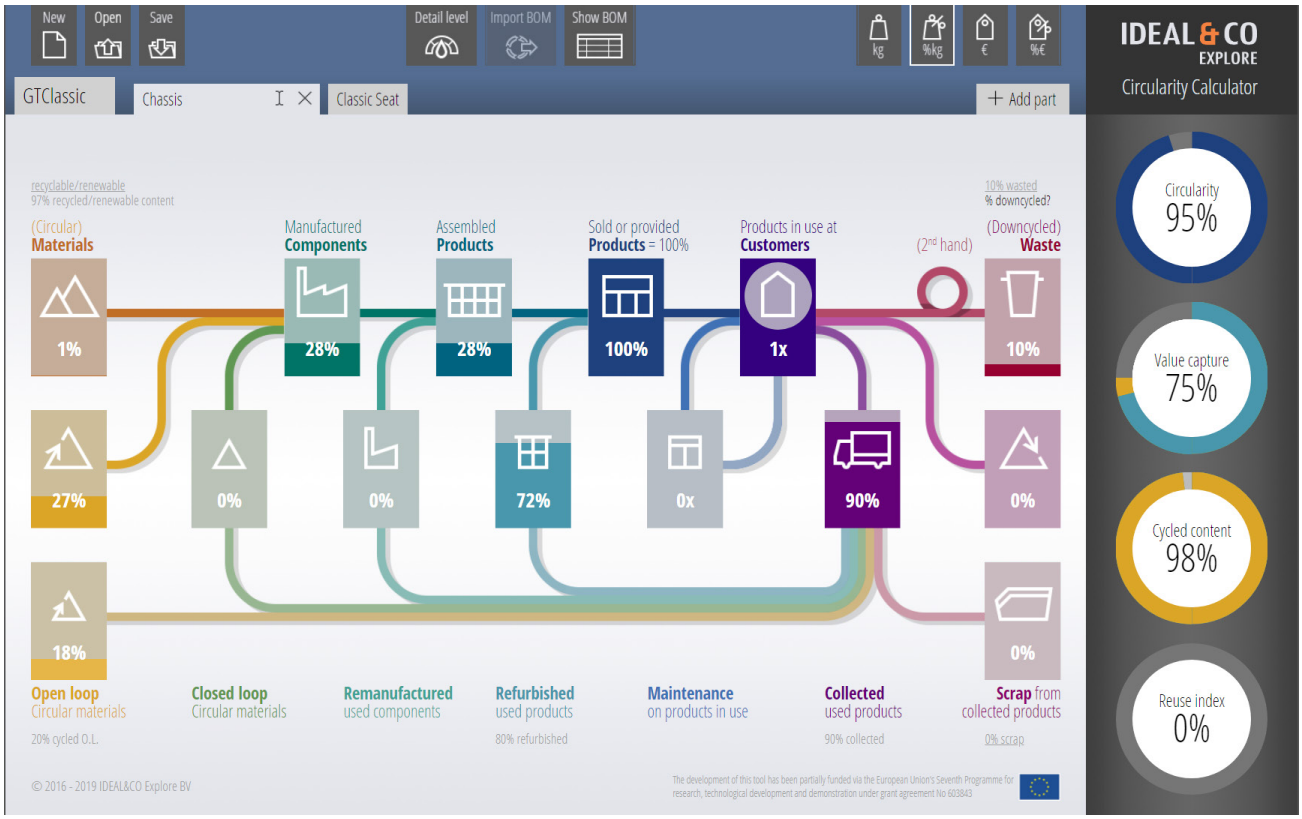


Figure 169 - Circularity Calculation (in kg percentage) of the Chassis in its future product life cycle

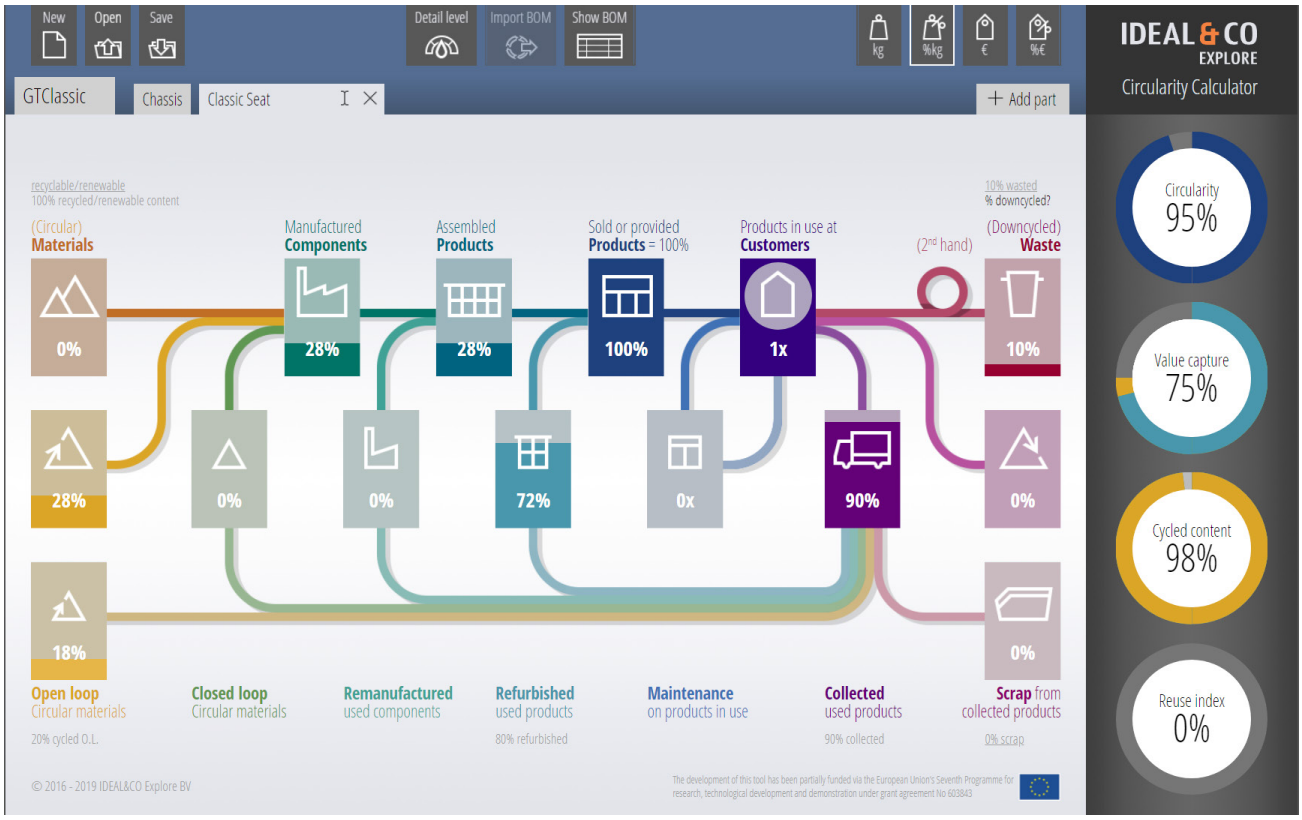


Figure 170 - Circularity Calculation (in kg percentage) of the Classic Seat in its future product life cycle

A8 Interview - User

After putting an announcement up on the social media platform Facebook, asking hand cart users that would like to help me with my research to send me a message, I was able to get in contact with several hand cart users. I was able to set up an interview with one of them on the 24th of october at the faculty of Industrial Design Engineering. Not only did she bring her hand cart, but she also brought her two toddlers that also like to sit inside the hand cart.

I explained the interviewee that the goal of the interview was to get to know about the preferences of hand cart users, and about the point of improvements in current hand carts. Furthermore, I told her that the interview was going to last 30 minutes, would be entirely anonymous, and that the results would only be used for analytical purposes during the research phase of my graduation project. I was given permission to record our conversation during the interview on my phone, and to make pictures when they would use the hand cart.
While I interviewed her, I kept the toddlers entertained with a colouring picture book, toy cars, and Fristi drinks.

The interview is transcribed in such a way to be best readable, only including the 10 main questions I had asked the interviewee to reply on.

1. Which hand cart do you currently own?
The MacWagon by MacSports.

2. What is the reason that you bought a hand cart?
I had received it as a gift from my parents during Christmas or Saint Nicolas.

3. Why did you choose this specific hand cart?
Why they gifted it to me, I do not know; it is nice to have next to the stroller because the hand cart fits both of my kids whereas the stroller only fits one. Also, I can fit more belongings in it when we go to an attraction mark on the beach.

Before, I never oriented myself in hand carts, but nowadays, I see a lot of people taking hand carts to the Efteling.

Also, the children do not always have to both sit down. Some people buy twin strollers for two children, but we do not think that this is necessary. The children do not always have to sit down, and a hand cart can fit lots of other belongings. Also, if we had considered a twin stroller, that would mean we would have to buy one and discard the old stroller which I am already happy with. A hand cart is fine for me.

4. Which problems do you experience with your hand cart?
It is very difficult to pull it along with two children inside.
Also, the hand cart easily tips over when it is folded, and still remains pretty big.
Furthermore, the children sometimes have an argument in the hand cart. This is because they are not strapped into seats like in a stroller, but can move around. Then they try to stand up or both want to play with the plastic plug in the middle of the car.

On days out like in the Efteling, hand carts can be very handy, but I actually never use the hand cart in the city. This is because the hand cart is big, not practical in the city because it is difficult to maneuver with it, you ride over everyone's feet because it is crowded, and you also pull it behind you instead of in front of you. However, MacWagon also sells all kinds of accessories such as extra bags, a tent roof, but also something which enables you to push the cart instead of to pull it. I think that is handy, because then you see what you are doing! You can check on the kids, and you can watch out that you do not accidentally ride over people's toes. Also, it is not handy to use in stores, because the corridors are not wide enough. In location such as the Efteling it is not only less crowded, but you can also leave the hand cart outside of the attractions or restaurants, creating hand cart and stroller 'parking lots'. Some even leave it outside without locking it to something.

If I have considered buying other hand carts? Well, I do not think my hand cart is very pretty, and there are lots of prettier, cooler hand carts, but they often have a thick frame and big wheels. I think this one fold up smaller than those. For example, my parents have had a wooden hand cart, which you were not able to fold. That one is of course even bigger and heavier than this one, but my parents also had more space in their house than I do now. My hand cart is also quite heavy: the girl weight 20kg, the boy around 15kg, and together with the cart that adds up. The hand cart also is also being used in a way that is of course not very ergonomical.
The Efteling allows hand carts, because you cannot ask families not to take a stroller along with their children, same goes with hand carts. It is difficult to pinpoint the border of what is allowed and what not in such a case. The Efteling also rents out one-person hand carts.

What else is that my finger sometimes gets stuck between the two pulling handle parts when the upper half slides down or is put against the cart, and also that my hand sometimes gets stuck between two rails when folding the hand cart.

If the children do not sit well in the hand cart, there is a chance that it can tumble! That also has to do with the fact that children do not sit still in the hand cart, whereas they do sit still in a stroller. However, they of course like it more that they are not strapped to their seat, but that would be more practical. Perhaps a combination is needed.

When moving up a hill, it is fine, but walking down a hill, I need to let the handle lean against my back when walking down so that I do not have to pull it in front of me.

5. What aspects are you happy with in your hand cart?

That fact that you can fold it. You can easily clean it because you can take the textile off (but I've never tried throwing it in the washing machine; that would be a plus!). It is nice that both of the kids fit in it, and on a day out or on a holiday we use it often because you can, for example, fit more belongings in it like towels.
The hand cart is not something that I use daily, and it is big so it can stand in the way. But on a holiday we do use it often, and we also often lend out the hand cart to friends.
Also we use it to transport glass when we throw that in the glass bin.

6. Where do you use your hand cart for? [children, belongings, pets?]

a. Type of locations?

Most commonly on days out; which does not have to be attraction parks or the beach necessarily, but also when we go to the children's farm or the beach. And we also use it when we need to transport things like glass (because a lot of things fit in it). The neighbours also borrow it when they need to throw away their glass. When our car was

broken, we also used it to go grocery shopping because it fits so many things. I can imagine students also have a hand cart to transport things like beer crates.

You can also take it along in the plane on a holiday, there is a bag for that but I lost it. However, we have never tried that.

Also, when we want the children to sit, for example when eating ice creams, we take the hand cart along. In a stroller that is more difficult when they are eating ice cream, since one is sitting, and the other is standing on a board behind the stroller.

b. Number and age of the children?

Two children. The oldest is 5 now. I do not know until what weight the hand cart supports it, but until then it is fine. I do not know until what age they could sit in it. If you would ask me, until they cannot fit in it anymore or until they do not like to sit in it anymore. But they can sit in it from the age that they can sit well independently; later then they can sit in a bike seat with straps, because in a hand cart they are not strapped in and bags can move. If they fall, they can hurt themselves!

The oldest child said that she prefers to sit in the hand cart more than in the stroller and that she like to play with the plastic plug in the middle of the hand cart (that helps folding the cart).

c. Short/long distances? [in km?]

Short distances because it is very difficult to pull it along. However, if it would be easier to pull it, I might use it for longer walks for example in the park. It of course also has to do how well it steers and rides on difficult surfaces. My stroller can ride over branches and things like that because you can push it, but the hand cart is already difficult to use when you want to pull it up or off the sidewalk.

7. How often do you use the hand cart?

Not very often. Maybe once a month, and more often in the summer. Also, we do not have a tent roof, so when it rains, you cannot go outside with it, whereas with a stroller, you can go outside with its rain cover. So during rain I never take it outside. When it snows, I also never tried it. Perhaps it does not steer well. Also I would go outside with a sled instead of with a hand cart.

8. What were the first things that you were looking for when choosing a hand cart?

I think my parents selected the hand cart because it is foldable, but also because they might have bought it in an impulse when they came across it. Because we do not have enough room to fit a wooden hand cart, and a foldable one fits in a car trunk.

9. What are the most important aspects that you would like to see in your ideal hand cart? [in descending order of importance?]

The most important aspect would be that you can walk well with it.
Then, also, that you can choose your own style or covers. Usually, hand carts are very ugly.
That it is foldable so that I can fit it in my home or in my car.
I am doubting if I would like the ability to strap my children inside the hand cart. The smaller they are, the easier they fall down. Or that there would be a possibility to fit a children's car seat (does not even have to click in).

The children have never complained that they do not sit comfortably, so I assume that they sit comfortably in it.

10. How much may your ideal hand cart cost?

If it would be really perfect, then I would be willing to pay €200 for it.

11. Are there any other suggestions/remarks that you would like to mention?

Yes! I noticed that there are a lot of cargo bikes (bakfietsen) that are designed for men, with different kinds of materials. So maybe, you can think of of who your target group is when designing a hand cart. And for myself: Many mothers, including myself, find environmental friendliness very important, to also leave a good world for your children. For example, I do not know if my hand cart is environmentally friendly or not. But if a hand cart would be, for example, recyclable, then that would be a plus point for me! I find that important and would like it.

On the one hand you would like a good planet to leave behind to your children, and on the other hand you produce a lot of garbage which should be reduced. Also, the urbar arrow, for example, is a cargo bike which is made out of a composite with a cool look. There are really a lot of cool cargo bikes. That may be because I heard that men do not like to bike with the cargo bike.

In a cargo bike you can also fit your children, but there you have a seat, straps, and also it is much more expensive than a hand cart. Also, I do not have the room for it. It would have to be left outside of the house. I would be nice to have a cargo bike, but then just for fun, because we do not need it. We do not need to bring away the children because we live closeby. Many people I know who have a cargo bike use it to bring away their children to school, but we can walk because we live closeby.

A hand cart is something you take along on days out, a cargo bike is something more for close to your home. You would not take that on a holiday.

A9 Interview - Retailer

The interview is transcribed in such a way to be best readable, only including the five main questions I had asked Mr Hofte to reply on.

Introduction by Mr Hofte:

"The hand carts originated from Germany, and are still the most popular there.

In the early 60s, hand carts were mostly made by people themselves from wood. The wooden bars in the sides were typical. The first producers of hand carts in Europe were Mammoet (dark brown hand carts), Berg, and also Van Wijk Toys (which is now out of business). Mammoet and Berg both started as manufacturing companies for skelters. This is why the hand carts were so robust.

Modern hand carts look more flashy and are more compact than the wooden hand carts, which make them become more popular nowadays.

The main reason for families to use the hand cart, is because once they have 2 to 3 children, the stroller becomes unhandy. Transporting goods and children on days out is more handy with a compact hand cart.

A good idea would be to introduce hand carts at places where the young families go to on their days out, such as the zoo or places like the Keukenhof or Efteling. Unfortunately, those places are not that willing to acquire them, because the many hand carts can soon stand in the way of people.

Bart van Heijt has also done an interview with Ted Hofte for a Bachelor End project regarding Yepp. His outcome with a hand cart for Yepp during this Bachelor End project received the grade of a 10."

1. "What are the preferences of parents/children regarding hand carts?"

"My advice of hand cart depends on the customer's answer of what they will do with it.
If customers want to use it once or twice a year for trips to a luna park, I recommend not spending a ton of money and picking the cheaper version. If customers want to use it for trips to the beach or the forest, I recommend hand carts with more comfort and bigger wheels."

Comfort

"However, even when buying cheaper hand carts, customers find comfort very important and buy all accessories for it, such as a tent roof, mattress, etc. (especially women find comfort for their kids important)."

Wheels

"Regarding the wheels: the bigger the wheel, the better it is to use on the beach. However, if the wheels are too big, the hand cart becomes less compact (especially men take notice of the wheels).

There are two types of wheels: air tyres or puncture proof tires.

Air tyres add to comfort, but have to be pumped up periodically (men tend to have preference for air tyres because they think they are better)
Puncture proof tires can be practical (and can look or feel the same as air tyres), but they tend to sink in after long use.

When a family has 2-3 kids, they start wanting a hand cart. This is because during their days out with the kids or when going on a holiday, they want to leave the stroller at home, but still be able to bring their belongings and transport their children without the stroller.

The cheapest hand cart is sold the most, but after 3 months the cheap hand cart tends to break."

What customers find the most important are, in order from most to less important:

1. The wheels
"Big wheels are needed for comfort during multiple days out, opposed to the less comfortable little swiveling wheels (which may be okay if the hand cart is used only once a year)"

2. The volume
"Customers want everything (for example, 2 to 3 kids) to fit in a hand cart. Typically, hand carts are 1 meter wide (to fit in a car)."

3. Compactness
"80% of hand carts sold nowadays are foldable. Wooden ones are mostly to transport goods or if a customer prefers them.

The Beach Wagon Lite (copied from the Beach Wagon One; Ted knows the designer well) would score well as a hand cart, however, it remains very large when folded, due to the big wheels and unfoldable bottom surface. Some of the many positive points are that the hand cart is designed with the user well in mind, and that it is the only hand cart with ball bearings (kogellager) while others have roll bearings (rollager).

Looking at different folding types, a simple folding system is preferred: if different pieces have to be taken out during folding, customers often come to say they lost a piece. Thus, "the more the folding system is simple and the less different parts have to be used, the less the hand cart breaks and the less parts become lost."

4. Aesthetics (the Wow! feeling)
"The way the hand cart looks can lead to a customer's Wow feeling. This tends to be especially import for women when buying a waking wagon.

However, you should not have a second Wow! reaction when seeing the price. A too high price leads to the customer not buying the product it loved so much. Thus, the price has to match with the customer's expectations. The price should not be higher than €300.

Also, ill or old dogs, or puppies are getting transported with hand carts!"

2. “What are the main reasons to buy a hand cart?”

“Parents with two to three children want to use the hand cart on days out since they find the stroller for so many children unhandy and want to leave it at home. Usually, children up to 5 years old sit in the hand cart.“

3. “Where is the hand cart the most popular? Or for what kind of families? [cities, villages, ground floor?]”

“Hand cart customers can be linked directly to people who buy strollers, since they usually want to buy a hand cart after getting two to three children when a stroller is unhandy for that many kids on days out. Thus, the popularity for hand carts only cannot be directly pinpointed to demographics.

In the north of the Netherlands, it seems that the hand cart is the least popular (Friesland, Drenthe, Groningen). Perhaps, because they are more traditional there (taking the bike or just walking).

The cheaper hand carts (around 100 euros) are usually bought by families with a lower income.”

4. “What are some point of improvements in current hand carts?”

“The ideal hand cart should have the best features of of all hand carts. It should be:

- *Light*
- *Have the best materials (for example, aluminum with cloth)*
- *Foldable*
- *Manoeuvrable (Does it pull well?)*
- *Comfortable*
  - *Is it comfortable for the children (bottom or neck)*
  - *Usually, customers buy all accessories to make sure the hand cart is comfortable. Ted is also selling his self produced cushions with the hand carts.*
- *Safe (seats with safety belts, breaks and other safety laws!)*
  - *Usually, these solutions are not able to be integrated in the cloth that hand carts have.*

The Eckla Express could have been one of the best hand carts with its material possibilities. Unfortunately, the company has an outdated mindset, and makes the hand cart too traditional and robust for it to be successful.

Furthermore, red and green least sellable colours. Dark colours sell better (perhaps because dirt is not as quickly visible). Also the colours should be neutral, not particularly for boys or girls. This is because most families with two or three children do not only have girls or boys.”

Hand carts are made to be pulled because they are officially not meant for transporting children. As soon as they can be pushed (with a handlebar), the wagon becomes a sort of stroller and has to comply with the pushchair and prams safety norms."

5. “Any tips for the project?”

“Make different colours available, make it hip, make it light (however that proves to be very difficult for manufacturers), do not exceed the €300 euro.

In Germany, the hand carts are sold the best, in other parts of Europe, it is almost impossible because people do not

know the product. For big batches, the amount of orders/need is too low. Kiboka (€700, way too expensive!) failed to produce on big scale in the Netherlands and has to wait manufacturing until sufficient order are made. Beach Wagon One also collects orders until it produces. Ulfbo produces in small batches to try the market in Europe.

However, the hand cart (bolderkar), does very well on Google. Since no one knows where to get a bolderkar (you can only get it at a retail store in may, june for €69,95), people use the internet to find it. If you are the only one selling it, people will find your product first!

The hand cart market is becoming bigger due to the folding, compact system.

In Germany, it is a tradition for fathers to take and pimp their hand cart each year on Father's day. This is also why everybody knows about a hand cart in Germany. On father's day, it is mostly used as a beer holder, but they pimp it in creative ways, like on Carnival in the Netherlands.

I recommend an extra bag behind the hand cart for belongings to lie in. I don't understand why there are very few companies that do that.

I have also received questions if it is possible to fit a baby car seat into the hand cart.

Hudora copied Ulfbo. Fuxtec copies from Beachtrekker. Neuheiten still makes very traditional (but very expensive) wooden hand carts.

Check out pictures of ulfBo pictures on my website, to see how people are using the hand cart.
Check out report by Rob Johann from UTwente about the analysis of a hand cart for handicapped people.
Check out the hand cart concept for Yepp that Bart Heijt had made during his Bachelor End Project."

A10 Alternative End-of-Lifes

Alternative ways to reuse, remanufacturing, refurbishment, or recycling, are the often heard terms 'biodegrading' and 'composting'. What do these terms mean and how do they compare?

A10.1 Biodegrading

Biodegradable materials dinintegrate and decompose under specific conditions in a natural environment, which depend on temperature, oxygen and the presence of microorganisms, breaking them down into CO_2, methane and biomass. (Norwexmovement, n.d.) (InnProBio, n.d.)

When a material is labeled 'biodegradable', it means that the material will break down in a 'reasonable' amount of time, which is less than non-biodegradable materials which biodegrade 10 - 600 years (Soest, n.d.). However, this time can still range from 1 month up to 5 years (Lewis Thomas, N., n.d.), making them unsuitable for industrial composting facilities which needs a material to decompose within six months, leaving the material only to be incinerated for energy recovery. (InnProBio, n.d.)(Bos, et al., 2017)

Another common misconception is that biodegradable materials can decompose at landfills, which they cannot due modern landfills lacking oxygen, light, and sufficient microorganisms for the material to break down. (Patagonia, 2012)

Furthermore, it is important to make sure that also the microscopic parts of the material will decompose within this natural environment, since failing to do so would result in only dinintegration into smaller particles, such as microplastics, posing a thread to the environment. Therefore, if a material is certified with a label "OK biodegradable MARINE" or "OK biodegradable SOIL" this does not mean that consumers should be encouraged littering in these environments. (Patagonia, 2012)(Bos, et al., 2017)

In conclusion, biodegradable materials used for the Greentom hand cart would not add any benefit to the product since they cannot be decomposed within six months in an industrial composting facility, do not decompose on landfills (of which there are none in the Netherlands in any case), and would only decompose faster than non-biodegradable materials if users would litter parts of the product in nature. A better example of a biodegradable product would be biodegradable cleaning agents or soaps, which easily break down and do not release harful phosphates and volatile organic compounds after breaking down, opposed to non-biodegradable detergents. (Patagonia, 2012) (Norwexmovement, n.d.)

A10.2 Composting

When a material is labeled 'compostable', this means that the material is not only biodegradable (within six onths) in an industrial composting facility, but also releases valuable nutrients and leaves no toxic residues. (Norwexmovement, n.d.)

It should be noted that materials that are compostable, cannot be composted at an industrial composting facility only, unless it is stated that the material can be composted at home as well, each having their own certification (see Figure 171).(Allthings.bio, 2018) (Song, Murphy, Narayan, & Davies, 2009)

Figure 171 - Certificates stating that the material is compostable. The right two indicate the material to be suitable for home composting.

A11 Chassis and textile EoL

Refurbishing, remanufacturing, or recycling of rigid parts or textiles requires more than meets the eye. This section gives further information on the requirements and process of these end-of-life processes of the chassis or textiles, and implications of alternatives to the recycling textiles such as composting.

A11.1 Design for (dis)assembly

Refurbishing, remanufacturing, or recycling cannot be done without disassembling the product, and in the case of refurbishing/remanufacturing reassembling the product after the process, as was discussed in Section 2.3.1.2.1. Thus, the product has to be designed to be (dis)assembled. What does this imply and why is this important?

Design for Disassembly is crucial to implement since this would speed up the separation and collection processes for refurbishment, remanufacturing, and/or recycling. "Products designed with DFD in mind very often prove to be more profitable, with economic benefits arising from reduced component counts, reduced parts and materials inventories and fewer joints and connectors" (to decrease (dis)assembly time and improve recyclability) (Bogue, 2007)

However, when designing also for the reassembly of the product, it should be noted that, as Bogue (2007) suggests, design for disassembly is not the reverse of Design for assembly, since good assembly techniques may not be suitable for disassembly and visa versa.

A11.2 Recycling - Textiles

Ideally, textiles ought to be recycled back into yarn in a closed loop system for the same product textiles. When can this be done, and what are implications when recycling textile?

There are two types of textile recycling: *mechanical recycling* and *chemical recycling*.

Mechanical recycling can be done by "[cutting] fabric into smaller pieces and then progressively shred the fabric until it is in a fibrous state suitable for other processes such as re-spinning into yarn or for manufacturing into nonwoven textiles." (Payne, A, 2015) However, post-consumer apparel often includes different fibre types and blends that are difficult to separate. This causes the mechanically recycled fibre to be "generally of a low quality in terms of fibre length and colour (generally black or grey), making it inappropriate for reuse within apparel. [...] [This fibre is used] for applications such as nonwoven textiles or insulation" (Payne, A, 2015) Even with clean pre-consumer waste, the textile gets shorter fibre lengths and should be blended with virgin fibres for apparel applications. (Payne, A, 2015) rPET is not possible to be mechanically recycled. (Shen, Worrell, & Patel, 2010)

Chemical reycling is done by "chemically breaking down the fibre to a polymer and then repolymerising it before passing through the spinneret to generate new fibre to be spun into yarn, ready for weaving or knitting into fabric." (Payne, A, 2015) This requires clean, sorted pre-consumer or post-consumer waste sorted by fibre type. (Payne, A, 2015) In the case of rPET textile, a percentage of more than 70% rPET in the textile makes the textile good to chemically recycle. Greenblue (2017) However, Shen *et al.* (2010) argues that even though chemical recycling is technically possible, the economic viability of large scale operation is still to be proven.

The process of chemically recycling textile has a twice as big of an impact in kg CO_2-equivalent compared to mechanical recycling, but this carbon footprint, and assumingly the eco-costs, is still twice as low as the impact of the production of virgin PET fibre, as shown in Figure 172. Furthermore, chemical recycling can also achieve a quality close to its original feed properties opposed to the quality after mechanical recycling which only worsens or has to be mixed with virgin material for it

to be suitable for garments. (Shen, Worrell, & Patel, 2010 However, what is also important to take into account is that chemical recycling is more expensive than mechanical recycling and usually requires a large scale, becoming only cost-effective starting at 10.000 tonnes, according to an interview with Dr. ir. Bouwhuis. Thus, finding a good, local partner for this process is essential for Greentom to make the process economically viable.

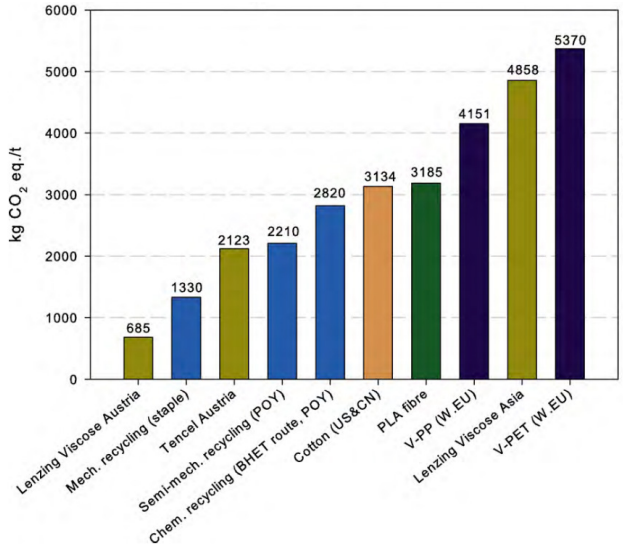


Figure 172 - Comparison of the carbon footprint of different virgin or recycled materials and processes from cradle-to-grave. (Shen, Worrell, & Patel, 2010)

In the Netherlands, the only known company chemically recycling textile is SaXcell, a new company providing a 100% recycled textile made out of post-consumer cotton, can be recycled after use without loosing its properties, is well dyeable and 40% stronger than cotton. (Huijerman, 2018; Boer group recycling solutions, 2019; Oelerig, 2016; Dr. ir. Bouwhuis, personal communication, 2019) Whether this material is suitable is discussed in Section 2.3.2.3.

A11.3 Composting - Textiles

An alternative to recycling, ommiting the need for it, is the composting of biodegradable and renewable textile. What are the options, and is it a good alternative to either mechanically or chemically recycling textile?

Figure 172 shows another possible textile type which is bio-based and biodegradable: Lenzing Viscose Austria, which has a lower cradle-to-grave carbon footprint than the mechanically recycling process of textile. A second material is Tencel (a brand under Lenzing) Austria, which has a higher cradle-to-grave carbon footprint than mechanically recycling process, but a lower carbon footprint than the chemically recycling process of textile. Both materials are spun from dissolved pulp derived from cellulose from wood sourced from certified sustainable natural forests and sustainably managed plantations while maintaining a closed chemical loop production for the recycling of chemicals. However, Lenzing Viscose Austria only seems to be biodegradable but not compostable whereas Tencel Austria fibres are compostable as well as biodegradable under industrial, home, soil and marine conditions, and is also embedding the upcycling of cotton scraps from garment production called REFRIBA claiming to be produced with 95% less water than needed for the production of cotton. (Lenzing, 2019; Tencel, 2018; Lenzing AG, n.d.; Lenzing Group, 2019 [VIDEO])

Since Figure 172 only shows the carbon footprint of different textiles and processes and not the more relevant environmental impact indication in eco-costs, it is not possible to conclude which textile is the best alternative based on the figure alone. Whether the collection and composting of the Tencel Austria textile is economically and sustainably more attractive than chemically recycling rPET or SaxCell bio-cotton is therefore also discussed in Section 2.3.2.3.

A12 Defining materials

A12.1 Chassis

CES Edupack is used to plot possible suitable materials against each other to use as the main Chassis material. The materials are plotted against their yield strength (y-axis) and costs (x-axis). Figure 173 shows the comparison with recyclable materials, with materials not suitable to be recycled in grey. Figure 174 shows the comparison after the addition of the criteria that the material should be suitable to use in (fresh) water, the material should be suitable to use in soil (clay), and the could not be brittle (glass) which would not be suitable for applications in a hand cart.

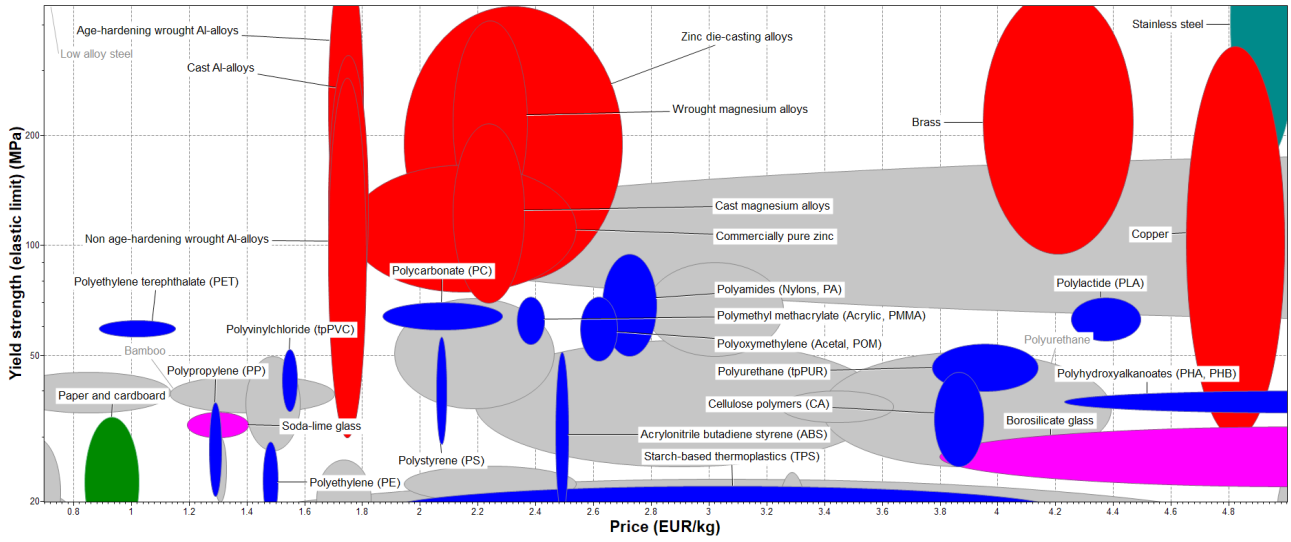


Figure 173 - Global comparison materials for Chassis. (Unsuitable materials are shown in grey). CES EduPack (2018)

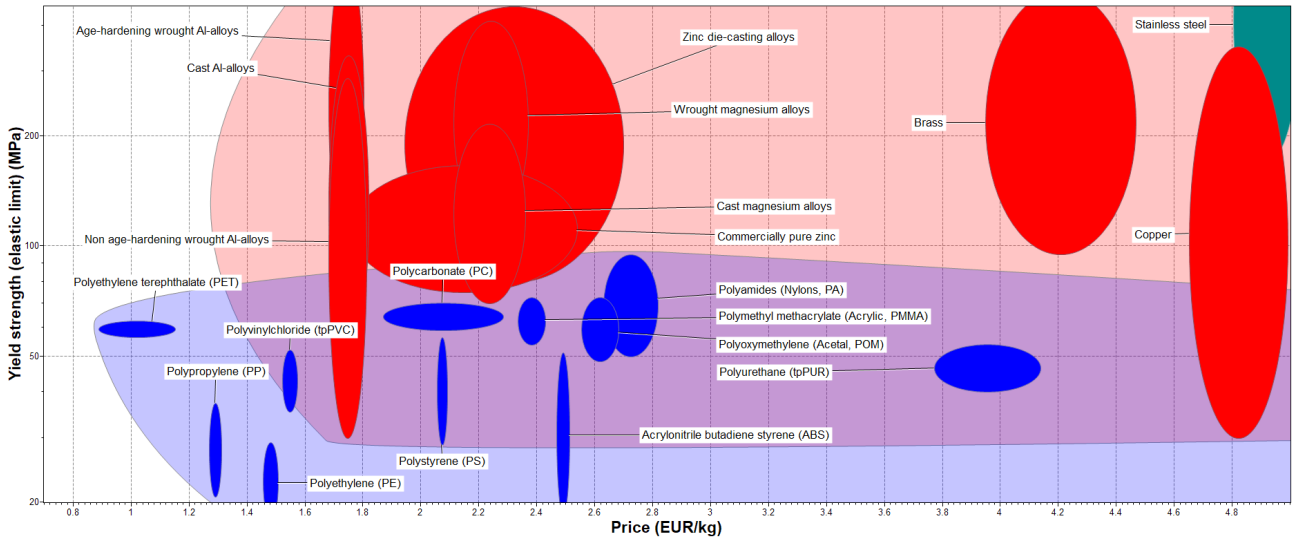


Figure 174 - Global comparison materials for Chassis after added criteria. CES EduPack (2018)

Next, selection in Figure 174 is evaluated on the material's eco-costs/carbon footprint (Figure 175 and Figure 176), density (Figure 177), and price (Figure 178). (See Appendix A12 for the data behind these figures). Furthermore, the recycled variants of the materials are mentioned, since it is concluded in Section 2.3.1.3.1 that the materials should not only be recyclable but also from a recycled source.

What can be concluded in Figure 176, is that rPP relatively has the highest eco-costs from the list of selected materials. All metals, zinc (secondary), magnesium (secondary), and aluminium (secondary), seem to have the lowest eco-costs.

From Figure 177 can be concluded that all metals relatively have the highest density, with Zinc standing out. It should be noted that since these materials have a higher yield strength than rPP (as shown in Figure 174) the wall thickness and needed material for the same strength would most probably be less, resulting in possibly the same total weight.

From Figure 178 can be concluded that rPP shows to be the least expensive materials, only being beaten by rPET. rtpPUR stands out having the highest price.

Next, the selection is further narrowed down by removing zinc and r-tpPUR due to discussed reasons, as well as rPVC due to it releasing toxins during recycling making it unsuitable to recycle with other plastics (Belliveau & Lester, 2004). This resulted in the selection of materials as discussed in Section 2.3.2.2.

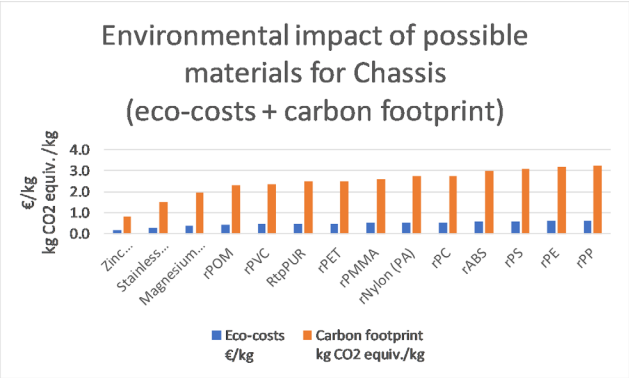


Figure 175 - Eco-costs and carbon footprint of selected Chassis materials (Idemat, 2015)

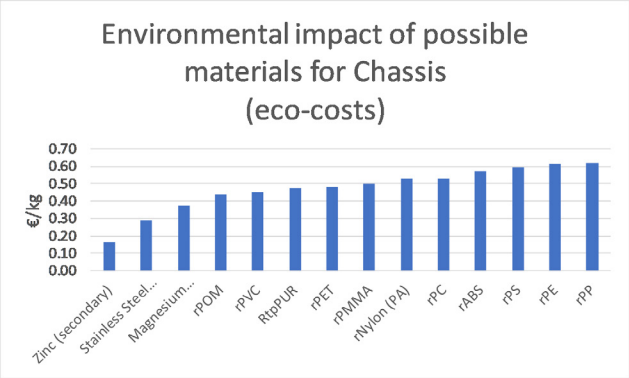


Figure 176 - Carbon footprint of selected Chassis materials (Idemat, 2015)

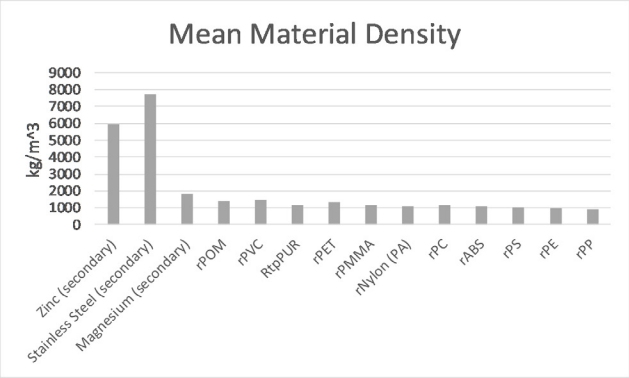


Figure 177 - Mean material density of selected Chassis materials (CES EduPack, 2018)

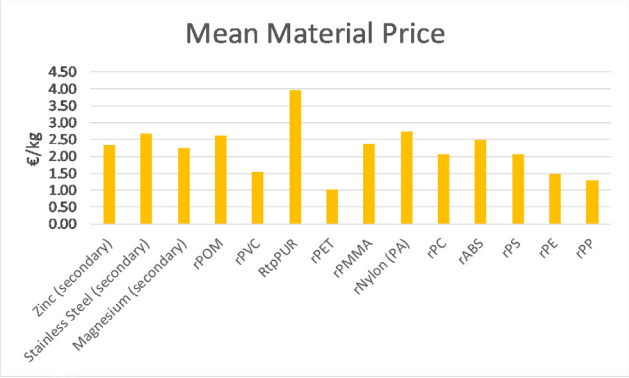


Figure 178 - Mean material price of selected Chassis materials (CES EduPack, 2018)

A12.2 Textile

In order to evaluate the possible materials for the textile as selected in Section 2.3.6.3, the materials database Idemat 2015 is consulted, and an interview is carried out with textile technology expert and CEO of SaXcell, Dr. ir. Gerrit Bouwhuis. The materials as selected in Section 2.3.6.3 that are being evaluated are: Biodegradable and compostable Tencel (Lyocell or Model) fibre made out of dissolved pulp from cellulose, chemically recyclable rPET recycled from post-consumer PET bottles, and chemically recyclable cotton called SaXcell made by a new company in the Netherlands.

According to Dr. ir. Bouwhuis, virgin cotton has a carbon footprint which is 2,2 kg CO_2 eq./kg less than Tencel. By looking at Figure 179, we assume that Lenzing Viscose Asia is meant by this, of which Tencel is a brand. Next, Dr. ir. Bouwhuis says that chemically recycled cotton as SaXcell has a carbon footprint of 0,5 kg CO_2 eq./kg less than virgin cotton.

The latter is a claim of which is assumed that Dr. ir. Bouwhuis means the carbon footprint during the production of SaXcell without taking into account the carbon footprint of the virgin Cotton material. Since the carbon footprint of recycled materials is represented in Idemat 2015 as the recycling credit in carbon footprint of a material added to the carbon footprint of the virgin material accordingly, it is assumed that the carbon footprint of recycled cotton represented such as it would be in Idemat 2015 is the carbon footprint of virgin cotton plus the carbon footprint of chemically recycling materials.

Figure 179 shows the carbon footprint of the materials from cradle-to-factory gate (meaning footprint of the virgin materials and the footprint of the materials processed up to fibre, but not the textile itself). In the study by (Shen, Worrell, & Patel, 2010) the method of representing these values for recycled materials is not to add the carbon footprint of the virgin material to the carbon footprint of the recycling credit, but by adding the carbon footprint of the collection and transportation of the "waste", and adding this to the carbon footprint

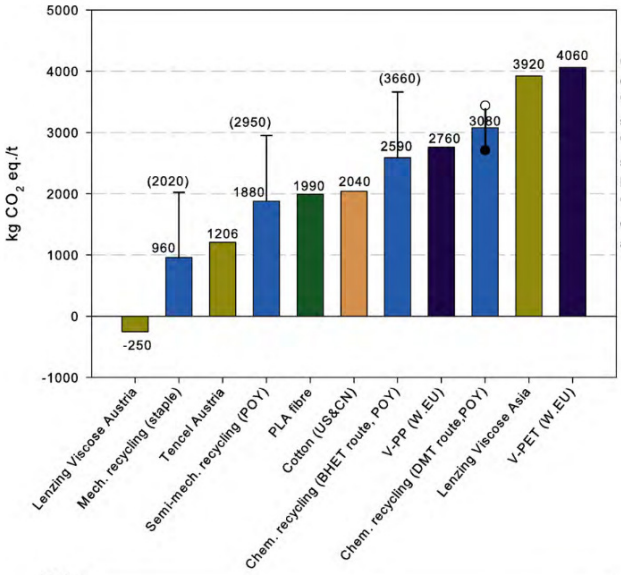


Figure 179 - kg CO2 eq./ton material from cradle to factory gate (Shen, Worrell, & Patel, 2010)

of the conversion steps of the "waste" into the recycled material. (Shen, Worrell, & Patel, 2010)

With the help of Figure 179, taking into account fluctuation in results per material compared to the data in Idemat 2015, but assuming that the ratio of the carbon footprint of virgin materials is more or less correct compared to the data in Idemat 2015, the figure as seen in Figure 180 is made. (See Appendix A11.2 for the data behind the graph).

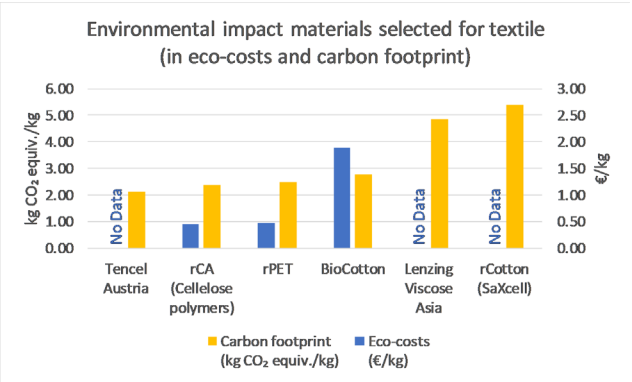


Figure 180 - Combined impact values of several textile materials

A13 Requirements and Wishes

A13.1 Requirements

1. Greentom:
    a. Product should encourage customers to use other Greentom products as well by making integration with Greentom accessories possible.
        i. Such as the Greentom Car Seat
        ii. Such as the Greentom Carrycot
        iii. Such as the Greentom Reversible
    b. Product should comply with Greentom's mission:
        i. "To create smart, functional and sustainable products." Interpreted as:
            1. Should be simple in its design (smart)
                a. Simple in its aesthetics **[See 1. Greentom: d.i and d.ii]**
                b. Simple in its components **[See 1. Greentom: d.iii]**
            2. Should be easy to use (functional) **[See 7.Usability]**
                a. Users should easily understandable folding steps/functionalities
                b. The amount of steps needed to complete an action should be low.
                c. Product should have folding system that does not require disassembly of parts
            3. Should be sustainable **[See 4. Environmental Sustainability]**
    c. Product should comply with Greentom's vision:
        i. Product should help the company to "become a circular lifestyle brand that grows with the life stage of the consumer"
            1. Product should be sustainable: being able to become part of Greentom's future circular economy **[See 4. Environmental Sustainability]**
        ii. Product should be affordable **[See 3. Costs]**
        iii. Product should be safe **[See 10. Safety]**
        iv. Product should be of high quality **[See 5.Materials; 9.Forces]**
        v. Product should be comfortable **[See 7.Usability]**
    d. Product should follow Greentom's form family:
        i. Straight lines, light curves, support where it matters
            1. "No-nonsense mentality"
        ii. Dutch-design: Form follows function
        iii. Simple, with no superfluous details or components
2. Users:
    a. Product should be suitable for parents with up to three children up to six years old. **[See 6. Dimensions]**
    b. Product should be suitable for babies, toddlers, preschoolers, and young grade schoolers (0 - 6 years) **[See 6. Dimensions]**
        i. In an attachable car seat (from birth to 6-7 months) **[See 7.Usability: d]**
        ii. Strapped in seat belt (from the moment they can sit individually (7-8 months) - 1 year) **[See 10. Safety: b.2]**
        iii. Freely in the cart (From 1 year until 6 years)

3. Cost:
    a. Product should have a selling price between 100 and 250 euros
        i. Which should not exceed a customer's perceived price expectations.
4. Environmental Sustainability:
    a. Product should fit a future circular economy
        i. Product should be able to be part of a material techno-cycle (focus within this project) that is able to be integrated in a sustainable circular economy (beyond project boundaries)
        ii. Product should have the same as or better end-of-life scenario than the Greentom Classic. (However, its logistics system can only be suggested since it is outside of project focus)
    b. Product should be made of suitable materials **[See 5. Materials]**
        i. Materials used for the hand cart should have the same or a lesser relative environmental impact than those materials used in the Greentom Classic.
5. Materials
    a. Product should be made of recyclable materials
    b. Product should be made of as less different parts as possible
    c. Product should be made of as less different kinds of material as possible
    d. Product should not contain any toxic materials or additives that would worsen the recyclability of the material.
    e. Product should have its materials, particularly plastics, be marked in accordance with standards (e.g. ISO 1043) for identification purposes
6. Dimensions:
    a. Product should be compact when folded
        i. Product should have folded length smaller than that of the folded Beach Wagon Lite: {103 x 55 x 18} cm
        ii. Product should fit in a small car trunk (not wider than 1 meter)
        iii. Product should fit through gates:
            1. Hallway doors (83 cm [s])
            2. Station gates
            3. Tram
        iv. Product should be compact even with big wheels
    b. Product should have large volume
        i. To fit up to two children (6 years old, P90) freely with room for bags OR should fit three children (6 years old, P90) tightly with little room for bags.
            1. From the age they can independently sit (1 year old)
            2. Up to 6 years old
7. Usability:
    a. The product should steer well/be well manoeuvrable
        i. By having wheels:
            1. Which should be big
                a. To reduce pushing/pulling force
                b. To be able to ride well over sand
                c. To be able to easily ride up and off of sidewalks
            2. Which should not be too hard to prevent vibrations
                a. For comfort (for users that use the hand cart more than twice a year)

3. Which should roll without applying too much force
    a. The wheels should use ball bearings (kogellagers) instead of roll bearings (rollagers)

ii. By enabling the pushing of the hand cart apart from only pulling
1. Which reduces the force needed to move the hand cart since two hands are used compared to one hand when pulling.
2. Which improves the body ergonomics compared to pulling

iii. By using wheel configurations and wheel systems that are suitable for pulling situations and pushing situations

b. Product should be lightweight, weighing less than the average hand cart
i. To be easy to transport when folded
ii. To be easy to pull along **[See 7.Usability: c]**

c. Product should be comfortable for the passengers (children/pets)
i. When sitting or leaning against a side

d. Product should have the ability to attach a baby car seat to it

e. Product should be able to stand by itself when folded

f. Product should be able to be used on several different terrain types:
i. On sand:
1. On the beach (56%)

ii. On concrete:
1. In the zoo (44%)
2. At an amusement park (31%)
3. In the city/village (25%)

iii. On grass and sand:
1. At the camping (43%)

g. Product should be easy to clean

h. The feet of the user should not be able to hit the bottom of the product during normal pushing/pulling of the product.

i. Product should be able to be used in different contexts:
1. During a holiday (63%)
2. On a day out (63%)
3. During walks (31%)
4. During doing errants/groceries (31%)

i. Should be suitable to be used once or multiple times a month.
ii. Should be suitable for both short (81%; ≤0 to 2 km) and long distances (19%; around 5km)

j. Transport
i. Product should be able to be transported with one hand when folded

8. Aesthetics:
a. Product should look attractive enough to give the customer a “WOW!-feeling” [S]
b. Product should look and feel sturdy when in use
i. By adding the look and feel of big wheels
ii. By adding the look and feel of big bars for the structure
iii. By adding a sound structure that does not deform more than 4 cm during intended use. **[See 9.Forces]**

9. Forces:
    a. Product structure support maximum intended weight
        i. Product should support weight of:
            1. 3x P90 three-year olds
                a. Which is 3 * 26kg = 78kg
10. Safety:
    a. Product should not be able to tip over when in use
        i. With steering wheel in any possible orientation
        ii. With load not evenly distributed
        iii. Should prevent fingers or hand getting stuck in parts during use (for example, when adjusting the pulling handle)
        iv. When children are standing
    b. Product should comply with safety norms
        i. For regular toy standards (interaction with small children)
            1. Should comply with toy standard EN71
                a. Maximum of {60 Sb, 25 As, 1000 Ba, 75 Cd, 60 Cr, 90 Pb, 60 Hg, or 500 Se} mg/kg after analytical correction.
        ii. For a stroller (if pushing the cart is intended)
            1. Should comply with standard EN1888
                a. Should have one-step-break
                b. Should have five point safety buckle
                c. Should have safety harness
                d. Should have belt pads
        iii. Should comply with parents' popular worries:
            1. Should be BPA free
            2. Should be PVC free
            3. Should be Phthalate free
            4. Should not use chemicals
            5. Should not use coatings
            6. Should have a UPF rating of 50+ if sun protection is used (Sun Protection Category: Excellent).
        iv. Take into account the seats with safety belts, breaks, and other safety laws that cannot be integrated in just the cloth.

A13.2 Wishes

- Aesthetics:
  - Fashionable/in for at least 5 years.
- Design:
  - Product could have extra dedicated space for placing (hand)bags or accessories
  - Product wheel could have springs for smooth ride
  - Product could have a rain cover
  - Product could have a sun cover
  - Product could have textile that is waterproof
  - Product could have wheels which are air tyres or puncture proof tyres:[seller, questionnaire]
- Safety:
  - Could have a handbrake to be able to use the hand cart better on slopes.
  - If it uses the same material as the Greentom Classic:
    - Should use 100% natural, renewable and biodegradable Texel wool combined with 15% organic cotton organic cotton
      - The wool is also flame retardant, hypo-allergenic and antibacterial.
      - Certified by the Global Organic Textile Standard (GOTS) and OEKO-TEX Standard 100
  - Product could have the possibility to strap the children to their seats
- Environmental sustainability:
  - A suggestion can be made for a same or better end-of-life system can be made.
  - A suggestion can be made to decrease the impact of transportation, even though it currently has the lowest relative impact compared to the other stages in the case of the Greentom Classic.
- Users:
  - Product could have extra accessories that parents could buy.
  - Product could also be used by dogs.
- Usability:
  - Product could be made suitable to use on uneven, earthy surfaces
    - In the forest (13%)
    - In the park (13%)
  - Product could be made easier to walk down a hill without pulling the cart too much
    - Product could have a break to make it easier to walk down a hill
  - Product could have an additional locking system to prevent theft.
  - Product could have a handle bar that retracts upright when not in use.
- Context:
  - Should be able to be used:
    - On uneven, earthy surfaces
      - In the forest (13%)
      - In the park (13%)
  - Could be protected against
    - Sun (To have a sun protection)
    - Rain (Have a rain cover)

A14 Idea generation

The idea generation consisted out three used methods.

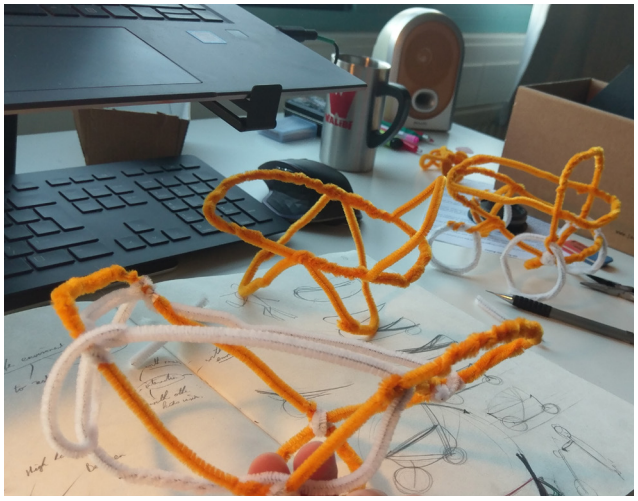
During the image-associative brainstorming, images are as a stimulus for thoughts and ideas to come in mind by associating any shape, feeling, colour, or other seemingly random element from the picture.

The structure model making is done to visualise ideas quickly in 3D, which can act as a way to create new, previously unthought of ideas.

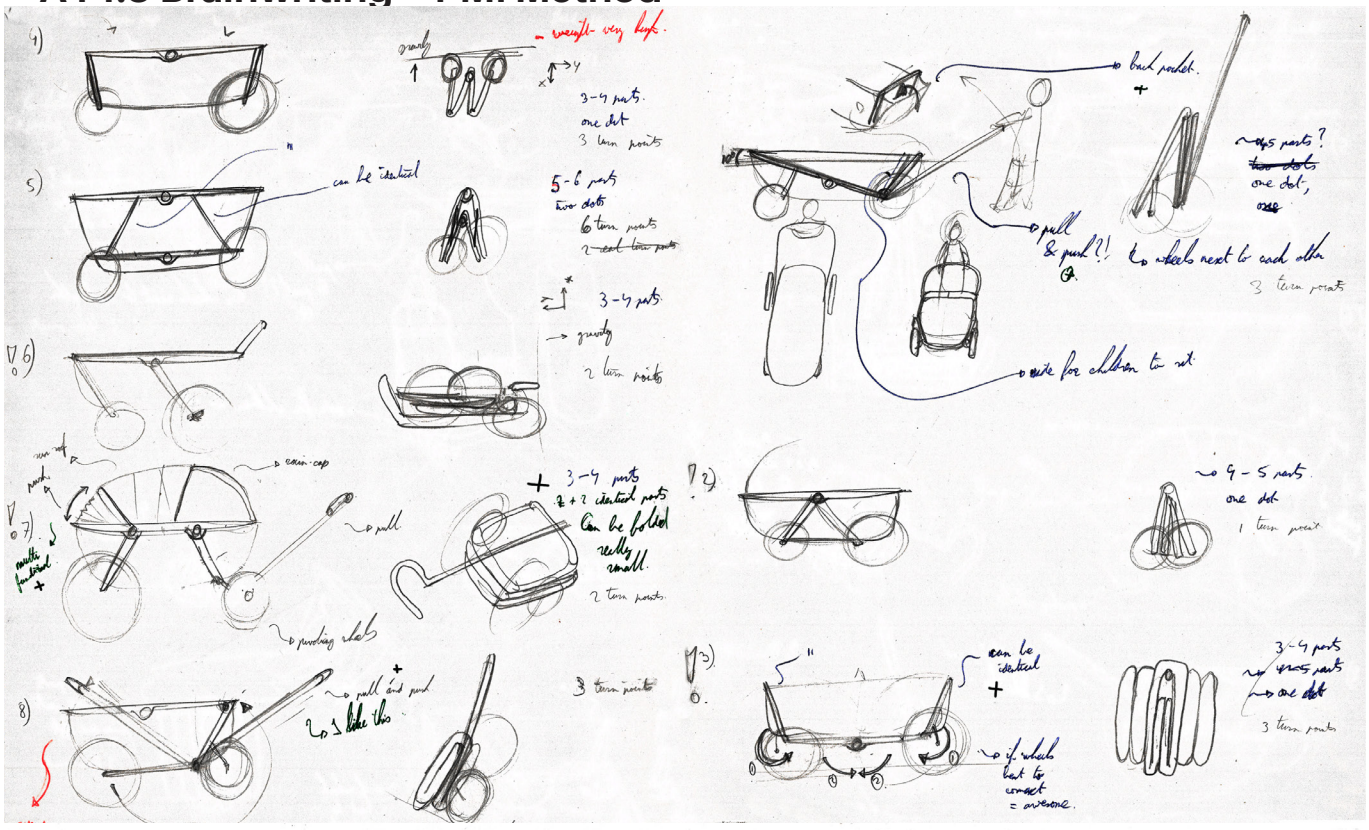
During brainwriting, ideas are laid out on paper regarding folding structures, after which good, bad, and implicative elements are selected.

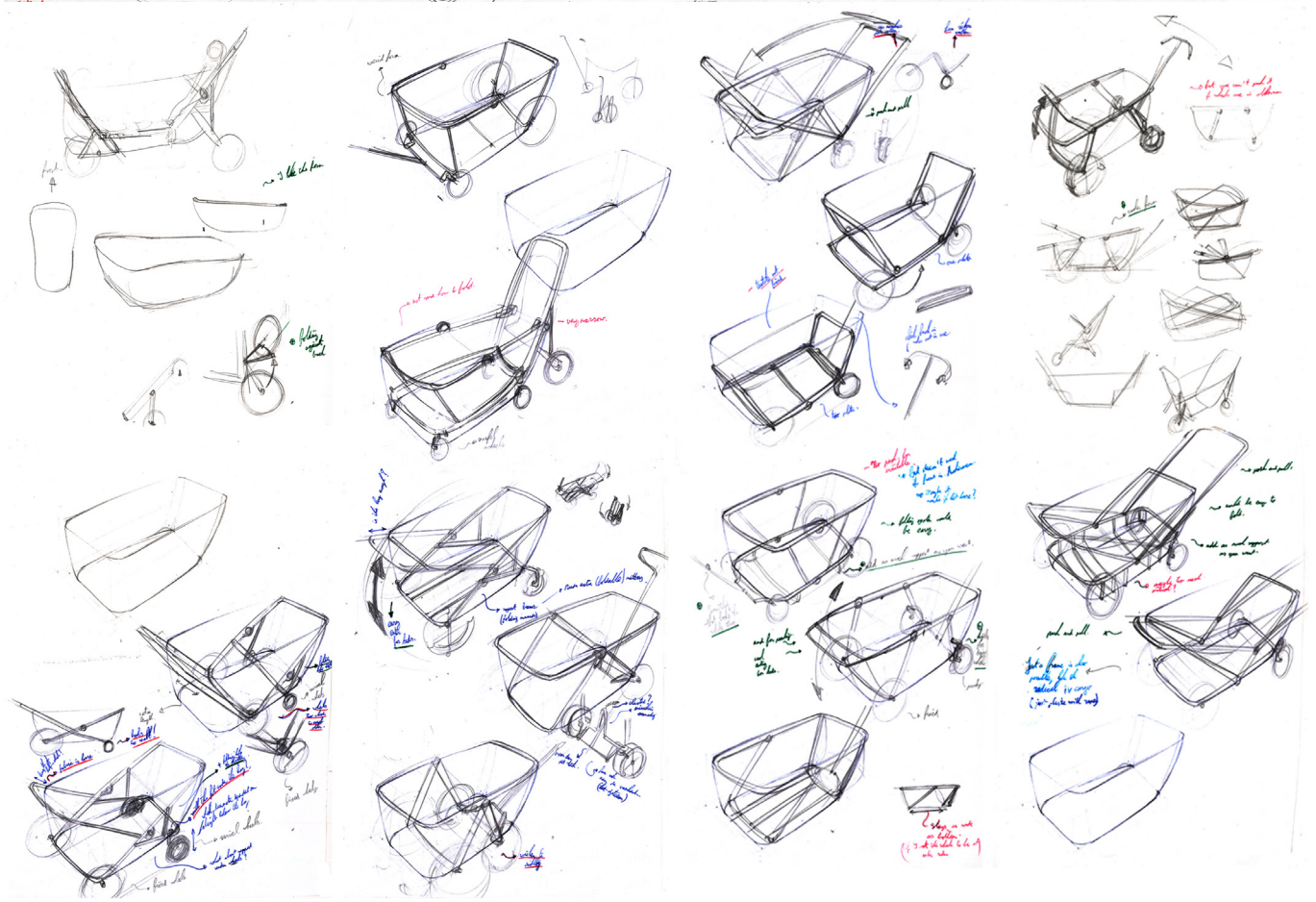
A14.1 Image-associative brainstorming

A14.2 Structure model making



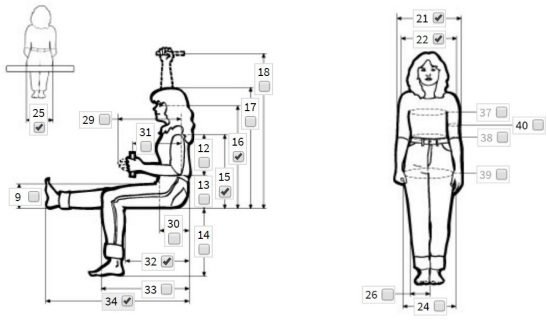
A14.3 Brainwriting + PMI Method



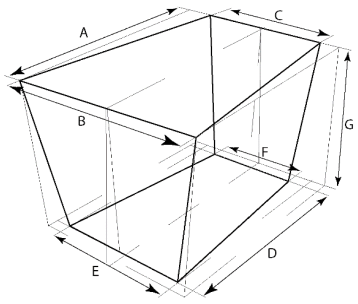


A15 Hand cart dimensioning

	DINED antropometric data (DINED 2017a)				
Data #	DINED reference #	DINED data name	DINED user group name	Percentile	Dimensions (mm)
1a	15	Shoulder height, sitting	Dutch children 2, mixed	P50	335
1b			Dutch children 4, mixed	P50	363
1c			Dutch children 6, mixed	P50	404
2a	16	Eye height, sitting	Dutch children 2, mixed	P10	418
2b			Dutch children 3, mixed	P90	269
3a	21	Breadth over the elbows	Dutch children 4, mixed	P90	308
3b			Dutch children 5, mixed	P90	315
3c			Dutch children 6, mixed	P90	319
4a	22	Shoulder breadth (bi-deltoid)	Dutch children 3, mixed	P90	268
4b			Dutch children 4, mixed	P90	285
4c			Dutch children 5, mixed	P90	299
4d			Dutch children 6, mixed	P90	309
5a	25	Hip breadth, sitting	Dutch children 3, mixed	P90	217
5b			Dutch children 4, mixed	P90	233
5c			Dutch children 5, mixed	P90	245
5d			Dutch children 6, mixed	P90	252
6a	32	Buttock-popliteal depth	Dutch children 4, mixed	P90	315
6b			Dutch children 5, mixed	P90	345
6c			Dutch children 6, mixed	P90	365
7a	34	Buttock foot length, sitting	Dutch children 4, mixed	P90	659
7b			Dutch children 5, mixed	P90	718
7c			Dutch children 6, mixed	P90	763
8a	2	Stature	Dutch children 3, mixed	P90	1071
8b			Dutch children 4, mixed	P90	1140
8c			Dutch children 5, mixed	P90	1228
8d			Dutch children 6, mixed	P90	1288
9		Difference between bottom and top sides (incl. front and back)	-	-	80



DINED mannequin with DINED reference numbers



Hand cart illustration with reference letters

Main hand cart dimension					
Calculation #	Main dimension edge name	Calculation	Dimension (mm)	Dimension (cm)	Conclusions
A	Top length	Calc. F + Data 9	1135	**114**	
B	Top back width	2 times mean of Data (3a, 3b, 3c)	628	**63**	*1
C	Top front width	Calc. F + Data 9	399	**40**	*2
D	Bottom length	Mean of Data (6a, 6b, 6c) + Mean of Data (7a, 7b, 7c)	1055	**106**	*3
E	Bottom back width	2 times mean of Data (5b, 5c, 5d)	487	**49**	*4
F	Bottom front width	Data 3c	319	**32**	*5
G	Textile height	Mean of Data (1a, 1b, 1c)	367	**37**	*6

Conclusions	
*1	The top back width of 63mm fits: Two P90 4-year olds (breadth over elbows). Two P90 5-year olds (breadth over elbows). One P90 5-year old and one P90 6-year old (breadth over elbows). Two P90 6-year olds, tightly (breadth over shoulders). Verified to be bigger than 538mm (2*Breadth over the elbows Dutch children 3, mixed, P90)
*2	The top front width of 40cm fits: Up to two P90 6-year olds (breadth over elbows) Verified to be bigger than 319mm (Breadth over the elbows Dutch children 6, mixed, P90)
*3	The bottom length of 106cm fits: Two sitting P90s 5-year old (Buttock foot length + buttock popliteal depth) (for sitting opposite of each other). Two sitting P90 6-year olds, bent knees (Buttock foot length + buttock popliteal depth) (for sitting opposite of each other). Full length (head to toe) of P90 3-year old, or crawled up up to P90 6-year old (for sleeping). Verified to be bigger than 763mm (Buttock foot length, sitting Dutch children 6, mixed, P90)
*4	The bottom back width of 60cm fits: Tightly, up to two P90 6-year olds (hip breadth, sitting)
*5	The bottom front width of 32cm fits: Up to two P90 6-year olds (hip breadth, sitting)
*6	The textile height of 32cm: Is < eye height of sitting P10 2-year old (to ensure view on surroundings) Verified to be smaller than 418mm (Eye height, sitting Dutch children 2, mixed, P10)

A16 Handlebar calculations

```
> restart : withplots :
```

Calculating the best handle bar positioning

In order to determine which handlebar configuration (pushing, pulling, angle) would work best, the situation is simplified with a situation of pulling or pushing a crate under different angles.

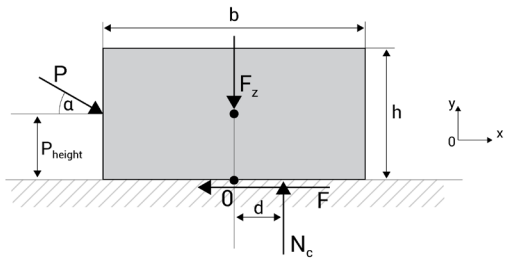


Fig.1: FBD of crate being pushed with pushing force P

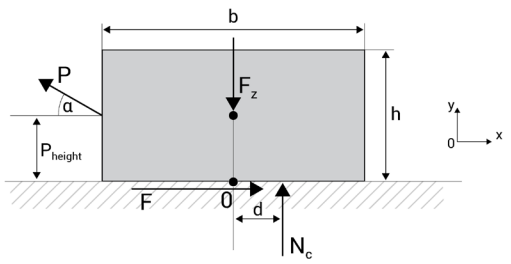


Fig.2: FBD of crate being pulled with pulling force P

```
> P := 80 : #in Newton
  α := 30·(Pi/180) : #in radians
  μs := 0.3 : #coefficient of static friction
> cratemass := 80 : #in kg
  g := 9.81 : #in m/s^2
  Fz := cratemass·g : #in N
> b := 1.33 : #in m
  h := 0.66 : #in m
> Pheight := (1/2)·h;
```

$$Pheight := 0.3300000000 \quad (1)$$

1. Now starting the calculations for the pushing force:

```
> equ1 := P·cos(α) − F = 0 :
> equ2 := -P·sin(α) − Fz + Nc = 0 :
> equ3 := P·sin(α)·((1/2)·b) − P·cos(α)·Pheight + Nc·d = 0 :
> F := solve(equ1, F) : 'F' = evalf[3](F);
  Nc := solve(equ2, Nc) : 'Nc' = evalf[3](Nc);
  d := solve(equ3, d) : 'd' = evalf[3](d);
  Fmax := μs·Nc : 'Fmax' = evalf(Fmax, 3)
```

$$F = 69.2$$
$$Nc = 825.$$
$$d = -0.00453$$
$$Fmax = 247. \quad (2)$$

```
> if evalf(F) < Fmax then print('not slipping') else print('slipping') end if;
  if d > ((1/2)·b) or d < -(1/2)·b then print('tipping') else print('not tipping') end if
```

not *slipping*

not *tipping* **(3)**

1.A. Now let's see how the height of the pushing force influences F, Nc, and d.

```
> unassign('Pheight','d','F','Nc','d', 'Fmax') : Pheight := x :

> equ1 := P·cos(α) − F = 0 :
> equ2 := -P·sin(α) − Fz + Nc = 0 :
> equ3 := P·sin(α)·((1/2)·b) − P·cos(α)·Pheight + Nc·d = 0 :

>
> F := solve(equ1, F) : 'F'= evalf[3](F);
  Nc := solve(equ2, Nc) :'Nc'= evalf[3](Nc);
  d := solve(equ3, d) :'d'= evalf[3](d);
  Fmax := μs·Nc :'Fmax'= evalf(Fmax, 3)
```

$$F = 69.2$$

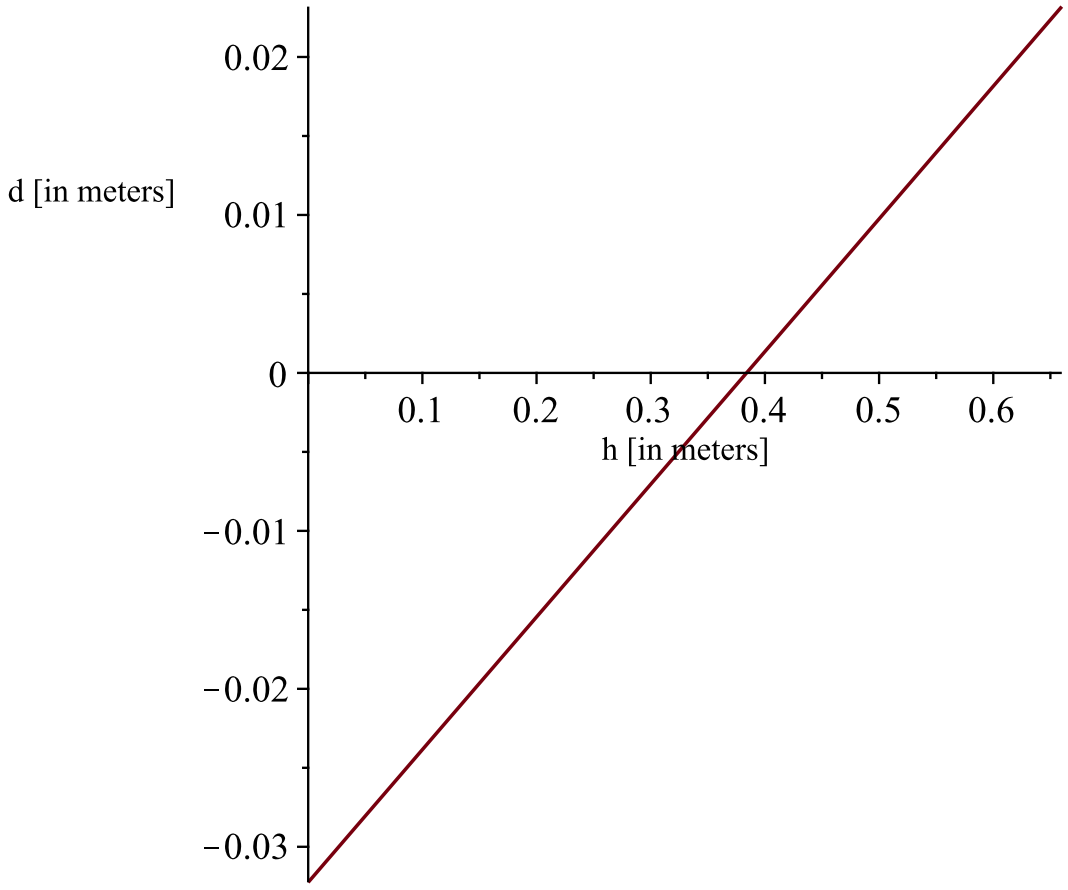
$$Nc = 825.$$

$$d = -0.0323 + 0.0840\,x$$

$$Fmax = 247.$$

(4)

```
> plot(d, x = 0..h, labels = ["h [in meters]", "d [in meters]"]);
  x := 0; 'd'= evalf[3](d);
  x := h; 'd'= evalf[3](d);
  unassign('x') :
```



$x := 0$

$d = -0.0323$

$x := 0.66$

$d = 0.0231$ **(5)**

We can see that only d is influenced by the change in height of P, moving to the right of 0 as the height of P increases.

1.B. Now let's see how the angle of the pushing force influences F, Nc, d, and Fmax.

> $unassign('Pheight','F','Nc','d','\alpha','Fmax') : Pheight := \frac{1}{2}\cdot h : \alpha := x\cdot\left(\frac{Pi}{180}\right) : \#in\ radians$

> $equ1 := P\cdot\cos(\alpha) - F = 0 :$

> $equ2 := -P\cdot\sin(\alpha) - Fz + Nc = 0 :$

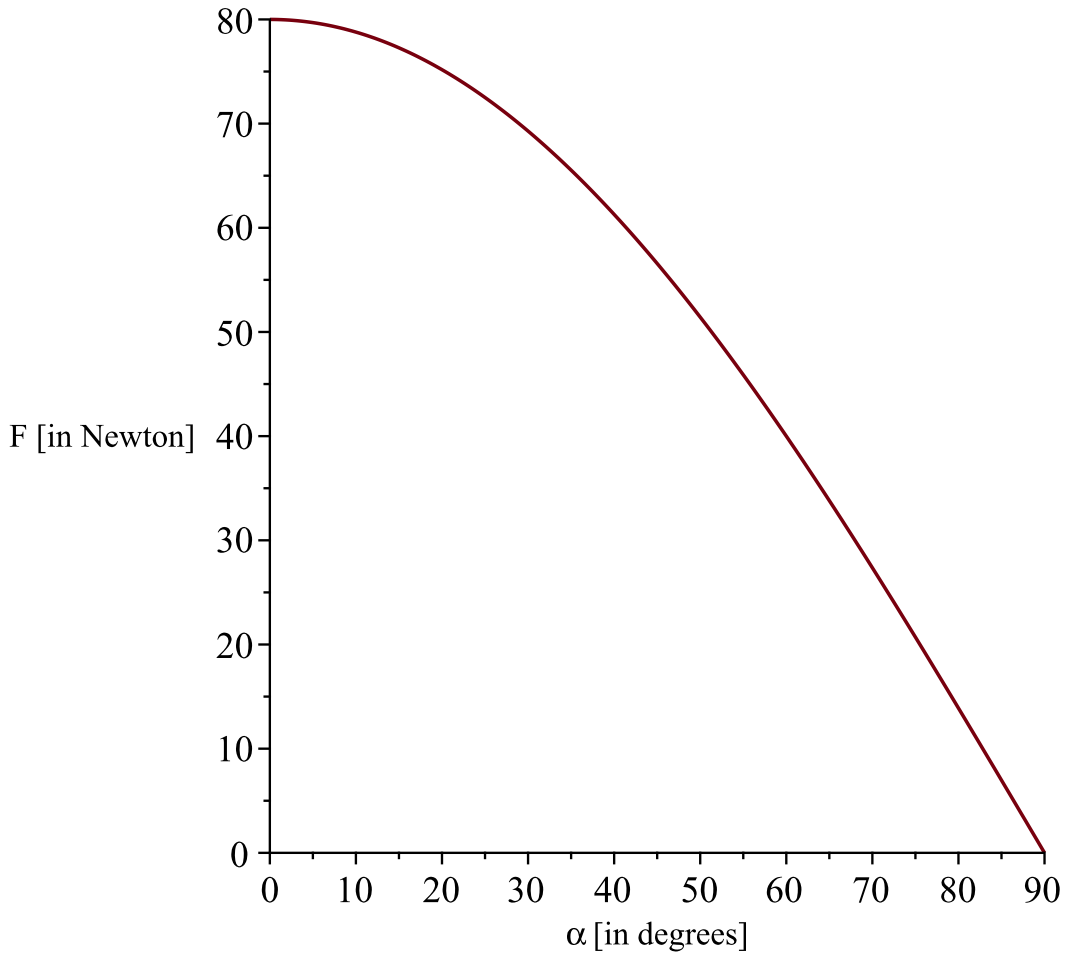
> $equ3 := P\cdot\sin(\alpha)\cdot\left(\left(\frac{1}{2}\right)\cdot b\right) - P\cdot\cos(\alpha)\cdot Pheight + Nc\cdot d = 0 :$

>

> $F := solve(equ1, F) : 'F' = evalf[3](F);$
> $Nc := solve(equ2, Nc) : 'Nc' = evalf[3](Nc);$
> $d := solve(equ3, d) : 'd' = evalf[3](d);$
> $Fmax := \mu s\cdot Nc : 'Fmax' = evalf(Fmax, 3)$

$$F = 80.\cos(0.0175\,x)$$
$$Nc = 785. + 80.\sin(0.0175\,x)$$
$$d = -\frac{0.500\,(133.\sin(0.0175\,x) - 66.\cos(0.0175\,x))}{100.\sin(0.0175\,x) + 981.}$$
$$Fmax = 235. + 24.0\sin(0.0175\,x) \quad \textbf{(6)}$$

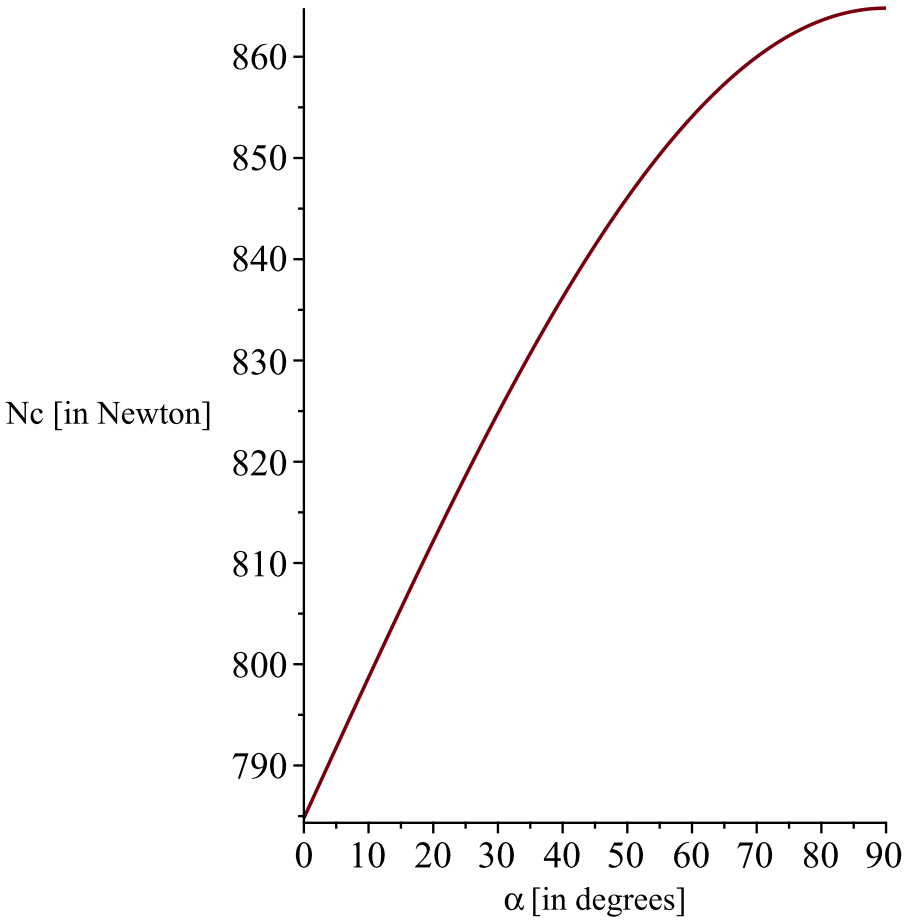
```
> plot(F, x = 0..90, labels = ["α [in degrees]", "F [in Newton]"]);
  x := 0; 'F' = F;
  x := 90; 'F' = F;
  unassign('x') :
```



$$x := 0$$
$$F = 80$$
$$x := 90$$
$$F = 0 \quad \textbf{(7)}$$

```
> plot(Nc, x = 0..90, labels = ["α [in degrees]", "Nc [in Newton]"]);
  x := 0; 'Nc' = evalf[3](Nc);
  x := 90; 'Nc' = evalf[3](Nc);
```

```
unassign('x') :
```



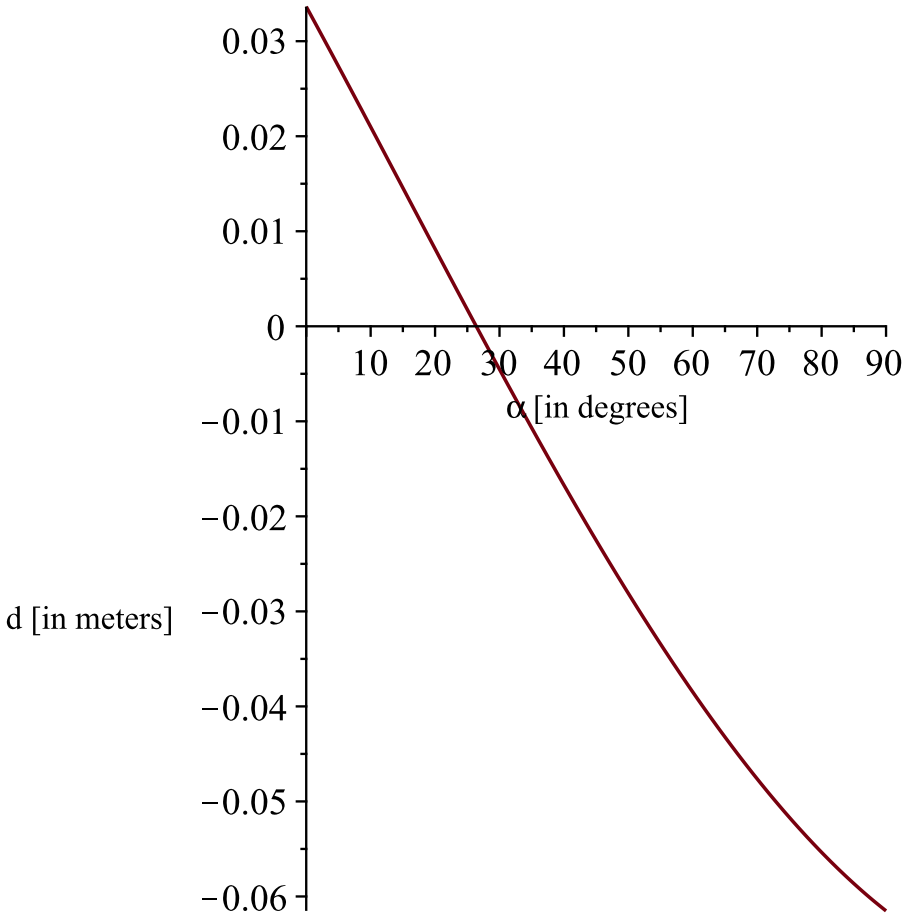
$$x := 0$$

$$Nc = 785.$$

$$x := 90$$

$$Nc = 865. \quad \textbf{(8)}$$

```
> plot(d, x = 0 ..90, labels = ["α [in degrees]", "d [in meters]"]);
  x := 0; 'd' = evalf[3](d);
  x := 90; 'd' = evalf[3](d);
  unassign('x') :
```



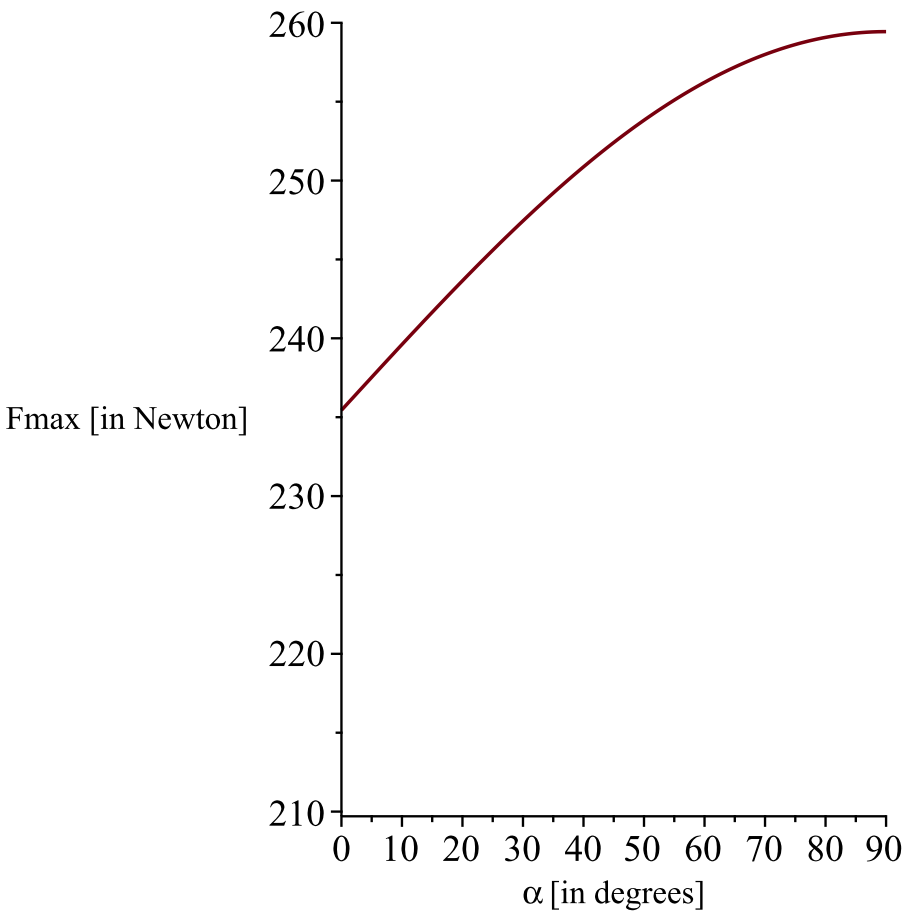
$x := 0$

$d = 0.0336$

$x := 90$

$d = -0.0620$ **(9)**

```
> plot(Fmax, x = 0..90, y = 210..260, labels = ["α [in degrees]", "Fmax [in Newton]"]);
  x := 0; 'Fmax' = evalf[3](Fmax);
  x := 90; 'Fmax' = evalf[3](Fmax);
  unassign('x') :
```



$x := 0$

$Fmax = 235.$

$x := 90$

$Fmax = 259.$ **(10)**

We can see that Nc gets lower, as angle α gets smaller. This means that the maximum friction force (Fmax) of the object is lower if the angle of the pushing force acts more horizontally on the object, which will make it easier to push the object forward.
Furthermore, of course the hand cart will have a low dynamic friction coefficient (μ[d]). Thus, the finding can be translated in how much force is needed to set the hand cart in motion in relation the angle and height of the force.

2. Now starting the calculations for the pulling force:

> $unassign('Pheight','F','Nc','d','\alpha','Fmax')$

> $Pheight := \left(\frac{1}{2}\right) \cdot h :$

> $\alpha := 30 \cdot \left(\frac{Pi}{180}\right) : \#in\ radians$

> $equ4 := -P \cdot \cos(\alpha) + F = 0 :$

> $equ5 := P \cdot \sin(\alpha) - Fz + Nc = 0 :$

> $equ6 := -P \cdot \sin(\alpha) \cdot \left(\left(\frac{1}{2} \right) \cdot b \right) + P \cdot \cos(\alpha) \cdot Pheight + Nc \cdot d = 0$:

> $F := solve(equ4, F)$: 'F'= $evalf[3](F)$;
$Nc := solve(equ5, Nc)$:'Nc'= $evalf[3](Nc)$;
$d := solve(equ6, d)$:'d'= $evalf[3](d)$;
$Fmax := \mu s \cdot Nc$:'Fmax'= $evalf(Fmax, 3)$

$$F = 69.2$$
$$Nc = 745.$$
$$d = 0.00502$$
$$Fmax = 223. \quad \textbf{(11)}$$

> **if** $evalf(F) < Fmax$ **then** $print('$**not** *slipping*$')$ **else** $print('slipping')$ **end if**;
if $d > \left(\frac{1}{2} \cdot b \right)$ **or** $d < -\frac{1}{2} \cdot b$ **then** $print('tipping')$ **else** $print('$**not** *tipping*$')$ **end if**

not *slipping*
not *tipping* **(12)**

2.A. Now let's see how the height of the pulling force influences F, Nc, and d.

> $unassign('Pheight','d','F','Nc','d','Fmax') : Pheight := x$:

> $equ4 := -P \cdot \cos(\alpha) + F = 0$:

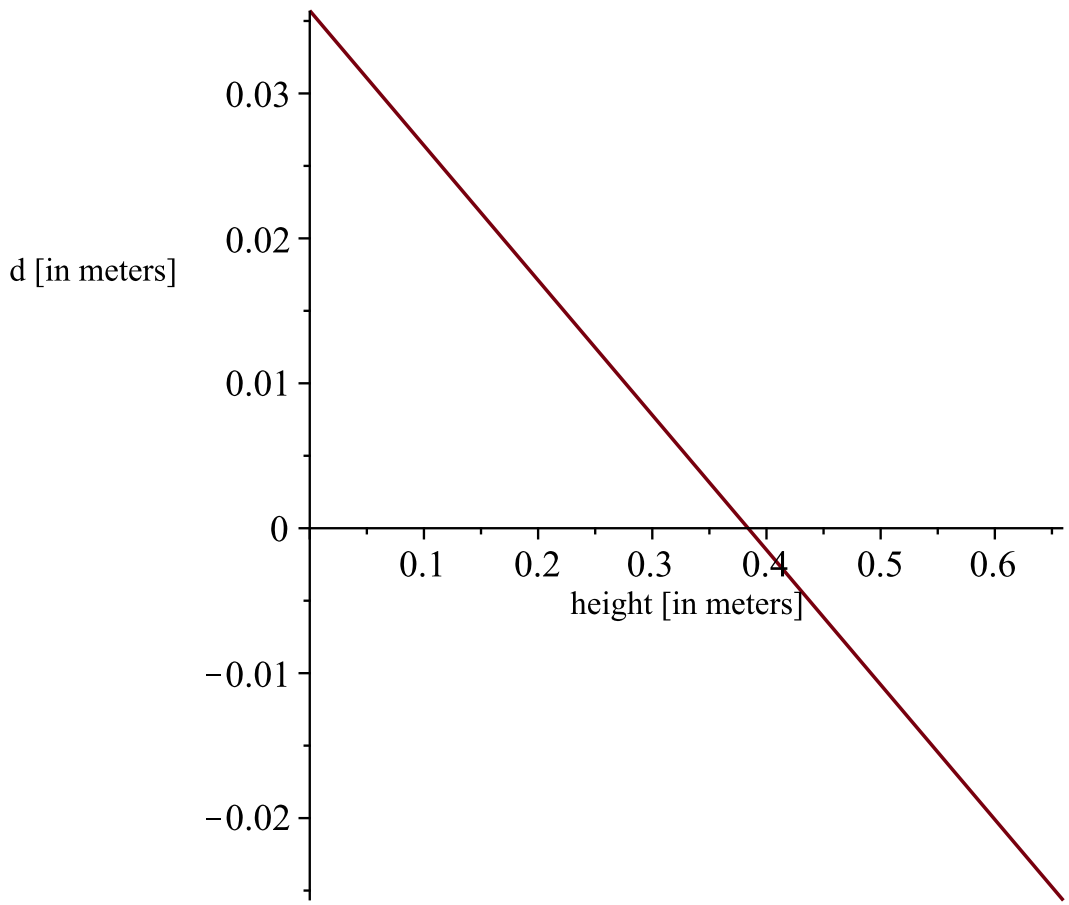
> $equ5 := P \cdot \sin(\alpha) - Fz + Nc = 0$:

> $equ6 := -P \cdot \sin(\alpha) \cdot \left(\left(\frac{1}{2} \right) \cdot b \right) + P \cdot \cos(\alpha) \cdot Pheight + Nc \cdot d = 0$:

> $F := solve(equ4, F)$: 'F'= $evalf[3](F)$;
$Nc := solve(equ5, Nc)$:'Nc'= $evalf[3](Nc)$;
$d := solve(equ6, d)$:'d'= $evalf[3](d)$;
$Fmax := \mu s \cdot Nc$:'Fmax'= $evalf(Fmax, 3)$

$$F = 69.2$$
$$Nc = 745.$$
$$d = 0.0357 - 0.0930\, x$$
$$Fmax = 223. \quad \textbf{(13)}$$

> $plot(d, x = 0..h, labels = ["height [in meters]", "d [in meters]"])$;
$x := 0$; 'd'= $evalf[3](d)$;
$x := h$; 'd'= $evalf[3](d)$;
$unassign('x')$:



$x := 0$

$d = 0.0357$

$x := 0.66$

$d = -0.0257$ **(14)**

We can see that only d is influenced by the change in height of P, moving to the left of 0 as the height of P increases.

2.B. Now let's see how the angle of the pulling force influences F, Nc, d, and Fmax.

> $unassign('Pheight','d','F','Nc','d','\alpha','Fmax') : Pheight := \frac{1}{2}\cdot h : \alpha := x\cdot\left(\frac{Pi}{180}\right) : \#in\ radians$

> $equ4 := -P\cdot\cos(\alpha) + F = 0 :$

> $equ5 := P\cdot\sin(\alpha) - Fz + Nc = 0 :$

> $equ6 := -P\cdot\sin(\alpha)\cdot\left(\left(\frac{1}{2}\right)\cdot b\right) + P\cdot\cos(\alpha)\cdot Pheight + Nc\cdot d = 0;$

$$equ6 := -53.20000000\sin\left(\frac{x\,\pi}{180}\right) + 26.40000000\cos\left(\frac{x\,\pi}{180}\right) + Nc\,d = 0 \quad \textbf{(15)}$$

> $F := solve(equ4, F) : 'F' = evalf[3](F);$
> $Nc := solve(equ5, Nc) : 'Nc' = evalf[3](Nc);$

```
d := solve(equ6, d) :'d'= evalf[3](d);
Fmax := μs·Nc :'Fmax'= evalf[3](Fmax);
```

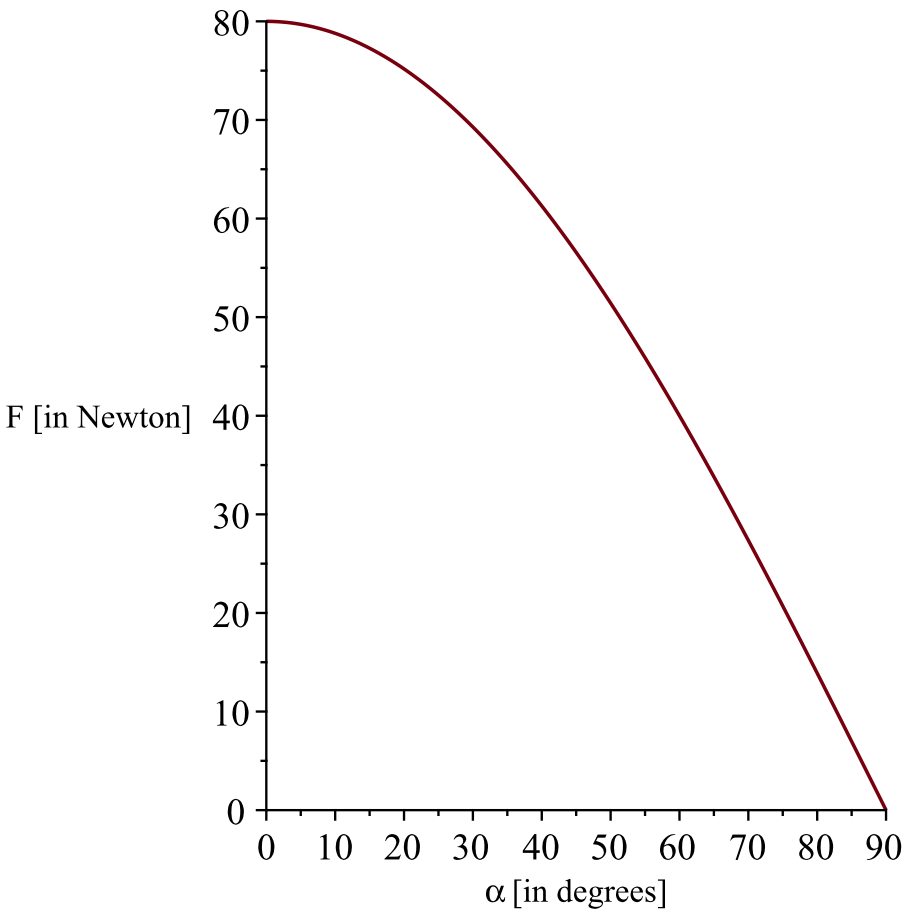
$$F = 80.\cos(0.0175\,x)$$

$$Nc = 785. - 80.\sin(0.0175\,x)$$

$$d = -\frac{0.500\,(133.\sin(0.0175\,x) - 66.\cos(0.0175\,x))}{100.\sin(0.0175\,x) - 981.}$$

$$Fmax = 235. - 24.0\sin(0.0175\,x) \qquad \textbf{(16)}$$

```
> plot(F, x = 0..90, labels = ["α [in degrees]", "F [in Newton]"]);
x := 0; 'F'= F;
x := 90; 'F'= F;
unassign('x') :
```



$$x := 0$$

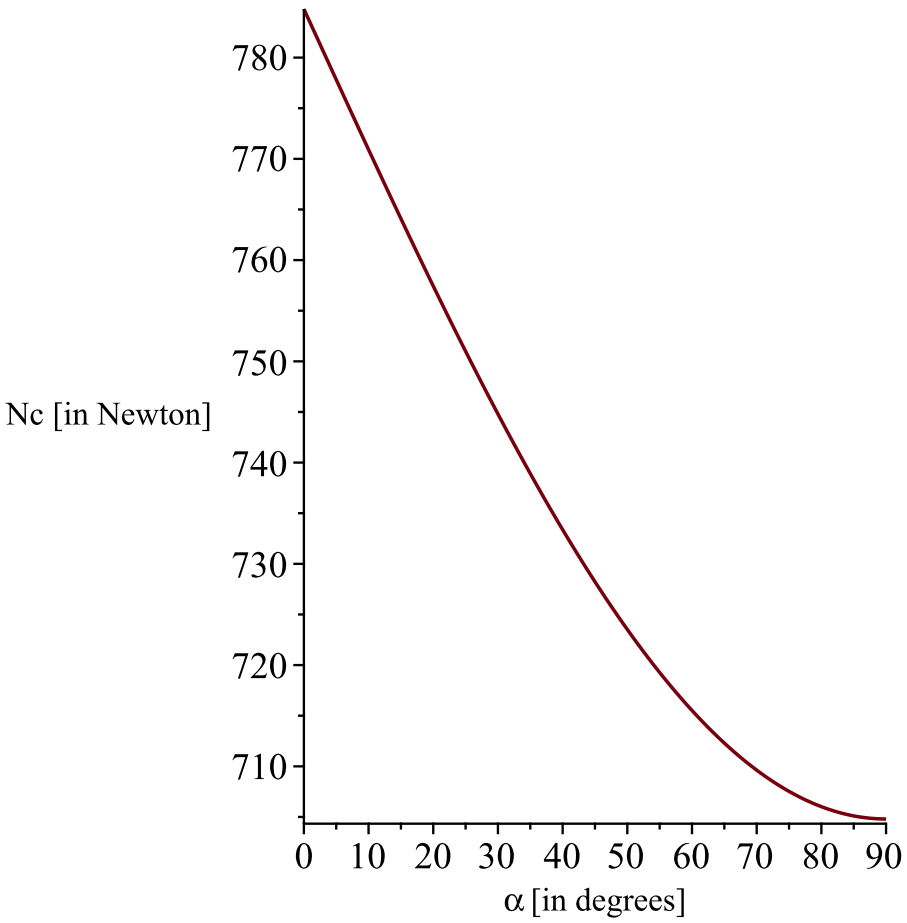
$$F = 80$$

$$x := 90$$

$$F = 0 \qquad \textbf{(17)}$$

```
> plot(Nc, x = 0..90, labels = ["α [in degrees]", "Nc [in Newton]"]);
x := 0; 'Nc'= evalf[3](Nc);
x := 90; 'Nc'= evalf[3](Nc);
```

```
unassign('x') :
```



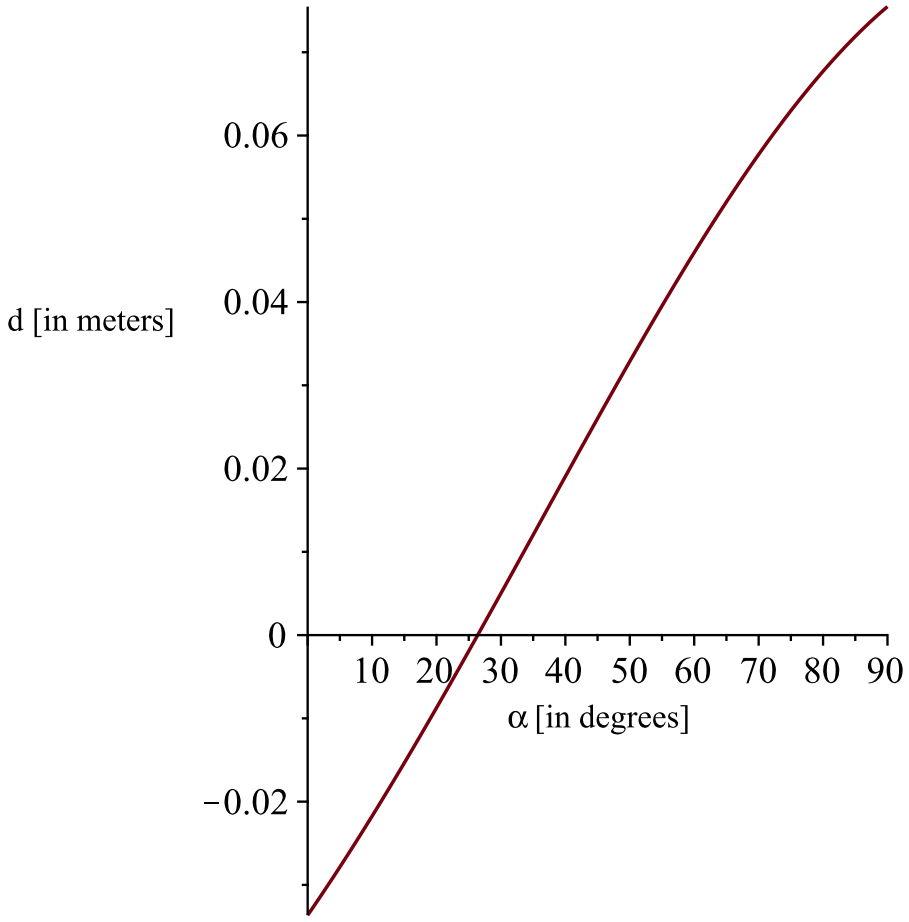
$x := 0$

$Nc = 785.$

$x := 90$

$Nc = 705.$ **(18)**

```
> plot(d, x = 0 ..90, labels = ["α [in degrees]", "d [in meters]"]);
  x := 0; 'd'= evalf[3](d);
  x := 90; 'd'= evalf[3](d);
  unassign('x') :
```



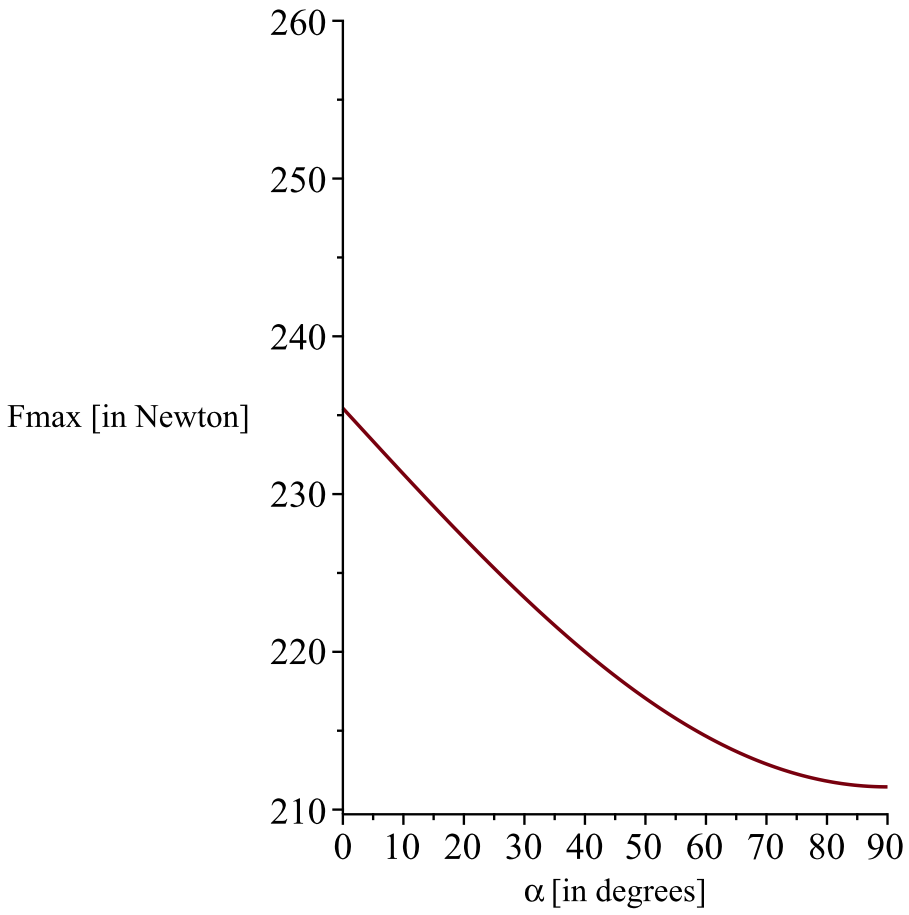
$x := 0$

$d = -0.0336$

$x := 90$

$d = 0.0760$ **(19)**

```
> plot(Fmax, x = 0..90, y = 210..260, labels = ["α [in degrees]", "Fmax [in Newton]"]);
  x := 0; 'Fmax' = evalf[3](Fmax);
  x := 90; 'Fmax' = evalf[3](Fmax);
  unassign('x') :
```



$x := 0$

$Fmax = 235.$

$x := 90$

$Fmax = 211.$ **(20)**

We can see that Nc gets lower, as angle α gets bigger. This means that the maximum friction force (Fmax) of the object is lower if the angle of the pushing force acts more vertically on the object, which will make it easier to pull the object forward. This is because the vertical force component of P helps reduce Nc.
Interestingly, when looking at the range {0≥α≤90}° we can see that the maximum Newton of Nc and maximum Newton of Fmax when pulling the cart is the exact number of the minimum Newton of Nc and minimum Newton of Fmax when pushing the cart. This concludes that pulling the cart should be slightly easier than pushing the cart.

> $FmaxdifferenceinNewton := \frac{(235 + 259)}{2} - \frac{(211 + 235)}{2}$

$FmaxdifferenceinNewton := 24$ **(21)**

> $Fmaxdifferenceinkg := \frac{FmaxdifferenceinNewton}{g} :'Fmaxdifferenceinkg'$
$= evalf[2](Fmaxdifferenceinkg);$

(22)

$$Fmaxdifferenceinkg = 2.4 \quad \textbf{(22)}$$

However, usually the cart will be pulled with one hand, but pushed with two hands, which makes pushing easier than pulling and better manouvrable.
Furthermore, of course the hand cart will have a low dynamic friction coefficient (μ[d]). Thus, the finding can be translated in how much force is needed to set the hand cart in motion in relation the angle and height of the force.

A17 Structure models insights

Below, the conclusions after analysing the five ideas. Green = positive point, red = negative point, Blue = neutral situation, orange = ideas to improve or next point of action.

Idea 1

- Compactness:
  - High
- Support:
  - Needs extra beam support. Make extra beam support.
  - Weight support can be challenging. Make suitable weight support
- Push/pull:
  - Push bar too low. Make extra long.
  - Legs touch bottom beam during walking. Might not be a problem once structure has wheels and is higher.
- Folding:
  - Folding steps might be confusing. (What are legs, what is the top?)
  - Does not stand on its own when folded (YET) Make it stand on its own.
- Design:
  - If folding mechanism will work, would be very handy due to high compactness!
  - If hand cart can remain flat when folded, then cool concept! Try making flat with wheels as well.
  - Fold beam down for easy entering
  - Fold up beam for pushing
  - Add push and/or pull

Idea 2

- Compactness:
  - Average
- Support:
  - Top beams and bottom beams can shift back and forth from each other. Make structure locked sturdy in place.
  - Evaluate weight support
- Push/pull:
- Folding:
  - Easy folding mechanism
  - Stands on its own when folded
- Design:
  - No extra capabilities
  - Add push and/or pull

Idea 3

- Compactness:
  - Average
- Support:
  - Needs extra beam support (at least for top beams). Make extra beam support.
  - Add better weight beam support
- Push/pull:
- Folding:
  - Stands on its own when folded
- Design:
  - Add push and/or pull

Idea 4

- Compactness:
  - Average
- Support:
  - Nice that there was weight support structure in model. Structure immediately feels sturdy when folded out.
  - Needs extra beam support (especially front beam). Make extra beam support.
  - Add better weight beam support
- Push/pull:
  - Pushing might be possible
  - Pulling handle bar needed when pushing structure is up. Also needs to easily be hidden/disabled.
  - Legs touch bottom beam during walking. Might not be a problem once structure has wheels, is higher, and has longer pushing beam length.
  - When pushing from the front, the back of the cart feels really big. If, in this way, the back acts as a 'front', then the two-person width should be eliminated or made more 'aerodynamic'. Or, the pushing bar could be in the back. Check this out.
- Folding:
  - Stands on its own when folded
- Design:
  - Fold beam down for easy entering
  - Sides might be too low to lean on. Check this out.
  - Add push and/or pull

Idea 5

- Compactness:
  - Average
- Support:
  - Weight support structure makes it feel sturdy
  - Needs extra beam support. Make extra beam support.
  - Add weight beam support
- Push/pull:
  - Will likely only be pushed
- Folding:
  - Does not stand on its own when folded
  - Folding design is the same as idea 4.
  - When completely folded against the Greentom Classic, the bottom bars rest against the toddler. Perhaps a different folding mechanism should be used.
  - One step before being completely folded, the design is spiky in the front. Perhaps a different folding mechanism should be used.
- Design:
  - Loose bar ends are difficult to handle. Should be fixed somehow (easier).
  - Children cannot step in and have to be carried to get in.
  - Perhaps try making car independent from stroller as well as dependent.
  - Add push and/or pull bar

A18 Rejected concepts

The developed concepts are shown in Figure 181 to Figure 186 in Section A18.1. However, an intermediate step between the concept phase and ideation phase is made in which several concepts are reevaluated. These reasoning behind the elimination of several concepts from the presented and evaluated concepts is discussed in Section A18.2.

A18.1 All developed concepts

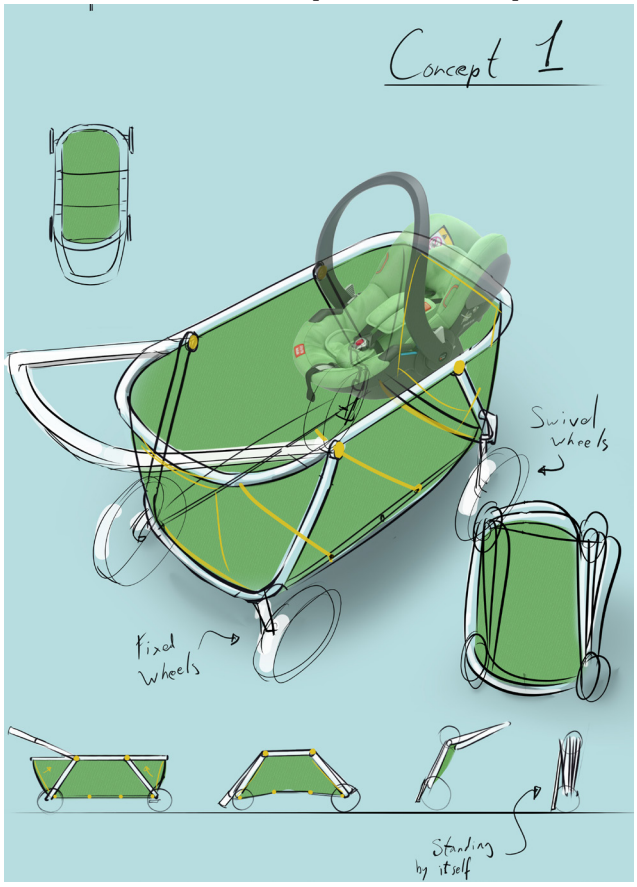


Figure 181 - Concept 1 - 'Threefold'

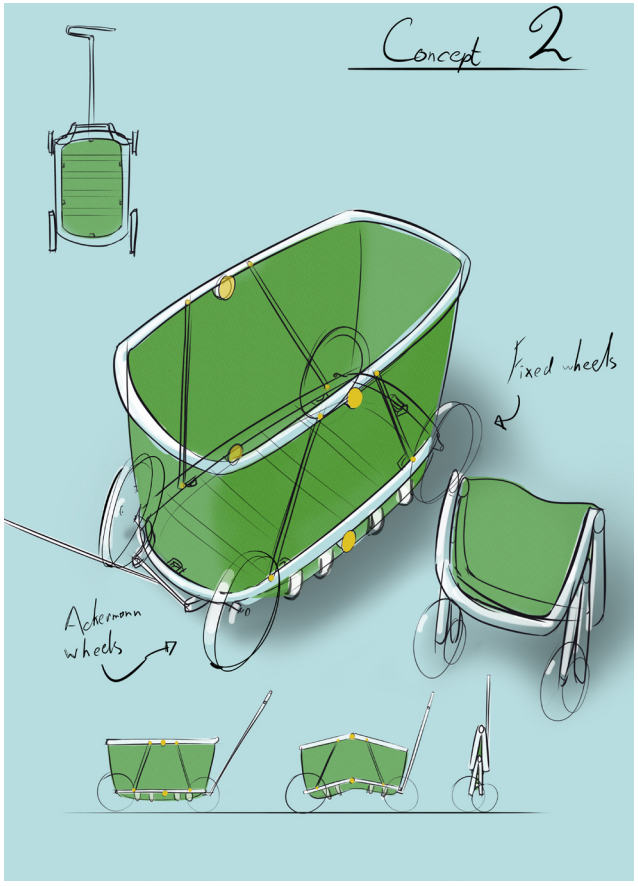


Figure 182 - Concept 2 - 'Horizontals'

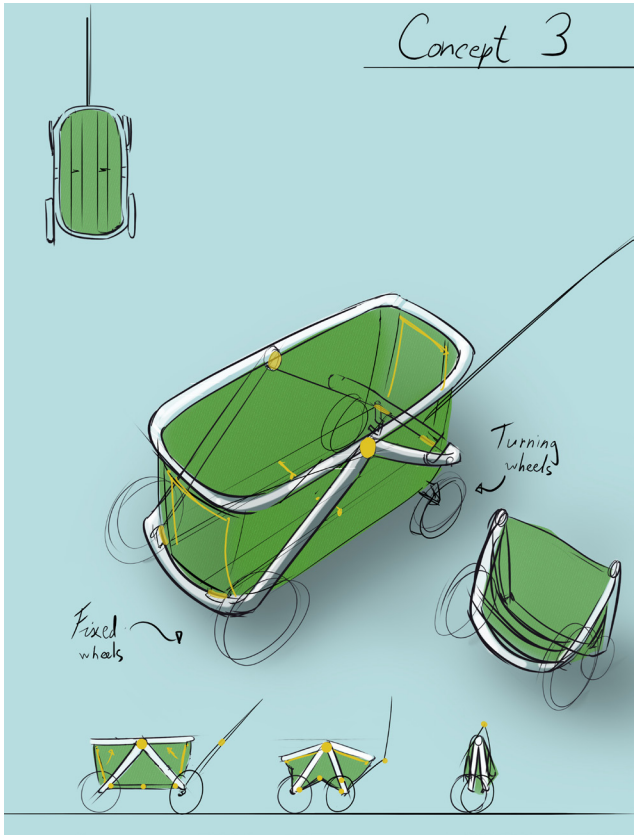


Figure 183 - Concept 3 - 'Twofold'

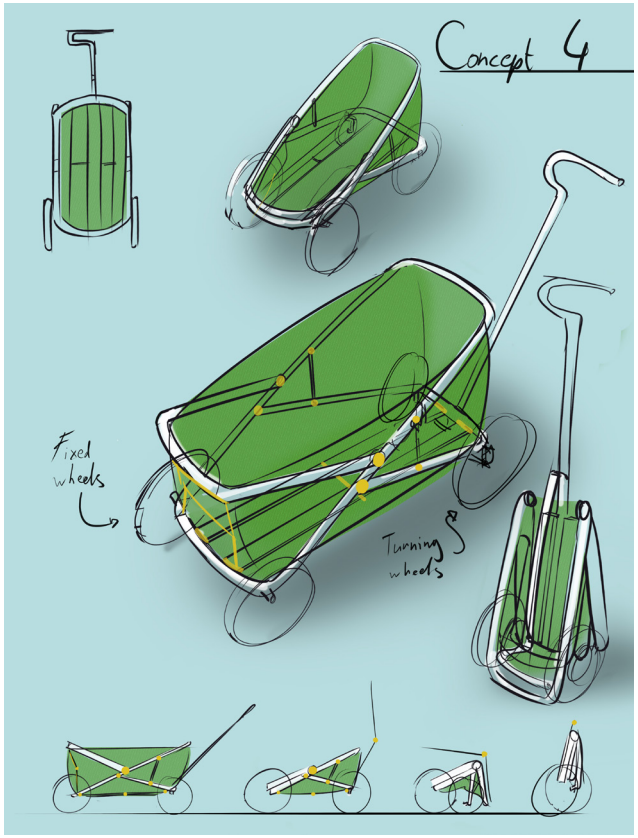


Figure 184 - Concept 4 - 'Diagonal'

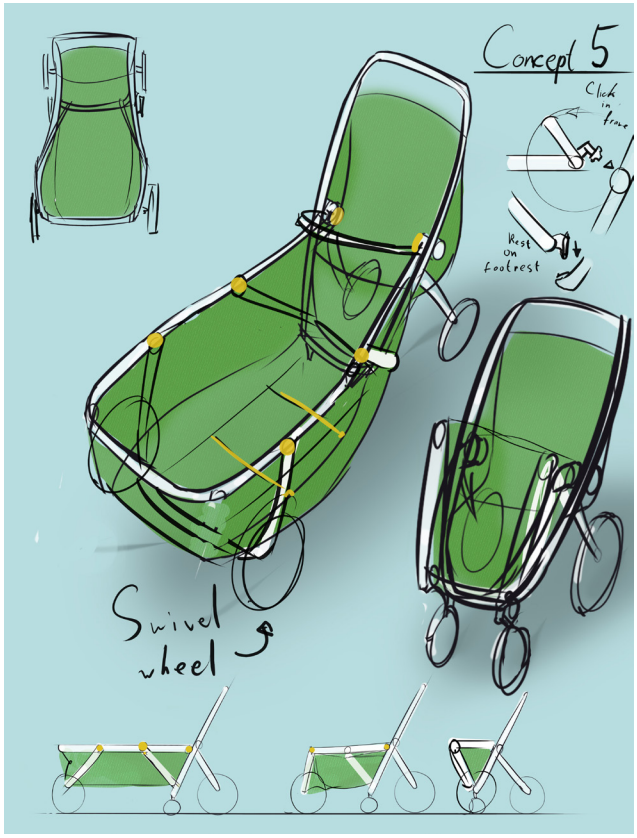


Figure 185 - Concept 5 - 'Combiner'

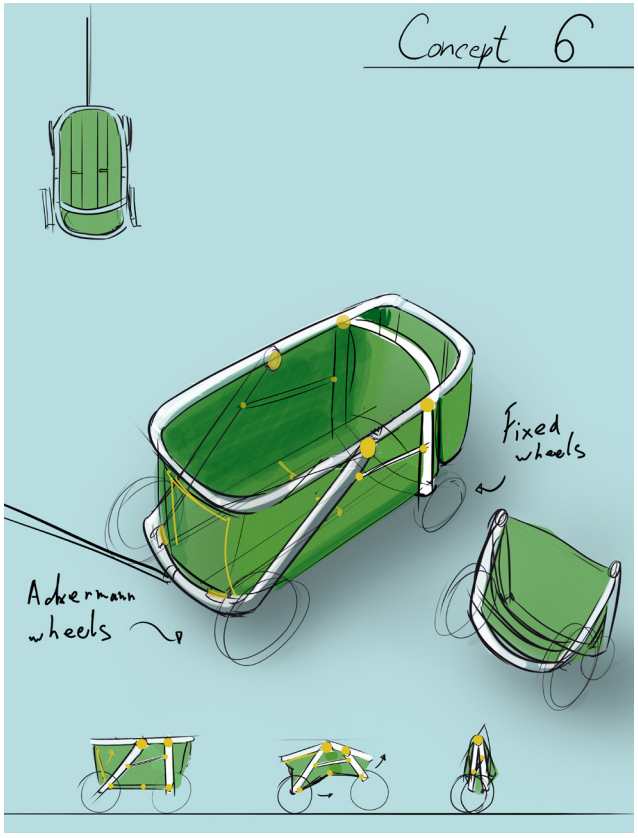


Figure 186 - Concept 6 - 'Back pocket'

A18.2 Reevaluated concepts

A18.2.1 Concept 1 - reevaluated

At first, concept 1 looked the most promising. However, when looking for structural improvements of the concept by means of a mock-up model, as well as after a recalculation of its dimensions, several challenges are found.

Firstly, as Figure 187 shows, the model of the concept is not able to fold due to the wheels getting stuck in the textile. Secondly, as Figure 188 shows, the bottom is not able to fold in three once attached to hinge around the beams. Thirdly, a miscalculation is made when calculating the diagonal beam length. As they should end underneath the ends of the top beams, the diagonal beams should have been made longer, which evidently would make the size of the folded concept larger, calculated to be almost the same compact size as a concept which folds in two instead of in three.

In conclusion, the challenges involved:

1. The hand cart being difficult to fold
2. The bottom principle not folding ideally
3. The 'compact' hand cart dimensions not being compact after all.

These challenges are solvable, but would decrease many of the anticipated benefits of the concept, including compactness when folded, and ease of folding. This is why it is chosen to re-evaluate the potentially best concept, with this new knowledge kept in mind.

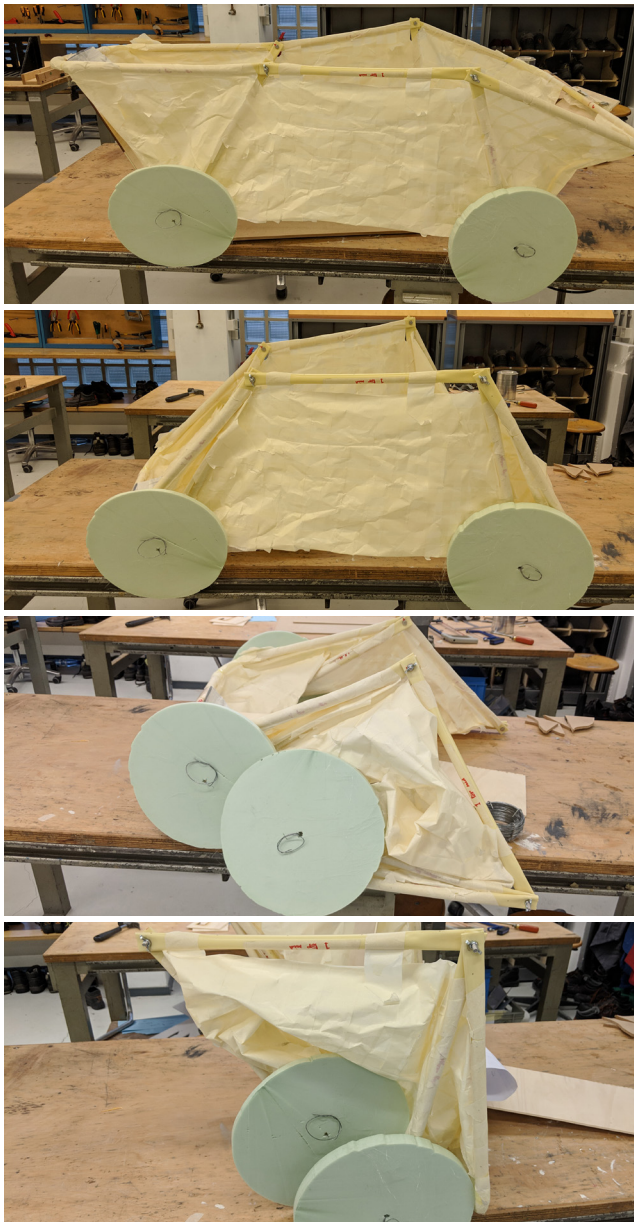


Figure 187 - Folding the mock-up model of concept 1 show not to be possible due to the wheels getting stuck in the textile

Figure 188 - The structure shows to be immovable as the bottom does not allow further movement of the beams when trying to fold in three

A18.2.2 Concept 5 - reevaluated

If the hand cart addition to the Greentom stroller (Figure 189) would be dependent on the Stroller, then only those customers with a Greentom Stroller with two or more children will buy this addition. It still could be a good idea for current customers: the cart would have to be made smaller, to only fit up to two six year olds, since the third one could sit in the Greentom Stroller, no back wheels would be needed, and only a pulling bar would be added for use at the beach. However, since only current customers with two or more children would be targeted, concept 5 would not create a new market or attract new customers.

If the hand cart would work with the Greentom stroller as well as independently from it -to target current as well as to attract new customers, then it could be convertible from an addition to an independent hand cart. If the hand cart would be made smaller, only holding space for two children, an interesting aspect would be that the cart would only have room for two P90 six year olds if used separately, but would allow for a place for a third six year old if attached to the Greentom Stroller. However, there are more parents with two children than parents with 3 children, which would mean that new customers buying the hand cart as an independent product would rarely later also buy the Greentom stroller as an addition for the third child. Thinking the other way around, the hand cart could be bought to provide space for the second or third child for customers that already have a Greentom stroller. However, this would again mean that the market of the new addition would only be focused on existing Greentom customers or new customers with a maximum of up to two children. For those new customers, the hand cart might be too small, since a large volume is preferred.

Furthermore, concept 5 would not comply with the following requirement:

"The product should comply with Greentom's form family: [...] simple, with no superfluous details or components".

The dependent-independent convertible hand cart addition would mean that the four integrated connection parts would always be visible, the fixed back wheels would be made detachable, and the pull/push bar may be placed on the product comfortably both when the cart is used independently as well as dependently in combination with the stroller. All these requirements, with detachables, would make the hand cart rather complex to use, and not have a form-follows-function look due to the visible integrated connector parts in a turnable top bar (even if hidden beneath the cloth).

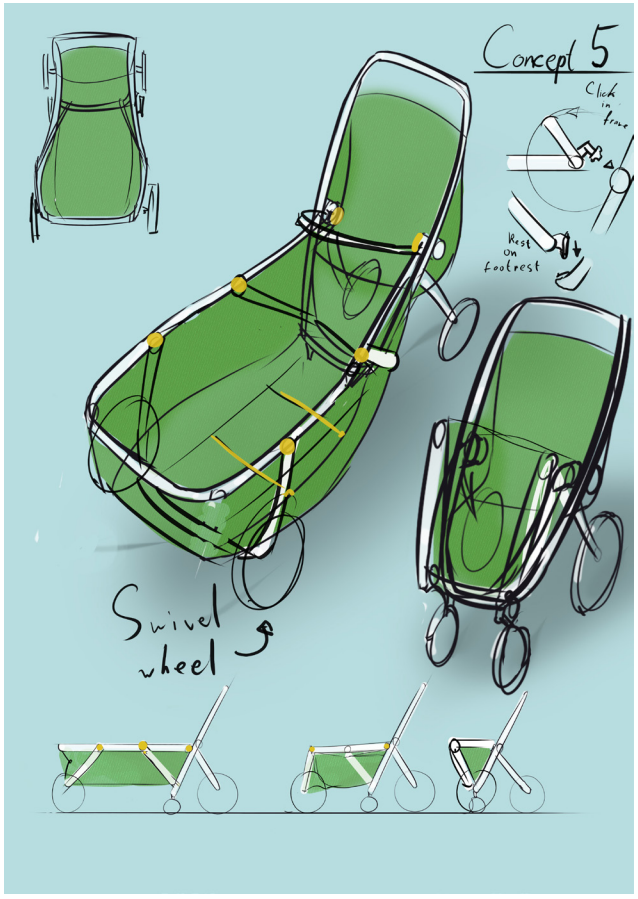


Figure 189 - Concept 5 - 'Combiner'

A18.2.3 Concept 6 - reevaluated

Regarding concept 6 (Figure 190), even though the design of it would ensure a better weight support on the back wheels due to the vertical bottom part with the back wheels attached to it, it would, as mentioned, also bring with it a compromise of the inner volume of the place the children can sit in due to the necessary addition of an extra bag to fill up the volume created when the cart folds with both wheels in one direction.

This would mean that at that point, if the hand cart has the same outer dimensions as the other concepts, then the concept would not comply to the following requirement:

"Product should have large enough volume to fit up to two children (6 years old, P90) freely with room for bags OR should fit three children (3 years old, P90) up to a mix of 4, 5, to 6 years olds (mean of P90, 4/5/6 years old) tightly with little room for bags."

If this inner volume for the children would be increased to match the length that is calculated to be needed for the children, then the folded dimensions (as well as the outer dimensions) would be 37 cm longer (the radius of the vertical back wheel part when folding + the diameter of the wheel) and then exceed the Beach Wagon Lite folded dimensions, making the folded length of concept 6 unpreferred. This would then mean that the concept does not fit the following requirement:

"Product should be compact (when folded) - (Smaller than the folded popular Beach Wagon Lite: {103 x 55 x 18}cm)"

If no pouch at all would be used and the inner volume would continue, then the cart would become unstable and unsafe if children would sit beyond the back wheel turning point, breaking the following safety requirement:

"Product should not be able to tip over when in use"

Finally, if no pouch would be used, and the cart would not be made longer past its back wheel turning point, then still the cart would be too big when folded if the required inner dimensions would be used since the wheels would fold past the unused space, elongating the folded dimensions by its radius. An extra pouch for belongings could still be a good idea, but might also be integrated in such a way that it can be hidden and not taking up space.

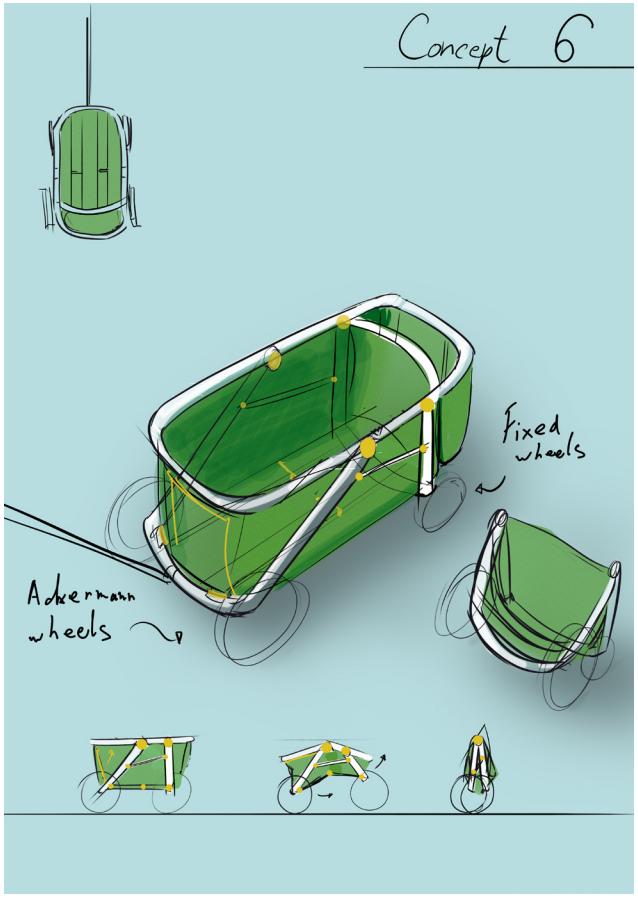


Figure 190 - Concept 6 - 'Back Pocket'

A19 Chosen concept evaluation

The five main requirements as defined in Section 2.4 are the following:

1. The product should be easy to use.
2. The product should be affordable.
3. The product should be attractive/aesthetically pleasing.
4. The product should be sustainable.
5. The product should be suitable for parents with up to three children.

Since all concepts score the same on the latter two requirements, they are evaluated by the degree with which they comply with the first three requirements.

The score which is given per criterion per concept is defined as follows (and later filled into the Harris Profile in Section 4.3 for visual comparison):

1. Ease of use

The number of steps it takes to (un)fold a concept is counted using storyboards:

Concept 1:

1. The two top parts are unlocked. 2. The two bottom parts are unlocked. 3. While the bottom is pulled upwards, the beams fold in half.

Concept 2:

1. The left top bar is pulled down. 2. Then the right top par is pulled down. 3. While the bottom is pulled upwards, the beams fold in half.

Concept 3:

1. The left top part is unlocked. 2. While the bottom is pulled upwards, the two bottom parts slide inwards by pressing down on the top right beam.

2. Affordable

The relative production costs of the concepts are evaluated by looking at the part complexity, part size, and number of parts:

Concept 1:

a. 'Part complexity': **Relatively complex** - Concept 1 has relatively complex as the cross-directional bottom beams are integrated in the beams. Furthermore, the beams have small hoops, to attach the textile to, integrated as well.

b. 'Part size': **Medium** - All concepts have beams of the same size as all concepts fold in half.

c. 'Number of parts': Unique parts (excl wheels): 10 parts
Number of moulds: **9 moulds**

- Two top parts
- Two bottom parts
- Two pivoting side plates in the front and back of the hand cart
- Two unique thin beams in between the horizontal beams (which can be 'family moulded'/mirrored in one mould)
- Two parts of the pulling bar

Concept 2:

a. 'Part complexity': **Not complex** - Concept 2 does not show any parts with many details or complex forms.

b. 'Part size': **Medium** - All concepts have beams of the same size as all concepts fold in half.

c. 'Number of parts': Unique parts (excl wheels): 10 parts
Number of moulds: **10 moulds**

- Two top parts
- Two diagonal bottom parts
- Two unique bottom weight parts of the support beams
- Two pivoting side plates in the front and back of the hand cart
- Two parts of the pulling bar

Concept 3:

a. 'Part complexity': **Not complex** - Concept 3 does not show any parts with many details or complex forms.

b. 'Part size': **Medium** - All concepts have beams of the same size as all concepts fold in half.

c. 'Number of parts': Unique parts (excl wheels): 11 parts
Number of moulds: **10 moulds**

- Two diagonal top parts
- Two diagonal bottom parts
- Two unique bottom weight support beam parts

- Two unique thin vertical support beams (which can be ‘family moulded’/mirrored in one mould)
- One pivoting side plate in the back of the hand cart
- Two parts of the pulling bar

3. Aesthetically pleasing

Concept 1:

a. 'Simplicity': **Simple** - The concept looks simple in its design without unneeded extra details.

b. 'Style': **Little form freedom** - The design of the hand cart (inclinations, curves, etc.) cannot be changed well to fit future style keywords, since the folding principle requires the shape to stay symmetrical. This gives little form freedom to let the concept fit the Greentom form family and defined hand cart style.

c. 'Uniqueness': **Unique** - None of the competing hand carts have a comparable design to this concept, which makes this concept look unique.

Concept 2:

a. 'Simplicity': **Simple** - The concept looks simple in its design without unneeded extra details.

b. 'Style': **Promising** - The design of the hand cart (inclinations, curves, etc.) can be changed to fit the Greentom form family style and defined hand cart style.

c. 'Uniqueness': **Not unique at first glance** - The design is similar to that of the Coocarooc Breeze and the NPK walking wagon even though the structural shape is hidden beneath a cloth in the two latter hand carts.

Concept 3:

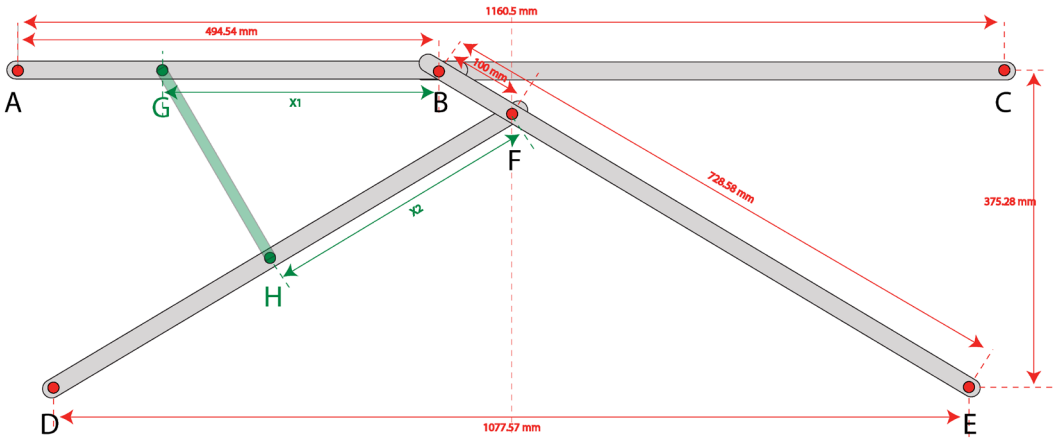
a. 'Simplicity': **Medium** - The concept looks a bit complex at first glance due to its unusual diagonal structure. However, for existing Greentom customers, the working structure might look similar to that of the Greentom stroller.

b. 'Style': **Promising** - The design of the hand cart (inclinations, curves, etc.) can be changed to fit the Greentom form family style and defined hand cart style.

c. 'Uniqueness': **Very unique** - Compared to the other concepts and other analysed hand carts in the market, this concept is the only concept using non-horizontal or vertical lines, apart from the cheap scissor-model hand carts.

A20 Side rod calculation

Calculating the joint location for beam GH suitable for the construction in unfolded as well as folded form.




```
> restart : with(plots) :
```

Setting up the knowns for the calculation (in the unfolded situation)
[Measurements of each beam were derived from the Solidworks model created after the defined hand cart volume dimensions]

```
> height := 375.28 : #mm
> lengthBE := 728.58 : #mm
> lengthDF := 628.58 : #mm
> lengthBF := 100 : #mm
> lengthAB := 494.54 :#mm
> lengthAC := 1160.5 :#mm
> #equ1 :=sin(alpha) = height/lengthBE :
> #alpha :=solve(equ1, alpha) #This is the angle between BE and DE in radians
> alpha := arcsin(37528/72858);
```

#This is the angle between BE and DE in radians. Height and lengthBE is written without decimals, to get around a Maple error.

$$\alpha := \arcsin\left(\frac{18764}{36429}\right) \tag{1}$$

Now let's set up the coordinates for G and H with point B as the origin in unfolded situation.

```
> Gx := -x1;
  Gy := 0;
  Hx := -(cos(alpha)·x2 - cos(alpha)·lengthBF);
  Hy := -(sin(alpha)·x2 + sin(alpha)·lengthBF);
```

$$Gx := -x1$$
$$Gy := 0$$

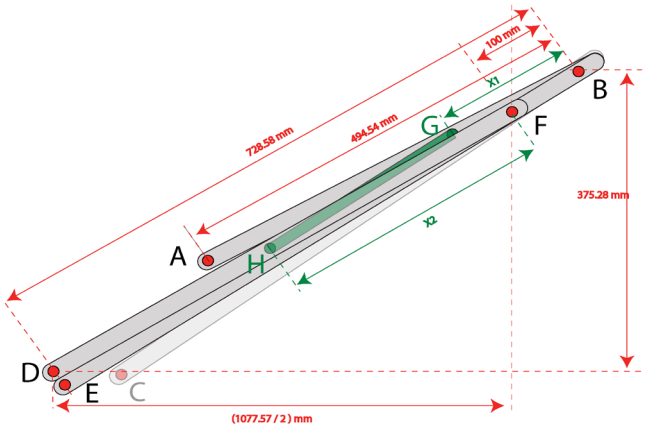
$$Hx := -\frac{\sqrt{143763829406910905}\ x2}{442357347} + \frac{100\sqrt{143763829406910905}}{442357347}$$

$$Hy := -\frac{18764\,x2}{36429} - \frac{1876400}{36429} \quad (2)$$

> $lengthGH\_unfolded := \mathrm{sqrt}\left((Gx - Hx)^2 + (Gy - Hy)^2\right);$

$$lengthGH\_unfolded := \left(\left(-x1 + \frac{\sqrt{143763829406910905}\ x2}{442357347} - \frac{100\sqrt{143763829406910905}}{442357347}\right)^2 + \left(\frac{1876400}{36429} + \frac{18764\,x2}{36429}\right)^2\right)^{1/2} \quad (3)$$

Now let's set up the coordinates for G and H with point B as the origin in folded situation.



> $lengthGH\_folded := x2 + lengthBF - x1;$

$$lengthGH\_folded := x2 + 100 - x1 \quad (4)$$

Now, let's calculate x1, x2, and the length of GH which is valid in both unfolded and folded situation.

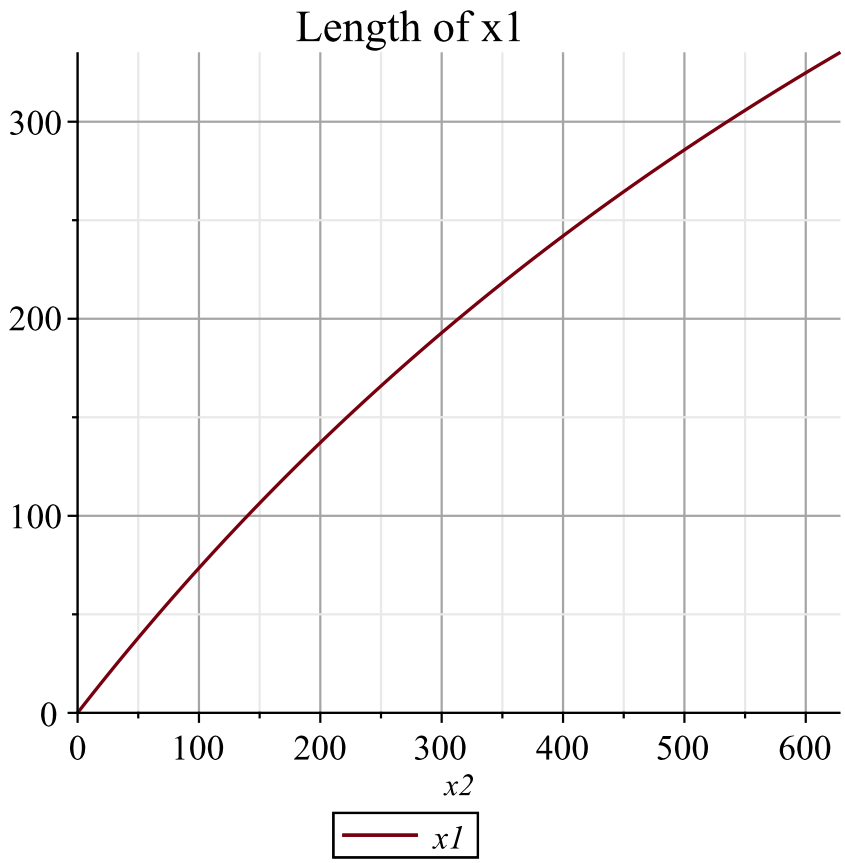
> $equ2 := lengthGH\_unfolded = lengthGH\_folded;$

$$equ2 := \left(\left(-x1 + \frac{\sqrt{143763829406910905}\ x2}{442357347} - \frac{100\sqrt{143763829406910905}}{442357347}\right)^2 + \left(\frac{1876400}{36429} + \frac{18764\,x2}{36429}\right)^2\right)^{1/2} = x2 + 100 - x1 \quad (5)$$

> $x1 := solve(equ2, x1);$

$$x1 := -\frac{194996869000\,x2}{36429\left(\sqrt{974984345}\ x2 - 100\sqrt{974984345} - 36429\,x2 - 3642900\right)} \quad (6)$$

> $plot(x1, x2 = 0..lengthDF, gridlines = true, legend = 'x1', title = \text{"Length of x1"}, titlefont = [\text{"ROBOTO"}, 16]);$



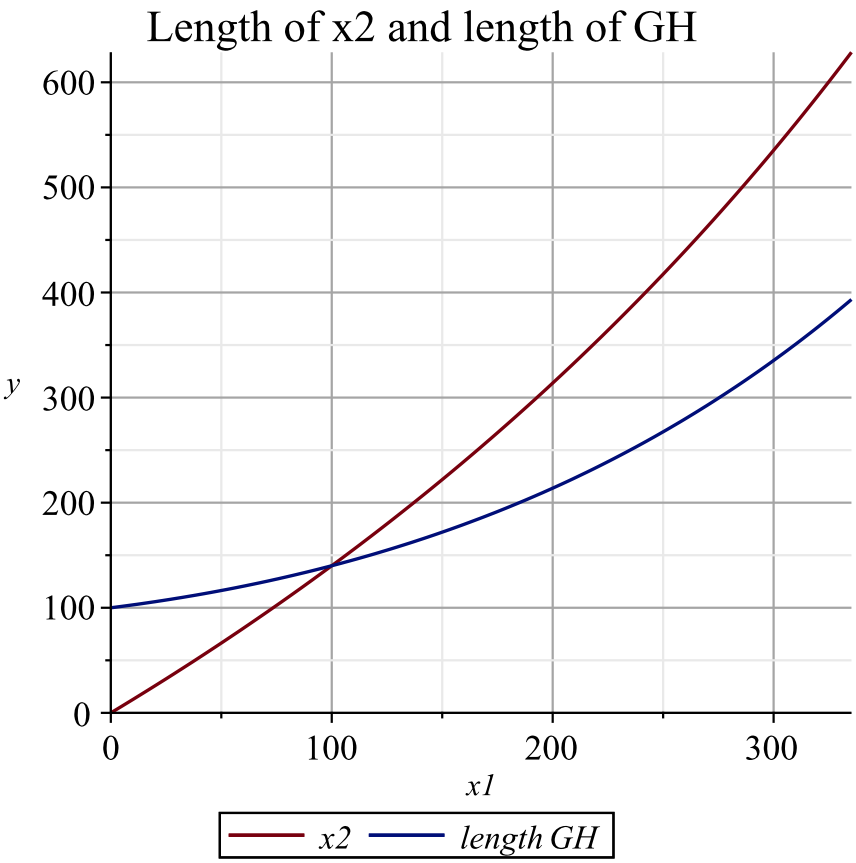

```
> x2 := lengthDF : evalf(x1); #This is the max reach of x1 in -x direction.
```

335.2365660 **(7)**

```
> unassign('x1','x2') :
> x2 := solve(equ2, x2);
```

$$x2 := \frac{3642900\, x1 \left(36429 + \sqrt{974984345}\right)}{194996869000 + 36429\, x1 \sqrt{974984345} - 1327072041\, x1} \quad \textbf{(8)}$$

```
> plot([x2, lengthGH_unfolded], x1 = 0 ..335.2365660, y = 0 ..lengthDF, gridlines = true, legend
    = ['x2', 'length GH'], title = "Length of x2 and length of GH", titlefont = ["ROBOTO", 16]);
```



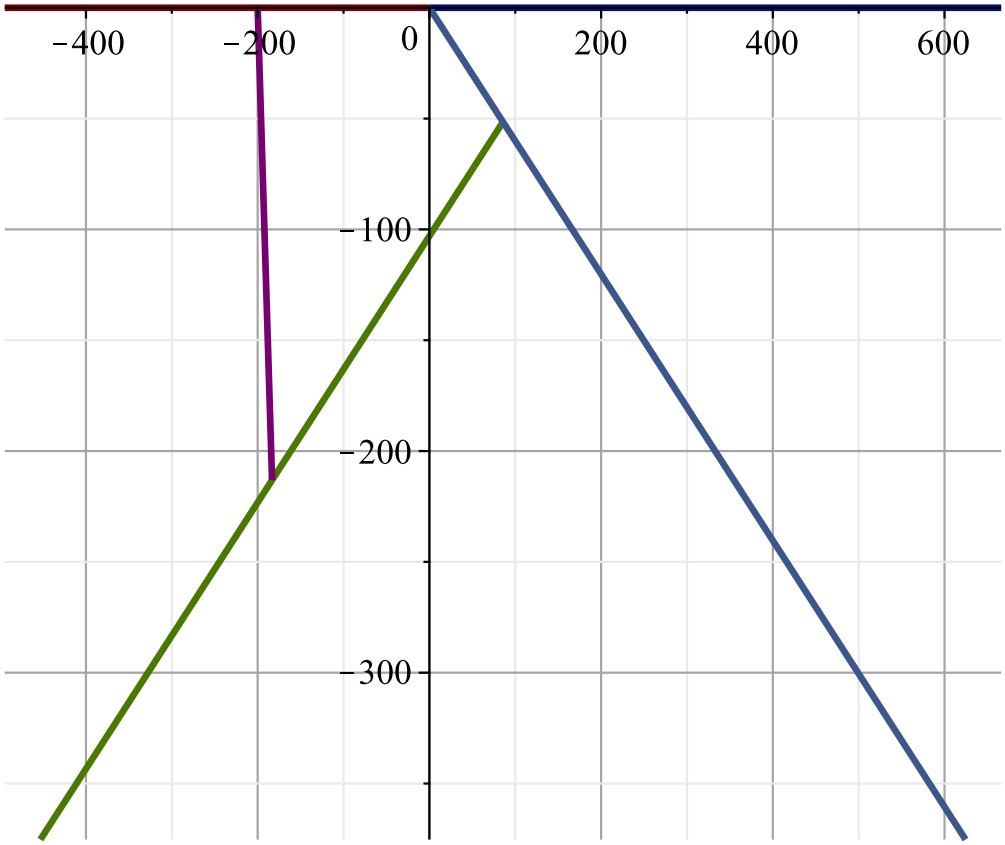

```
> pA := [-494.54, 0]:
  pB := [0, 0]:
  pC := [665.96, 0]:
  pD := [-453.0668615, -375.2800000]:
  pE := [624.4947863, -375.2800000]:
  pF := [85.71396224, -51.50841363]:
  pX1 := [-x1, 0];
  pX2 := [ -cos(alpha)·x2 + cos(alpha)·lengthBF, -sin(alpha)·x2 - sin(alpha)·lengthBF];
```

$$pX1 := [-x1, 0]$$

$$pX2 := \left[-\frac{100\sqrt{143763829406910905}\, x1\,(36429+\sqrt{974984345})}{12143\,(194996869000+36429\, x1\sqrt{974984345}-1327072041\, x1)} + \frac{100\sqrt{143763829406910905}}{442357347},\ -\frac{1876400\, x1\,(36429+\sqrt{974984345})}{194996869000+36429\, x1\sqrt{974984345}-1327072041\, x1} - \frac{1876400}{36429}\right] \quad (9)$$

```
> x1 := 200:
> AB := [pA, pB]:
  BC := [pB, pC]:
```

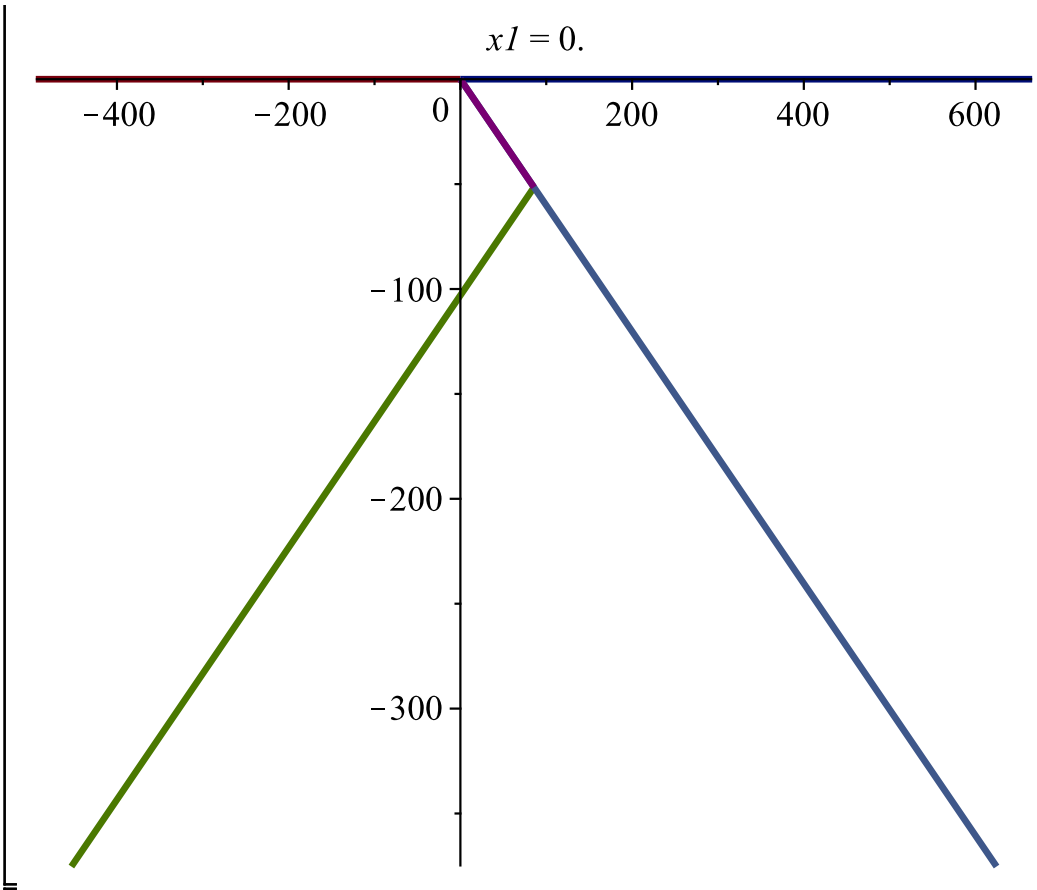
```
DF := [pD, pF]:
BE := [pB, pE]:
X1X2 := [pX1, pX2]:
plot([AB, BC, DF, BE, X1X2], gridlines = true, thickness = 3)
```




```
> unassign('x1')
> x1;
X1X2 := [pX1, pX2]:
```

$$x1 \tag{10}$$

```
> animate(plot, [[AB, BC, DF, BE, X1X2], thickness = 3], x1 = 0..335.2365660)
```



>

Defining x2 and LengthGH_unfolded, depending on x1.

> $x1 := 200$:

> $'x2' = evalf(x2); 'lengthGH' = evalf(lengthGH\_folded);$

$$x2 = 313.7972119$$

$$lengthGH = 213.7972119 \quad \textbf{(11)}$$

>

A21 Handlebar length

As is concluded in Section 5.2.2, the pulling height is considered to be 995mm which is the mean hip height for 20-30 year old (P90) (DINED, 2017b). As can be seen in Figure 191, when pulling a hand cart, the pulling hand hovers around hip height, which confirms this defined height. Interestingly, the push bar height of the Greentom Classic is 103 cm (Greentom, 2018d), which further confirms that this assumed ideal ergonomic pushing height estimation is plausible.

Figure 191 - Posture during pulling a Cruiser Veer hand cart (Albee Baby, 2017)

As is concluded in Section 5.2.2, the pushing height is considered to be 1097mm, which is the mean elbow heigh for 20-30 year olds (P50, mixed) (DINED, 2017b). As can be seen in Figure 192, when pushing a hand cart, the pushing hand hovers around elbow height, which confirms this defined height.

Figure 192 - Posture during pushing a Cruiser Veer hand cart (Albee Baby, 2017)

As is concluded in Section 5.2.2, to prevent the heels or toes of a person to touch the chassis when pulling or pushing, the average step distance is measured by hand, which serves as a indicator of the needed horizontal distance from the pulling or pushing hand to the hand cart, being 50cm.

Based on these dimensions, it can be concluded from Figure 194 that the best suitable handlebar length is 77cm (length l_1 as seen in Figure 193), considering that the handlebar length is smaller than the folded dimensions of the hand cart to remain foldable: being <87cm which the largest beam length of the chassis (729mm (Figure 195), plus the radius of 145mm of the back wheel.

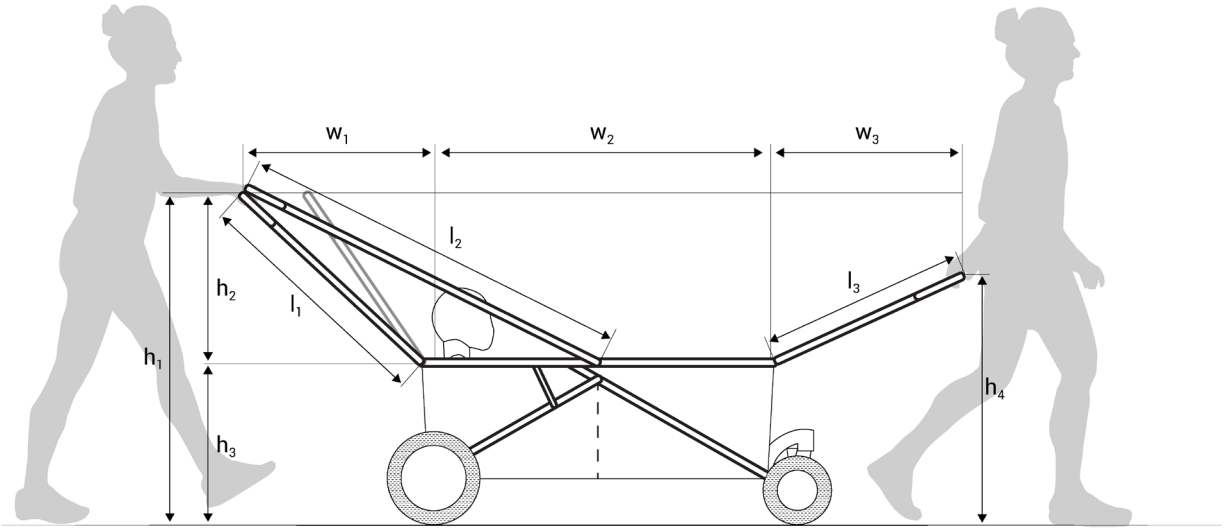


Figure 193 - Possible handlebar lengths and positions

```
> w1 := 500 : #in mm (Average measured step distance)
  w2 := 1135 :#in mm (From defined hand cart measurements)
  w3 := w1 :
  h1 := 1097 : #in mm (Acquired from DINED)
  h3 := 515 :
      #in mm (From defined hand cart measurements: height of hand cart volume (370) + wheel
      radius (145))
  h4 := 995 : #in mm (Acquired from DINED)
```

```
> eq1 := h1 = h2 + h3 : h2 := solve(eq1, h2); #in mm
```

$$h2 := 582 \quad (1)$$

Pushing a hand cart from the top back

```
> l1 := evalf(sqrt((w1)^2 + (h1 - h3)^2), 4) mm
```

$$l1 := 767.4\ mm \quad (2)$$

Pushing a hand cart from the middle.

```
> l2 := evalf(sqrt(((1/2)·w2 + w1)^2 + (h1 - h3)^2), 4) mm
```

$$l2 := 1216.\ mm \quad (3)$$

Pulling a hand cart from the top front.

```
> l3 := evalf(sqrt((w3)^2 + (h4 - h3)^2), 4) mm
```

$$l3 := 693.2\ mm \quad (4)$$

Figure 194 - Calculations regarding handlebar lengths as proposed in Figure 193

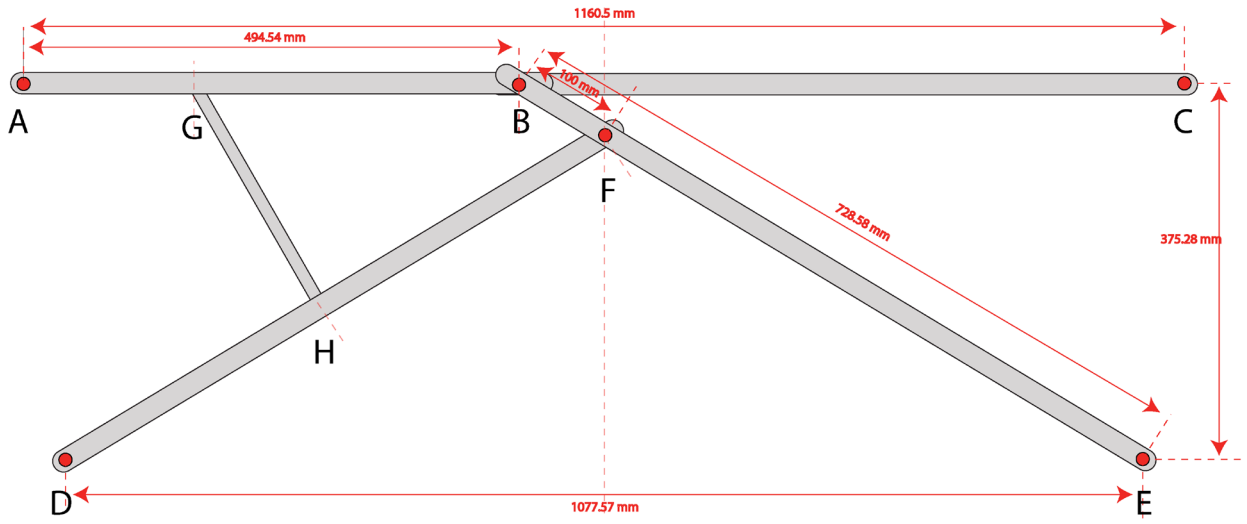


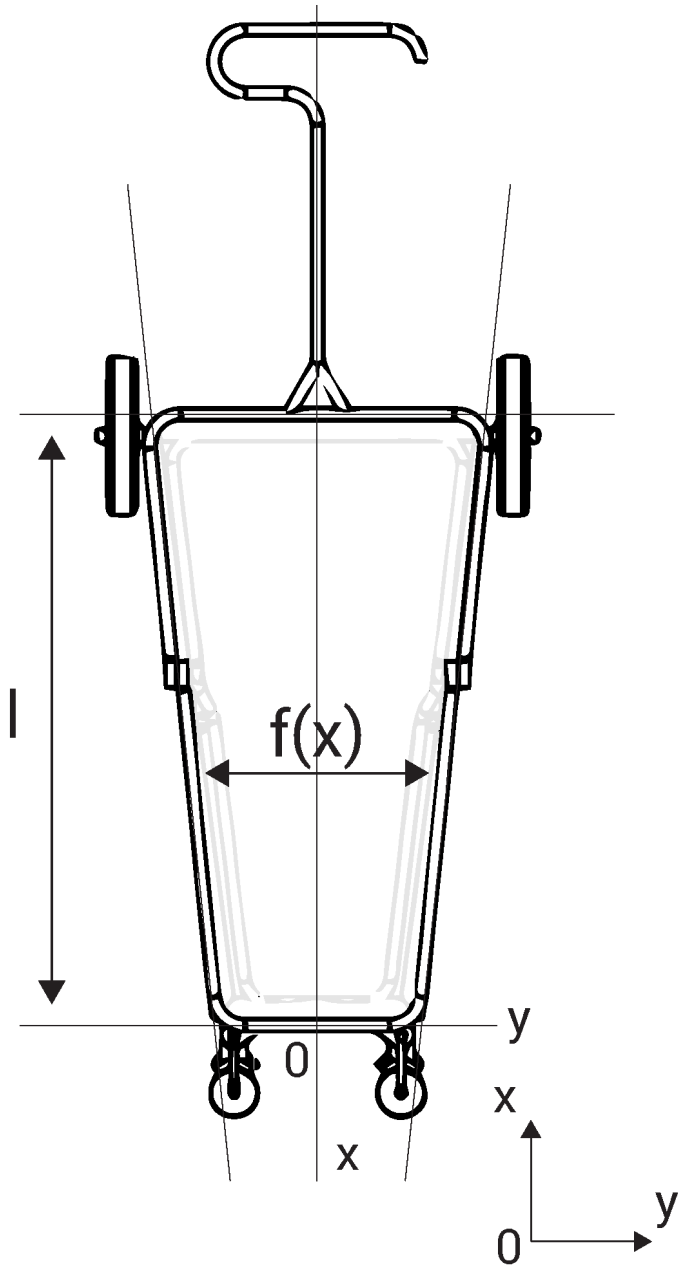
Figure 195 - Hand cart beam measurements (derived from the Solidworks model created after the defined hand cart volume dimensions)

A22 Attachment accessories

Calculating the optimal attachment point positioning and stump length for attachable accessories

> *restart* :

Defining the function dependent on x (which calculates the width of the hand cart at that point)



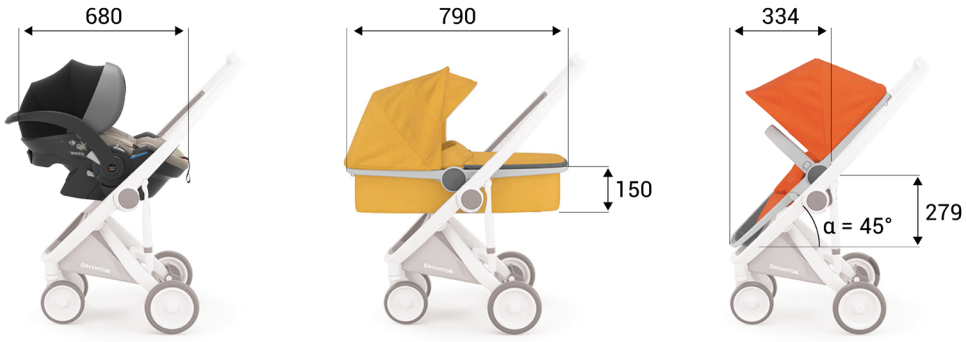
> *l* := 1135 : *#in mm (From defined hand cart measurements)*
> *w0* := 400 :*#width at f(0) in mm (From defined hand cart measurements)*
> *w1* := 626 :*#width at f(626) in mm* (*From defined hand cart measurements, Solidworks*)

> $equ1 := f(x) = 2 \cdot \left(\frac{w0}{2} + \frac{\left(\frac{(w1 - w0)}{2} \right)}{l} \cdot x \right)$

#This function calculates the width of the hand cart at a given position on the x-axis.

$$equ1 := f(x) = 400 + \frac{226\,x}{1135} \quad \textbf{(1)}$$

Defining the accessory dimensions and their attachment point locations (to fit onto the top chassis of the hand cart)



Width: 430 Width: 400 Width: 400

All measurements in mm

Attachment point widths: 370 (outer) and 285 (inner)

> *AttachmentpointOuterWidth* := 370 :
#in mm (The outer width of the two attachment points for all accessories)

> *AttachmentpointInnerWidth* := 285 :
#in mm (The inner width of the two attachment points for all accessories)

For the Greentom Car Seat:

> *CarSeatLength* := 680 : *#in mm*

> $CSeatAttachmentPoint := \frac{1}{2} \cdot CarSeatLength$: *#in mm*

For the Greentom Carrycot:

> *CarrycotLength* := 790 : *#in mm*
CarrycotDepth := 150 : *#in mm (Distance that the accessory reaches into the hand cart)*

> $CcotAttachmentPoint := \frac{1}{2} \cdot CarrycotLength$: *#in mm*

For the Greentom Reversible:

> $\text{alpha} := \frac{45 \cdot \text{Pi}}{180}$: *#45° in rad*

> $ReversibleLength := evalf\left(\frac{3}{5} \cdot \cos(\text{alpha}) \cdot CarrycotLength, 3 \right)$; *#in mm*

$ReversibleDepth := evalf\left(\frac{1}{2} \cdot \sin(\text{alpha}) \cdot CarrycotLength, 3 \right)$; *#in mm*

$$ReversibleLength := 334.$$
$$ReversibleDepth := 279. \quad (2)$$

> $ReversibleAttachmentPoint := evalf\left(\frac{1}{2}\cdot \sin(\text{alpha})\cdot CarrycotLength, 3\right); \#in\ mm$

$$ReversibleAttachmentPoint := 279. \quad (3)$$

Defining the best position of the attachment points on the frame to fit the accessories on.

Let's calculate the stump length on which the accassories can be attached at the Car Seat attachment point

> $x := CSeatAttachmentPoint; \#in\ mm$

$$x := 340 \quad (4)$$

> $framewidth := evalf(equ1, 3); \#in\ mm$

$$framewidth := f(340) = 468. \quad (5)$$

> $stumplength := evalf\left(\frac{(framewidth - AttachmentpointInnerWidth)}{2}, 3\right); \#in\ mm$

$$stumplength := 0.500\, f(340) - 142. = 92. \quad (6)$$

> $evalf\left(\frac{CarSeatLength}{l}\cdot 100, 2\right);$
> $\#Percentage\ that\ the\ accessory\ accupies\ of\ the\ total\ length\ of\ the\ hand\ cart.$

$$60. \quad (7)$$

Let's calculate the stump length on which the accassories can be attached at the Carrycot attachment point

> $x := CcotAttachmentPoint; \#in\ mm$

$$x := 395 \quad (8)$$

> $framewidth := evalf(equ1, 3); \#in\ mm$

$$framewidth := f(395) = 479. \quad (9)$$

> $stumplength := evalf\left(\frac{(framewidth - AttachmentpointInnerWidth)}{2}, 3\right); \#in\ mm$

$$stumplength := 0.500\, f(395) - 142. = 98. \quad (10)$$

> $evalf\left(\frac{CarrycotLength}{l}\cdot 100, 2\right);$
> $\#Percentage\ that\ the\ accessory\ accupies\ of\ the\ total\ length\ of\ the\ hand\ cart.$

$$70. \quad (11)$$

Let's calculate the stump length on which the accassories can be attached at the Reversible attachment point

> $x := ReversibleAttachmentPoint; \#in\ mm$

$$x := 279. \quad (12)$$

> $framewidth := evalf(equ1, 3); \#in\ mm$

$$framewidth := f(279.) = 456. \quad (13)$$

> $stumplength := evalf\left(\frac{(framewidth - AttachmentpointInnerWidth)}{2}, 3\right); \#in\ mm$

$$stumplength := 0.500\, f(279.) - 142. = 86. \quad (14)$$

> $evalf\left(\frac{ReversibleLength}{l}\cdot 100, 2\right);$
> $\#Percentage\ that\ the\ accessory\ accupies\ of\ the\ total\ length\ of\ the\ hand\ cart.$

30. **(15)**

Even though the Carrycot occupies 70% of the total length of the hand cart, it would still leave enough space for two children in the back of the hand cart as seen in the following calculations.

> *HandcartDepth* := 370 : *#in mm (From defined hand cart measurements)*

> *ChestDepth* := 170 ; *#in mm (the chest depth of a P90 six−year−old, DINED 2017a)*

ChestDepth := 170 **(16)**

> *ThighThickness* := 101;
#in mm (the chest thigh clearance of a P90 six−year−old, DINED 2017a)

ThighThickness := 101 **(17)**

> *WidthLeft* := 0.3·*l* ;

WidthLeft := 340.5 **(18)**

> *DepthLeft* := *HandcartDepth* − *CarrycotDepth* ;

DepthLeft := 220 **(19)**

As can be seen in the above calculations, the width left after inserting the carrycot is larger than the chest depth, and the left depth is larger than the thigh thickness of P90 six year old children. In conclusion, retractable stumps of 98mm at x = 395mm would be the best positioning for the attachment points, since all accessories would safely be able to fit attached to the hand cart.

A23 User test - questions

Conducting an in-depth interview during a user test without having the exact questions prepared is likely to fail. Therefore, questions are set up for the user test in advance, to be able to consistently ask all users the question in the same manner, and making sure that all questions are asked for the needed results.

Questions

Introducing the user test (Part 1)

First, the subject of my graduation project is explained to the user, after which I explain the goal of the user test. I explain that the test model is meant for testing only the designed functionalities and proportions for feedback from users, but that the final concept might look differently or have added features to it.

Secondly, I ask permission to film the interaction of the user with the product. I explain that all records will be destroyed after the end of the graduation project, and that any pictures that might be used in the report will not contain any faces or if so, any faces will be blurred for anonimity.

User test (Part 2)

Below are the questions that are asked to the user, stated in both Dutch and English to show the nuance of the question in each language. In brackets is stated what needed actions are before asking the questions. If the user is doing these actions, the interaction will be filmed. Questions marked in bold are the questions that should not be skipped. In normal type are the questions that can be asked if the user has not mentioned the answers of those when answering the questions in bold. Behind each question is the product requirement the question is giving answers to, to later be evaluated and processed as results.

A. [Hand cart in unfolded position - no interaction]

1. What is your first impression of the hand cart?
   // Wat is uw eerste indruk van de bolderkar?
2. **What do you think of the size and inside volume of the hand cart?**
   // Wat vindt u van de grootte en inhoud van de bolderkar? [Suitable/Dimensions]
3. Do you think that this size is suitable for your use, for example when transporting children or belongings?
   // Denkt u dat deze grootte geschikt is voor uw gebruik, bijvoorbeeld wanneer de kinderen of spullen worden vervoerd? [Suitable/Dimensions]

B. [User pulls hand cart - Ask to talk out loud]

1. What did you consider as positive when pulling the hand cart?
   // Wat vond u fijn bij het trekken van de bolderkar? [Manourvrability]
2. What did you consider as negative when pulling the hand cart?
   // Wat vond u minder fijn bij het trekken van de bolderkar? [Manourvrability]
3. **What did you think of the manoeuvrability when pulling the hand cart?**
   // Wat vond u van de manoeuvreerbaarheid bij het trekken van de bolderkar? [Manourvrability]
4. **What do you think of the size of the wheels?** Suitable for the beach?
   // Wat vindt u van de grootte van de wielen? Geschikt voor het strand? **[Manourvrability]**

C. [Show how front can be pulled down]

[Ask user to do the same - ask to talk out loud]

1. How do you think this could be used for?
   // Waar denkt u dat dit voor gebruikt kan worden?

[Explain function]

2. **Do you think that the walk-in entry is an addition that you would consider valuable?**
   // Denkt u dat het inloopluikje een toevoeging is die u handig/waardevol zou vinden?

D. [Pull bar is switched to push bar]

[User pushes hand cart - Ask to talk out loud]

1. **Which aspects of pushing the hand cart do you think are better or worse compared to pulling the hand cart?** In terms of manoeuvrability, force, view, body ergonomics?
   // Welke aspecten van het duwen van de bolderkar vindt u beter of slechter t.o.v. het trekken van de bolderkar? Qua manoeuvreerbaarheid, kracht, view, ergonomie? **[Manoeuvrability]**
2. **Do you think that the possibility to push a hand cart is an addition that you would consider valuable?**
   // Denkt u dat u de mogelijkheid om de kar te duwen een toevoeging is die u handig/waardevol zou vinden? [Manoeuvrability]

E. [Show how to fold]

[Ask user to do the same - ask to talk out loud]

1. **How easy did you find to fold the hand cart?**
   // Hoe makkelijk vond u het om de bolderkar op te vouwen? [Easy to use]
2. What did you like when folding the hand cart?
   // Wat vond u fijn bij opvouwen van de bolderkar? [Easy to use]
3. What did you dislike when folding the hand cart?
   // Wat vond u minder fijn bij het opvouwen van de bolderkar? [Easy to use]
4. **What do you think of the size of the hand cart when it is folded?**
   // Wat vindt u van de grootte van de bolderkar in opgevouwen positie? [Suitable/Dimensions]

F. [Show how to unfold]

[Ask user to do the same - ask to talk out loud]

1. **How easy did you find to unfold the hand cart?**
   // Hoe makkelijk vond u het om de bolderkar uit te vouwen? [Easy to use]
2. What did you like when unfolding the hand cart?
   // Wat vond u fijn bij uitvouwen van de bolderkar? [Easy to use]
3. What did you dislike when unfolding the hand cart?
   // Wat vond u minder fijn bij het opvouwen van de bolderkar? [Easy to use]

Possible functions and evaluation (Part 3)

G. [Explain that car seat could be attached to hand cart, as well as other seats]

1. **Would you consider the possibility to add a (car) seat as an addition that you would consider valuable?**
   // Zou u de mogelijkheid van het toevoegen van een (auto)zitje een optie zijn die u handig/waardevol zou vinden in een bolderkar? [Easy to use]

H. [Ask user to indicate on the chart what price she thinks the hand cart might have. Chart shown in Figure 196]

1. **If you look at the prices of other hand carts, which price do you think this hand cart would have?**
   // Als u kijkt naar de prijzen van andere bolderkarren, welke prijs denkt u dat deze bolderkar zou hebben? [Affordability]
2. **Which price would you pay for a hand cart with similar functionalities?**
   // Welke prijs zou u voor een bolderkar willen betalen met dergelijke functionaliteiten? [Affordability]
3. **In summary: what do you think are the positive and negative aspects of the hand cart?**
   // Samengevat: wat vind u de positieve en negatieve aspecten van de bolderkar?
4. Are there any further comments you would like to add?
   // Heeft u nog verdere opmerkingen die u kwijt wil?

Ending

After having asked all the questions, the user is thanked for participating with the user test.
Chocolate is given as a thank you and small stuffed animals for the small children.

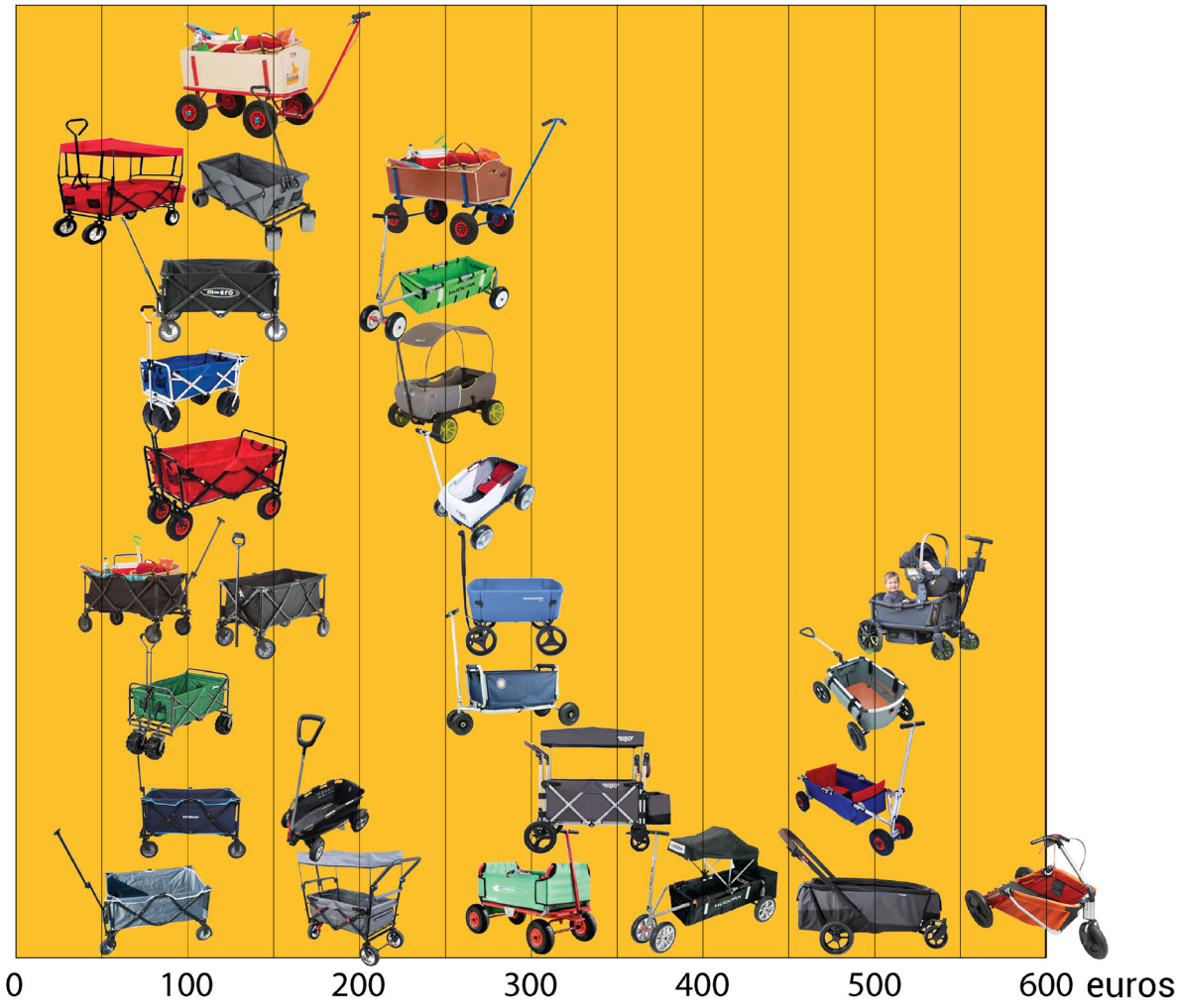


Figure 196 - Price chart of competing hand carts used to let users estimate the Greentom Hand Cart price better

Answers - User 1

Below are the answers as answered by the user during the first user test, with the letter of the section, and the number of the question in front of it. These results are summarized in Section 5.3.

A.

1. "Pretty. It is nice that it is big! And it is pretty that it is wide in the back, but less wide in the front! I like that there is a board for the bottom instead of a railing, which might be more comfortable. We use a cushion on top of the railing-like bottom. I dislike that there are two pieces of metal sticking out of the back." *(for the attachment of the back handlebar.)* "And why is the front lower than the back?" *(The front wheels were giving away and about to fail.)*
2. "I like that it is big! Our hand cart just doesn't fit everything, and this hand cart would fit two children ánd our groceries. There is room to separate the children from the groceries. "

B.

1. "The cart rides lightly. I like that it is relatively long in length."
2. "The car drops down a bit every time I slow down my pace and wiggles a bit." *(This is due to the wheels giving away and about to fail.) "*I would like it more if the wheels would be under the hand cart or on the side of the hand cart, instead of in front of it. I would have liked it if the pull bar could be left pointing upwards instead it falling down."
4. "The sizes of the wheels are fine. The back wheels are good. The front wheels could be bigger. The back wheels seem practical for the beach, but the front wheels less so."

C.

2. "What a great addition! I thought that the sides of the hand carts were high to lift the children in, but that can be solved in this way."

D.

1. "Being able to see the children is very nice! Making turns with the cart goes well. The front wheels could be better." *(They failed at this point, and had to be kept upwards during use by pulling up the cart when the user was pushing the push bar.)* "The handlebar itself seems to give in a bit." *(This is due to the front wheels not functioning well, putting extra force on the push bar.)*
2. "For us it would be a great addition, since it is nice to see your children in front of you. The oldest tends to get in and out by herself sometimes!"

E.

1. "Folding it speaks for itself." *(The user was able to fold it successfully without instructions.)*
2. "Folding went fine."
3. "I would prefer being able to fix the structure once it's folded. Also, the ability to fix the handlebar would be nice, for example with velcro. Also, some kind of solution would be nice to be able to easily take it with you once it is folded. Lastly, it was less nice to have an extra item in your hand after folding the hand cart to only later fix the front entry with when you unfold the hand cart again." *(This item is only used for the prototype but will not be necessary for the final concept.)*
4. "The folded dimensions are fine. However, it would be nice to be able to detach the back wheels, so he hand cart would fit better in the back of the trunk. But the size of the wheels are fine, especially for on the beach."

F.

1. "It went super easily!"
2. "Being able to fix the handlebar somehow would be nice. While unfolding the hand cart, it hit my head."

G.

1. "Super! Being able to attach a Maxi Cosi is super! To carry it is very heavy. But I would let my older children sit in the hand cart instead of in a seat."

H.

1. *(Users found it difficult compare this hand cart with competing hand carts since they could not see how prices related to the type of hand cart. They immediately went to say what they would pay for this hand cart, instead of showing it in the figure.)*
2. "I would be willing to pay 200-300 for this hand cart" *(The husband would be willing to pay 300 - 350 euros for the hand cart.) (Their current hand cart, the MacWagon - MacSports, costs €124.)*
3. "I like the length and size of the hand cart; it is pretty that it is wide in the back and less wide in the front, and you can fit groceries as well as your children. I like that you can push it (to be able to keep an eye on the children). I think it is very handy that the front can be used as an entry for the children! I like that it is possible to attach a Maxi Cosi." *(The husband agrees with all these points when the hand cart was shown again returned with the wife from the walk.)* "I like the folding system. I think it is handy that you could be able to take it to the beach (due to the big back wheels). Normally we only use our hand cart for groceries. Also, I like that the that the textile is detachable (for easy cleaning." "However, I think that the front wheels point too far out (which could be better attached underneath the hand cart or on the side, for aesthetics). Also, I would like the back wheels to be detachable to better fit our small car. Also, I would like to be able to fix the pulling bar upright, so that it doesn't fall down. And a water repellant textile would be nice."
4. "What would be nice is if the textile would be water repellant, to be able to quickly clean it with a cloth if something is spilled on it. I read it on many forums as well that users would like this. Also, maybe some kind of plastic could be put in the bottom for stiffness and against the wind. Also, I would like pockets in the textile to be able to put small things in it, such as little stones or shells picked by our children. A sun/rain roof would not be necessary for us."

A24 Weight estimation

Determining the weight of the Greentom Go (excluding textile)

> *restart* :

Let's estimate the weight of the Greentom Go chassis

> $rPPdensity := 900$: *#kg per m3*

> $Solidmaterialpercentage := \frac{1}{2}$:
#estimated percentage of solid material in gas−aid injection moulded rPP parts

> $VolumeGreentomGo := 0.01656750599$:
#Volume in m3 of rPP parts determined from 3D Solidworks model.

> $equ1 := Solidmaterialpercentage \cdot rPPdensity \cdot VolumeGreentomGo$:

> $WeightChassis := evalf(equ1, 3)\ kg;$

$$WeightChassis := 7.46\ kg \quad \textbf{(1)}$$

Let's estimate the weight of the Greentom Go textile

> $rPETweightperm2 := 0.22$: *#Weight in kg per m2 rPET fabric*

> $rPETarea := 0.48507$:*#Surface area in m2 determined from 3D Soldworks model*

> $equ2 := rPETweightperm2 \cdot rPETarea$:

> $WeightTextile := evalf(equ2, 3)kg;$

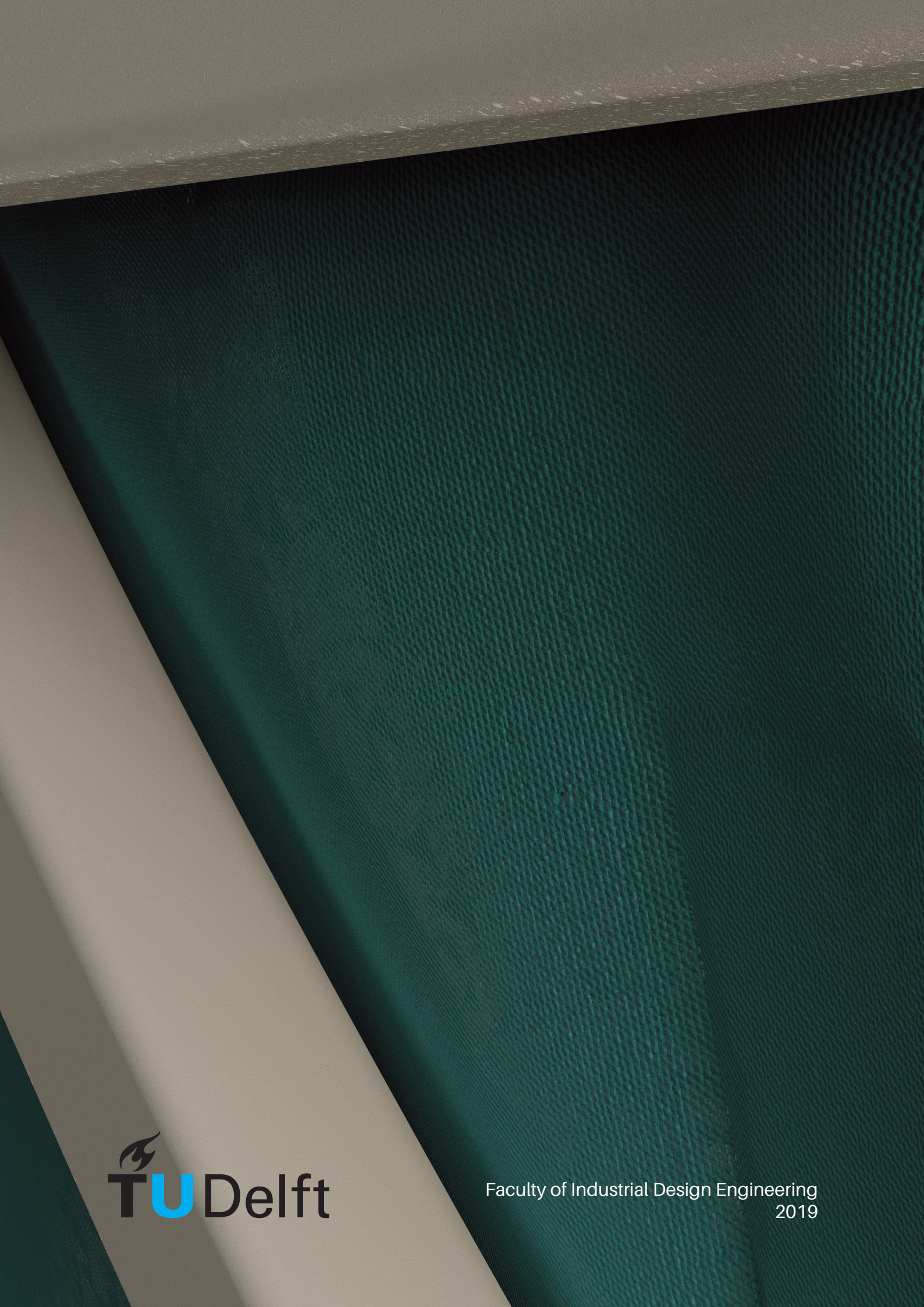
$$WeightTextile := 0.107\ kg \quad \textbf{(2)}$$

Let's estimate the weight of the Greentom Go

> $TotalWeight := WeightChassis + WeightTextile;$

$$TotalWeight := 7.567\ kg \quad \textbf{(3)}$$

The average weight of hand carts is calculated to be 13.85 kg, based on the data from Appendix A2. Therefore, the Greentom Hand Cart being 7.57kg can be considered light weight as it weighs almost half of the average weight.



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