FLO

Melle Grössl

FLO

One step ahead | A kickscooter design for the last mile

Delft University of Technology

Faculty of Industrial design engineering
Landbergstraat 15
2628 CE Delft
The Netherlands

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Graduate student

Melle Grössl
MSc. Integrated Product Design

Chair

Em. Prof. B.Ninaber van Eyben
ID | Design Aesthetics

Mentor

Ir. S.G. van de Geer
ID | Design Aesthetics

“Why do we assume that simple is good? Because with physical products, we have to feel we can dominate them. As you bring order to complexity, you find a way to make the product defer to you. Simplicity isn’t just a visual style. It’s not just minimalism or the absence of clutter. It involves digging through the depth of the complexity. To be truly simple, you have to go really deep. For example, to have no screws on something, you can end up having a product that is so convoluted and so complex. The better way is to go deeper with simplicity, to understand everything about it and how it’s manufactured. You have to deeply understand the essence of a product in order to be able to get rid of the parts that are not essential.”

Jony Ive

Acknowledgements

This project has benefitted from the guidance and encouragement of my supervisors, Bruno Ninaber van Eyben and Stefan van de Geer. I was also hugely supported by my study colleague and dear friend Maurizio Filippi, who strengthened my knowledge regarding user-product interaction and with who I shared endless discussions about simplicity and beauty. Thank you to my partner Bill Hu, who instilled a degree of elegance in every part of the project and without whom I would have never arrived here. My sincere gratitude goes to my father, Rob Grössl, for supporting my growth and inspiring me with his wisdom in all the moments of reflection throughout my studies. The development of the prototypes would not have been possible without the incredible help of Don van Eeden, Carlo Buhrer Tavanier and most notably Rene van de Schuur, who taught me the basics in CNC machining and provided the rare opportunity to use his machine. And finally, thanks to all the friends who demonstrated their support during the time of this project.

Abstract

The aim of this graduation project was the design of a compact, simple, and effective means of transport for the last mile, suitable for an environment with a system of shared usage. The focus of the project lied on the design of the vehicle itself, while the design of the marketing strategy and the sharing system were left out the scope.

A university campus environment was chosen as context for the research and development of the product, due to its medium-large scale, its enclosed nature, and the wide variety of users. This combination of factors made the design feasible in the timeframe of the graduation project, while keeping it open for possible future applications in other environments such as factories, hospitals, and airports.

The vehicle typology to design was not set upfront or arbitrarily chosen in the beginning, but it was determined by process of analysis, during which a design vision and a set of requirements were created.

In a cycle of three iterations, concepts were created by following an incremental process in which insights from one idea served as a starting point for the next, leading to well-defined product architecture. This was built with simple prototyping techniques to generate a proof of concept, ready to be tested by users.

Finally, the embodiment design phase elevated the product architecture to a detailed state, defining construction, mechanisms, materials and form through the use of a variety of techniques, ranging from sketching, digital visualisation and simulation, physical prototyping and user testing.

The result is a dynamic, elegant and robust kickscooter with a stable three-wheel tilting and steering mechanism, an expandable compact cargo solution and a nestable configuration, specifically designed to answer the demanding requests of a chaotic shared mobility environment. Its name is Flo.

Contents

1 PROJECT

2 ANALYSIS

3 IDEATION

4 EMBODIMENT

5 CONCLUSION

6 BIBLIOGRAPHY

1 PROJECT

Project introduction

According to the World Health Organization, health cannot be only conceived as the absence of ill-health but as a state of complete physical, mental and social well-being (World Health Organization, 1946). In other words, health is no longer merely a question of access to medical treatment, but it is determined by a range of factors related to the quality of our environment.

By 2050, almost 70% of people are predicted to be living in urban areas (UN, 2017). “On average, city dwellers are wealthier and receive improved sanitation, nutrition, and healthcare.” (Dye, C., 2008, p. 319). But urban living is also associated with a more demanding and stressful environment with an increased risk of chronic disorders. It is therefore fundamental to rethink how we live in the city by incorporating products, environments, and services that have a positive impact on people’s health.

Physical activity in the form of active mobility has been identified as one of the core features in the development of healthy cities in the 21st century (Rydin et al., 2012). Active mobility positively impact health by providing a daily dose of physical exercise, decreasing the overall level of air pollution, and reducing traffic-related stress. Apart from its health benefits, human powered vehicles (HPV’s) can also positively influence the efficiency of transportation. They are agile, compact and allow us to move vast distances with limited energy.

The good news is that recent trends have shown a growing willingness from the users’ part to abandon the car or traditional public transports in favor of healthy and dynamic new forms of active mobility, and this desire has been accommodated and promoted by the introduction of cheap and easy to use shared mobility solutions.

The idea of shared mobility originates from the observation that an increasing amount of users value access over ownership (Kelly, 2011). Even in the Netherlands, where cycling is the most common mode of transport and the Dutch own on average 1.11 bicycles per capita (fietsberaad, 2009), shared bicycles have been introduced and are recently gaining popularity due to the exceptional advantages that they provide. Sharing is quick, trouble-free for the user and goes down to the essence; quickly move between locations.

Sharing systems are getting more convenient and accessible thanks to the introduction of information technology, which enables people to easily borrow vehicles in one location and return it in another. Some new companies even allow users to pick up and leave the vehicle wherever they want (Van Mead, 2017). This modus operandi is very convenient for the final user, but it comes with its set of problems related to the maintenance of the vehicles and the impact of careless parking on city traffic.

Assignment

This self-initiated project concerns the design and development of a human powered vehicle suitable for an environment with a shared mobility system. The product aims to meet the requirements of the last mile, that is to say, the last few kilometers towards the final destination, taking into consideration the needs and concerns of the final user, as well of the service provider. In order to maintain the exploration feasible in the timeframe of the graduation project, the assignment focuses on the design of the vehicle itself and does not include the problematics related to the marketing strategy and the sharing system. The TU Delft campus is chosen as context for the research and development of the product as it is characterized by a large variety of users, a relevant scale, and it is highly accessible from the designer's part. The outcome of the project is expected to be a prototype that is preferably functional and visually accurate.

Problem definition

Existing design solutions used for shared mobility have never been designed from a holistic point of view. Features like internet connected locks and puncture proof tires have been added to existing solutions (mobike, 2017), but the overall design remained unchanged. Often products got even worse due to heavy components that are made to last longer, but compromise the user experience and therefore put at risk the success of the product. Moreover, stationless shared vehicles have often been accused of causing inconvenience due to the inappropriate way of parking of many careless users.

Design Process

The project was divided into three phases (Figure 1.1), which also form the three main chapters of this report; Analysis, Ideation, and Embodiment. Rather than being strictly divided, the three phases significantly overlapped as a hands-on design approach was applied. This method allowed for the completion of many product iterations which provided valuable data for the completion of the analysis and the generation of a well-defined design vision. Great emphasis was put on the ideation and embodiment phases which resulted in the creation of several models and a final prototype.

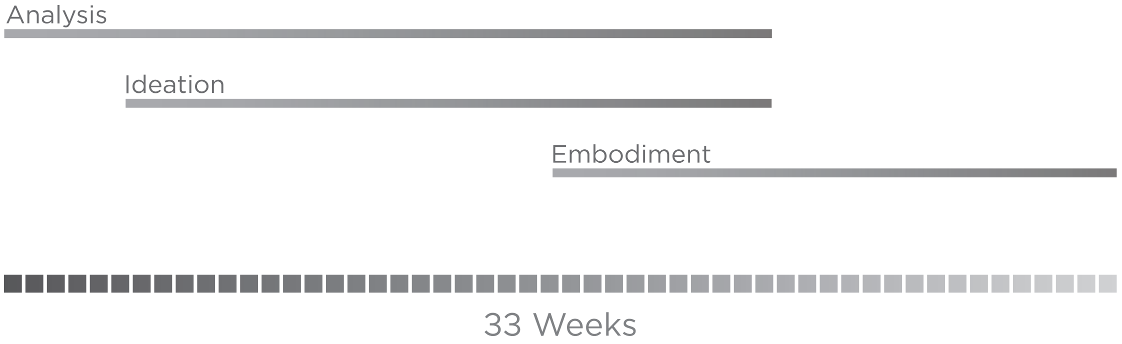


Figure 1.1 Project planning

Approach & methodology

With a technical interest, the designer of this project focusses on working in 3D, elevating ideas on paper to physical objects we can touch, try and re-iterate. In the designer's vision, design cannot be separated from how objects are made, from the processes that form materials. Those have to be developed incredibly coherently and together. This project was therefore also tackled with a hands-on approach, where insights generated from one made mockups or prototypes were used as a starting point for the next, an approach which relates but not copy the Phal and Beitz' model (Roozenburg & Eekels, 2003). In fact, the applied approach slightly differs from Pahl and Beitz' four phases model as instead of generating several concepts at once, insights were harnessed from one concept to generate the next one (Figure 1.2). It takes away and builds constraints in your mind and lets you focus on the next challenge, allowing the designer to dig deeper into many subproblems of a product. Design challenges were generated based on literature review, and together they contributed to the creation of the design vision. From there on, a product architecture was generated in a cycle of three iterations, and the embodiment phase further elevated this product architecture to a physical prototype. The final outcome of this process sits at the materialised stage of Pahl and Beitz' model. Further development should aim to detail and optimize the product, making it ready for mass manufacturing.

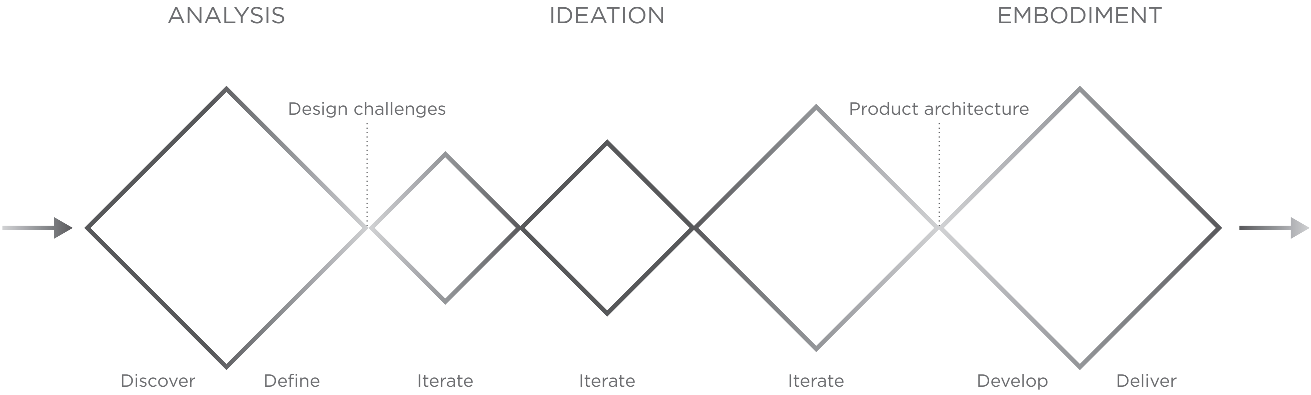


Figure 1.2 Design approach

2 ANALYSIS

Introduction

This chapter presents a series of short analyses found to be relevant to the design process. The findings are generated from literature reviews and physical tests. The aim is to converge rapidly towards a design direction with a set of design challenges. The analysis is presented in the form of five sub-chapters discussing the influence of bicycle sharing, the opportunity in the market, a contextual case study, the ergonomics involved when using a kickscooter and vehicle dynamics. Requirements are filtered form the analyses and presented as part of the design challenges. A final chapter conludes all these findings and forms a design vision with a set of challenges.

ANALYSIS

Shared bicycles

This section offers an overview of the history and recent developments of shared bicycle systems. An analysis of the different generations of shared bicycles and related product characteristics are presented, together with takeaways for the future generations of shared personal transport systems.

Three generations

Bicycle sharing systems have evolved over the past five decades, shaped by societal demands and technological developments. The history of shared bicycle systems is here divided into three generations, as proposed by Susan Shaheen, Professor of Sustainable Transportation and Research Director at Berkeley University.

The first systems were set up in Amsterdam, by the Provo, a group of environmentalists, who started the White Bike plan in the mid-1960's (Figure 2.1). The white bicycles became known as the free bicycle system and other cities, La Rochelle and Cambridge, implemented it as an environmentally progressive measure. This free bicycle sharing system is considered the first generation of large-scale sharing systems (Shaheen et al., 2010).

Theft and damage, the main problems of the first generation, encouraged the development of a new system, which was launched in 1995 as a large-scale sharing program in Copenhagen under the name of Bycyklen (Figure 2.2). The bicycles were locked with a coin-deposit system, which protected them from thefts. The Bycyklen program of Copenhagen is signified as the second generation and continues to operate nowadays. The successful model has led to the development of similar programs in other Scandinavian cities (Shaheen et al., 2010).

Figure 2.1 (top) Launch of the Provo's 'witte fietsenplan' in 1965. Fifty white painted, permanently unlocked, bicycles were placed throughout the city, free to use for the public.

Figure 2.2 (bottom) The Bycyklen shared bicycles in copenhagen are chained to a simple rack with a coin-deposit system, similar to a how shopping cart are chained.

The third and last generation bicycle sharing system has the same modus operandi of the second generation, only enhanced by information technologies. Bicycle reservation, tracking information and exact pickup & return times are all integrated into IT-based systems. Payment has evolved to electronic payment, connected to memberships and bank accounts (Shaheen et al., 2011).

Design qualities

Every generation of bicycles for the sharing system comes with a set of design qualities based on the problematics found in the previous generation and the possibilities given by technological advancement. Mainly in the second generation, there are progressive developments in the way the bicycles are locked and parked. From the coin-depositing systems used on the Danish Bycyklen to one of the latest developments where users present a membershipcard (Figure 2.3). A list of design qualities that characterize each of the generations is presented on the right page (Figure 2.4).

Figure 2.3 Veloh! bicycles in the city of Luxembourg. These docked bicycles can be used with a subscription. A card is presented at the locking pole, verifies the user and deducts a certain amount of money when the bicycle is returned to any docking station in the city. According to Shaheen e.a. one of the latest developments in the second generation.

Generation	Design qualities	Example sharing programs
I	Distinct colors Freely available, no charge for use Unlocked Standard bicycle Traffic reducing Located haphazardly throughout an area	Witte fietsenplan Amsterdam Green bicycle scheme Cambridge Vélos jaunes La Rochelle
II	Specific frame designs Advertisement Locked in docking stations Coin-deposition Designated doking stations Serviceless, no restrictions	Bycyclen Copenhagen
III	Docked, later dockless User interface technology for checkin and checkout Internet connected, smartphone, bank-card etc. Theft deterrents Membership based Solar-charged Electrically assisted	Velóh! Luxembourg Mobike Rotterdam, Delft, Shanghai, Beijing, Hangzhou and many more cities Urbee Amsterdam

Figure 2.4 Design qualities filtered from the different generations

Next generation

The latest innovations in telecommunication have enabled companies to deploy large quantities of free-floating shared bicycles, which have resulted in new problems (Figure 2.5). Technological innovations and more integration with public transport, flexible pickup and return possibilities are essential aspects of the next generation. According to Shaheen, Guzman, and Zhang the ‘fourth generation’.

Conclusion

The new generation of shared mobility aids should take advantage of the IT-based systems, but prevent the confusion currently created by the dockless solutions. The idea of letting bicycles freely float (lock and unlock wherever you are) may seem ideal to the final user, but it comes with a set of problems, mostly related to careless parking practices. Both users and shared vehicles service providers could also benefit from the implementation of better low maintenance solutions. Current vehicles are in fact slow and liable to failure due to complex and heavy components and mechanisms.

Design vision / A new shared hpv benefits from a compact and organized docked position. Allowing large quantities in a limited amount of space.

Design vision / Reduce maintenance to a minimum

Figure 2.5 A shared bicycle graveyard in Xiamen. For the past 18 months, many cities in China have been flooded with millions of dockless share bikes. Authorities have removed those that block pavements or apartment entrances to vast storage areas. Many broken bicycles also end up at these graveyards because it is more affordable to deploy new bicycles rather than repairing the broken ones.

Market segmentation

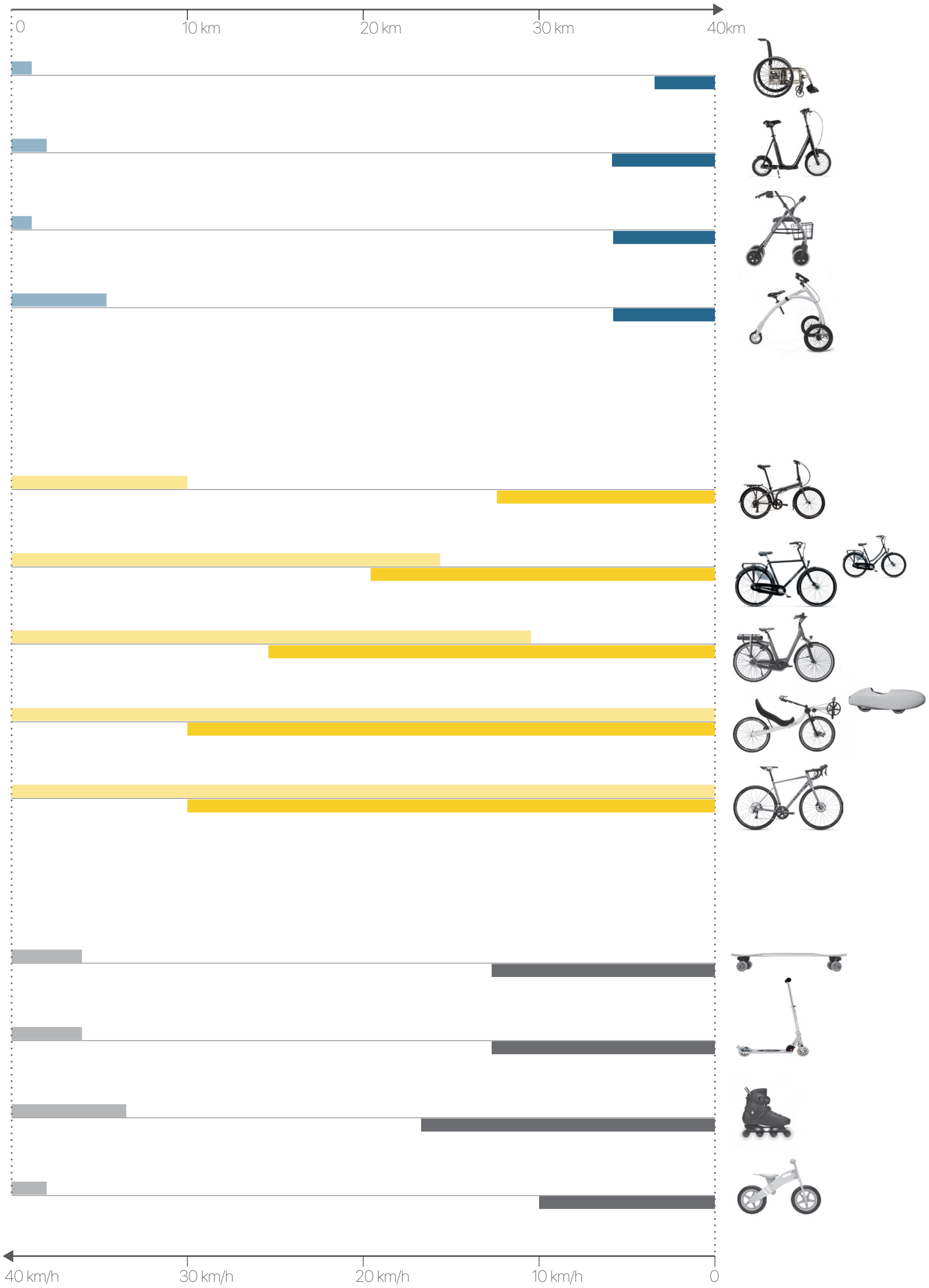
The Human-Powered Vehicle's market is filled with many different product typologies. The analysis presented in this chapter aimed to identify these different typologies, their characteristics, and their targeted user groups, in order to propose a design direction relevant to the chosen context, namely a shared mobility system at the TU Delft campus.

User group

Bicycle manufacturers typically propose a product range to satisfy the needs of different customers. Gazelle and Batavus, for example, segment their portfolio into 7-8 different categories, based on the context of use, user's lifestyle and gender. Most of these bicycles are, from a fundamental point of view, the same. They consist of a frame, a saddle, a steer, a drivetrain, etc. They differ from one another only by little variations in the geometry and size of the components, mostly dictated by the context of use and the needs of the user group. Apart from bikes, the HPVs market is greatly diversified, ranging from dynamic products such as the skateboard to more slow-paced such as the balance bike. It is worth noticing that, while bicycles have been adopted by a great variety of users within the Adult age group, other types of HPVs still remain confined to specific target groups. Design could play a role in this matter, bringing the benefits of certain product types to a wider audience by redefining the overall perception of products.

Current product typologies are here compared based on three main criteria: age group, speed, and distance coverage. Figure 2.6 provides an overview of the abovementioned typologies. This overview is divided into three sections, each of which relates to a different age group (Elderly (disabled), Adults, and Youth).

Figure 2.6 Archetypes of human-powered vehicles grouped according to their targeted age. Both the group on the top (elderly mobility) and the group on the bottom (young mobility) show vehicles that are suitable for the targeted distance.


0
10 km
20 km
30 km
40km
40 km/h
30 km/h
20 km/h
10 km/h
0

Distance, speed & others

Average distance coverage and speed (Figure 2.6) are two criteria that played an important role in the analysis of the existing vehicles. However, taken in isolation, they do not provide enough information to guide a choice for the design. The TU Delft campus covers a surface of 161 hectares, an area easily ridable with many different types of HPVs. Most of the products marketed to the Youth group (figure 2.6) such as the skateboard and the inline skates are in fact as suited as the bike for short distance rides. To choose the most appropriate solution for a shared mobility system on campus other elements had to be considered. These are; liability to failure, ease of repairability, size (which influences the size of the parking slots and the possibility of riding indoor), manoeuvrability, accessibility (learning curve, ease of interaction, stability) and product perception.

By comparing all the HPVs on the market (Figure 2.7), using the abovementioned criteria as a meter of judgment, it was possible to identify the vehicle with the most balanced set of characteristics, which turned out to be the kickscooter.

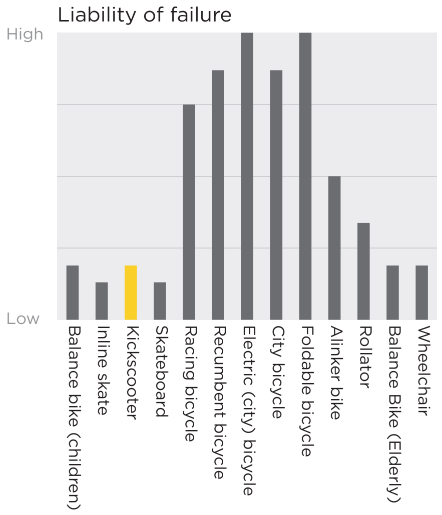
The kickscooter, a product with stigma

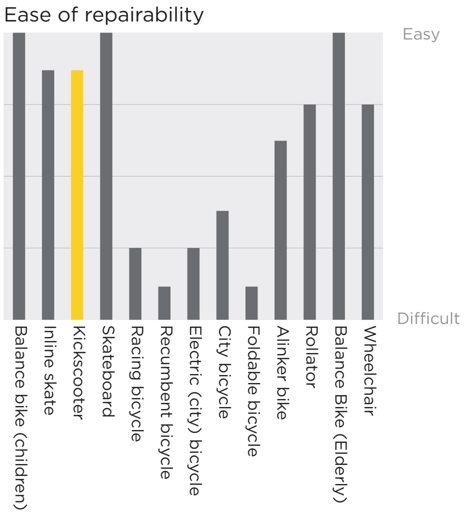
The kickscooter is a vehicle which notoriously appeals to a very young audience due to a series of characteristics that make it very easy and fun to use. The problem is that through time the kickscooter has been stigmatized, and it is now conceived as a children-only product by many adults. This is an unfortunate fact as it prevents many people to benefit from its peculiar characteristics.

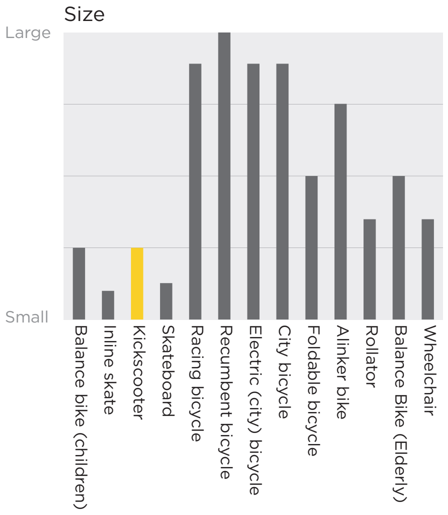
From a design perspective, little work has been done to remove this stigma. A simple visual comparison between products from the same brand (Mirco Mobility Systems) shows that shape, materials, and sizing remain almost unchanged between the child and the adult version (Figure 2.8), a recurring issue also among other brands. This careless approach has only the effect of reinforcing the stigma, without bringing any benefit, neither to the producer nor to the user.

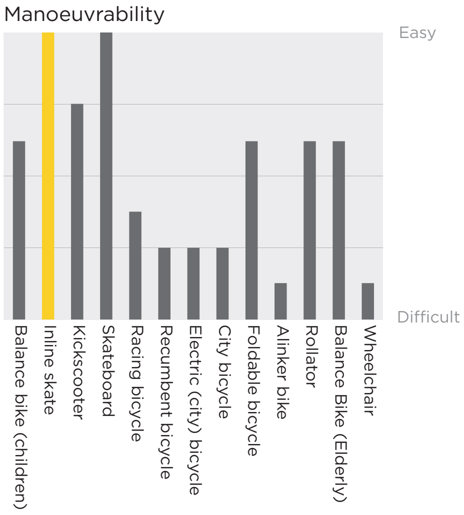
To create a kickscooter used by adults in a shared mobility environment means first elevating the vehicle from its childish state to a more mature and appealing one, which can only be done through a thoughtful design process.

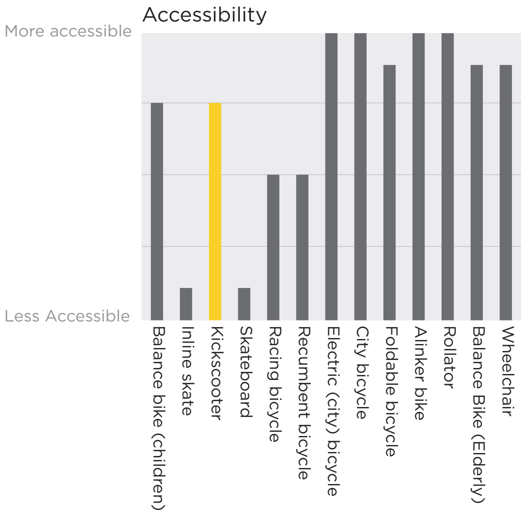
Figure 2.7 Comparing the elements liability of failure, Ease of repairability, size, manoevrability, accessibility and product perception

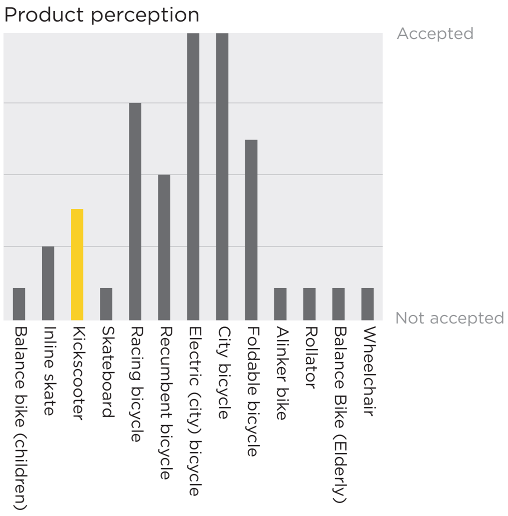

Liability of failure
High
Low
Balance bike (children)
Inline skate
Kickscooter
Skateboard
Racing bicycle
Recumbent bicycle
Electric (city) bicycle
City bicycle
Foldable bicycle
Alinker bike
Rollator
Balance Bike (Elderly)
Wheelchair


Ease of repairability
Easy
Difficult
Balance bike (children)
Inline skate
Kickscooter
Skateboard
Racing bicycle
Recumbent bicycle
Electric (city) bicycle
City bicycle
Foldable bicycle
Alinker bike
Rollator
Balance Bike (Elderly)
Wheelchair


Size
Large
Small
Balance bike (children)
Inline skate
Kickscooter
Skateboard
Racing bicycle
Recumbent bicycle
Electric (city) bicycle
City bicycle
Foldable bicycle
Alinker bike
Rollator
Balance Bike (Elderly)
Wheelchair


Manoeuvrability
Easy
Difficult
Balance bike (children)
Inline skate
Kickscooter
Skateboard
Racing bicycle
Recumbent bicycle
Electric (city) bicycle
City bicycle
Foldable bicycle
Alinker bike
Rollator
Balance Bike (Elderly)
Wheelchair


Accessibility
More accessible
Less Accessible
Balance bike (children)
Inline skate
Kickscooter
Skateboard
Racing bicycle
Recumbent bicycle
Electric (city) bicycle
City bicycle
Foldable bicycle
Alinker bike
Rollator
Balance Bike (Elderly)
Wheelchair


Product perception
Accepted
Not accepted
Balance bike (children)
Inline skate
Kickscooter
Skateboard
Racing bicycle
Recumbent bicycle
Electric (city) bicycle
City bicycle
Foldable bicycle
Alinker bike
Rollator
Balance Bike (Elderly)
Wheelchair

Conclusion

The analysis of the HPV market sheded a light on the untapped potential of the kickscooter, a vehicle which use is mostly limited to a very young user group, but that actually possesses many positive qualities adults could benefit from. This project aims to develop a vehicle suitable for an environment with a shared mobility system and the kickscooter appears to be a good starting point for the design. However, the analysis made it clear that, to make the kickscooter a successful means of transportation for an environment with a shared mobility system, some problems had to be solved. One of them being the stigma that the product carries, while others related to the shared mobility system itself such as encouraging ordered parking and reducing the risk of product failure.

Design vision / A kick type motion provides fun and is exceptionally suited for short distance quick rides. The bare essentials of wheels and a means to steer keeps the mobility aid virtually maintenance free.

Design vision / A kickscooter is stigmatized as a vehicle only for the young and adventurous user. To encourage people to use a kickscooter a last mile mobility aid should be removed.

Figure 2.8 A visual comparison between kickscooters targeted at children (left) and targeted at adult commuters. The brand Mirco Mobility Systems produces all shown examples.

Context

Case Study: TU Delft Campus

The TU Delft university campus was selected as a case study context for this project, due to its large variety of users, a relevant scale, and its high level of accessibility from the designer's part. This combination of factors made of TU Delft a good starting point for the design of a vehicle for a shared mobility system, that could, later on, be exported to other contexts that share some commonalities with the TU Delft campus such as company campuses, factories, warehouses, airports, and hospitals.

Observations made on the context revealed that movements across the TU Delft campus are in most cases performed by bike and on foot, with a tiny percentage of people relying on buses, cars, and other HPVs. Nevertheless, biking remains the most appreciated means of transportation among students and employees of the campus, as it is quick, reliable and fun. However, only because biking on campus is a well-established practice, it does not necessarily mean that the bike would be the vehicle best suited for a shared mobility system on campus. Previous analysis revealed that among all the different types of HPV's, the kickscooter is the most suitable for such a task. According to Anja Stokkers, director of campus development at TU Delft, "the challenge lies in developing a shared mobility aid for the last mile that can safely blend in with a large number of people already cycling on campus". The introduction of a shared human powered vehicle targeted to the last mile on campus would provide many benefits to both students and employees, allowing them to quickly move in between buildings for meetings and lectures, but also enjoying fun rides that will boost their energy and motivation. More generally, this solution will contribute to the improvement of people's wellbeing and the creation of a healthier and happier campus.

Design vision / The design integrates a small amount of cargo (the size of a briefcase) and allows the employees to transport themselves and their cargo safely.

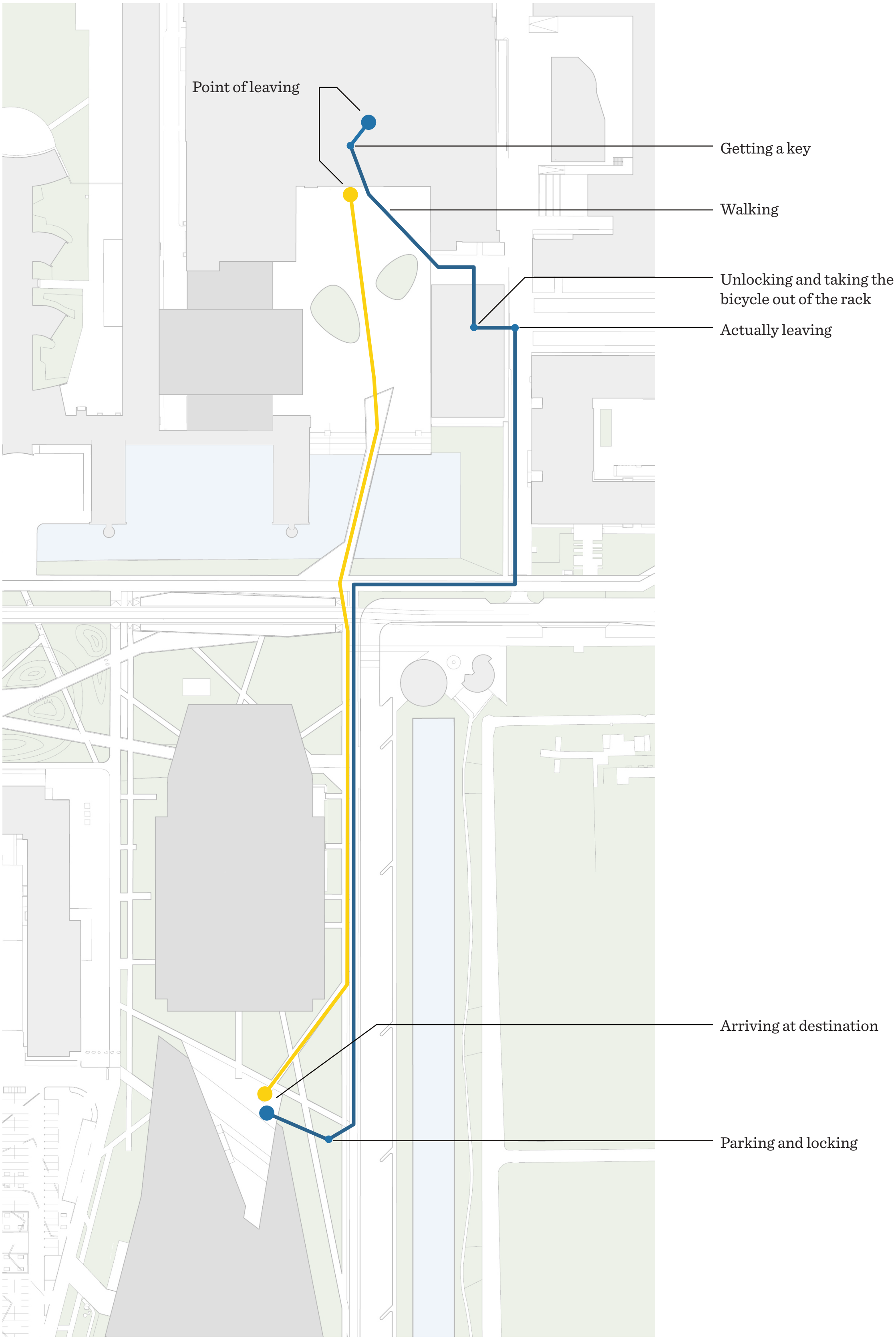
Figure 2.9 (top) The TU Delft campus with buildings on a site of 161 hectares

Figure 2.10 (bottom) The High Tech Campus in Eindhoven is a high tech center and R&D ecosystem that house 160 companies.

User journey

Rhythm exists in every product interaction and is pervasive in everyday life (Reddy and Dourish 2002). Interaction design that reflects an understanding of rhythm can feel more aligned, or in tune for the user (Spillers, 2008). To apply this notion to the case at hand means supporting the experience of going from point A to point B in the most efficient way, reducing interruptions and deviations as much as possible. This could be done by locating a fleet of kickscooters right in front of each faculty so to eliminate unnecessary steps which are present in the case of riding a bicycle such as walking to the bike garage, finding the specific bike in the rack and unlocking the bike. Students and employees could arrive at the campus with their long-distance vehicles and let it parked until they leave, as moving in between faculties will be supported by the shared kickscooters. The user journey map (Figure 2.10) visualizes the difference between using the bike and the hypothetical shared kickscooter. It seems almost unnecessary to point out that the user experience would become much smoother with the introduction of the new solution.

Figure 2.11 Two user journeys on the TU Delft campus. Blue represents a person taking a bicyle from the IO building to the libray on a bicycle. Orange represent a person with the same starting point and destination on the hypothetical kickscooter.


Point of leaving
Getting a key
Walking
Unlocking and taking the bicycle out of the rack
Actually leaving
Arriving at destination
Parking and locking

Kick ergonomics

Kickscooting burdens evenly throughout the body, moving almost all muscles. You activate both the lower and upper limbs, but also the abdominal and back muscles. Physiotherapists recommend kickscooting as a supplement to rehabilitation, or prevention of pain in the cervical and lumbar spine and it saves the joints. One foot kicking gives it a stable character and natural freedom of movement that can be handled by everyone. If needed, you can easily step back from the kickscooter and go walking. During one hour of kick scooting you can burn from 400 to 500 calories (1680-2100 kJ) at a lower speed and shorter distance compared to cycling. Kick scooting burns up to 30% more energy compared to riding a bicycle (Yedoo, 2015; Crussis, 2018; Micro Mobility, 2018).

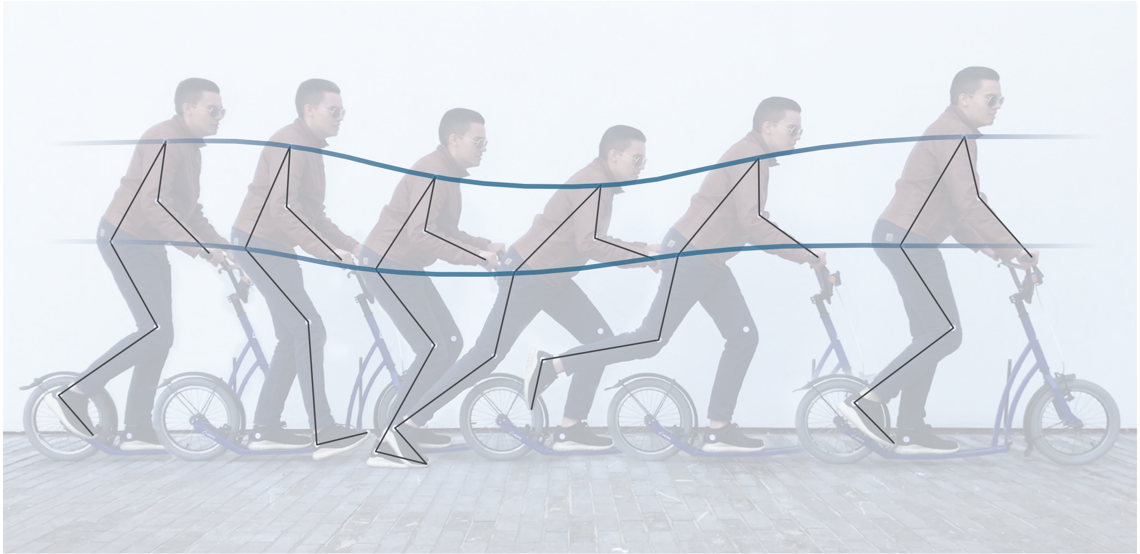
Motion

The ergonomics of a person on a kickscooter is analyzed to determine the constraints of the human body and a the new type of scooter. Stability with conventional kickscooters is ensured by the riders ability to balance on two wheels. Figure 2.12 shows a deconstructed body motion. Several users proved that kick scooting is not always found to be so easy, some testers felt insecure and lacked stability.

Constraints

Creating more stability and staying upright when not in use ideally uses more than two wheels. Or at least a configuaration of wheels that keeps itself upright. The position and size of a three wheel configuration influence the person's kick scooting ergonomics. When seen from above the area of movement, positioning and size of the wheels can be further explored. Figure 2.13 marks the areas of movement, placement of the stable foot and constraints to work within.

Design vision / The design needs to be self-stable both in a riding and idle situation. Stability is increased by adding a third wheel, without obstructing the user' leg movement



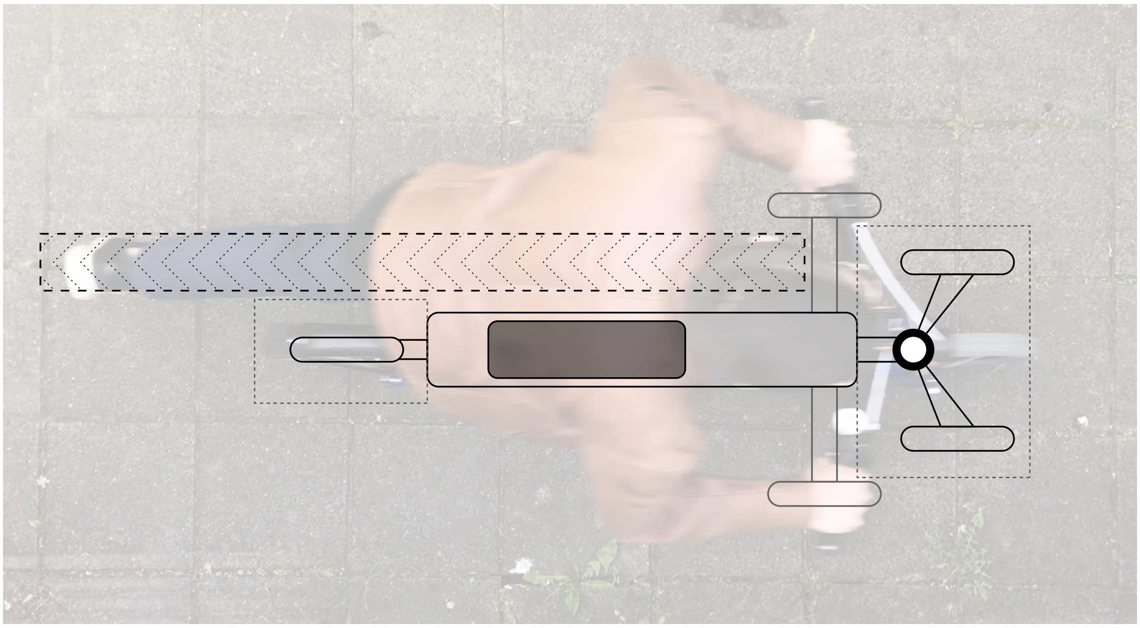


Figure 2.12 (top) The diagram follows the movement of the kicking leg, taken from a slow-motion video capture in side view. The white stickers track the rider's joints. Notice the placement of the kicking foot, placed slightly in front of the stable foot, before stretching to exert the kick (which forces the scooter forward). To maximize the kicking force and keep the foot in contact with the road, the rider's upper body moves downwards during the leg's stretch.

Figure 2.13 (bottom) The movement seen from above to map the constraints. Possible wheel sizes and placements are mapped. The swinging leg needs an area to freely move and not feel obstructed. Wheels can be placed in the dotted areas marked in the map above.

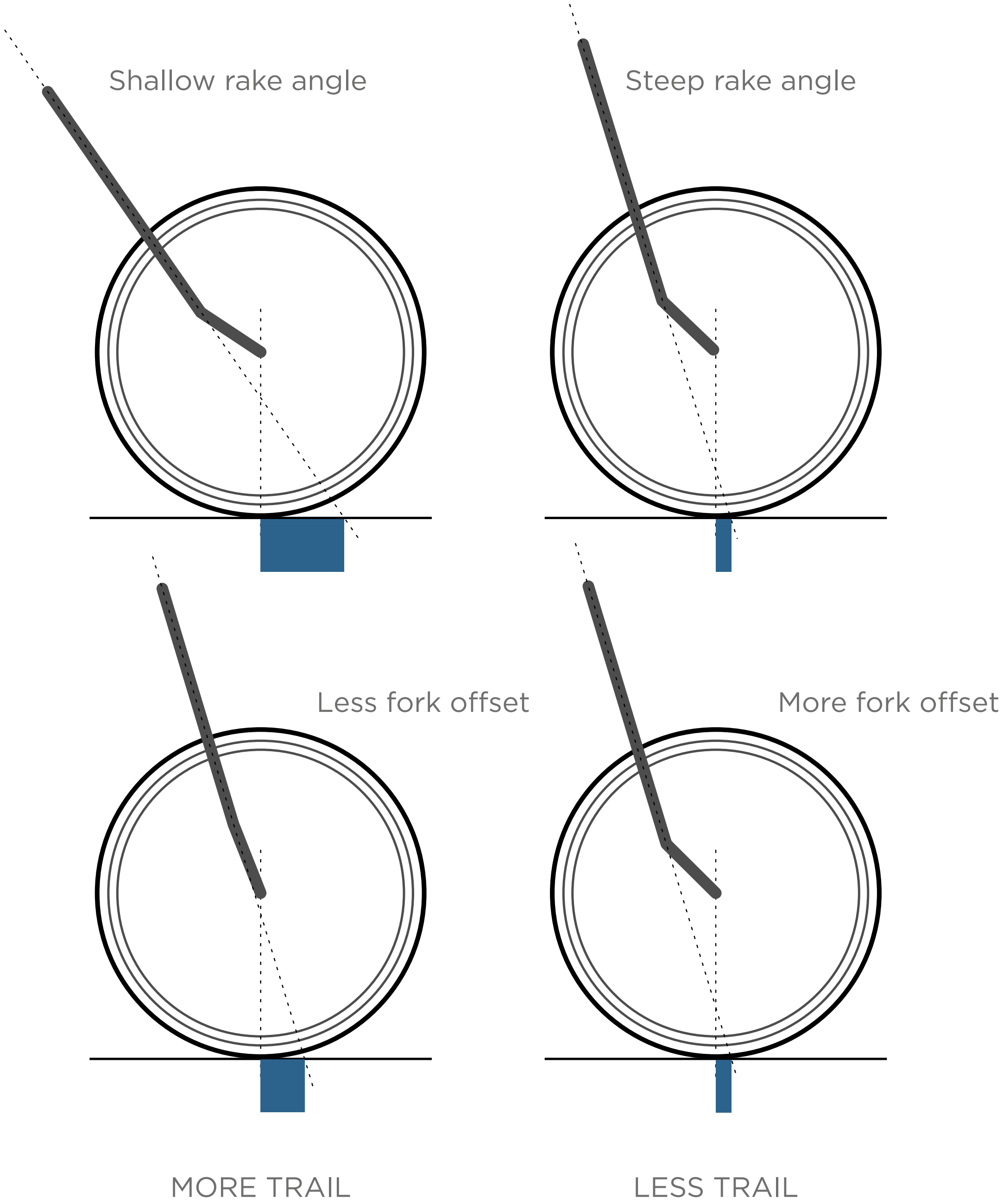
Vehicle dynamics

This chapter explores the crucial basics in vehicle dynamics, which helps to design a comfortable and stable kickscooter that can be driven with little training. Stability from trail & rake angles, mechanisms behind other three-wheeled vehicles and the Ackerman steering principle are analyzed.

Trail & rake

Two-wheeled vehicles are weird objects when it comes to physics and have complex dynamic systems. When standing still, any two-wheeled vehicle is incredibly unstable and falls over, however by increasing forward speed they become self stable. Research from the faculty of mechanical engineering at the TU Delft shows that this self-stability of a two-wheeled vehicle can be stabilized by making adjustments in the trail, front-wheel gyro and mass distribution of the steering assembly (Kooijman, Meijaard, Papadopoulos, Ruina, & Schwab, 2011). Adjustments in the trail are easily made by adjusting the rake angle or fork offset of the steering assembly (Figure 2.14) , and sizing & inertia of the wheels directly influences the gyroscopic effect. The same principle applies to two steering wheels, but the rake angle is then called caster angle. More trail results in a stable and challenging to steer the vehicle, where less trail results in unstable but agile cornering vehicle. Think about an American chopper motorcycle with its long shallow front fork compared to an Italian racing motorcycle with a steep front fork. The chopper is way more difficult to steer than the racing motorcycle.

Figure 2.14 The influence of a shallow and steep rake angle and less and more fork offset on the trail of a steering front wheel.


Shallow rake angle
Steep rake angle
Less fork offset
More fork offset
MORE TRAIL
LESS TRAIL

Leaning multi-wheels

A kickscooter (or any other HPV) that does not fall over when not in motion is inherently associated with vehicles that have multiple wheels. Early on in the process of making and testing the importance of leaning when turning a corner became evident. When a three-wheel vehicle with a static suspension turns a sharp corner one of the wheels is lifted, giving the user an insecure feeling. Solutions are found by examining how other leaning three-wheelers, like the Piaggio MP3 and Mercedes F300 Life Jet (Figure 2.16 & Figure 2.17), translate a leaning motion of the rider into tilting wheels. A leaning vehicle allows the two front wheels to tilt with the same angle as the back wheel utilizing a tilting mechanism

This works with the help of a so-called parallelogram tilting system. The geometry of this mechanism allows all wheels to maintain at the same angle with the road. The Piaggio uses a single parallelogram and the Mercedes a double parallelogram (Figure 2.15). Both types come with their advantages and disadvantages. Where the single parallelogram is relatively simple, adding suspension needs a separate structure. The double parallelogram, however, can simply implement suspension within each segment, but the suspension influences or even works against the leaning movement.

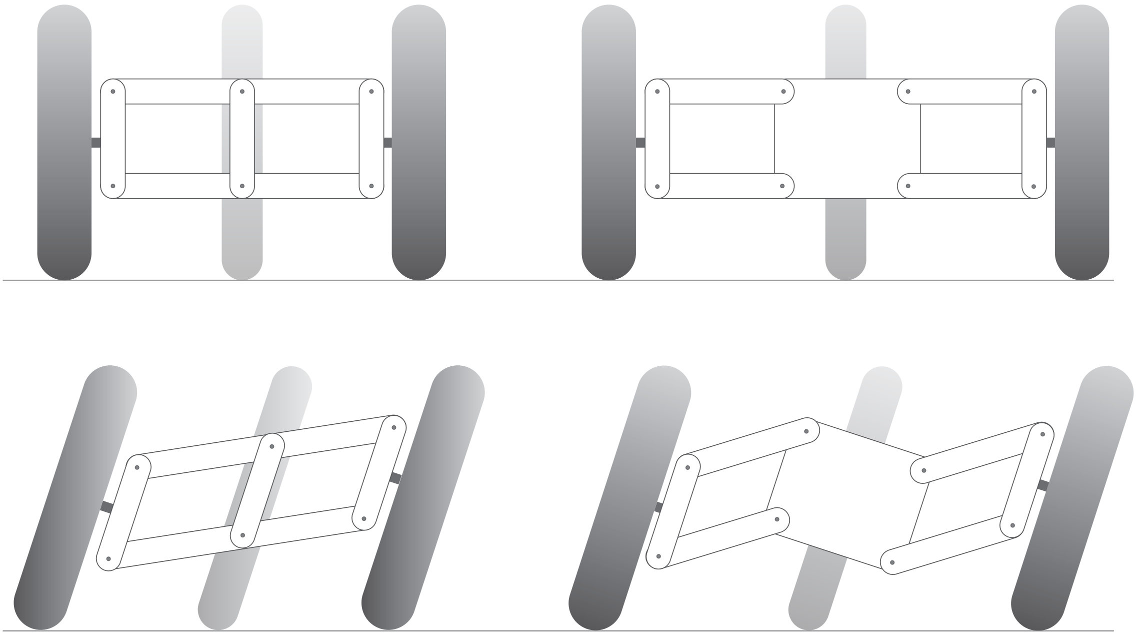


Figure 2.15 Two tilting mechanims in upright and leaning position.

Figure 2.16 (top) A Piaggio MP3. The front steering assembly allows the Piaggio to both steer and tilt. A single parallelogram performs the tilting action. The suspension is provided directly on the wheels

Figure 2.17 (bottom) A Mercedes F300 Life Jet. The front steering assembly allows the Mercedes F300 Life Jet to both steer and tilt. The tilting action is performed by two separate parallelograms, which also act as the suspension.

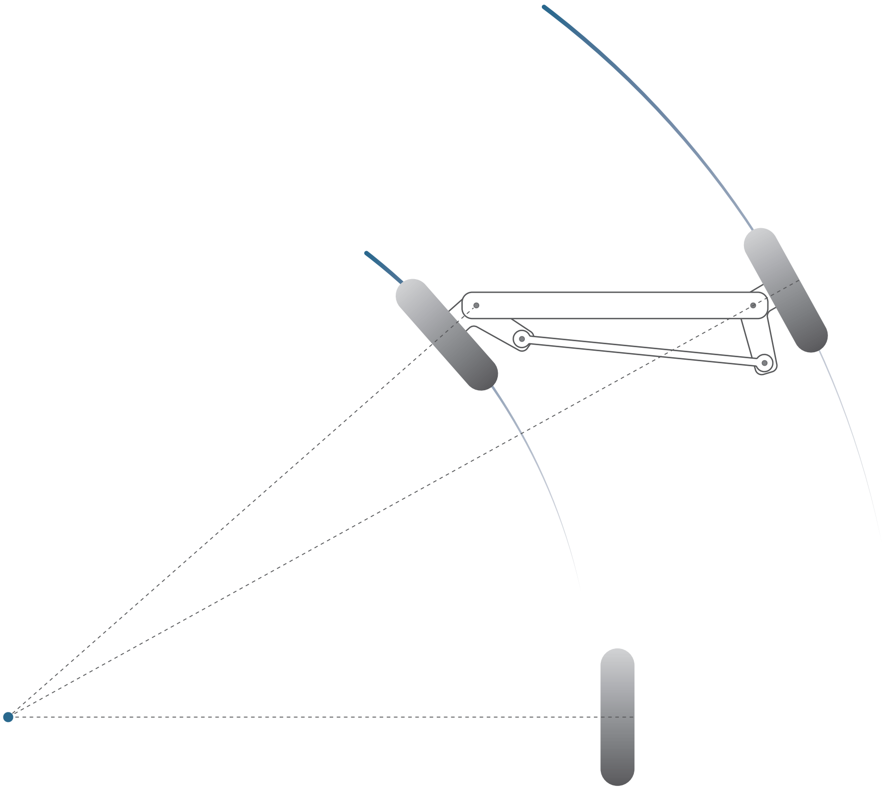
Ackermann

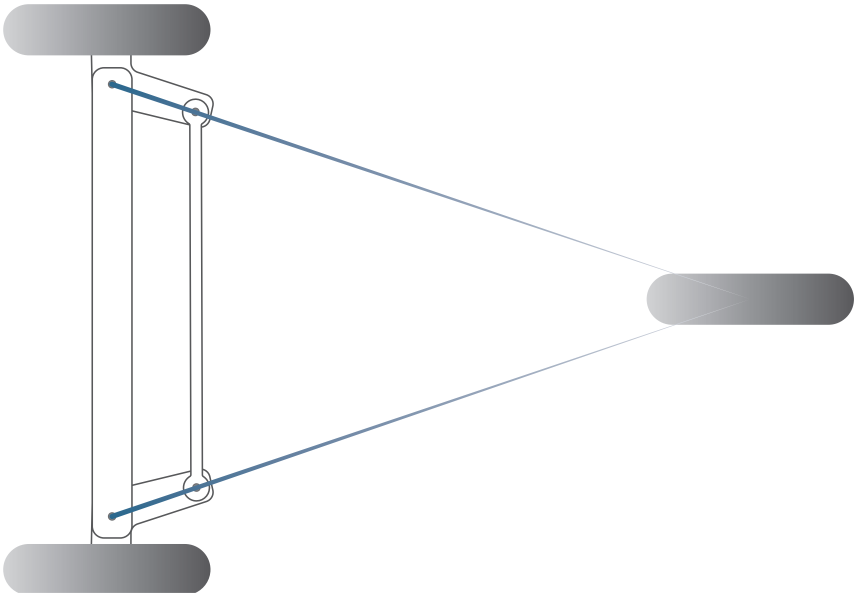
Both the Piaggio MP3 and Mercedes F300 Life Jet steer their front wheels according to the Ackermann principle. This way of steering avoids tires to slip sideways when following the path around a curve (Figure 2.18). Rather than turning both wheels around a common pivoting point, each wheel is turned around its pivot right next to its hub. The Ackermann principle arranges both front steering wheel-axles as radii of a circle with a common origin, which lies on a line extended from the rear wheel axle. As the front wheels turn when steering, the angle of the inner wheel is higher than the angle of the outside wheel. Coaches, car trailers and toy wagons steer both wheels on a common pivoting point, apart from slipping tires stability is also lost in sharp corners due to the decreasing track width. In order to synchronize the steering effect of both wheel, the wheel hubs are connected with a linkage. By not constructing a parallelogram shape, but creating a shorter length of track rod than the length of the wheelbase, the steering performs according to the Ackermann principle.

A simple approximation to design the Ackermann principle's steering is shown inFigure 2.19. The length of the track rod is determined by the angle of the pushrods on the wheel hubs, depending on the distance between the front wheels and back wheel(s)

Figure 2.18 (top) The Ackermann principle

Figure 2.19 (bottom) A simple approximation to design the Ackermann principle's steering.





Design vision

This chapter has, through the examination of literature, context, and users outlined the foundation for a set of functionalities and criteria relevant to the central aim of this graduation project - developing a shared-type kickscooter for a campus environment with a system of shared usage. Based on the visions found in the analysis, the following challenges are defined as a design outline for the ideation phase.

Neatly organized

A shared HPV with a reduced footprint from a compact and organized docked position. Allowing large quantities in a limited amount of space, no need for designated parking racks and an organized way when the vehicles are not in use.

Stability

When stepping off the kickscooter, it has to stand stable by itself, without leaning it against any other object. This quality is placed at any place without the need for a designated parking rack, while also reducing the need to keep balance while riding.

Cargo

Bringing a small amount of cargo allows people to move themselves and their items comfortably. Especially in the context of businesses where employees are always on the move with small items or a bag, not having to carry them on the body makes riding a lot easier. The challenge lies in a compact integration, without burdening the user.

Kick scooting

The core strength of the product lies in facilitating the end user with quick transport from one place to the other over relatively short distances; the last mile. Kick scooting is found as an ideal mode of moving in this case. It is simple in use, does not need to be adjusted to the rider’s size and reduces maintenance to almost nothing.

Stigma

The kickscooter has been stigmatized, and it is now conceived as a children-only product by many adults. From a design perspective, little work has been done to remove this stigma. To encourage people to use a kickscooter as a last mile mobility aid the stigma should be reduced. This challenge is largely adressed in the overall aesthetic of the product.

Design for manufacturability

The concept has to be manufacturable, the use of affordable mass production technique should be taken into account. Additionally where available standard off the shelve parts should be used. The product has to be simple, mechanical and operate with just the help of a human being. The challenge is to design a cheap kickscooter that still feels like a luxury mobility tool.

Maintenance

Design to reduce the amount of maintenance to a minimum. The choice of materials, sizing, and standard parts enhance the maintenance friendliness. Again keeping the design simple and only add the necessary.

3 IDEATION

Introduction

The aim of the ideation phase is to diverge in different product architectures. The core elements of standing by itself, compactness, steering and leaning are explored in rough kickscooter skeletons in this phase of the project.

Many ideas are validated with physical models and prototypes with a strong focus on steering and providing stability, while futher on in the process taking nesting into consideration. Integrating the cargo element follows in the embodiment phase. Most of the parameters and standards are formulated piece by piece from the ground up building forward to a final design. The most efficient way to set up this system is to use physical full scale prototypes that can be directly measured, adjusted, and related to the human body by driving them.

The starting point for the product architecture was setting the position of the wheels. Building a kickscooter that does not fall over, like any two wheel vehicle would do if not supported by a third touchpoint, is inherent to integrating three or more wheels. Two directions where subsequently explored, starting with two wheels in the back and a single wheel in the front, followed by the reverse.

Iteration I

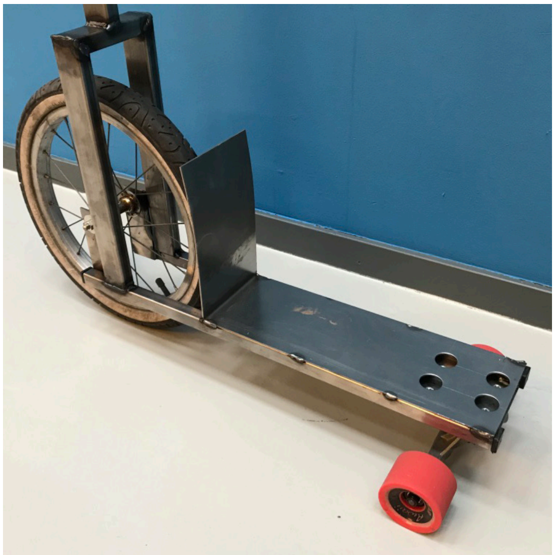
Iteration I explores a three wheel configuration with two wheels in the back and a single wheel in the front. Steering was both tested in the front and in the back or a combination of both. By using standard parts and materials, quick prototypes were realised.

The first configurations were build up out of skateboard trucks and bicycle wheels. The first test uses skateboard wheels in the back allow for a steering movement when the rider leans into the corner (Figure 3.1). Riding this prototype needs some skateboard riding skills. The second test could be configured to direct and indirect front wheel steering (Figure 3.2). Direct steering on the front wheels was found most comfortable. The third test has a shorter wheelsbase with direct frontwheel steering (Figure 3.3). The only problem left was the backwheels lifitng in a corner. Dimensions and angles are found by quick riding tests and modifications on the prototypes. The tension of the rubber was also adjusted to test steering capabilities of the skateboard truck.

Figure 3.1 (top left) The first test

Figure 3.2 (top right) The second test

Figure 3.3 (right) The third test.



Iteration II

Iteration II improves directly on the first iteration. Early on in process of making and testing the importance of leaning the scooter when turning a corner became evident. A parallelogram tilting mechanism was set under an angle of 45 degrees, aiming to both allow the leaning motion to be translated in a tilting compensation and a steering motion of the wheels (Figure 3.5). Futher tests with the positioning of the parallelogram and turning points resulted in a parallelogram which both steers and keeps both wheels in the back on the floor while leaning (Figure 3.4). The second conceptual iteration settles on a combination of parallelogram leaning mechanism on the back wheels with a steering front fork on the front wheel (Figure 3.6).

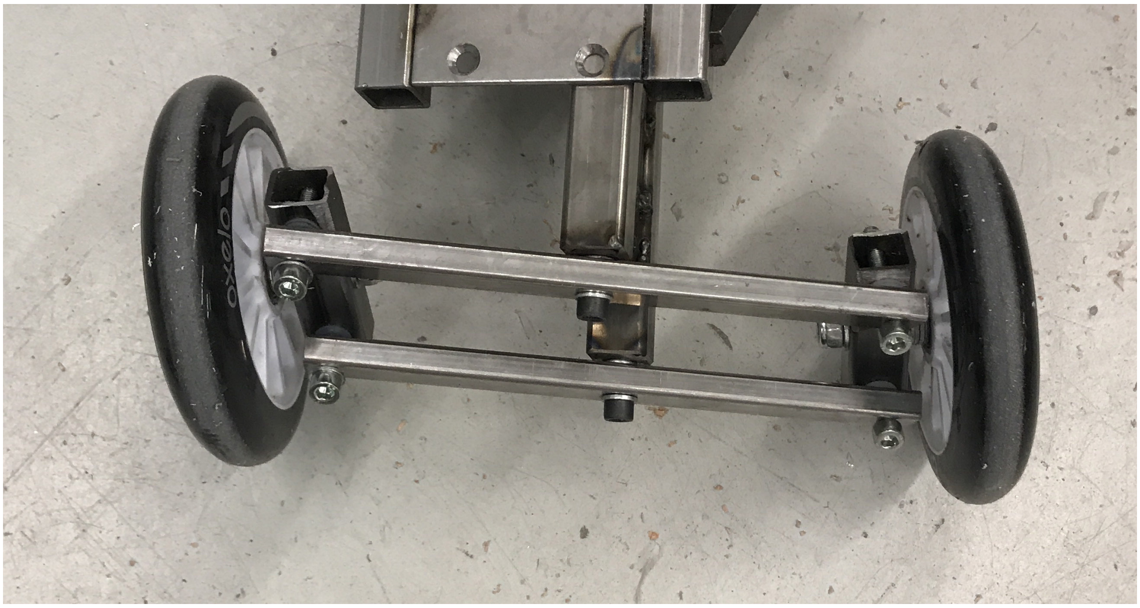


Figure 3.4 A parallelogram configuration that translates a leaning motion into both a tilting and steering action

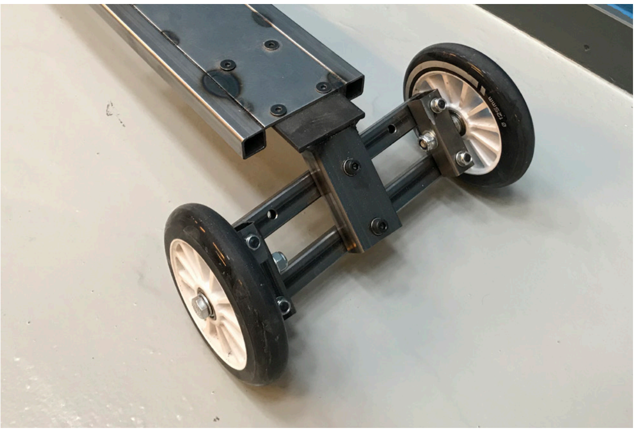


Figure 3.5 (top) The final mockup of the second iteration

Figure 3.6 (left) A parallelogram tilting mechnism applied on the two back wheels, allowing both wheels to lean when the scooter turns a corner

Figure 3.7 Outdoor tests with the final concept of iteration phase II

Nesting

During the ideation phase, it was found that sliding together, similar to what is done with shopping card at a supermarket and luggage card ar airports, is ideal to minimize the footprint. This compact way of fitting objects together is called nesting.

Nesting in iteration II is performed by placing the scooters into each other with the front wheel fitting in a slot of the deck of the one in front. The lower part of the frame functions both as foot support and rack. When users parks a scooter they lift the front wheel and push the wheel on the slot of the scooter in front (Figure 3.6) The back wheels are kept on the floor, keeping the line of scooter stable. When in position the front wheel sits in the front slot it will get locked in its position.

Figure 3.8 Nesting, interlocking shopping carts to create a compact and organized way of parking

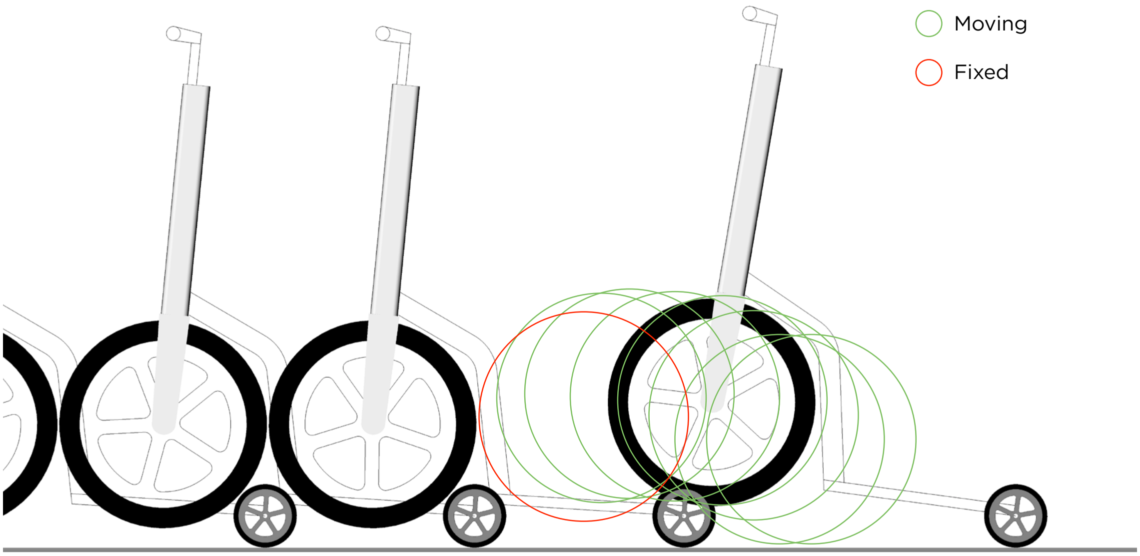


Figure 3.9 Nesting movement. Users park the scooter by riding against the back of the scooter in front, which moves the wheel in the slot of scooter's deck.

Iteration III

Based on the notion that the ideas of the first and second iteration phases will not trigger the user to neatly nest the scooter after use, a third iteration cycle is done on a more inviting product architecture; two wheels in the front and one wheel in the back. The two wheels in the front where put wider apart from each other to make the scooter more stable, while giving it a character that is inviting to nest like a shopping cart. The most compact solution would be just enough space for the foot standing on the scooter in between the two front wheels. By slightly extending the deck, the kicking foot is not colliding with one of the front wheels when swung forward.

Tilting & steering

The architecture with two wheels in the front and one wheel in the back combines steering with the ability to lean the front wheels. A tilting mechanism is combined with an Ackermann steering principle (Figure 3.10 & Figure 3.11). The parallelogram allows both front wheels to tilt, while the Ackermann steering principle steers both wheels taking their different turning cricle into consideration. The axis of the front wheels is placed under the lower bar of the paralellogram, allowing the back wheel to roll underneath.

Figure 3.10 (top) The front wheels tilting at the same angle as the backwheel and steering column.

Figure 3.11 (bottom) The ackermann steering rod placed behind the parallelogram construction


200 MM - 87A


oxelo
200 MM - 87A


oxelo
200 MM - 87A

Nesting

Nesting is performed by riding the front part of the kickscooter over the back part of the kickscooter in front. The opening at the front and slim footsupport with backwheel neatly slides into each other. The combination of two larger 200mm front wheels not only give this product architecture a dynamic character but it also evolved out of a necessity. To be able to move the tilting mechanism over the back wheel, the bottom arm of the parallelogram needs to sit at a minimum height of the backwheel. A large wheel in the back would result in a higher placement of the mechanism (Figure 3.12, Figure 3.13).

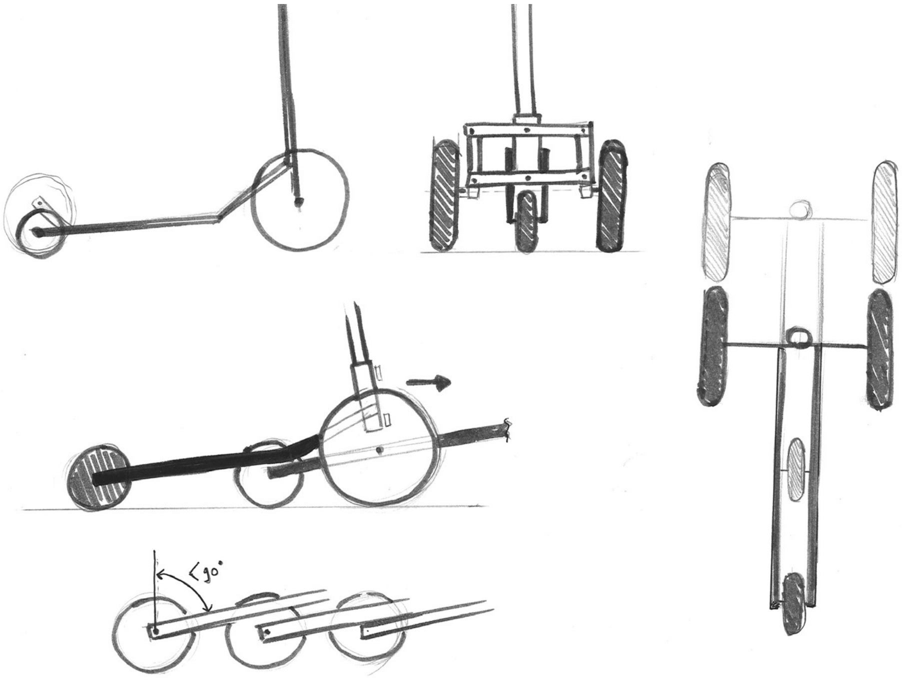


Figure 3.14 Nesting exploration; how to develop a simple construction

Figure 3.12 (top) The backwheel slides underneath the front construction into the slot of the deck

Figure 3.13 (bottom) Two models in the nested position

4 EMBODIMENT

Introduction

After having determined the product architecture, iteration III is taken into an embodiment phase. This phase is characterized by an iterative process on the frame, steering & tilting mechanism and cargo arrangement. The ideas implemented are generated from an incremental hands-on process. This chapter is divided into five subchapters as presented in the visual on the right page; Frame, Tilting & steering mechanism, Nesting, Wheels & brake and Cargo rack. Each subchapter discusses a specific element of the kickscooter and process towards the outcome.

A broad variety of techniques are adopted in the design process, from sketching, digital modeling, digital simulation to prototyping and validating. This series of activities led to one final design that was developed to an ‘advanced concept’ with a functional prototype that is visually close to the final renders. This last step could be called iteration III since a series of prototyping and engineering cycles would still be required to bring the scooter to a detailed product.

The final design is a process of subtraction, in which the things that are not providing functional benefit are stripped. The result is a lightweight, elegant and robust kickscooter with an ambiguous appearance and functionality.


Frame
Cargo rack
Tilting & steering mechanism
Nesting
Wheels & brake

Frame

The frame is the skeleton of the kickscooter. It provides a structure and support for its human rider and elements to be mounted. Based on the initial design challenge to make a simple and affordable design, suited for scalable production, an exploration into different materials and production methods started. Different techniques and materials to construct the frame where explored in sketches and cardboard models, such as folding sheet metal, using a steel tubular skeleton as structure, monolithic and lightweight strucutures (Figure 4.2 & Figure 4.3). The embodied design settles on a welded construction of two purposefully designed aluminium extrusions.

Aluminium extrusion was the ideal choice for a simple appearance, both concerning construction and finish. The extrusions for the board provide features for mounting the back wheel, nesting the kickscooter and above all support for the user' foot. The steering stem incorporates not only the steering tube but also a slotted feature for the cargo rack.

Figure 4.1 The frame constructed out of two aluminium extrusions

EMBODIMENT

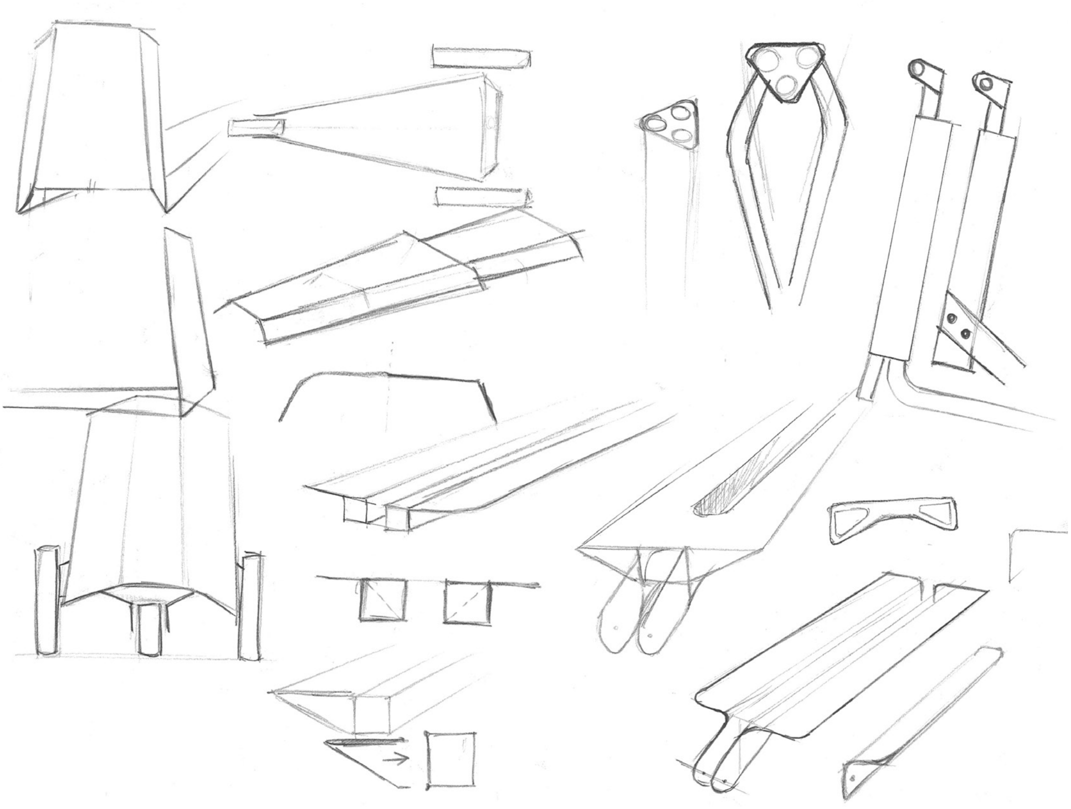


Figure 4.2 The frame construction exploration

Figure 4.3 Cardboard exploration of a tubular frame with covering panels

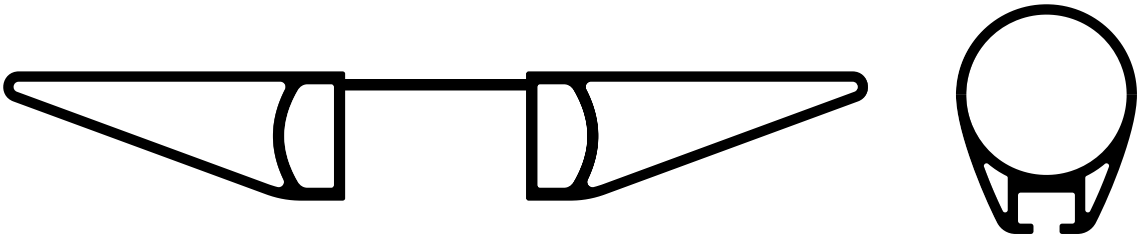


Figure 4.4 Cross-sections of the aluminium profiles

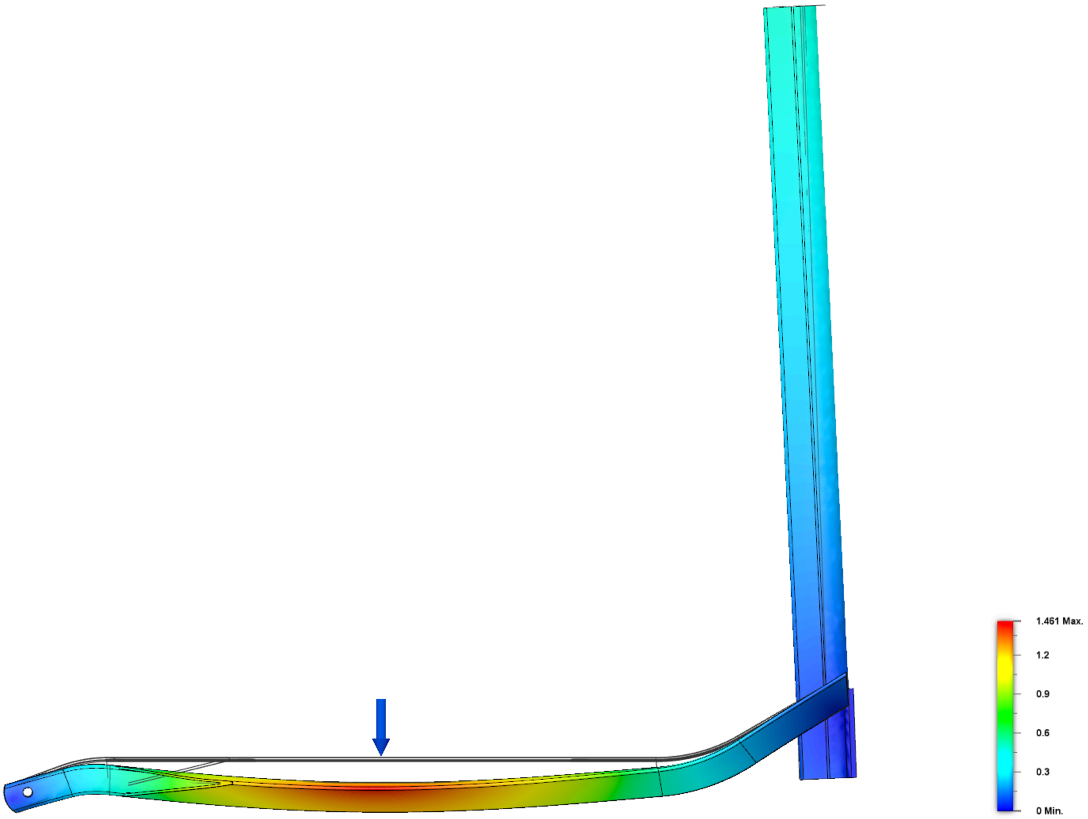


Figure 4.5 Displacement of the extruded aluminium board when a distributed load of 2500N is placed on the deckprofiles. Simulating a heavy adult riding the kickscooter. Red indicates a maximum displacement on the outer edges of the profile of 1.45mm (the image shows a deformed scale of the displacement)

Aluminium extrusion

Two aluminium profiles, based on a boxed cross-section (Figure 4.4 & Figure 4.6), form a durable and lightweight frame. The footboard extrusion is build up out of two shapes that allow for structural rigidity, space for the foot of the rider and the possibility to extend a single shape to support the backwheel. To create the desired shape, the profiles are cut to length, sawn, CNC milled/turned and finally bent. They are then TIG-welded, with a welding rod from the same aluminium alloy as the base material, to form the rigid frame. Before the finishing process, the entire frame is T6 hardened to bring back the lost strengths from the welding process.

The strength has been analysed to optimise wall-thicknesses. A finite-element analysis in CAD-software shows that an exaggerated load of 2500N (roughly 250kg) only displaces the frame slightly with 2mm wall-thicknesses, without being enough to deform the frame (Figure 4.5).

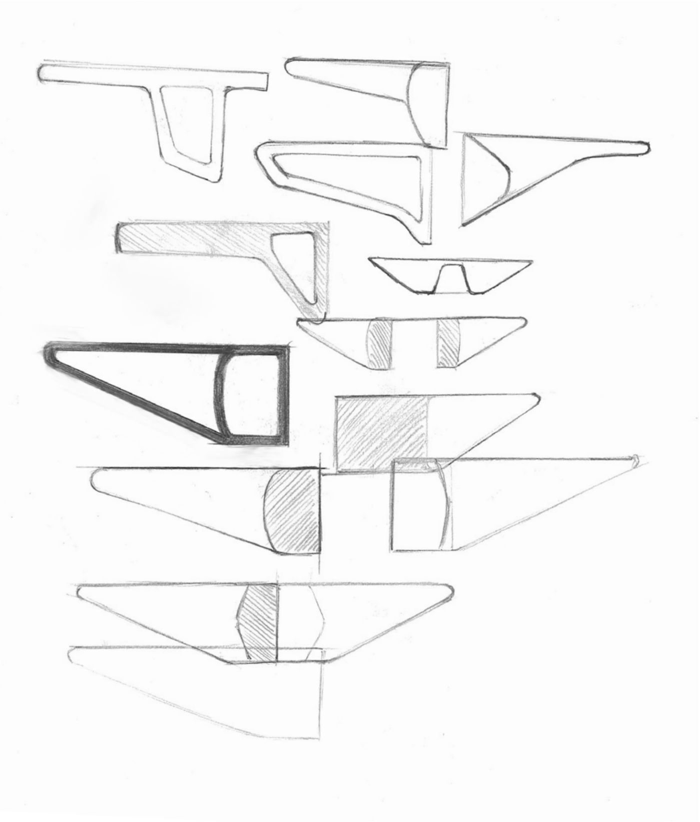


Figure 4.6 Foot-support extrusion shape exploration

Prototype

The aluminium extrusion is simulated in reallife with a combination of sheet aluminium and rectacgular stock. Sections of sheet aluminium are bend and welded together to form a prototype footboard. The long steering head with carrier for the cargo rack is simplified to a tube with a folded sheetmetal attachment welded on the back (Figure 4.7, Figure 4.9, Figure 4.8 & Figure 4.10).

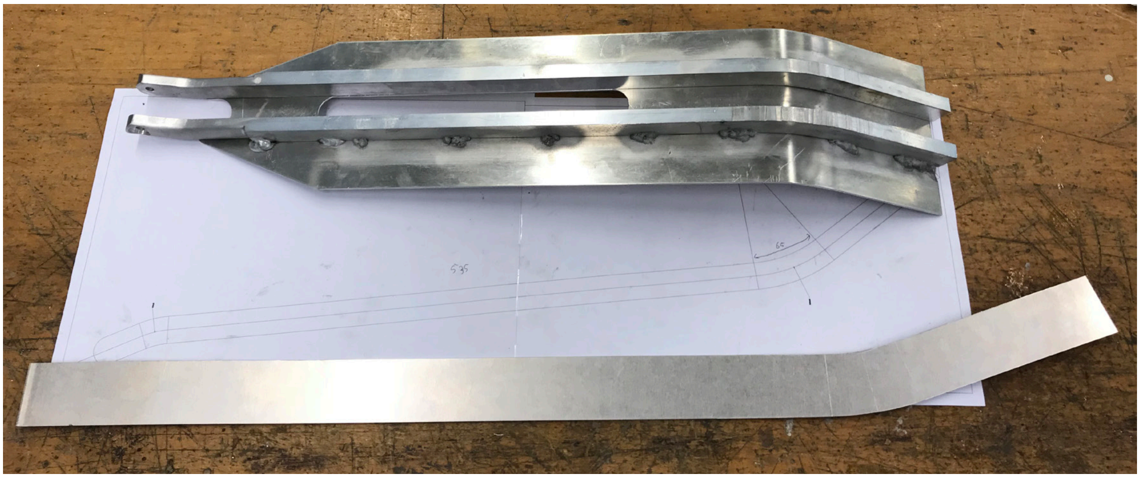


Figure 4.7 (top) Prototyping and simulating the extruded aluminium footboard

Figure 4.8 (right) Bending the central structure of the frame. Heating the aluminium right before the melting point softens the aluminium.

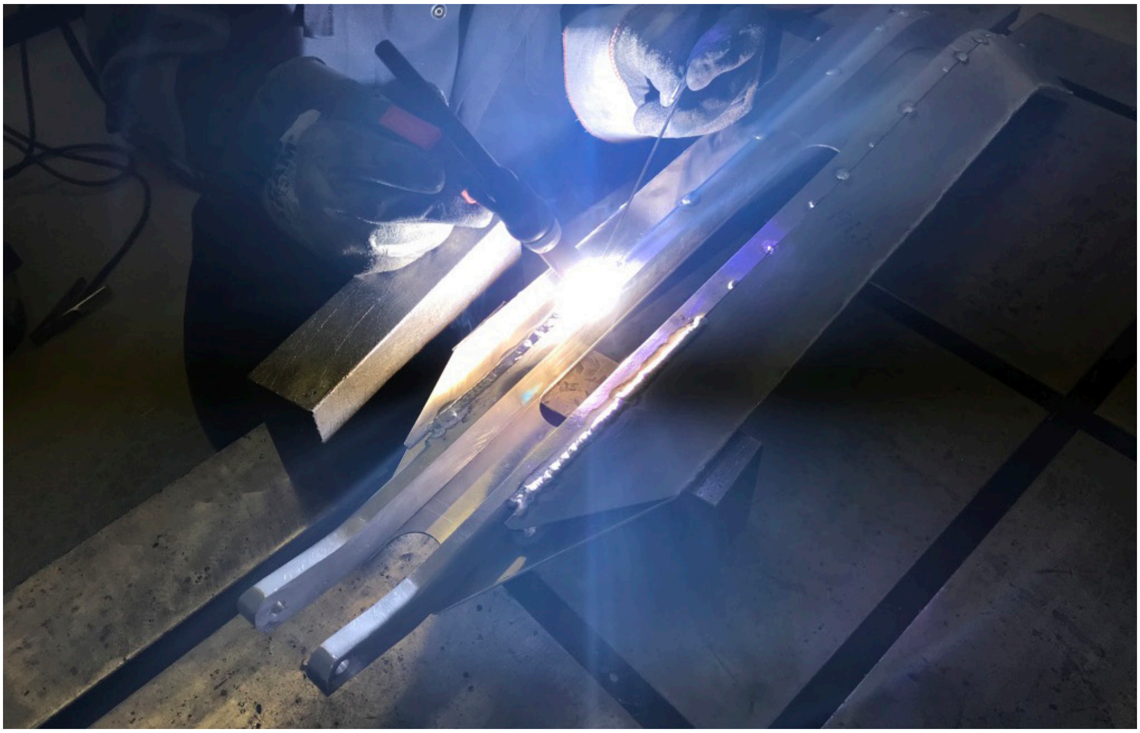


Figure 4.9 (top) TIG welding sheet aluminium to simulate the extruded profile

Figure 4.10 (right) The welded frame complete

Finish

The frame is surface treated with an anodized layer. Anodizing creates a corrosion-resistant and hard wearing layer, while also providing the decorative finish. Anodizing creates an abbrasian resistant layer, similar to the hardness of saphire (the second hardest material on earth), making it more resistant than any paint finish. A space gray in combination with colorless dye is chosen to keep the product as natural and pure as possible, giving it professional character. The anodised layer highlights the use of aluminium and gives the product a precious appearance. A selection of metal objects with different anodised finishes create a pleasant interplay (Figure 4.11). The products merely uses silver and black, both in different textured and polished finishes.

The aim was to bring the prototype to a level that is both functionally and visually accurate. The aluminium frame was therefor send to an anodising company. The results were disappointing due to the fact that too much heat and the wrong weldingalloy distorted the kristaline structure of the aluminium. Resulting in too much variation of the color (Figure 4.12 & Figure 4.13). A final product which is professionally welded, and most importantly with the correct weldingalloy, will not show these effects and can be anodized with a uniform anodized layer.

Figure 4.11 Selection of materials, colors and textures

Figure 4.12 The anodized layer clearly reveals the weldingseams and heated spots.

Figure 4.13 The deanodizing process highlights all the welded spots and seams. The bath contains an alkaline dissolved in water and kept at 60°C. Once an aluminium object is place in the bath the chemical reaction between aluminium/aluminium oxide removes a thin layer of the surface, either deanodizing it or preparing the surface for anodizing.

EMBODIMENT

Tilting & steering mechanism

Both the tilting and steering mechanism have changed in their embodied state. The goal was to simplify both mechanisms in terms of appearance, they needed to look less mechanical/technical, and make them more maintenance friendly. Another goal was to transform the face of the scooter, it needs to be inviting to nest. Both mechanisms are discussed separately in this subchapter

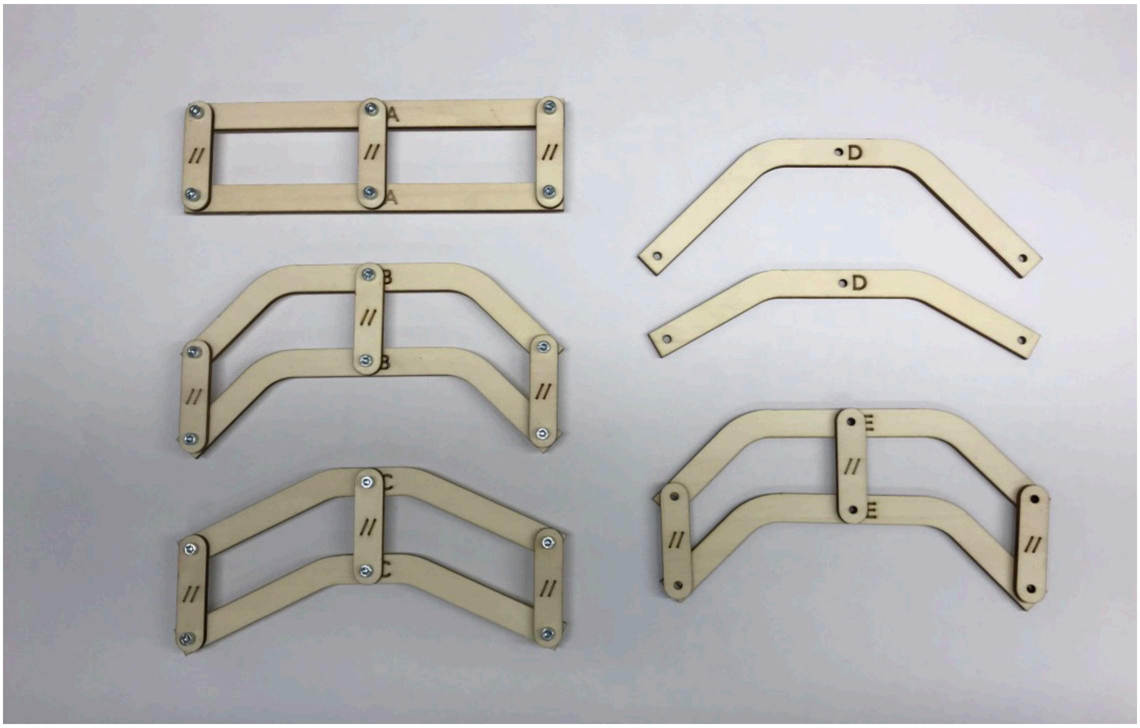
Tilting mechanism

The starting point of the tilting mechanism was the conventional parallellogram with four parallel arms. Explorations in shapes that would create a mouth-like opening to invite people to nest the kickscooter are explored and tested with scaled mockups (Figure 4.14). Another feature that was implemented in this geometry is the range of motion when tilting, the angled arms limits the parallelograms on both sides. This range was determined in iteration II by the degrees of freedom in the rod-ends of the ackerman steering mechanism. The parallelogram is styled to give an calm appearance and eliminates the need to cover the mechanism (Figure 4.15). The slimmer arms not only provide appearance, they also serve a mechanical purpose and reduce weight. Two cycles of prototyping resulted in a rough testing model (Figure 4.16) and evolved into visually and functionally accurate prototype of the mechanism (Figure 4.17).

When mass manufactured the aluminium arms and pivots would be die-casted in aluminium and machined to fit PTFE bushings and powdercoated for a protective layer. All rotating pins are machined from steel and assembled with bronze bushing, nylon rings and C-clips.

Figure 4.14 (top) tests with different parallelogram geometries. Simple lasercut arms validate the degrees of freedom.

Figure 4.15 (bottom) exploration of the front appearance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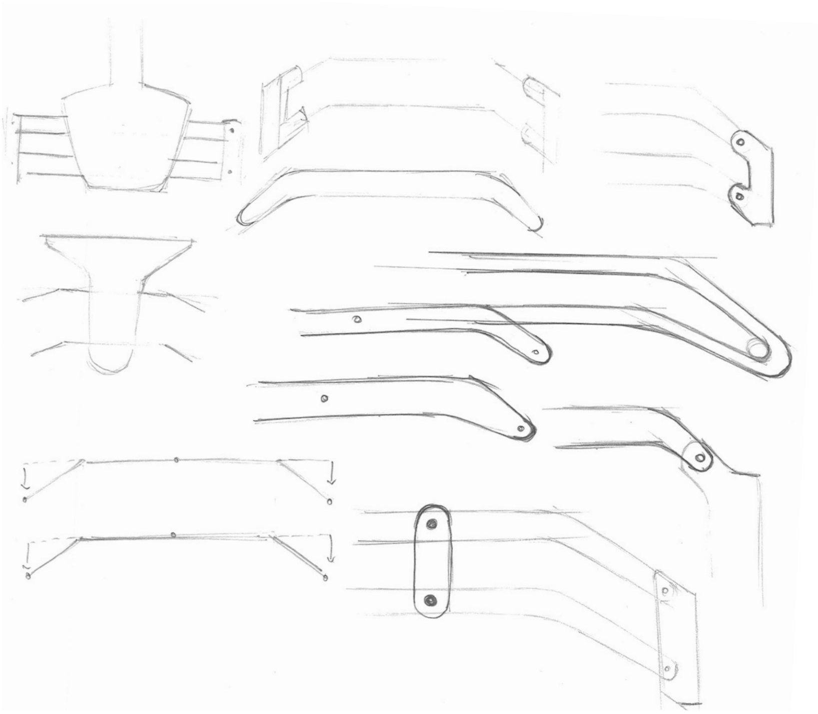


Figure 4.16 Testing model of the angle tilting mechanism, with integrated wheelpivots.

Figure 4.17 CNC machined aluminium final prototype. The Aluminium parts are anodized colorless and black.

Figure 4.18 Paralellogram pin details. The arms are held in place with steel pins and C-clips for a minimal appearance.

Figure 4.19 Paralellogram pivot detail.

Steering mechanism

The steering mechanism, more specifically the ackermann steering mechanism, is optimized in two areas. As a first improvement the linkage from the two wheels and central steeringhead is simplified from a sliding motion to a rotating bellcrank (Figure 4.20). Two identical steeringrods connect the wheels diagonally to a central bellcrank allowing both wheel to steer according to the ackerman principle.

The second improvement is noticebale in the riding character. Tests with the users asked for stabler steering character. By both increasing the caster angle and giving a negative axis offset (referred to as fork offset in the analysis), more trail is generated providing more steering stability. Both front wheels act like swivel casters (found on shopping trolleys and office chairs), they always try to roll in the direction of movement (Figure 4.21)

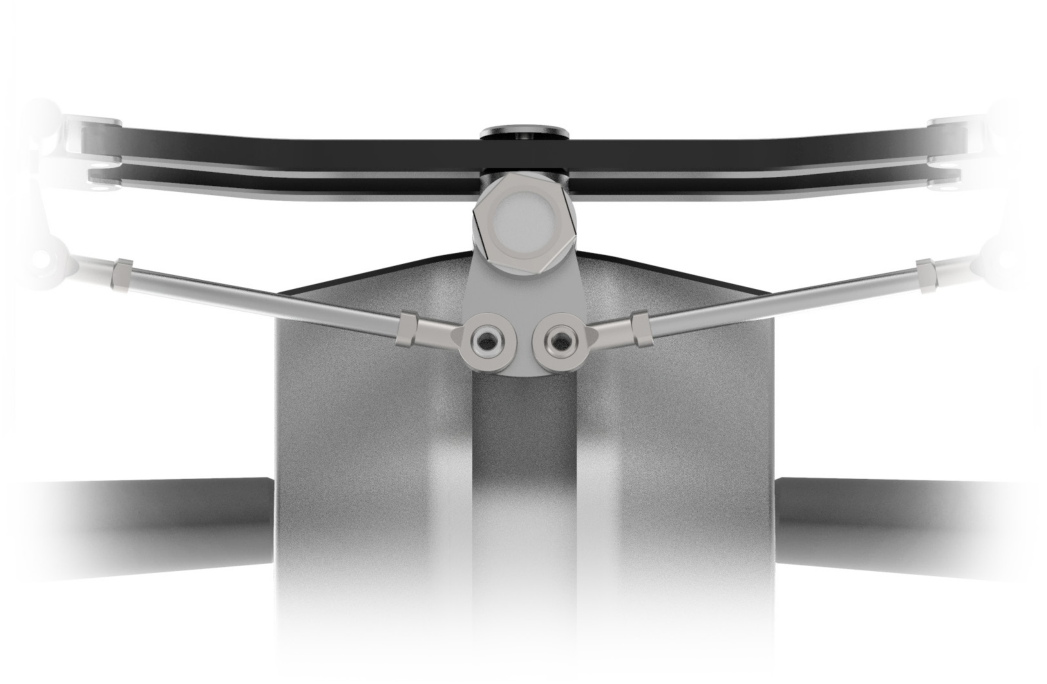


Figure 4.20 The bellcrank replacing the sliding joint on the ackermann steering mechanism

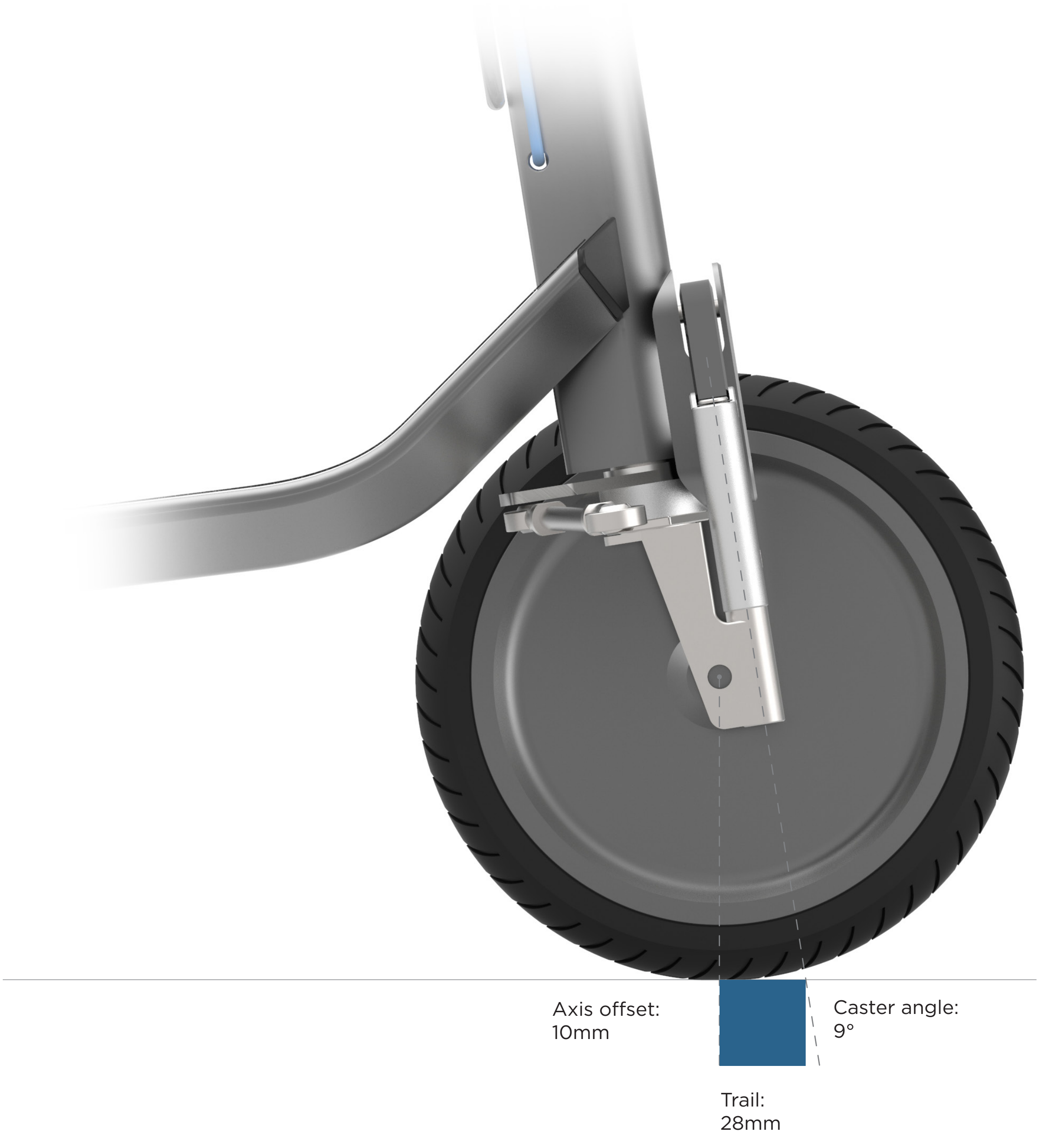


Figure 4.21 Trail and caster

Figure 4.22 Steering and tilting mechanism in upright position

Figure 4.23 Steering and tilting mechanism in right steering corner

Nesting

In the Ideation phase a nesting princicple was defined. The kickscooter in use would be parked over the scooter placed in front, with the wheel of the parked scooter coming through a slot in the middle.

The middle of the board in the final integration is only opened there where the wheel protrudes the frame. Visual guidance and an invitation to nest the scooters is given by the front, a generous tapered opening shaped by the parallelogram. To futher guide the wheel inside the slot, two guiding strips of plastic are positioned underneath the front part of the frame (Figure 4.24)

Figure 4.24 Plastic strips shaped to guid the smaller wheel in the back into the slot of the kickscooter being parked

Wheels & brake

Two large 200mm frontwheels and a smaller 100mm wheel in the back where chosen in iteration III and tested in the mockup. Both sizes are standard off the shelve kickscooter wheels. The same size frontwheels are chosen in the front in this final design, but the smaller backwheel is replaced with a 125mm kickscooter wheel. To make the ride over bumps effortless, instead of the relatively hard and solid PU wheels, the design would benefit from a tubeless soft tire design(Figure 4.25). Keeping the low maintenance since the risk for flat tires is eliminated, but the soft inner layer increases comfort. A hard wearing outer layer of rubber with a soft foam core or perforated rubber tires exists for bicycles but would have to be custom developed for the smaller 125mm and 200mm kickscooter wheels.

The brake design is kept simple and is taken from conventional kickscooters. A springloaded fender on the back creates friction against the wheel when the users push it against the wheel with their heel. In future version this type of brake could also be actuated by a wire and handbrake on the steeringbar.

Figure 4.25 Puncture proof bicycle tires. Left a foam core with rubber outer layer, right a perforated full rubber tire

Cargo rack

A small wireframe cargorack is placed behind the steering stem onto a slotted feature of steering pole extrusion. An exploration in different cargo features resulted in a simple rack close to the rider that can be mounted as an accessory (Figure 4.26). Mounting a rack as an accessory allows it to be an option, some business situation might need a different cargorack specified to their needs, some might no need one at all. While riding the cargo stays still, keeping the ride stable. Moving the load on the steer would result in a heavy steering action, comparable to a basket mounted on the steering handle of a bicycle.

The hook, formed into the wireframe, allows users to hang the lugs of any small bag and keep it in place with the two blue elastic strings(Figure 4.27)

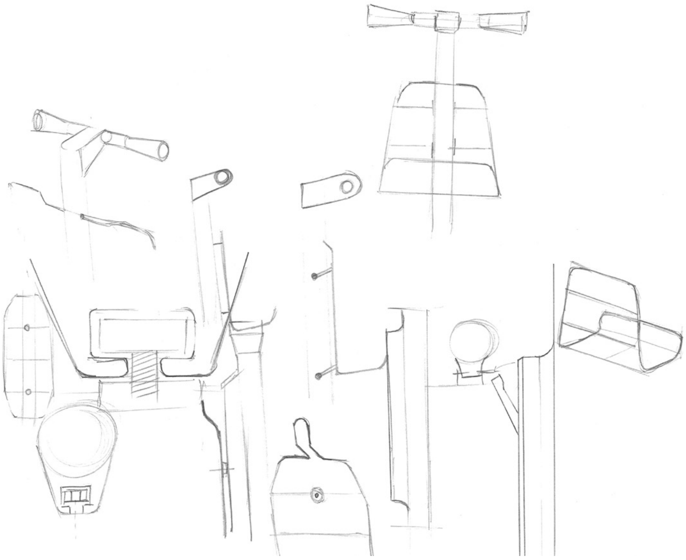


Figure 4.26 Cargo rack exploration

Figure 4.27 Cargo rack mounted on the extrused slot of the steeringstem. Cargo can be held stable by the elastic string

Final design

The final design is the result of a process of subtraction, in which what does not matter has been eliminated. It is a robust and elegant kickscooter with a simple shape. It has a professional look and with its tilting mechanism a new, yet familiar riding character. Its name is FLO, a reference to the increased flow we will experience with shared kickscooters.

Cost estimation

Throughout the embodiment design process all the different parts are designed to be mass manufactured, with scalability in mind. The discussed production methods, aluminium extrusion and casting, allow for both large and smaller quantities. This rough cost estimation considers batchsize of a 1000 kickscooters. Imagining a first series to be deployed, among 10 large organizations in The Netherlands which would buy on avarage 100 kickscooters for their business. Prices are based on consulting manufacturers and supply chains in Europe and Asia.

Some of the manufacturing techniques require a minimum quantity for a single batch. The limiting factor for FLO would be the extruded frame parts. Aluminium extrusion requires a minimum quantity of 500 kg. The slim aluminium steering pole would limit the batch to 800 pieces if the minimum of 500kg would be bought. An investment in two dies need to made to produce both extrusions, they will cost approximately €3000,- and €2000,- for the footboard and steering pole respectively. Postprocessing the extrudsion, both CNC milling, bending and hardening, is offered by the same extruding company and is included in the cost estimation.

Parts for the mechanism and steering assembly are for a first series of 1000 units aluminium investment casted and when batchsizes are increased die casted in aluminium for a better precision and surface finish. Pivoting holes are postprocessed to fit press bushings.

Standard parts like wheels and fixing material can be ordered as off the shelve parts.
An overview of all the estimated costs is presented on the next page (Figure 4.28). It should be noted that this price only provides an indication. A market research should first define the total batchsize and further engineering should lower the costs.

Frame

Aluminium extrusion I	€30.000,-	
Aluminium extrusion II	€25.000,-	
Die I	€3000,-	
Die II	€2000,-	
Machining & bending	€28.000	(CNC milling & turning)
Welding	€7500,-	(€7,50 per unit, based on an hourly rate of €75/h)
Anodizing	€15.000,-	
Total	€110.500,-	
Price for one frame	€110,50	

Steering & tilting mechanism

Parallelogram arms castings	€2.920,-	(€1,46 per arm, 2000 arms per product)
Paralellogram pivots castings	€6.800,-	(€3.40 per pivot, 2000 pivots per product)
Steering head	€9.100,-	(€3,61 per steering head)
Postprocess machining	€8.000,-	
Turned parts	€12.000,-	
Powdercoating	€8.000,-	(total of all parts to be powdercoated)
Total	€46.820	
Price for one kickscooter	€46,82	

Wheels, fixing material & misc.

Wheels 200mm	€6.000	(€3 per wheel)
Wheel 125mm	€2.000	(€2 per wheel)
Fixing material	€3.500	
Rack	€650	
Total	€12.150	
Price for one kickscooter	€12.15	

Total costs 169,47

Figure 4.28 Cost estimation

5 CONCLUSION

Future steps

The end of this report does not correspond to the end of this design project. This graduation project introduced a detailed concept that has the potential to be further developed to a design that can be mass manufactured. The future course of action; This project concludes with a full-scale prototype that can be tested by users and fine tune the ergonomics in terms of optimal sizes. A user test with a larger set of scooters would also determine the potential in the market. This chapter highlights several recommendations for future development.

Market exploration

The market needs to be further explored to see if enough campuses and companies would be willing to adopt a kickscooter as a shared mobility aid. The first batch size would largely depend on this factor. This also determines if the calculated costs are reasonable or whether the design should be adapted to reduce mass manufacturing costs.

Detail design

The majority of the parts need to be further detailed and engineered. For example, the bellcrank allows the wheel that sits on the inner corner to oversteer and turns passed a dead point. In the current design, this is solved by a physical stop, allowing the wheels to turned within a specified range. The bellcrank should, however, be further detailed to eliminate the dead point.

Wheels

As mentioned in the chapter about the wheels and brake, further investigation is needed in the rubber material for the tires. A softer rubber would result in a much more comfortable ride but also more wear.

Tilting mechanism

The tilting mechanism is currently held stable by friction. However, over time this type of fixation would loosen and let the scooter lean towards one side in an idle position. A promising solution that would also improve the riding characteristics in terms of stability, would be a spring type of solution that forces the scooter back to a middle position. An elastomer insert placed under tension in the middle joint of the mechanism would push the arms back to a middle position (Figure 5.1). Another option would be a cam that forces a linear coil spring force when the rotation is translated to a linear movement on the cam(Figure 5.2). The rotating part would be fixed on one of the paralellogram arm, while the spring assembly is fixed on the frame, allowing the rotational force of the arm to move the cam.

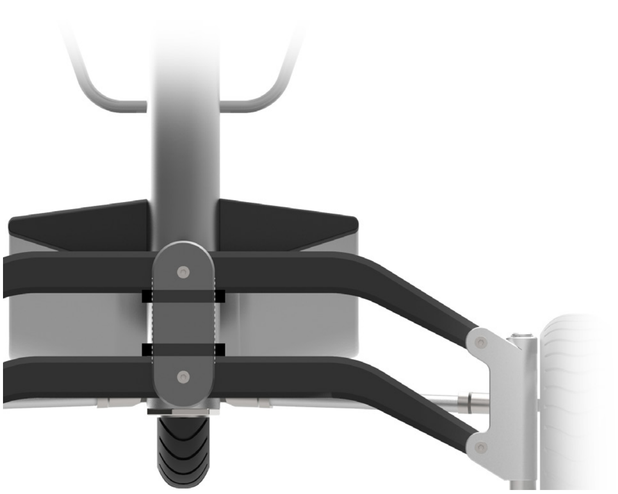
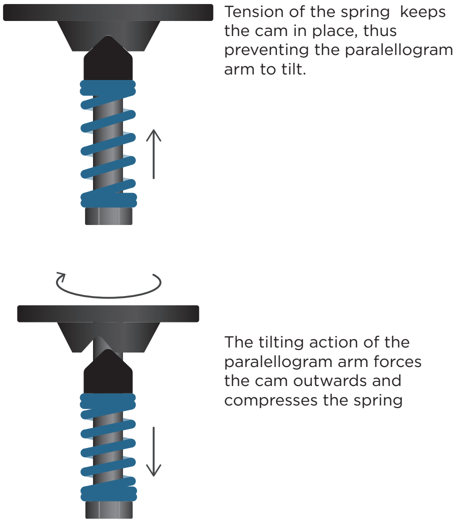


Figure 5.1 Elastomer spring blocks placed in the middle joint of the parallelogram



Tension of the spring keeps the cam in place, thus preventing the paralellogram arm to tilt.

The tilting action of the paralellogram arm forces the cam outwards and compresses the spring

Figure 5.2 Cam spring coil principle.

Lock

Implementation in a business context could need a locking system allowing a row of kickscooters to be locked and easily unlocked. For this graduation project, the locking system was out of the scope. Depending on the batch size an electronic lock or simple mechanical lock could be implemented.

Advertisement

Placing the kickscooters in a shared situation allows companies to place their logo on the scooter. This could, for example, be laser engraved in the anodized layer. Laser engraving in anodized aluminium results in a white permanent logo. The grip tape can also be cut in a particular shape to reveal a logo and/or name An example is visualized in the render below (Figure 5.3).

Figure 5.3 Engraved logo in the anodized aluminium

Notes from the author

I would like to end this thesis with a short reflection about my final project and experience as a student at the Delft University of Technology.

Industrial design has shaped and will significantly further influence the path of my life. Since the start of my studies in Delft there has never been a day that I regretted becoming a designer. When I first moved here I had little idea what I was getting myself into. I only knew I could turn a hobby called 'tinkering' into a full-time profession. From there on, design education has laid the foundation of how I see my role in this world and my contribution to it, as part researcher, part engineer, part artist, and part craftsman. In Delft I acquired the discipline and the methods to tackle complex problems but I also felt often limited by the kind of tasks I was given. The emphasis was always placed, by both teachers and student colleagues, on generating and justifying ideas, without considering other aspects of the process. I missed an interest to care about the details, which I only had the opportunity to explore in more independent works such as this graduation project. Discovering and executing techniques, and the detailed development of forms, materials and finishes, are for me essential parts of the work of an industrial designer and should not be purposely ignored or simplified. I often heard my colleagues pronouncing sentences like "show it in a render, there is no time to make that", which to me are the clear sign of a careless attitude. To make a genuinely great product all of the different facets of design have to be considered. And design education should create an environment where the exploration of these different facets are promoted and supported, not ignored.

In my career as a design student, I had the privilege to explore how design is taught in different schools around the world. With each place providing different views and values. I believe this, combined with the encouragement of my supervisors, helped me to develop my personal hands-on design method. I am thankful for this graduation project because it provided a great testing ground for this way of working.

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List of figures

Figure 3.4 Iteration II, A parallelogram configuration that translates a leaning motion into both a tilting and steering action

Figure 3.5 The final mockup of the second iteration

Figure 3.6 parallelogram tilting mechanism

Figure 3.7 outdoor tests

Figure 3.8 Nesting principle

Figure 3.9 Nesting movement iteration II

Figure 3.10 Iteration III, tilting mechanism detail

Figure 3.11 Ackermann steering principle detail

Figure 3.12 Iteration III nesting principle

Figure 3.13 Iteration III nesting principle

Figure 3.14 Iteration III nesting principle sketch exploration

Figure 4.1 Frame constructed out of aluminium extrusion

Figure 4.2 The frame construction exploration

Figure 4.3 Cardboard exploration of a tubular frame with covering panels

Figure 4.4 Aluminium extrusion cross-section

Figure 4.5 Displacement simulation

Figure 4.6 Foot-support extrusion shape exploration

Figure 4.7 Sheetmetal working

Figure 4.8 TIG-welding

Figure 4.9 Heat bending

Figure 4.10 The welded frame complete

Figure 4.11 Selection of materials, colors and textures

Figure 4.12 Anodized layer

Figure 4.13 Deanodizing process

Figure 4.14 Tilting mechanism tests

Figure 4.15 Front appearance exploration

Figure 4.16 Testing model of the angle tilting mechanism

Figure 4.17 CNC machined aluminium final prototype

Figure 4.18 Paralellogram pin details

Figure 4.19 Paralellogram pivot detail

Figure 4.20 Bellcrank Ackermann steering mechanism

Figure 4.21 Trail and caster

Figure 4.22 Steering and tilting mechanism in upright position

Figure 4.23 Steering and tilting mechanism in right steering corner

Figure 4.24 Plastic nesting guide strips

Figure 4.25 Puncture proof bicycle tires, retrieved september 10, from http://www.cyclingweekly.com

Figure 4.26 Cargo rack exploration

Figure 4.27 Cargo rack mounted

Figure 4.28 Cost Estimation

Figure 5.1 Engraved logo in the anodized aluminium

Figure 5.2 Elastomer spring blocks

Figure 5.3 Cam spring coil principle.

TU Delft | Integrated Product Design | September 2018