Enhancing Personal Micromobility

By

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Abstract

Micro-mobility is a solution for short-distance personal transportation that is less than 6km. The landscape of micro-mobility has evolved in recent years with many shared electric options appearing throughout cities around the world. The overarching goal of micro-mobility is to transport people as efficiently as possible from point A to point B, whilst reducing urban congestion, increasing sustainability and offering an enjoyable experience to the User. Shared electric scooters have been adopted in many cities, to the point, that they are now the most popular form of shared micro-mobility. Rideshare e-scooters might seem like a good solution; however, they have major issues. These scooters are currently very unsustainable due to their short lifetime, vandalism and charging infrastructures. The scooters do not accommodate User needs in regard to transportation and encompassing their lifestyles. This thesis will examine how might we enhance personal micromobility and create a solution that is effortless; safe; environmentally friendly and accommodates user's needs. A solution that delivers the function of micromobility when it is desired, but is unobtrusive to the User when not.

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First and foremost, I would like to express my gratitude to my Family, for the continued support and encouragement, especially during the unique circumstances of this year. I also would like to thank Bradley Staite and Moriah Gonidis for the many hours spent on video calls to make this experience more enjoyable. Additionally, I would like to thank our teaching assistant Reece Bennet, who provided amazing feedback, which greatly enhanced the concept.

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CHAPTER 1 – Problem Definition

1.1. Problem Definition

Micromobility is a form of transportation focused on short-distance transportation, typically up to 8 kilometers. According to a study by McKinsey Center for Future Mobility 60% of all car trips worldwide are less than 8 kilometers and could benefit from a micromobility solution (Heineke et al., 2019). Currently, Cities are changing rapidly through population growth and demographic shifts. It is estimated that by 2030 we will have 43 “megacities”, which means Cities with an excess of 10 million inhabitants (UN/DESA, 2018). This megatrend of urbanization accompanied by the increasing number of vehicles in urban areas has consequences on the mobility sector. Solutions are needed to reduce urban congestion, pollution and an individual’s carbon footprint. We need to transition into a future of predominantly utilizing shared mobility and public transportation to meet the demands of modern society. To facilitate a transition, we need solutions that increase the efficiency of and work in conjunction with them to offer instant, safe and sustainable mobility. This thesis will examine micro mobility solutions to enhance the future of mobility holistically. A solution that offers immediate mobility and combines short-distance travel with other transportation options. A solution that delivers the function of micromobility when it is desired but is not a nuisance to the user when not. This thesis will therefore analyze and consider Users of current mobility solutions; their stakeholders; and the environment of use. The problem of micromobility offers a great opportunity for in-depth study of ergonomics, user experience and product design to create a solution that enhances the human lifestyle whilst being socially and environmentally responsible.

1.2. Investigative Approach

The thesis topic being addressed is to enhance personal micromobility. The research plan aims to aid in creating a user-centric solution based on evidence produced by primary and secondary resources.

Research elements that will be considered and implemented include:

- Literature reviews
- Existing product benchmarking
- User observation
- Ergonomic Studies

Research sources that will be utilized predominantly focus on primary and secondary sources. Specifically, peer-reviewed articles (Humber Library, Google Scholar etc.); original documents (interviews, speeches etc.); and creative work like videos, will be utilized. The following key questions will be addressed:

How viable is micromobility?

What are current micromobility options?

Do these solutions meet User needs?

Where does Micromobility get used?

Can this product be integrated into cities?

What would enhance micromobility?

1.3. Background, History and Social Context

The International Transportation Forum has classified different levels of micromobility, this report will focus on type A micro vehicles. This category is defined as being powered or unpowered, with a top speed of 25km/h and weighing up to 35 kg (OECD/ITF, 2020). The definition for the word micromobility is implicit in the word itself. ‘Micro’ refers to small and ‘mobility’ to the freedom of movement. Micromobility can be human-powered or motorized and come in different forms such as bicycles; unicycle; electric scooter; monowheel; skateboards; rickshaws etc. Micromobility has been around for over 100 years and with the introduction of the bicycle, it first gained popularity. Whilst micromobility has been around for a long time, its purpose has adapted to the needs of different societies over the years. The UN-Habitat has estimated that around 1.5 million people move to cities each week (UN-Habitat: The Value of Sustainable Urbanization, 2020). This rapid global growth of urban spaces in modern society is affecting the mobility in urban spaces. Cars, which have been a primary mode of transportation for many, are not a viable solution for Cities. “Congestion is one of the most prevalent transport challenges in large urban agglomerations” (Rodrigue, 2020). Public Transportation is a viable alternative for urban transportation, it allows for a high energy efficiency per person. The problem with public transit is the spike of usage at certain times and the timing is not always convenient for the user. Shared Micromobility options such as electric scooters have shown a potential to work in synergy with other mobility options. A study in Portland Oregon showed that rideshare electric scooters were able to convert 46% people of people who would have used a car or public transportation for the trip (Hollingsworth et al., 2019). This showcases the ability for micromobility to enhance urban transportation and become a viable option. Shared electric scooters, whilst being adopted in many major cities, are not yet an instant, safe and efficient solution for Users. These scooters are not safe for users and pedestrians. “We identified 180 patients as having electric scooter-related injuries during our 130-day timeframe (Auckland City

Hospital, 2017)". Additionally, these scooters are not as sustainable as advertised, due to short lifecycles and infrastructure issues. According to a study on their holistic sustainability, they emit approximately 202g Co2/passenger mile (Hollingsworth et al., 2019). All of these solutions leave a desire for a product that is convenient, safe and provides mobility without burdening the user. This Thesis will examine, how might we create a mobility solution that is an addition to current mass transit, personal vehicles and shared mobility options. A solution-focused on being unobtrusive to the user and offering the freedom of mobility at any point.

2. Chapter - Research

This chapter outlines a variety of research that was conducted throughout the design process. It features research focused on both the User and products to develop a clearer understanding of the current solutions and user experiences.

2.1. User Research

The micromobility market is currently exhibiting promising growth in the demand market with urbanization and the problems it creates for Users (Daivanayagam, 2020). Cities often cannot facilitate more cars due to space scarcity. The trips that micromobility encompass, which are less than 8 km, currently account for 50 – 60% of all passenger miles travelled in China, the European Union, and the United States (Heineke et al., 2019). This potential market has the opportunity to be disrupted by micromobility. To better understand how to help this large and diverse target audience this report will focus on potential User profiles. An image search will be conducted to gather primary information on the user and what they look like. Additionally, a literature search will also be performed to better understand the user demographic and behavior.

User Demographics: Targeted demographic criteria for which general characteristics and information was sought included age, gender, ethnicity, income/purchasing power, and education and their transportation preferences. For more information on the research conducted, refer to Appendix I

Findings: Findings have been summarized below according to the relevant categories: Gender; Age; Race and Ethnicity; Income and Education.

Gender: An analysis of electric scooter riders in Portland Oregon with over 3,000 participants (n=3,366) showed the usage difference between male and female users. The Survey had participants of which 64% identified as male, 34% as female and 2% as transgender or non-binary. In Portland it showed that women did not use rideshare electric scooters as frequently as men. One finding was that 15% of men rode three times or more a week, compared to 7% of women.

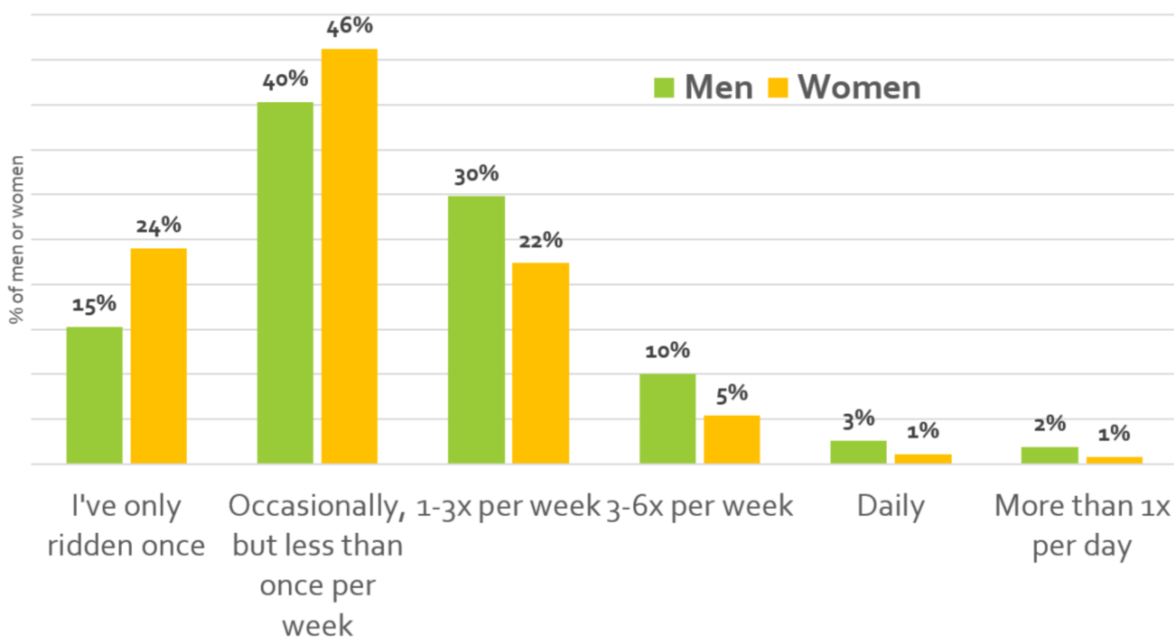


Figure 1: Rideshare Electric Scooter Users divided by gender and usage. [Image] (2019) Retrieved from https://jenniferdill.net/2019/02/01/the-e-scooter-gender-gap/

Age: This is hard to determine, since companies often keep this data for themselves. The Auckland City Council studied users age during a one-year trial period in the city. It showed that “Rental e-scooter use decreases with age – 48 per cent of those below 24 years old and under have tried a rental e-scooter versus only one per cent of those 65 years old and above" (Auckland City Council, 2019).

Race and Ethnicity: In terms of Ethnicity, users vary, depending on the country and its diversity. In the United States Lime revealed that "According to more than 1,600 participants who responded to the survey, 60% of San Diego Lime riders identify as Hispanic" (Lime, 2019).

Education: Education of Users varies but could be estimated through the statistics on users income and age.

Income: In terms of income Rideshare Electric Scooter users are predominantly low income with an income below $15,000. This shortly followed by users that earn up between $25000 to $50000.

Discussion / Conclusions

Based on the images and statistics of electric micro mobility users, it shows that users are mostly younger (>25 y/o), white and with a low to average income. These metrics could indicate that users are using these devices more for fun, than commuting. Additionally, the low income and age could indicate that the User demographic is still in education.

2.1.1. User Profile

Primary User **Young Professionals**

The primary user of this product are young professionals in urban areas. These men and women are predominantly exposed to Micromobility and the primary User of it.

Secondary User **Urban Inhabitants**

The secondary users are indirect users of micromobility, but direct stakeholders of the solution. People that live in the city and are in contact with the mobility solutions, without actually using them. They are 'obstacles' that need to be considered for safe usage.

Tertiary User **Governing Bodies**

The tertiary users or micromobility are governing bodies. These decide the legal requirements for micromobility, which can influence the use of them.

2.1.2 Current User Practice

Demographic Information

A literature search was conducted to discover micromobility user traits relating to user behavior. For this search Google and the Humber Library website were used to extract relevant information. The following search terms were used:

- *"Micro mobility acceptance"*
- *"Micro mobility usage"*
- *"Micro mobility statistics"*

Findings: Findings have been summarized below according to the relevant categories: Micro mobility Usage/Acceptance; Motivation and lifestyle; Income Level & Purchasing Power; Location; Personality and cognitive aspect

Usage/Acceptance: The adaptation of micro mobility is important to visualize trends. The survey results following indicate how many users chose an electric scooter over other forms of transportation. "In our survey of e-scooter riders, 7% of users reported that they would not have taken the trip otherwise, 49% would have biked or walked, 34% would have used a personal automobile or ride-share service, and 11% would have taken a public bus (table S7). These results are consistent with a survey conducted in Portland, Oregon, which shows 8% would not have taken the trip, 45% would have biked or walked, 36% would have used an automobile, and 10% would have used a bus or streetcar" (Hollingsworth et al., 2019).

Social: A survey in the Journal of Transportation Geography 86 had respondents write in a free text form, who is using these scooters and for what purpose. That survey revealed that "All sorts. Business people, tourists, high school kids & Uni students, drunk people getting home from the pub. Obviously people with disposable income. Young people as I think this is a more viable option then waiting for a bus for many. Middle aged professionals zipping quickly to meetings within a set area. Tourists - a good viable way to see a city. All kinds of people, but not the elderly. I've seen kids, teens, business people, couples, everyone. As e-scooter use matures as a practice, meanings may have evolving impacts on who chooses to use an e-scooter, and how they practice e- scootering" (Fitt & Curl, 2020). These findings show that Users are most often social and using these devices to and from social gatherings, work or just for pleasure.

Lifestyle & Motivation: Motivation for micro mobility is often the mobility. This is also shown by the user demographic often being younger and with low purchasing power. Figure 15, shows car ownership by age. It shows that younger users do not own a vehicles, but it can be assumed that their desire for mobility is there. Micromobility enable Users to have the function of mobility, without the burden of an expensive product.

Income Level: The income level of the target demographic is outlined in many surveys and reports as being on the lower end. This is also due to Users often being younger. "In free text comments, the most commonly mentioned groups of e-scooter users were young people (118 mentions) and commuters and business people (71 mentions). Students and tourists were also singled out as groups likely to be prevalent among e-scooter users" (Fitt & Curl, 2020).

Conclusions

The outcome of analyzing surveys and studies on User behaviors showed that users are predominantly young professionals and students. The lifestyle analysis shows a need for freedom of mobility.

User Profile Summary

User	Description
Primary	Young Male
Secondary	City inhabitants
Tertiary	City Councils

Primary User Profile

Demographics		User Behaviour		Personality		Cognitive Aspects	
Age	18- 25	Frequency of Use	3x a Week	Locus of Control	↓	Technical Skill	↑
Gender	Predominantly Male	Duration	Varies 1- 5 km Trips	Self-Efficacy	↑	Pre-Requisite Knowledge	↓
Ethnicity	Caucasian	Social	High-Social	Changeability	↑		
Income	Low to Middle Class	Level of Focus	High	Uncertainty Avoidance	↓		
Education	High School Diploma	Location	Urban				

User Persona

Name: Francis Davidson

Age: 24

Occupation: Entry Level Data Analyst

Income: $45,000/ year

Education: Bachelor of Commerce

Relationship Status: Single

Location: Hamburg, Germany

Career: Finance

Social: Drinking, Socializing, Exercising

Frequency of Activity: Socializing every weekend and exercising between 2 to 3 times a week.

Hobbies: Exercise, Work, Cooking, Socializing

Figure 2: Young Professional [Image] (2016) Retrieved from https://www.citizensone.com/student-loans/student-education-refinance-loan.aspx

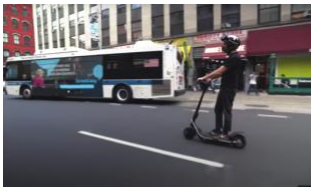
Profile: Francis is a 25-year-old young professional, who is currently working in Hamburg, Germany as an entry level business analyst. He is spending his time at the Library studying, exercising at the local gym and enjoys a social night on the weekend with friends on the weekend.

User Behaviour: Francis is a social person who often goes out and enjoys meeting up with friends. He also works a lot and is hoping to one day become successful in his field. This drives him to spend a lot of time in the library studying. He balances this with treating himself to go out for food with friends, going to the gym and enjoying an occasional party night.

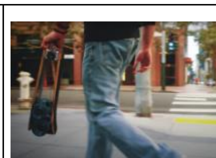
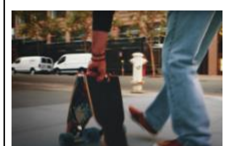
Frances Interaction with Micro Mobility: Frances currently utilizes public transportation to y get to events and social gatherings and the gym. He does not own a car, but due to his strenuous work he desires to not waste time and quickly get the place that he wants to go to. He uses micromobility in form of a bicycle, but cannot complete all trips with it, because of distance. Cycling and public transportation are currently his primary form of mobility.

2.1.2. User Observation – Activity / Workflow Mapping

User Observation 1: The activity of a user riding and interacting with the previously benchmarked Boosted Board Rev Electric Scooter

Riding the Board Riding the Board lets the user stand straight, with the arms extended. The foot position is not the most stable and the deck appears small.	
Folding For folding a latch is loosened at the stem of the steering rack. The User is bent forward with his legs nearly perpendicular to his body to achieve this.	
Folding continued. The top of the steering rack locks onto the deck of the Scooter. Again the user is still bent over, and needs both hands to achieve this.	
Accelerating & Braking The hand wheel allows the User to accelerate and decelerate easily by turning the knurled wheel with their thumb. The texture helps with grip and it is conveniently placed for easy access	
Riding – Point of View The and positions are shoulder width apart, which is a common position and easy on the users joints. A comment in the video was that it was hard to ride one handed.	
Carrying the Scooter When carrying the scooter the User does not look comfortable, with his harms angled and tensed. Additionally the overall size is very large.	

User Observation 2: The second User observation was conducted on BoardUp, a folding electric longboard. The BoardUp has a unique folding hinge in the center of the deck, which allows it to reduce its footprint significantly.

Carrying the board when not in Use The board has a Handle in the middle to make it easy to carry. The user can hold the board in the hand when he/she is not using it.	
Unfolding When unfolding the User drops the board closed to the ground, where it automatically opens up.	
Unfolding continued When the board is released the board folds flat	
Unfolding continued The User can jump on the board immediately after folding and use it like a normal longboard	
Folding For folding the foot is placed on the front of the board on a mechanism.	
Folding continued When the mechanism is engaged with the foot the board starts folding up behind the User.	
Folding continued The board jumps up and is folded together.	
Folding continued The user can now grab the handle and carry the device up. This is presented at a higher height for easy gripping.	

2.2. Product Research

This section will include a selection of the micromobility market and was chosen because of at least one of their qualities. Its inclusion in this report was judged by the micro-vehicles being classified as Type A micromobility (OECD/ITF, 2020), their uniqueness; size efficiency; weight; market adoption; positive reviews. It will highlight important aspects, in order to design a solution, based on the understanding of previous designs.

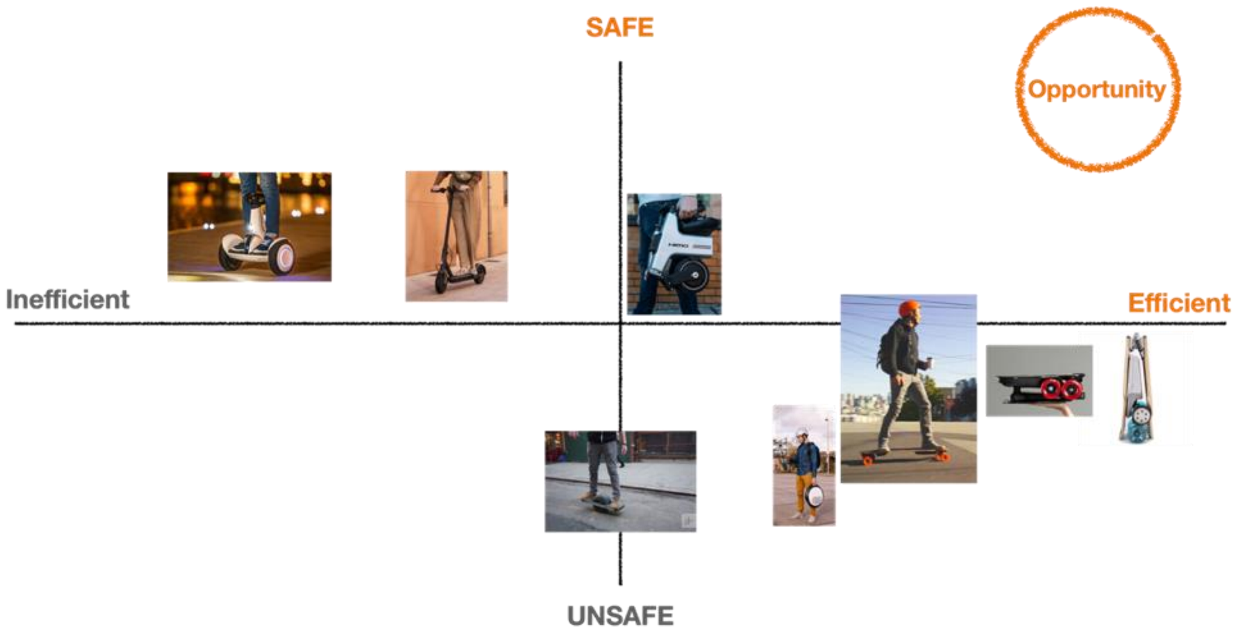


Figure 3: X/Y comparison of existing Micro vehicles (Efficient is measured by the devices size, weight and ability to transport) a possible design opportunity exists in the areas of safe & efficient micro mobility.

2.2.1. Benchmarking - Benefits and Features

Features and Benefits: To evaluate different micro vehicle options, the promotional material was used. The key features and benefits presented by the manufacture were then reviewed and analysed for word frequencies. This method is to identify key advertising features, it provides highlighted features of the benchmarked products.

Features	Key Benefits
Lightweight Materials	**Weight**
Freedom	**Speed**
Small Footprint	**Size**
Lighting	**Safety**
Large Battery	**Range**

This table highlights commonalities between different micromobility solutions, which shows that the advertising of the products is strongly targeted towards Weight, Size, Safety and Range. This is relevant, due to the user research conducted by the companies and their targeted marketing can be interpreted as a reflection of desired values from users.

2.2.2. Benchmarking – Functionality

The function of the benchmarked micro vehicles varies greatly from each over. Each of them provides a form of mobility, but the features change the target demographic of the product. The following list summarizes key findings related to the functionality of these products:

- *The more abilities a product has to fold, the smaller its footprint can become when transporting. A larger footprint often means a safer vehicle.*
- *The lighter the vehicle, the more portable.*
- *The products that are considered to be safer, have two or more points of direct contact with the micro vehicle.*
- *The User experience is increased, if the user has to fulfill less functions to move.*

The table below highlights some of the key benefits of each benchmarked product, to gain a better understanding of some key metrics of benchmarked micromobility solutions.

	Brompton M6L	Mi E-Scooter Pro	OneWheel Pint	Boosted Rev	Boosted Stealth	Segway Z10	NineBot S	BoardUp
								
Features & Benifits	•Pedal Assist •Compact Package •Upright riding position. •Detachable Battery	•3 Modes •Easy folding mechanism •Easy to Carry	•Easy to Carry •Tilt & Go Movement • Offroadable	•Boosted Throttle Wheel •Regenerative Braking. •Wide Tires •Composite Deck	•Easy to Carry •Tilt & Go Movement • Offroadable	•Easy to Carry •Small footprint •Tilt & Go Movement • Offroadable	•Portable •Lightweight	•Easy to Carry •Small footprint •Lightweight
Top Speed (kmh)	25	25	26	39	38.5	45	20	40
Range (km)	30 - 70	45	10 - 13	35	22.5	90	22	25
Tire Size (Inch)	16	8.5	10.5 x 6.5	9	3.3	18	10.5	3,27
Power (Watt)	300W	600W	750W	1500W	2100W	1800W	1600W	2x 350 W
Weight (KG)	18	14.2	11	20.9	7.7	24	12.7	7.6
Street Legal (Germany)	Yes	Yes(ish)	No	No	No	No	No	No
Dimensions Unfolded (cm)	64.5 x 58.5 x 27.0	113 x 49 x 43	68.6 x 26.7 x 22.2	111.7 x 61 x 51	96.5 x 28.8 x 14.5	53 x 45.7 x 17.8	59.5 x 54.8 x 26	42 x 22 x 12,7
Volume when Folded								
Length (cm)	65	113	69	112	97	45	60	43
Width (cm)	59	49	27	61	29	42	55	22
Height (cm)	27	43	22	51	15	18	26	13
Volume shown in Liters (dm^3)	**103,5**	**238,1**	**41,0**	**348,4**	**42,2**	**34,0**	**85,8**	**12,3**

Figure 4: Benchmarking Table

To accompany the benchmarking table, below is a visual size comparism**.** In type-A micromobility one important factor is portability when not in use. The Chart below compares the size of and user experience. The size is determined by the Length Height and Width measurements of the folded vehicle provided by each manufacturer. The dimensions were converted into litres of volume. The Figure x also shows the size difference during transport, as reference a medium sized backpack is usually around 30L – 35L.

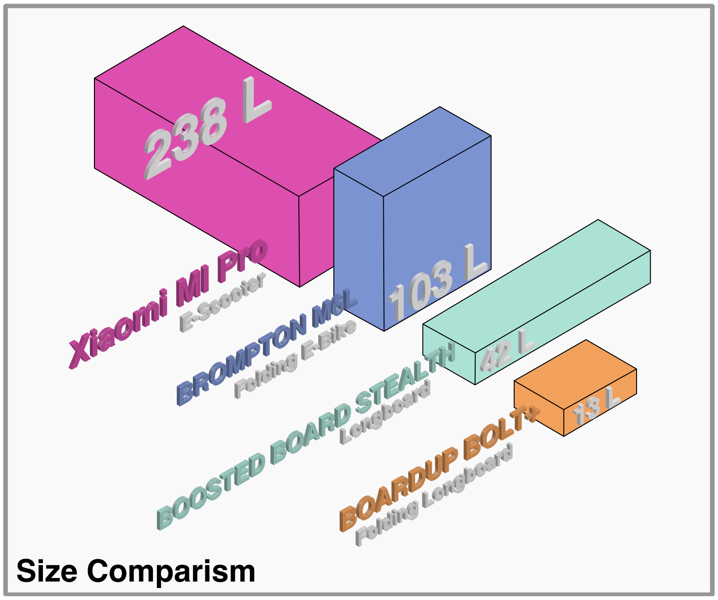


Figure 5: Size Comparism

2.2.3. Aesthetic and Semantic Profile

Aesthetics

Aesthetics in micromobility varies between devices, brands, markets and tasks they are designed to complete. Micromobility vehicles don't have a distinct aesthetic or feel, due to the multitude of variations of function and form. Since these devices are designed for a small footprint, the aesthetics follow the function. Nonetheless, the design language utilized are mostly focused on rugged, futuristic design through a sleek, portable design. Since these Micro vehicles are quite small, an important visual aspect of their aesthetics is the User. This has the effect, that the user is part of the silhouette of the device and influences the aesthetic design. Standing/sitting positions can change the overall aesthetics. Self-Balancing Board incorporate a more static standing position, making the User lean and appear hovering. Electric Longboards provide the user with a much more dynamic standing position, this makes the overall appearance more dynamic. Additionally, associations between longboarding and other board sports on water or snow can be drawn, which can subconsciously influence the aesthetic profile.

Semantics: The design semantics on existing solutions are driven by user contact points and safety considerations. Color is utilized to highlight features that are folding, or the user needs to interact with. Texture is used to highlight contact points, such as standing surfaces and the handle grip. These textures make the usage more natural, since they are already used in the built environment and are associated with creating grip and human interaction. Graphics are used to convey Messages to the user, without having to think about them. The boosted board Rev accelerator, for instance, used a knurled metal wheel. The graphics are simple to decipher with a plus indicating faster and minus slower. This affects the safety of the overall design, due to the user not having to focus on it Graphics since they are not in the peripheral vision when driving. The aim for of micromobility is to become an extension of the body, the user should feel natural, comfortable and safe. Products semantics utilized in benchmarked designs aid in providing a feeling of safety.

Figure 6: Boosted Rev Accelerator [Image] Retrieved from https://www.redbull.com/mx-es/boosted-rev-patinete-electrico

2.2.4. Benchmarking – Materials & Manufacturing

Since Micro mobility options are restricted in weight and by other classifications, it is crucial to consider material choice and manufacturing methods to optimize the functionality. Materials in micromobility solution vary dependent on the price point and mechanical properties required.

The analysis of current materials and manufacturing processes is used as a baseline to seek improvements for sustainability, weight saving, safety, usability and cost reduction.

Materials: The Micromobility solution needs to be portable, sturdy, sustainable and as affordable as possible. This means that materials need to be lightweight and strong. The main materials utilized in current micromobility solutions are Aluminum, Plastic, Composites, Wood, Steel Alloys. The choice of materials is not arbitrary, and materials appear to be chosen by strength and manufacturing capabilities rather than design.

Manufacturing: Micromobility solutions mainly designed with functionality in mind. The ability to provide mobility is the core feature. This has the effect that most current solutions are designed to last. It has however become evident, that especially shared micromobility solutions have become very wasteful. In Hollingworth's study on the lifecycle analysis of shared electric scooters, he estimates the impact of materials used on the overall sustainability of the vehicle. "Using the recycled content approach with 24% recycled content of aluminum, the aluminum frame and lithium-ion battery make up 53%–73% of impacts in manufacturing and materials across all impact categories" (Hollingsworth et al., 2019). These factors can be increased with constantly improving battery technology and the ability to exchange batteries at the end of their lifecycle. Additionally, ensuring the manufacturing method and manufacturer are compliant to regulations, can greatly increase the sustainability impact of a component. Manufacturing methods that are typically used, are Extrusion, Casting, Injection Molding and Metal Stamping.

2.2.5. Benchmarking Sustainability

Research was conducted to benchmark current health, safety and environmental realms to uncover possible material and manufacturing improvements in regard to sustainability. The Micromobility solution needs to be portable, sturdy, sustainable and as affordable as possible.

This means that materials need to be lightweight and strong. A major component of the micromobility solution is the main frame. The frame needs to withstand the weight of the user and its usage in rough urban terrain. This requires a lot of strength. Additionally, the proposed micro vehicle utilizes hinge. Bike frames have to withstand similar loads and need to be lightweight.

To analyze a possible materials bicycle frames can be used as a reference. A study by Duke University in partnership with Specialized Bicycle Components conducted a lifecycle analysis on existing bicycles. The figure below shows the lifecycle analysis between bike components and Levi's 501 blue jeans. The Roubaix Frame is made from a Carbon Fiber Composite. The Allez Frame is made from Aluminum. The table shows that the Aluminum frame consumes less freshwater and less solid waste, however it has a higher energy expenditure and with that a higher global warming potential (Johnson et al., 2014).

Table 1. Impacts of a pair of Levi's 501 © blue jeans and all parts analyzed (Levi Strauss, 2009).

Part	Freshwater Consumer (L)	Gross Caloric Value (kWh)	Global Warming Potential (kg CO_2-e)	Solid Waste (kg)
Levi's 501 © Blue Jeans	1,905	48.1	13.4	0.18
Roubaix Frame	2,300	467	67.2	1.01
Roubaix Fork	880	205	29.9	0.39
Allez Frame	1,670	2,380	255	0.058
Allez Fork	900	229	33.5	0.41

Figure 7: Aluminum Bike Frame vs Carbon Fiber Bike Frame [Image] Retrieved from https://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/8483/Duke_MP_Published.pd f

An advantage of using aluminum is that it can be recycled, with the main downside being high energy expenditure. Aluminum therefore can be used with conjunction of renewable energy to reduce its overall footprint, making it a valuable material for a micromobility solution. Another alternative to Aluminum is an Magnesium Alloy, which is highly efficient in Casting applications, and recyclable.

Other materials that are used are engineering plastics and composites. These materials, if created in the right composition, can be easy to recycle and made from renewable resources. Additionally, they have the benefit of being lightweight and moldable. The ability to use complex molds, can reduce the amounts of parts needed and increase the overall sustainability. Materials such as Hemp in conjunction with a recyclable resin can create composites that are strong, lightweight and affordable. As an engineering plastic, materials such as Covestro Maezio, which combines carbon with a thermoplastic. Their solution enables high moldability and a higher specific strength compared to aluminum and magnesium. It is also recyclable and reformable at the end of its lifecycle. (Maezio®: Lightweight Composites by Covestro | Covestro AG, n.d.)

2.3. Summary

The conducting of detailed research of the current industry standards and proposed target user revealed opportunities for improvement. The research outlined the ways the user group interacts with micromobility and areas where it might be lacking. The next chapter will focus on documenting and analyzing the exact needs of the user, and how they could be met.

Chapter 3 - Analysis

This chapter will analyze the primary user's needs, and how they could be met through an improved product solution. It will utilize findings from the previous chapters, research and benchmarking, to derive critical design decisions.

3.1. Needs Analysis

Current Micromobility solutions require the fulfillment of a variety of needs. The device needs focus on the users safety, portability, convenience and design language in order to compete with existing solutions. This thesis is focused on enhancing current solutions, to deliver the function when the user desires it, and is not a nuisance when not. It is therefore critical to analyze user needs to make the product as unobtrusive as possible.

3.1.1. Needs/Benefits Not Fulfilled by Current Products

The largest need is for a micro vehicle that is space efficient when not used is safe for users when not in use. Current solutions have either a too large footprint for transportation, are too heavy or not safe enough to be adoptable into the market. Each product has their own features and advantages, however the need for efficient and safe short distance micro mobility has not been met by current solutions. The table below outlines some of the needs that that are not or partially being fulfilled.

Needs and Benefits Table

Needs	**Benefits**
Efficiency	• *Fast mobility between places* • *Convenient Transportation*
Safety	• *Reducing risk of injuries* • *Making Cities safer* • *Increased awareness*
Comfort	• *Lightweight and enjoyable to transport when not in use*
Appearance	• *Increase visibility* • *User adoption*

Figure 8: Needs and Benefits Table

3.1.2. Latent Needs

Fundamental Human needs evaluated alongside the benefits of enhancing micromobility. This is done with reference to Maslow's Hierarchy of Needs chart.

Latent Needs Table

Benefit	**Fundamental Human Needs**	**Relationship with Benefit**
Efficiency	*Self-actualization, Esteem*	*Strong*
Safety	*Physiological, Safety, Esteem*	*Strong*
Comfort	*Safety*	*Moderate*
Appearance	*Esteem, Love/Belonging*	*Moderate*

Figure 9: Latent Needs Table

3.1.3. Categories of Needs

The design goal is to develop safe and efficient micro mobility with a focus on the user experience.

Wishes/Wants

- A product that integrates into the Users lifestyle
- A product that is unobtrusive when not in use

Immediate Needs

- Enhancing Safety
- Enhancing Portability
- Enhancing Sustainability
- Easy familiarization

Latent Needs

- Stylish Solution
- Easy to Repair

3.1.1. Needs Analysis Diagram

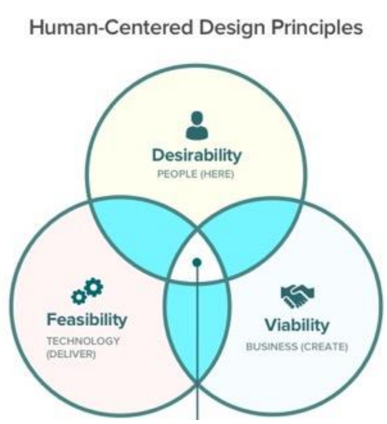


Figure 10: Human-Centered Design Principles

Desirability The customer desires the function of instant mobility without the burden of the product of micromobility. The desirability for the User is to minimize interaction with any devices and focus on the destination rather that the transportation there.

Feasibility A Micromobility solution that is space efficient and safe is partially proven to be feasible. There is the opportunity to expand into solutions that have not been explored

Viability A solution that offers safe and efficient short distance micromobility has the ability to provide mobility that is not fulfilled by current products. The solution has many future opportunities, in regard to shared economy, customization and as expansion in other mobility options.

3.2. Analysis Usability

This Section is focused on understanding a User's workflow and interaction with current micromobility devices. Due to the constraints on freedom of movement caused by the covid-19 pandemic, this research was conducted through videos.

Activity / Experience Graph

For the purpose of this report and the aim to reduce the overall footprint, when the device is not in use, the experience graph focuses on transporting and folding the device. The graph compares products highlighted in the Benchmarking Section. It shows the impact of usability base.

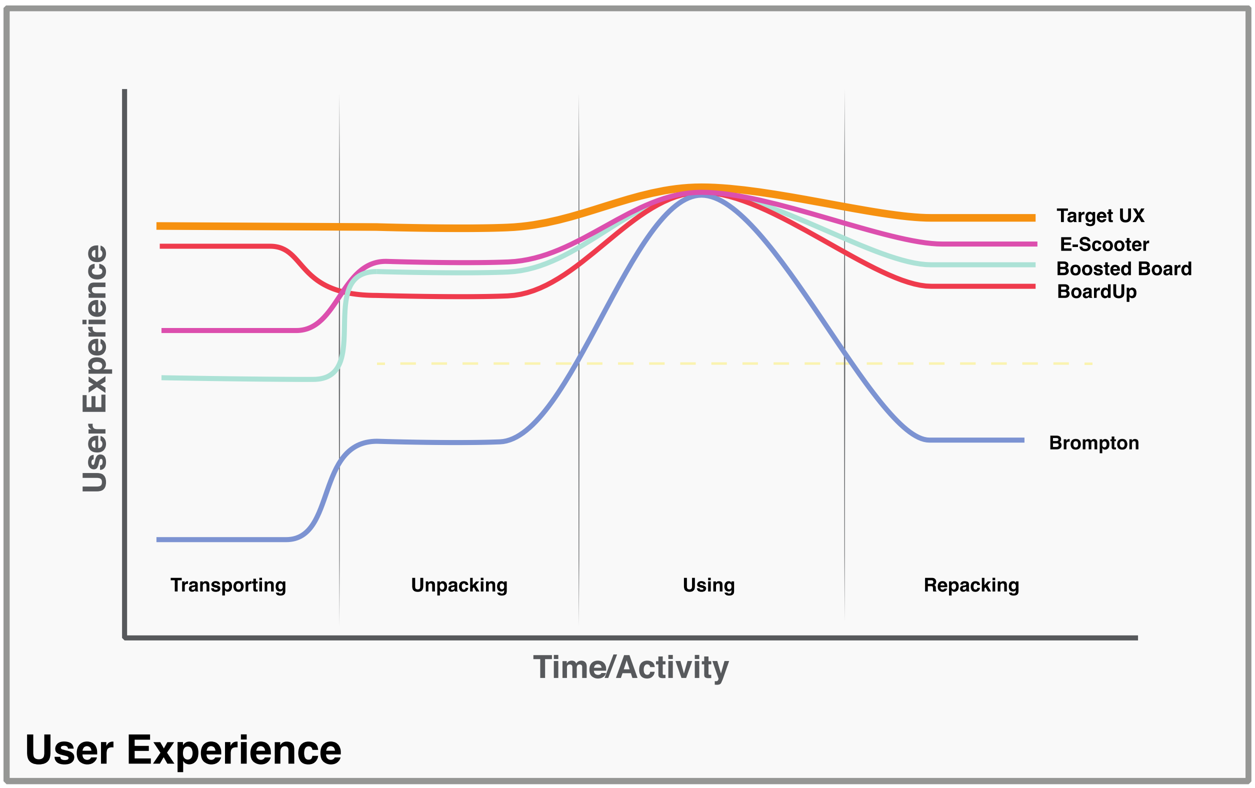


Figure 11: User Experience Graph

3.3. Human Factors

Introduction

Micromobility is focused on creating a solution for short commutes. This makes it essential that the devices works in synergy with the user and their movement. User take these devices into their living spaces; use it to commute and take it into public places. The aim is to reduce negative experiences associated with the ergonomics of current solutions. It is apparent that creating a solution that encompasses and aids a user’s workflow requires certain ergonomic requirements. These requirements are reviewed and analyzed to create a physical mockup.

Literature Review

In order to establish a baseline of accurate ergonomic dimensions the publication of Henry Dreyfuss named *The Measure of Man and Woman; Human Factors in Design* was referenced. This was used final overall evaluation and to extract key measurements. Additionally, online resources and academic papers were used to identify key measurements. The academic paper *Analysis of 1.2 million foot scans from North America, Europe and Asia* (Jurca et al., 2019) was used for accurate measurements on recent foot size data.

Methodology

The ergonomic and analysis of current micromobility solution was conducted with the following considerations:

Objectives

The aim of this process was to evaluate the full-bodied human interaction design and full-bodied ergonomic challenges of micromobility solutions. While full-bodied as a term may have several meanings, pertinent to the thesis criteria, this report evaluates only three major body part areas relevant to full-bodied human interaction design (Chong & Zacollo, 2021). This ergonomic evaluation report assesses the human factors, ergonomics and convenience of use and evaluates the three major body part areas.

Decisions to be made

The following interactions relevant to three specific major body part areas were investigated to minimize negative experience and maximize the positive experiences of:

1. Operating the Micromobility solution (Head Neck Shoulders)
2. Folding and Unfolding the device (Hands and Arms)
3. Mounting and Unmounting the Device (Legs)

Description of Users Targeted by Product

The target demographic are individuals who live in an urban environment to use for commuting between other mobility solutions. The target demographic is predominantly Male and aged between 20 – 30 years old. For the User observation two videos were analyzed. These were selected on the basis of fitting the target market; design brief and were part of benchmarking.

Evaluation process

The evaluation process consisted of designing a full scale 1:1 ergonomic buck of the proposed mobility solution which allowed for critical observation of the following:

1. Observe how users folding and unfold current Micromobility solutions
2. Observe stability when riding the vehicle
3. Identifying critical human dimensions affecting product use

Description of User Observation Environment Used in this Study

As stated previously, the User observation was completed by analyzing YouTube Video's of two products that fulfill functions set in the design brief. The first products is the Boosted Rev, which was tested by an experienced seasoned longboard rider in New York City. The video that was analyzed was created by Sam Sheffer, where the product was tested. The second video that was analyzed was the was a promotional video by Board Up, a folding longboard. An Observation of these two micromobility is attached in the Appendix.

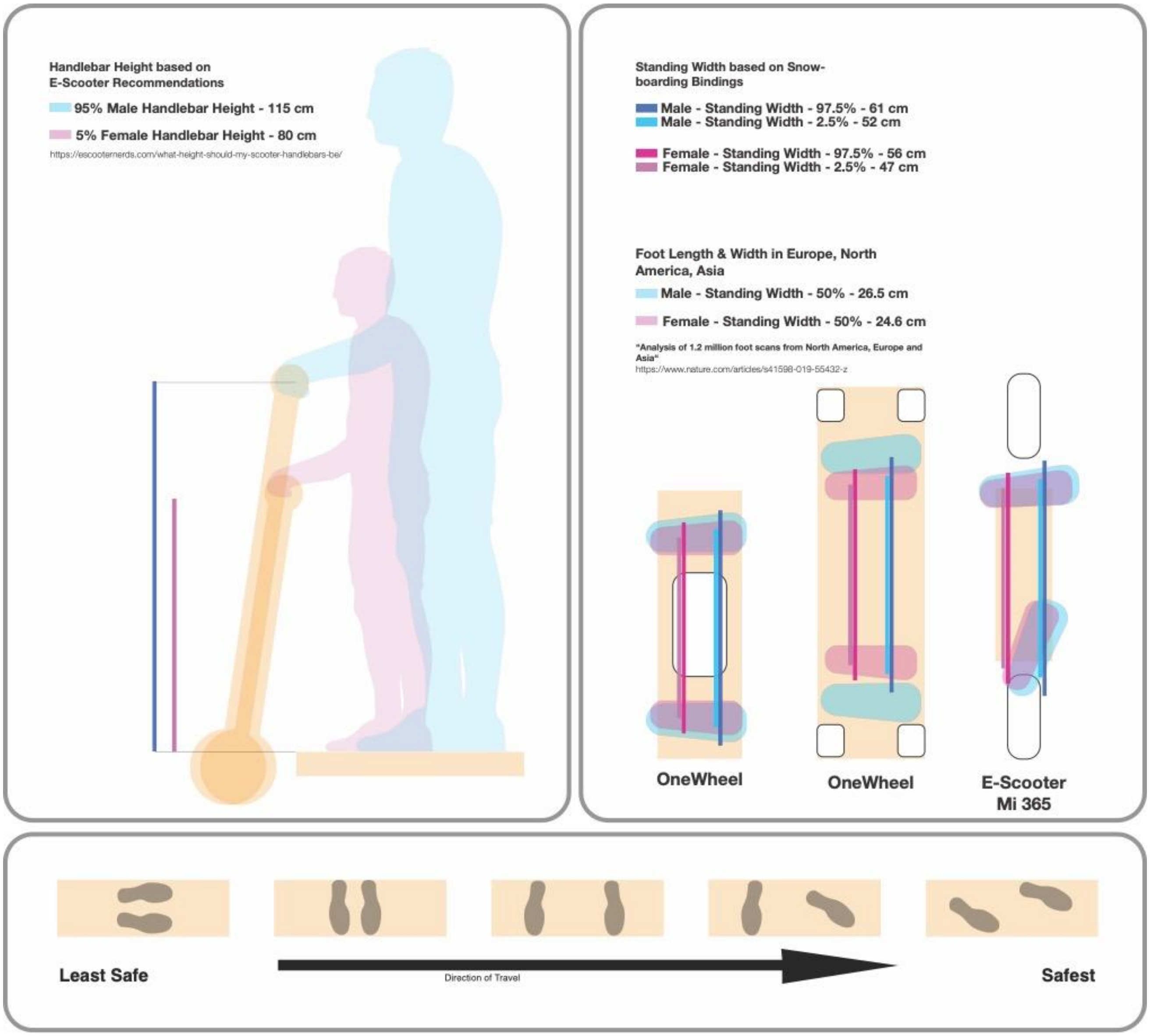
Location of observation:

Date of observation: Online, December 2020

Location of observation: Timmendorfer Strand, Germany

Results

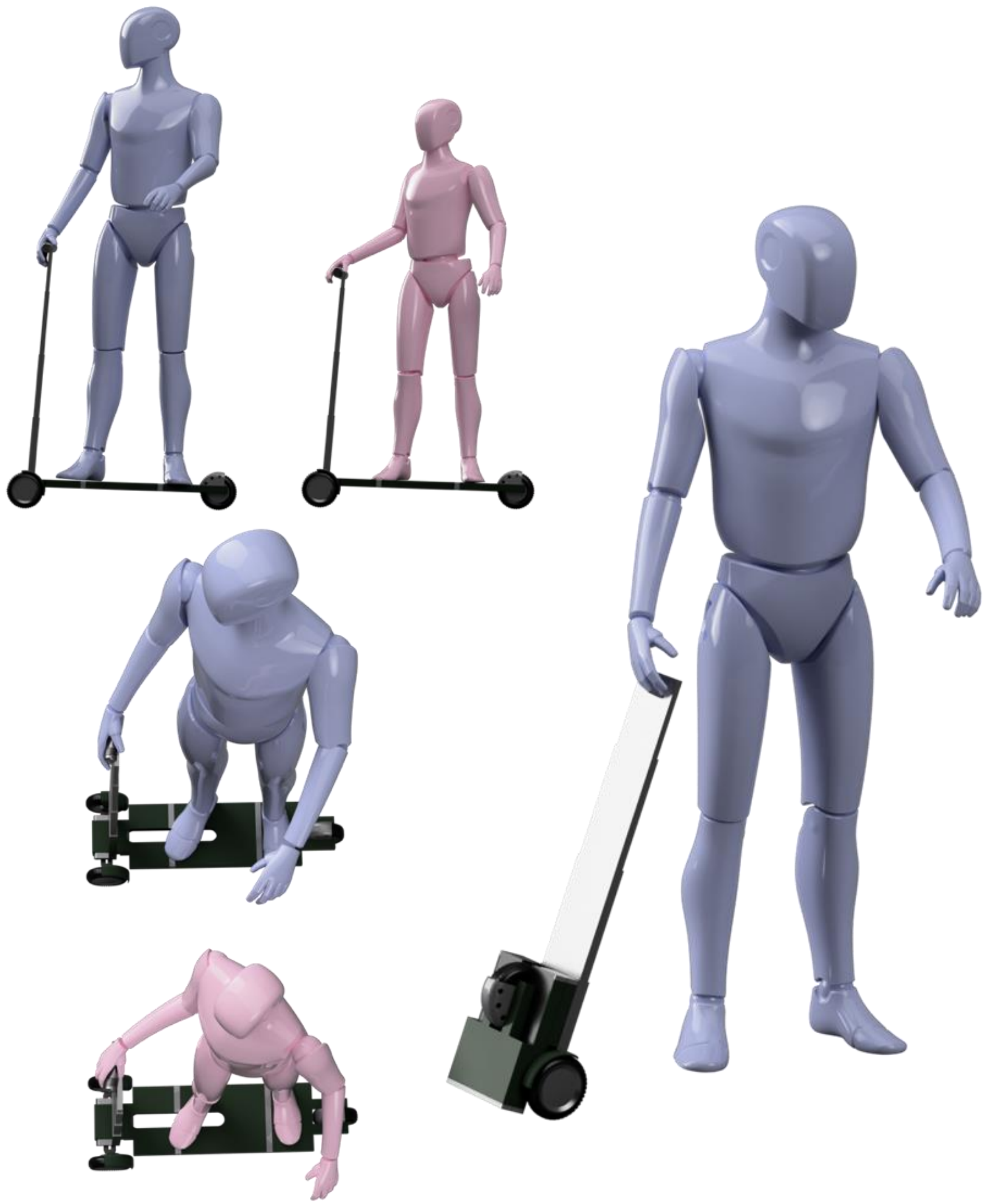
Figures below are visual interpretations of the data collected.



Computer Aided Design Iterations

The models below are scale models of the micromobility solution with 1:1 scale figures on them.

Blue indicates a 95th% -tile male and pink is 5th% -tile female.



1:1 Ergonomic Buck – Physical Model

The figures below show a 1:1 Ergonomic Buck. This is to emulate the dimensions and folding mechanism of the final design. As reference, according to Henry Dreyfuss, the figure is just about the 97.5th % - tile.

Analysis

The dimensions that were found in the literature review aid in creating overall design limitations and requirements. The findings from Henry Dreyfuss provide a holistic view of the measurement of Man and Women. To establish a comfortable and stable standing position design recommendations of Snowboard fittings was used. Snowboard fittings have a similar standing position, and with a hard deck connecting the users feet. The standing width recommendation of Snowboard fittings are that users feet are a little wider than shoulder width apart. According to online resources, the measurement is roughly 29% of a Males height and 27% of a Females height (Mechanics of Sports, 2007). This these dimensions coupled with Henry Dreyfuss show that a standing width of 2.5% -tile females is approximately 47 cm and 97.5% -tile male is 61 cm. To accommodate for most sizes the deck needs to accommodate for the 95% -tile male measurements which is approximately 60 cm.

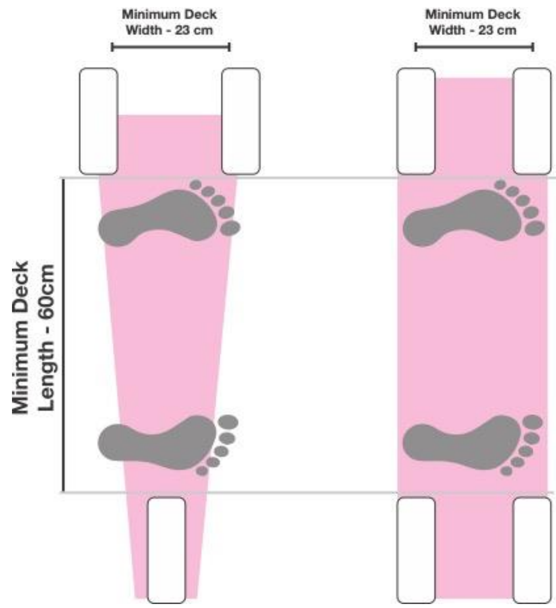


Figure 12: Illustration of the Deck Safety Considerations

The deck width of many micromobility options vary and often don't support the full foot of the Users. It is not necessary to accommodate for the full foot, but it aids in adding stability for the user. As the user observation showed, a thinner deck as used on the Boosted Rev Scooter, can have influence on the user using the device one handed. The width of skateboards and longboards is a good indicator of a stable width, since these are ridden without the use of a handlebar. According to *Analysis of 1.2 million foot scans from North America, Europe and Asia* (Jurca et al., 2019) the mean foot length of females are 24.6 cm and for males it is 26.5 cm. These measurements were used mainly as a reference and positioned on deck widths that could support the heel and ball of a foot. With stable standing positions with dimension was resolved at 23 cm. The deck could be wider, but since the journey length is short and the focus on transportability the width was decreased to a minimum comfortable size.

Since the solution would be used on public roads and in urban environments riding stability was crucial. For this the standing stability was important to provide a planted feeling to the user. This helps when having to check traffic behind and in general with a safer riding experience. The user has to be able to keep their feet on the deck at all times and feel stable. This creates a limitation to a minimum of three wheels to provide a tripod. Two wheels in the front and one in the back was chosen due to its stable shape. The width of the front wheels directly correlates with riding stability. This width is wider than the deck to allow the deck to be lower to the ground, creating a lower center of gravity. Additionally, it creates a wider stance for the tripod wheel setup which minimizes tipping risk.

To provide a stable and safe riding experience the wheel size is a crucial factor. The wheels are the only contact point with the ground, which means they are highly influenced by the ground surface. Urban environments are known to have sometimes have rough surfaces due to the high usage and curbs that are high. To provide a safe experience the wheel size needs to be able to handle urban terrains the wheels need to be able to deal with small curbs and minor road inconstancies. The wheel size also directly correlates with how small the folded vehicle can be packaged. Through observations, skateboards wheels seem dangerously small with ø 83 mm and Scooter wheels (ø22 cm) seem to take road inconsistency without many issues. Due to the size limitations set by the folding restrictions, a wheel diameter of 15 cm was chosen. This coupled with the three wheeled designs should offer a safe and stable riding position.

The proposed design does not require a handlebar for the user but can aid in rapid familiarity of the micro vehicle. “Handlebars may facilitate the rapid familiarization with the vehicle (a reason why all shared micro-vehicles have handlebars)"(OECD/ITF, 2020). The proposed micro vehicle has a folding handlebar, which is optional, but provides stability when the user is turning and checking their environment. To find an ideal height for the User, the dimensions of (Trajkovski, 2020) were used. The article by Trajkovski provides a list of measurements for electric scooter handle bar heights in relation to body height. This article reveals that for a 5^{th} % -tile female the handlebar height should be around 80 cm. For 95^{th} % -tile males the handlebar height should be around 110 cm.

Since the folding mechanism is highly influenced by dimensions set by an ergonomic evaluation, this can only be considered post ergonomic evaluation. The overarching aim is to reduce strain from bending over, as done with the BoardUp (Appendix I). This means to bring the hinges as close to the User as possible and reduce the need for bending over. Additionally, it is imporant to consider the user carrying the device and loading it into a transportable storage container. This is an ongoing process, that will only be resoved at the end of the design process.

3.4. Aesthetic & Semantic Profile

Aesthetics

The aesthetics of the proposed micromobility solution based on elegance and automotive styling. Since the mobility solution is unique and would be sold at a higher price point, it is important for the design to reflect the high-end nature of it. The aesthetics should incorporate sleek automotive styling cues. The elegance can be achieved through sweeping surfaces and hard lines, to create a contemporary design. The design should make the user feel comfortable, without it looking like a toy. Additionally, design cues should be subtle, but disruptive. Since the way the user interacts with the proposed micromobility solution is unique, the design should highlight the features that make it unique. The handle for instance, does not need to turn, but is only for stability when leaning. This allows for the addition of design to enhance the visual composition of the handlebar.

Semantics

The design semantics should make it easy for the User to understand the function. The proposed twist throttle should have a texture that reflects the nature of its function. The standing surface must have a grip surface on it, which is visible only through texture not material. This could mean a textured clear coat on top, which does not change the material details or design lines. The design features should reflect the folding nature of the device, symbolizing the user how to interact with it to fold and unfold the device. The product semantics should also allow for easy familiarization with the vehicle. Cues such as a the handle and textured standing surface can aid in easy familiarization based on the design language. The form of the overall design should reflect an elegance of movement and freedom. It should appear as if it was shaped by speed and movement, with design cues such as long sweeping lines.

Conclusion:

The design of the proposed mobility solution should reflect the price point and high end nature of this device. It should feel elegant and contemporary, through sleek sweeping surfaces and hard lines. This will help in creating a micromobility solution that is visually interesting.

Additionally, product semantics should be considered for certain surfaces to aid in easy familiarization with the device.

3.5. Sustainability – Safety Health and Environment

Sustainability Initiatives: The designed micromobility solution should additionally adhere to design principles outlined in Cradle to Cradle (Braungart, 2002). Braungart states that one of the six core principles for sustainable design is design for disassembly. This has the ability for materials to be recycled, reused and replaced at the end of their lifetime. The effect of this can be that individual components that break can be replaced, to increase longevity of the device. For the micromobility solution this means, materials should stay in as pure as possible. Plastics that are over molded or similar are near impossible to recycle, since they are two different materials that are chemically bonded. Additionally, for design for disassembly it is important to consider consumable parts and reducing the amount of effort to exchange them.

Health: Whilst health is an important consideration, it is not a major factor for micromobility solutions. The vehicles are only used for a short amount of time, which is limited by their range. Additionally, these vehicles are mostly either self-propelled or electric, which is not impacting local air pollution. The main impact to health is the aim to use nontoxic materials, where users contact the device and ensure good ergonomics when folding and riding the device. A study on the lifecycle of shared electric scooters states that “Given that the e-scooters are manufactured in China and much of the primary materials are not sourced from the United States, these environmental harms are consequently not borne by the end users’ community in our study (Hollingsworth et al., 2019)”. Whilst health impacts might not be felt by the end user, it is crucial to consider health of workers and the environment during the manufacturing process. “The aluminum frame is found to be the highest impact driver of respiratory effects, accounting for

46% of the PM2.5-eq from materials and manufacturing, and the battery pack is found to be the highest driver of acidification, accounting for 46% of SO2-eq" (Hollingsworth et al., 2019).

Safety: A primary function and need of the proposed micromobility solutions is to provide safe transportation. Since the micromobility vehicles can be utilized in a variety of environments it has to withstand a variety different environmental factor. In regard to safety, this is an important consideration. The User has direct contact to the vehicle, and it is important to ensure that in any conditions the vehicle is controllable. Outside factors can influence the Users clothing choices, which have a major impact on usability. Different footwork like flip flops, boots or dress shoes can greatly impact the grip strength on the board. Additionally, if the device is utilized in colder climates, Users might be inclined to wear gloves, which can decrease hand dexterity. The design of the vehicle requires the accommodation of these variants and material choices need to reflect the consideration of safety.

Summary: The proposed micro vehicle can greatly enhance sustainability for short distance mobility. Besides the focus on mobility the impact of the vehicle can be reduced by material, manufacturing and design choices. The micro-vehicle design has to be designed for disassembly to allow the replacing of parts when they have reached the end of their lifecycle. The micro-vehicle should include aluminum for strength, weight and sustainability benefits. The additionally needs to focus on materials that create a safe riding experience through grip and texture.

3.6. Feasibility & Viability

Materials and Manufacturing

Material and manufacturing considerations have a major impact on the commercial viability of the proposed micromobility solution. Current materials that are implemented are mainly Aluminum, Engineering plastics and composites. To design a market competitive product and effectively enter the market, similar materials will be utilized.

For Manufacturing, methods that are have a low cycle time or are cost efficient will primarily be considered. Additionally, methods that are able to be sustainably justified, will be prioritized. Manufacturing methods that are mainly considered are Injection Molding, Die Casting, Extrusion and Sheet metal bending.

Cost

The cost of micromobility solutions greatly varies as do features and the uniqueness. Some micromobility solutions retail for $500, such as electric scooters and some, such as a Onewheel sell for $2500. Each price bracket serves a different segment of the market. For the proposed solution, the price is going to be at the higher end, due to the complexity.

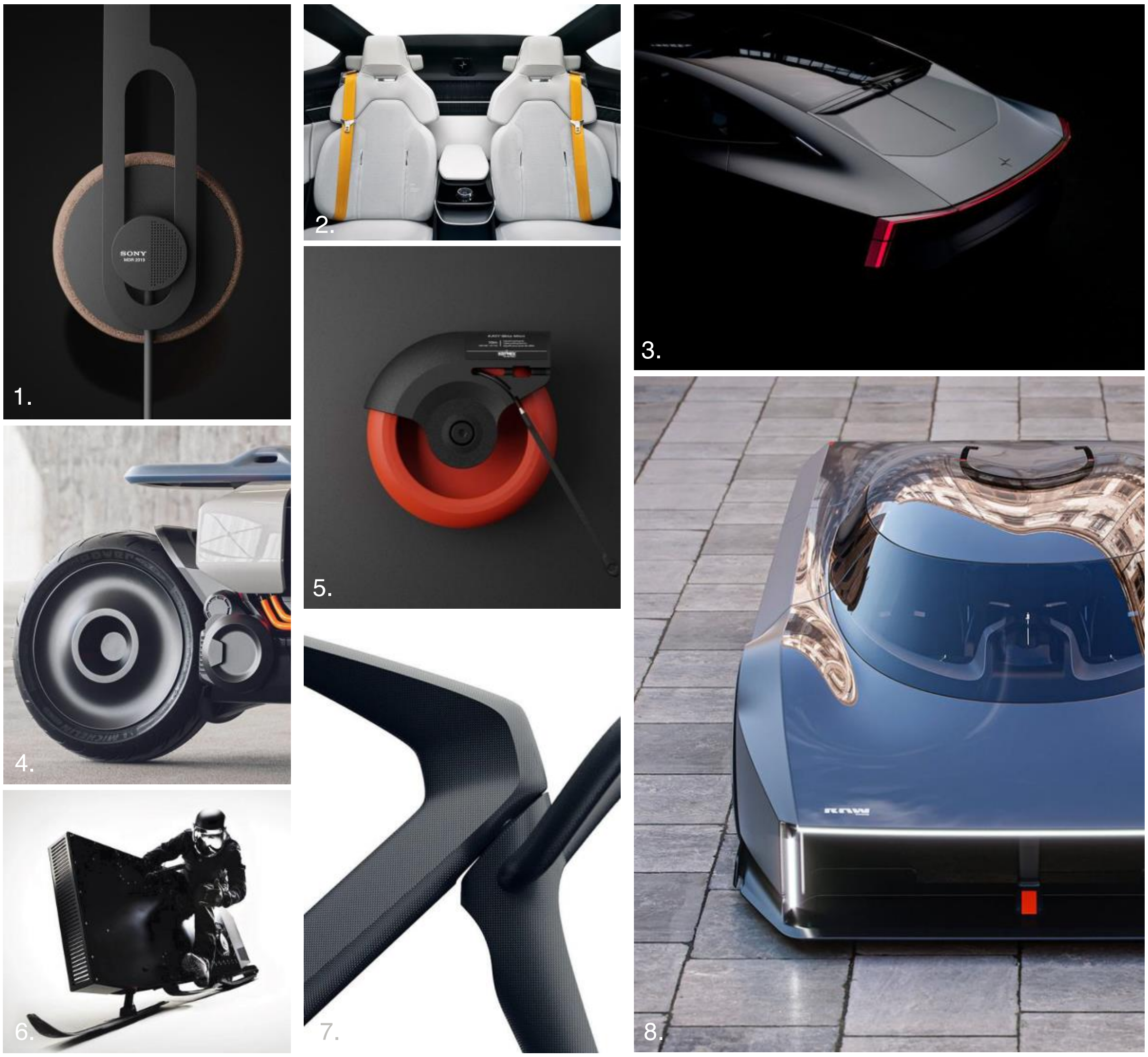
3.7. Design Brief

The aim of this thesis is to develop a micromobility solution that enhances Micromobility. The following list of ten objectives demonstrates the needs to be addressed by this design:

- **Reduce its Volume when not in Use and into a shape that easily fits into a Backpack.**
- **Weight less than 20kg**
- **Utilize a minimum of three wheels**
- **Must have a Handlebar**
- **Have a Wheel size of minimum 100mm**
- **Mitigate Safety issues of current solutions**
- **Increase Sustainability**
- **Integrated Visibility**
- **Designed for Disassembly**
- **Aesthetically Appealing**

Chapter 4 – Design Development

This chapter will focus on the design development process for the proposed micromobility solution. A variety of imagery, sketches, CAD models were utilized in order to accurately depict the steps taken throughout this design process.



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2. https://www.designboom.com/technology/polestar-precept-vegan-electric-concept-car-04-07-2020/
3. https://lemanoosh.com/publication/82211/
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5. https://www.noto.design/projects/kati-blitz-mini/
6. https://www.bikeexif.com/custom-bikes-week
7. https://www.searchsystem.co/image/152519314955
8. https://lemanoosh.com/publication/82371/

4.1. Idea Generation

4.2. Preliminary Concept Exploration

This chapter will focus on the design development of the proposed Micromobility solution, from early ideations, prototypes and to making of the final model. The early iterations of the design were driven by function, finding a solution within the set parameter. The entire design is based on the concept of reducing the footprint of the board, hence this is what the early iterations focus on.

Concept 01 – Inflatable Deck

Figure 13: Testing an Inflatable Dropstitch Mat

This early concept was based on research of Drop Stich Fabrics used in inflatable Stand Up Paddling boards (iSUP). “Dropstitch is a three-dimensional fabric; fibers connect an upper and lower layer, which leads to a flat shape when inflating the object (Klare et al., 2016)“. These boards are usually inflated to 15 psi and without the dropstitch weaving inside, would bulge and not hold its strength. The anatomy is slightly different depending on the manufacturing methods and optimization, but the strength of the top boards is similar. The boards strength is measured by measuring the deflection when a weight is applied to the center. The norm is to place the board on two posts 1.7m apart and load it with a weight of 75kg in the center on the board. It is then measured how much the boards shape changes. A conventional hardboard can bend around 5 mm and a similar sized iSUP can achieve around 8 mm (McConkey, 2020). Inflatable SUP boards offer a great reference for strength that can be achieved by utilizing air. The

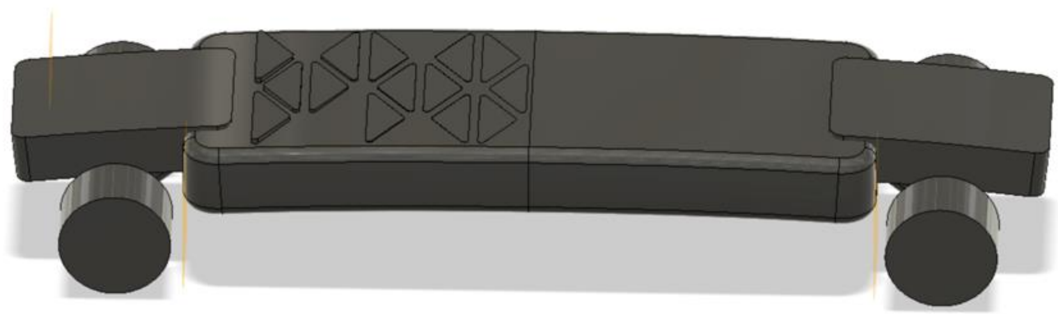


Figure 14: Inflatable Board Issues

when not in use. The disadvantages are that they have to be inflated by the user, with a pump. This can take 5-10 minutes to do since a board takes around 250L of air. The concept was to utilize the rear hub motors as the compressor. This and the folding of thick interweaved material was out of the scope of this thesis and further testing is required to create a working solution. Additionally, the thickness required to support a person would be around 10 cm, which is challenging to incorporate into an aesthetic design that matches the target demographic.

Advantages:	Lightweight Deck
	Compact when transporting it

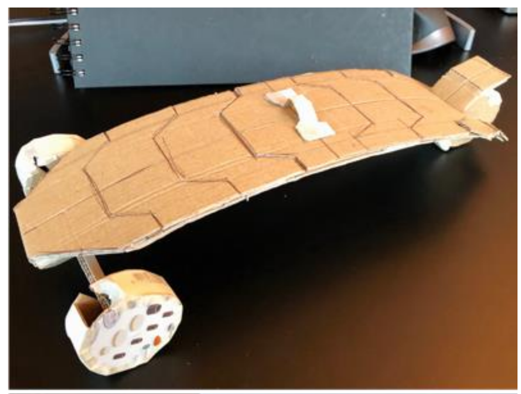
Disadvantages: Challenging to inflate

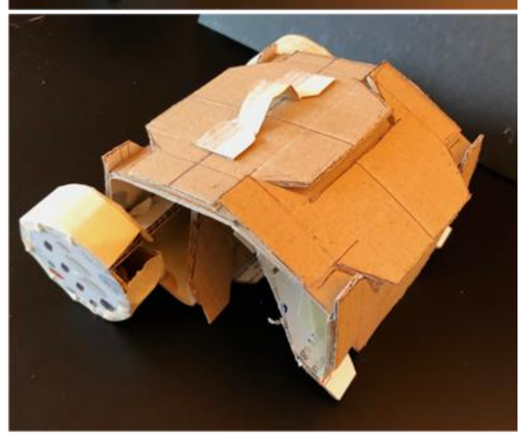
Folding when deflating

Longevity concerns

Concept #2 – Rolling Deck

The second concept, which was also known as the ‘Armadillo’, aimed to utilize hard panels which can roll up, like the armor of an Armadillo. This concept proved to have the most efficient utilization of space and seemed plausible, due to using techniques utilized in the bridge building to harness the strength of the Panels combined. The ‘Armadillo’ would be able to reduce its original footprint by 64%. It was constructed of seven individually hinged panels, which could roll up to be carried on the center handle. The preliminary concept achieved a overall footprint of 14,9 Liters of Volume with folded dimensions of 35 L x 25 H x 17 W cm. This concept however had a limited wheel size and no handle. This meant it did not meet the set design brief, and when modifying it to fit the brief, it was not able to perform as desired.





Advantages: Thin Deck

Lightweight

Compact

Disadvantages: No Handle

Small Wheels

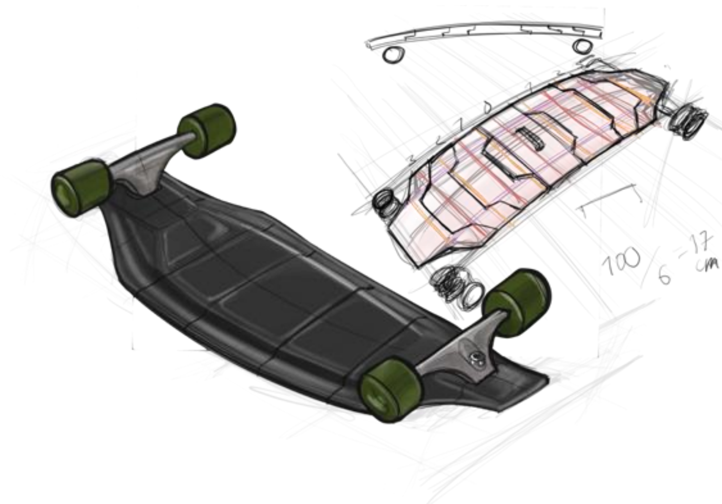
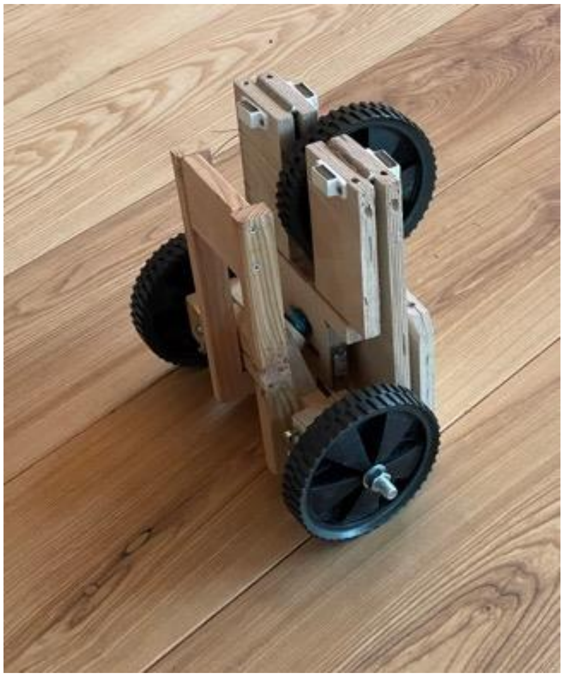


Figure 15: CAD Model of Concept 2.

Concept #3 – The Vagaboard Concept.

The third concept was based on the previous armadillo concept but aimed to reduce the complexity. The theory of this concept was to splits the overall length of the board into three sections. These three sections, then would then fold onto themselves. Quick Sketches and preliminary CAD iterations proved that this was a plausible solution. Upon further inspection and a 1:1 Scale mockup of the mechanism to test usability, this concept was the one to move forward with. The concept works by as shown in figure X, when its folded the steering handle wraps around the front of the board and locks underneath the steering axis. To unfold as the User places the board on the floor, wraps the handle around the steering handle to extend the front third of the deck. Once that is unfolded, the rear section can be unfolded. This is done by lifting the deck, which releases the rear hinges to untuck rear wheel from under the deck. To accomplish the compact form factor, the there are many restrictions on the design. The must have a cut out in the center, to house the rear wheel when folded. Additionally, the deck has to be completely flat. Because the rear wheel folds underneath, it can have a wheel cover, but the front section cannot be elevated. This is because the front section folds on top of the deck. The steering rack also needs to have a pivot point below the steering axis, to be able to wrap around it.

Figure 16: *Folding of the proposed Micromobility Concept*



Advantages: Small footprint

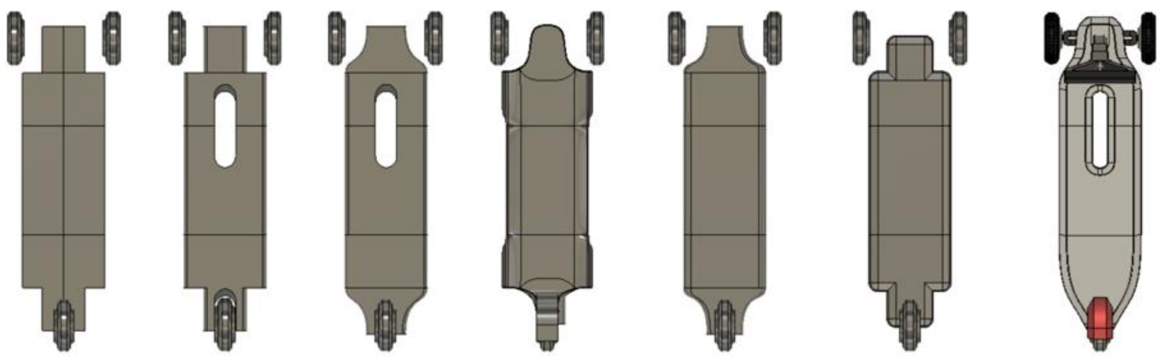
Optimized to fit user needs.

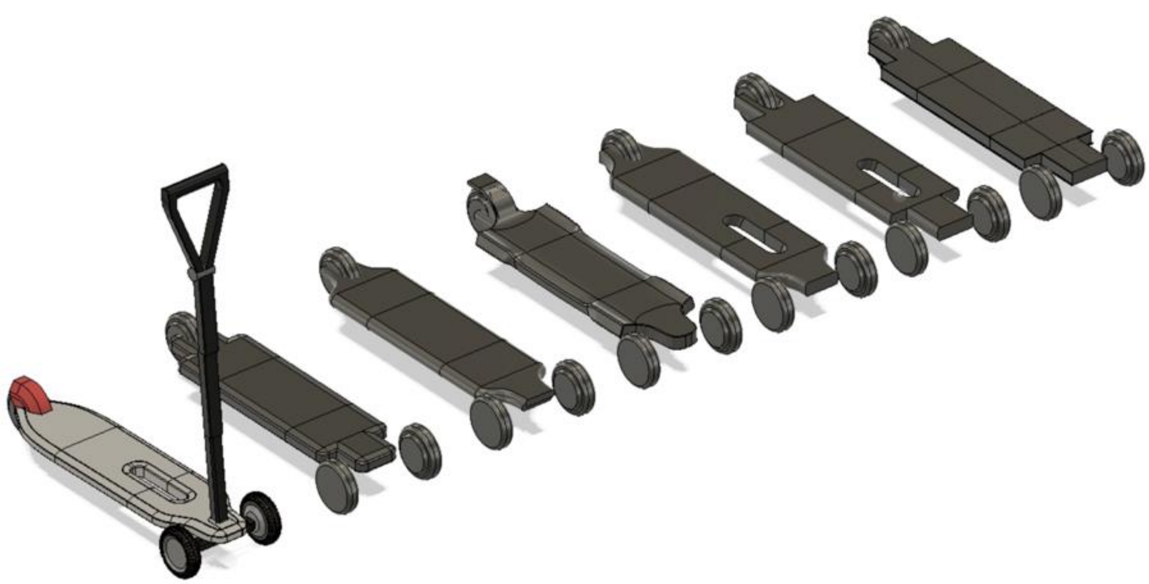
User experience

Disadvantages: Deck segments need to hold a lot of weight

4.3. Concept Strategy

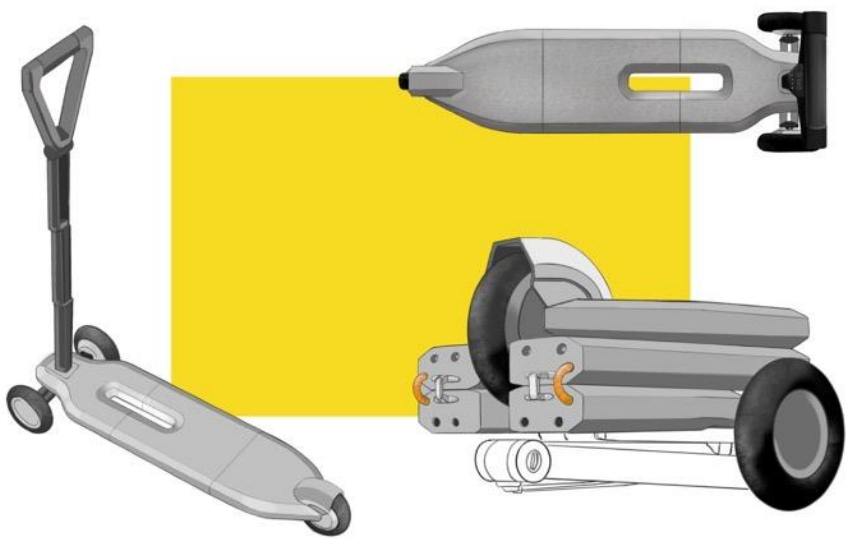
Each of the preliminary concepts was tested by quick mockup models, which helped in quickly discarding ones that did not function or meet the brief. The third concept was the one that was chosen, due to the ability to meet the design brief requirements. The development was mostly done through quick CAD Mockups. CAD was the chosen medium, due to the accuracy, which is required to meet the restrictions and a visual language.

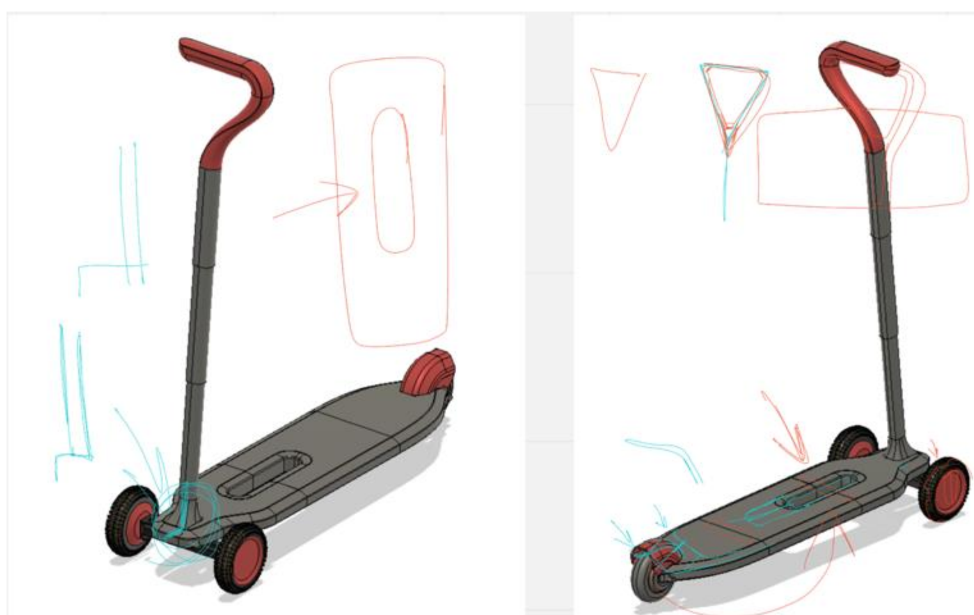




4.4. Concept Refinement

Once the mechanism was established and the design brief restrictions were met, the aesthetic profile was refined through sketch models, quick sketches and CAD models. The main part of the refinement was done using CAD, due to the high accuracy and tolerances needed to make the board fold. Below are some refinement sketches on CAD models to achieve the desired visual elegance and automotive styling.

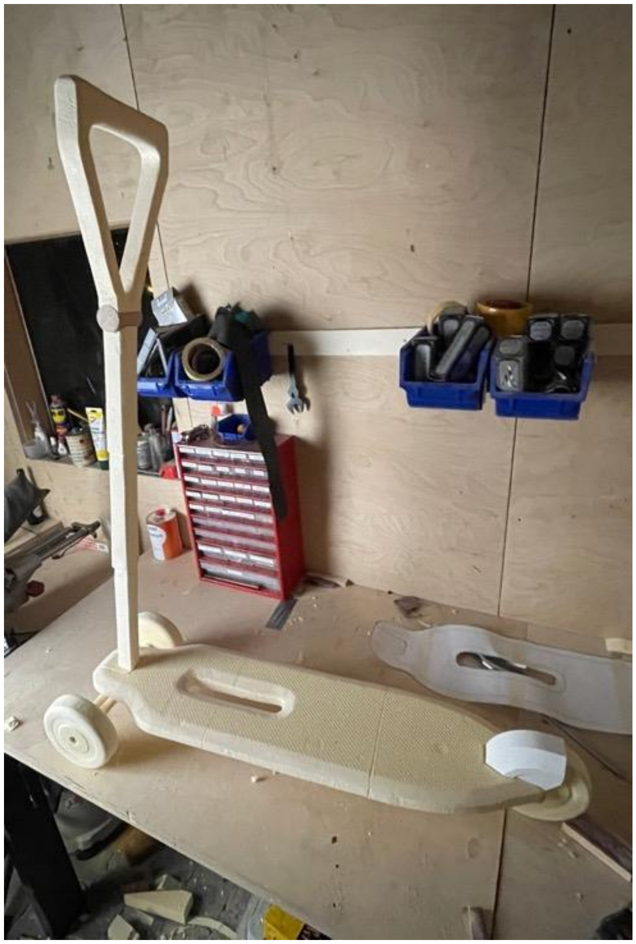




4.5. Design Realization

4.5.1. Physical Model Study

The proposed micromobility solution relied heavily on physical model studies, in order to meet ergonomic demands and to make the functionality work. This section is going to focus on the first 1:1 Study to evaluate ergonomics and visual appearance.

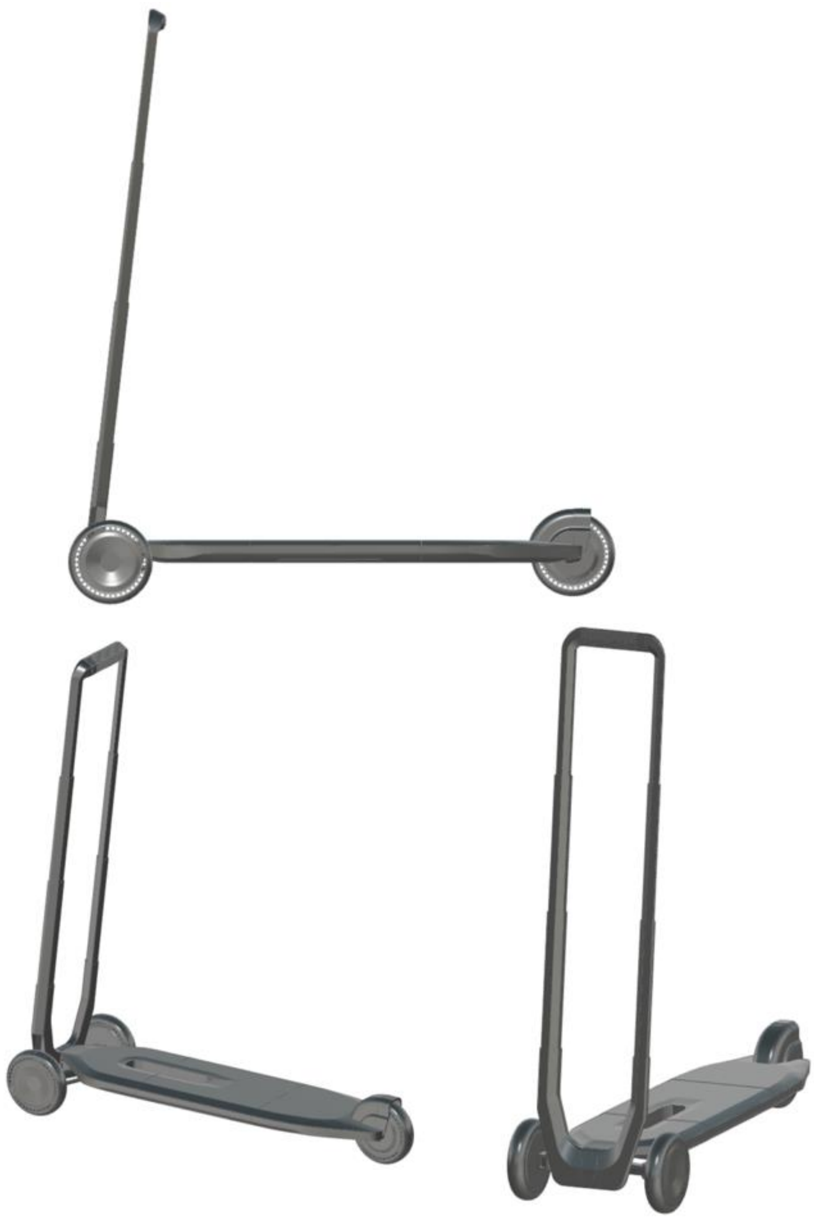


4.5.2. Product Schematic

The figure below are an accurate depiction of an 95th percentile male and a 5th percentile female.

4.6. Design Resolution

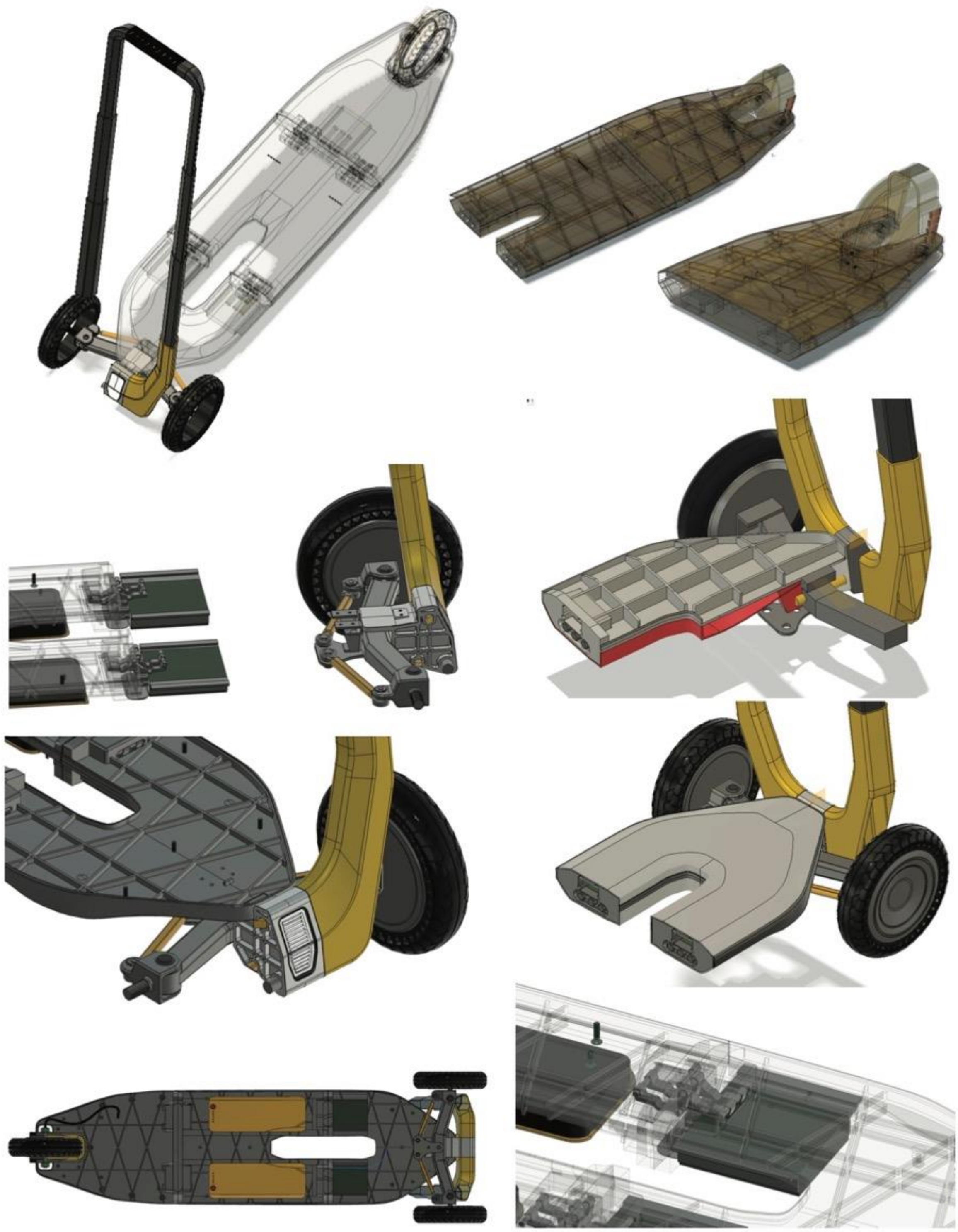
The final design was produced through a vigorous process of CAD optimization and quick ideation sketches. This section reflects the final form as a solidified design, which incorporates ergonomic elements and ergonomic considerations focused on the user needs. In the next section the design will be further developed to reflect internal components and manufacturing details.



4.7. CAD Development

CAD is utilized to develop the design of the proposed Micromobility solution. The majority of the visual design work was completed by surfacing the model in Fusion360. The utilization of surface modelling allowed for complex multi concave surfaces. The following CAD process includes vital steps of construction the deck and handlebar.

CAD Detailing: CAD Modelling was also utilized to add details such as ribs; fastening features; mechanical folding components; Steering Components etc. Since the device was designed for disassembly this was necessary for the later Rendering and Animation stages.

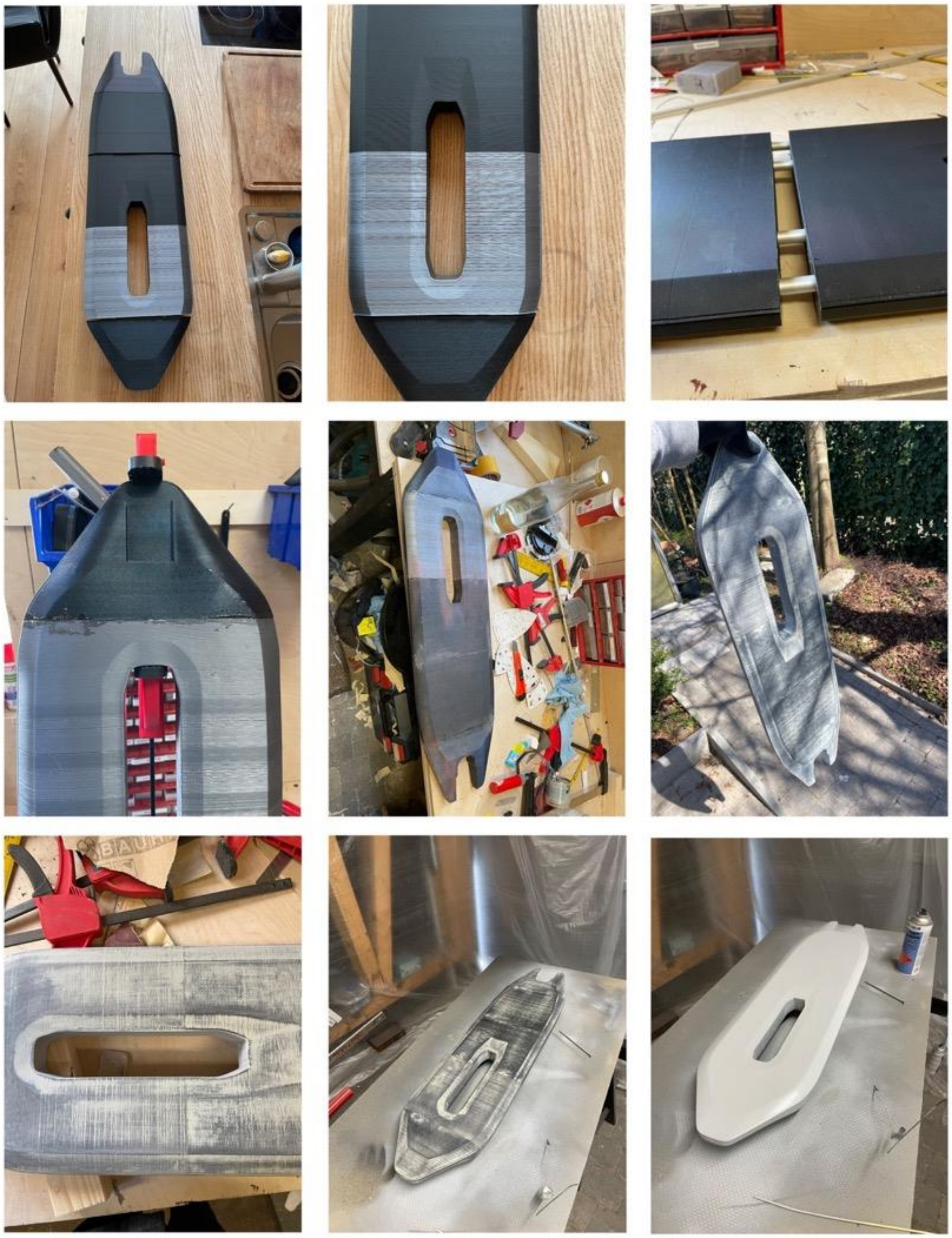


4.8. Physical Model

Pictured below is the process of creating a 1:1 Scale Physical Model of the Vagaboard Concept. The process is divided into different stages Printing; Preparation; Painting and Assembly.

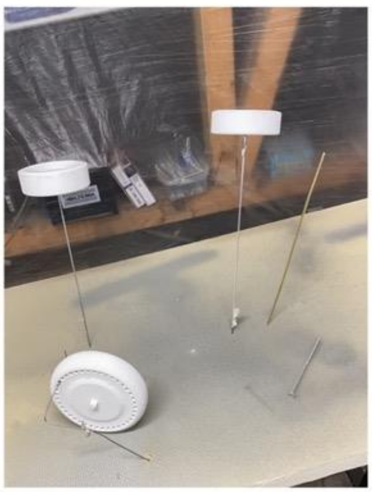
3D Printing: The entirety of this model was 3D printed on one desktop 3D Printer. This process took over 200 Hours to complete. The majority was completed using a 0.4mm Nozzle, with exception to the Standing Deck which was printed with a 0.6mm Nozzle.

Preparation: The deck was printed in five segments, each in different materials due to Filament shortages. The sections are mounted on four 10mm aluminum rods with epoxy. To prepare the deck for painting, it was filled, sanded and repeated till all of the gaps were filled.



Painting: All the parts were painted and primed. The wheels were coated with PlastiDip to provide a rubber finish.






Assembly and Finishing: The side of the Deck Frame was painted to mimic the metal midframe of the Vagaboard.

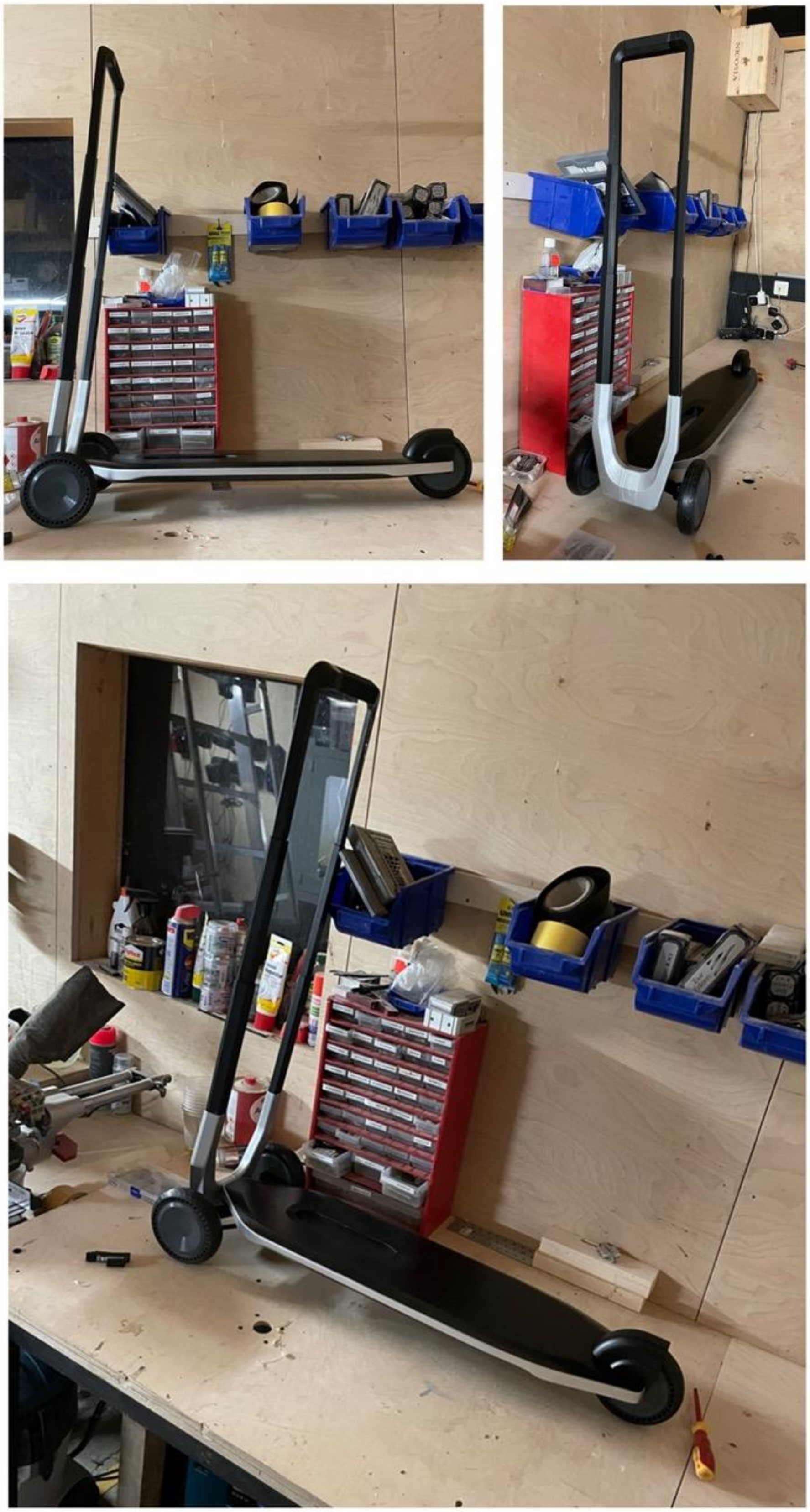








Assembly: The components were screwed and glued together to finish the process.



5 - Final Design

This chapter will synthesize data and summarize the final design. This chapter is a curation of design details; physical product design; manufacturing; ergonomics; sustainability and final renders, CAD and Physical Model Photography.

5.1. Summary

Description: Vagaboard is a unique and innovative folding urban mobility solution. It is designed to provide the User the function of micromobility when desired and be unobtrusive when not. Its folding mechanism allows the design to be packaged into 27 Liters of Volume, which allows it to fit into a medium sized backpack.

Explanation: Current micromobility solutions raise concerns in regard to safety, sustainability and convenience as discussed in previous chapters. Most micro mobility solution on the market can only decrease their size when folded marginally. This makes them inconvenient to transport and challenging to store. The impact of this is that Users don't always bring them along for the journey, which could increase vehicle usage and the negative effects associated. Aside from being inconvenient, existing solutions are unsafe for the user, especially in regard to smaller wheels and their physical position on the device. They require the user to have both hands on the Steering column, which makes it challenging for them to check their surroundings for potential hazards while driving. Since most existing solutions are two wheeled, they also are prone to tipping without user action. This can cause accidents at low speeds and when starting and stopping from a stand still. While sustainability is an inherent aim of most micromobility solutions, the materials and design of the devices often don't reflect this.

The Vagaboard is designed to offer the User freedom of mobility, when they desire it. It is able to reduce its footprint by over 90% of its original liter volume, as shown by Figure 17. The folding sequence is activated through a button in the handlebar, which collapses the rear hinge and tucks it underneath the middeck, with the wheel showing through the slot cutout of the middle of the board. The telescoping handlebar is then

Figure 17: 90% Volume Reduction

pushed down by the user, and in the upward motion the front hinge releases and folds on top of the middeck. Lastly, the handle is rotated onto the folded deck sections and can be carried with it. When folded the handle can also be extended, to allow the device to be pulled as a trolley.

The board has three 15 cm large wheels, which allow it to navigate rough urban environments. The three wheels provide a stable platform that allows the User to stay on the deck, even when stopped. The Vagaboard uses a tilting steering mechanism, this is to provides a natural feeling of movement similar to surfing on the street. The handle moves provide an extra contact point, for stability and is also the accelerator and brake. To accelerate the user twists the handle towards himself and the opposite for braking.

Benefit Statement

The Vagaboard is a micromobility solution that increase the efficiency of and works in conjunction with other mobility forms to offer instant, safe and sustainable mobility. The Vagaboard aims to enhance the future of mobility holistically. It is a solution that offers immediate mobility and combines short distance travel with other transportation options. A solution that delivers the function of micromobility when it is desired, but is not a nuisance to the user when not.

5.2. Design Criteria Met

The following section pertains the various elements that were successfully implemented in the Vagaboard concept.

5.2.1. Full Bodied Interaction Design

The Vagaboard accommodates user ergonomics through adjustability. The handlebar is height adjustable and can be set to a desired height, for different percentiles. The handlebar is configurable for left and right -handed users, this changes the position of the screen, which should be located close to the users' thumb. The folding mechanism was determined on the bases of ergonomics. The mechanism ensures that the user can maintain a straight back when lowering themselves to fold the board. Additionally, the Vagaboard can be used as a trolley, which reduces physical stress when transporting. Full bodied human interaction was also considered in the overall position of the user. The user stands parallel to the road, which allows their legs to be utilized as suspension and weight shifting for steering. The user has both feet planted on the board, and the handle provides a third contact point for increased safety and intuitive familiarity with the device.

5.2.2. Materials, Processes and Technology

The Vagaboard is deck is made from three main components the top deck, midframe and bottom surface. The top deck and bottom deck are made from an continuous fiber composite that is injection molded. The continuous fibers provide strength whilst, the internal molded details provide the necessary fastening features and structure. An additional benefit the composites are that they are lightweight and can be made sustainably. The midframe is made from Cast Magnesium Alloy, which allows the deck to be lightweight, whilst providing the strength required to hold the three deck section under load. The midframe is first Die Cast which allows for a high part complexity, and the magnesium alloy allows for thinner wall thicknesses than with aluminum casting. Post Die Casting, the connection surfaces are machined an details for the hinges and connection pistons are created. Other parts such as the steering rack bracket is created from bent sheet metal, to create a cost efficient and strong mounting bracket. The board is designed for disassembly, which means any internal or external components are replaceable or upgradeable. All of the hardware for disassembly is located underneath the board. The top and bottom deck can be unscrewed out of the midframe and easily repaired or replaced.

Figure 18: Exploded View Vagaboard

The Handlebar is mainly constructed from extruded aluminum which is anodized to reduce the environmental impacts of painting. The bottom part of the handle, which holds the steering rack, is die casted magnesium and machined to add necessary details.

The main ‘technology’ in for board apart from the electronics are the locking mechanisms. These are piston actuators have lock themselves into the connected deck and are locked. The mechanism is inspired by automatic CNC tool changes, which have high strength and precision requirements. The technologies integrated and mechanical elements are designed to enhance the user experience and be invisible to the user. This is done in order to enhance micromobility by providing users the function.

5.2.3. Implementation – Feasibility & Viability

Whilst the concept is manufacturable and feasible, it still requires a lot of development to launch to market. Its uniqueness in manufacturing and design makes it challenging to estimate costs of components. Since this product needs to be reasonably affordable, economies of scale are crucial for the market success. The Bill of Materials (BOM) required to build the Vagaboard. In future stages, the BOM would be populated accurately to depict exact prices, but to highlight estimates it is divided into three price brackets. The main high-cost items are The Die Cast Magnesium Alloy components, due to material cost and post machining costs. The Battery pack and Motor are also higher cost items, but pricing is highly dependent on economies of scale. The top and bottom deck are rather low cost in manufacturing but sourcing sustainable engineering composites is at the higher end.

Bill Of Materials (BOM)

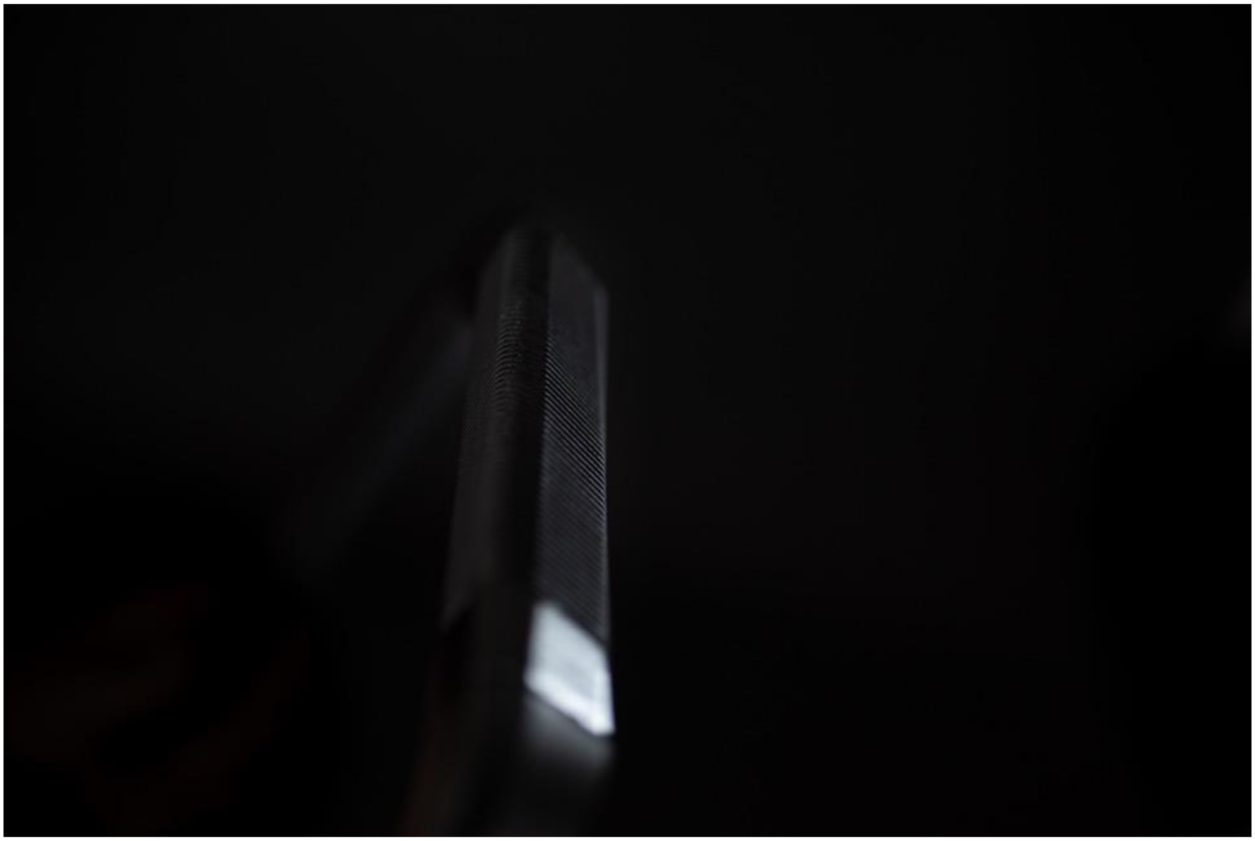
Quantity	Part	Price Point

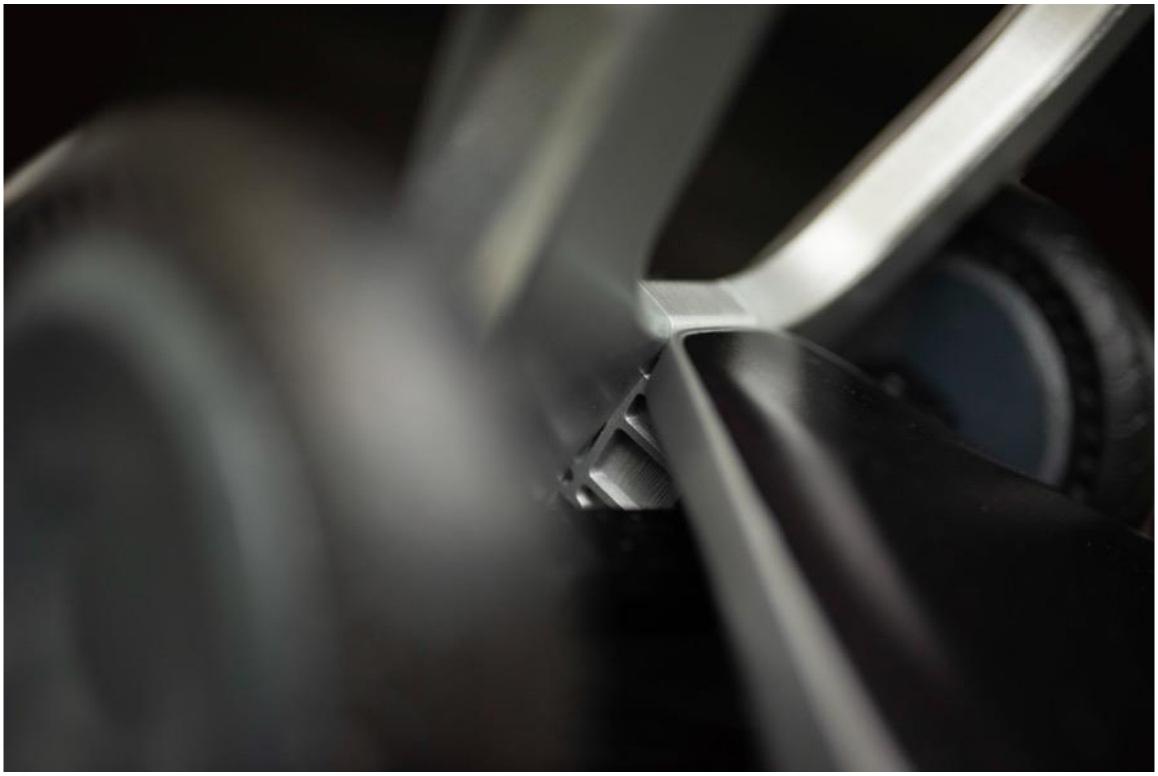
External Componets		
3x	Midframe - Cast Magnesium	
1x	Bottom Handle - Cast Magnesium	
6x	Top & Bottom Deck	
1x	Injection Molded Rear Wheel Cover	
1x	Aluminum Extruded Telescoping Handle	
Internal Components		
3x	Deck Locking Piston Assemblies	
4x	Concealed Hinges	
2x	Wheels with Electronic Drum Brakes	
2x	Tie Rods Steering Arm	
1x	Die Cast Steering Arm	
x	Fastening Features	
1x	Bent Sheet Metal Holder	
Electronics		
1x	350w Hub Motor	
2x	100WH Battery Pack	
1x	Speed Cotnroller	
1x	Twist Handle Accelerator	
1x	Electrionic LCD Screen	
1x	Headlight	
2x	Rear Light	

Color Key for Component Cost	
Higher Cost	
Medium Cost	
Low Cost	

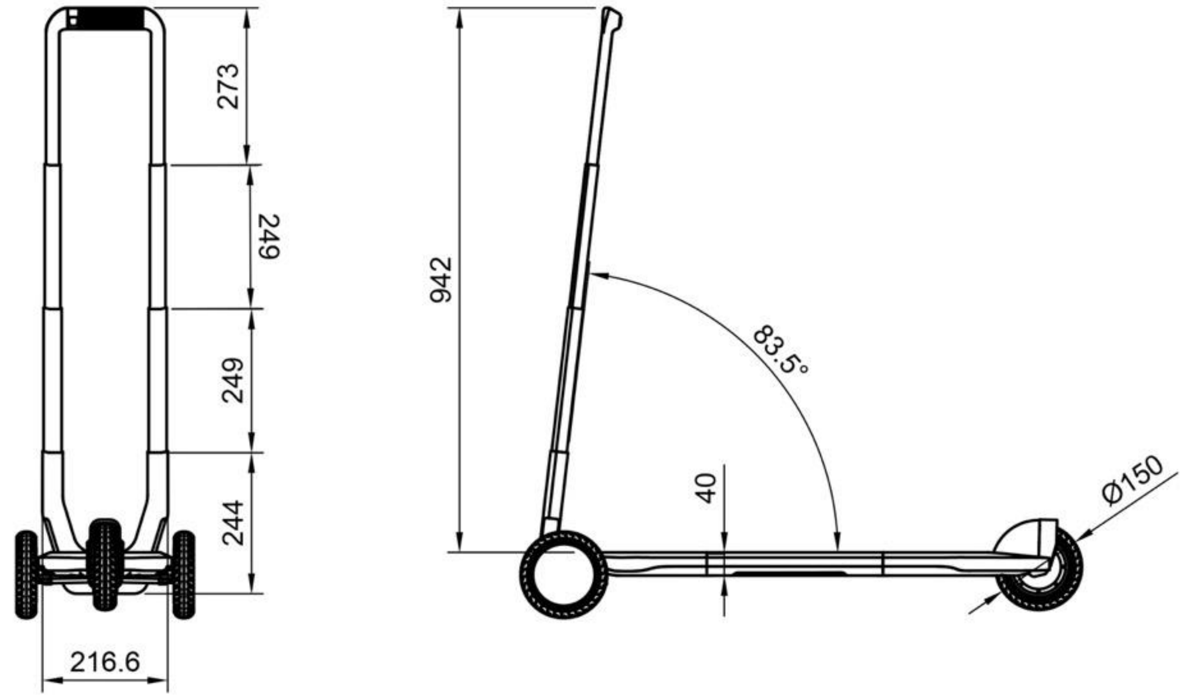
5.3. Final CAD Renderings

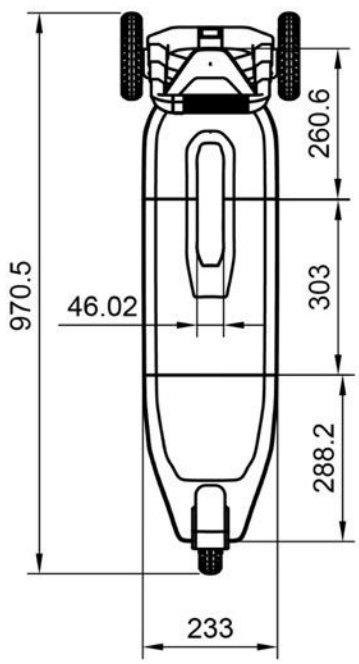
5.4. Physical Model





5.5. Technical Drawings





Technical Drawing outlining key dimensions
All Dimensions are in mm

5.6. Sustainability

The enhanced sustainability of the Vagaboard is primarily achieved through the function it provides, in reducing urban vehicle usage. It is also achieved through material and manufacturing choices. The Vagaboard is designed with Cradle to Cradle design principles to be part of the circular economy. Every part on the board can be disassembled and replaced or upgraded. This increases longevity, which is a major factor for sustainability. Additionally, material choices such as magnesium alloy and engineered continuous fiber composites can be sourced from renewable resources or have a high recycling rating. The environmental impact is considered throughout the design of the Vagaboard to ensure it adheres to Cradle to Cradle principles.

Chapter 6 – Conclusion

Vagaboard is an innovative solution that can reduce urban congestion, pollution and an individual's carbon footprint. The design assists in migrating to a future of predominantly utilizing shared mobility and public transportation in order to meet the demands of urban society. Vagaboard is a solution that increase the efficiency of and works in conjunction with public and shared mobility. A solution that offers immediate mobility and bridges the gap between short distance travel with traditional forms of mobility. Vagaboard that delivers the function of micromobility when it is desired but is not a nuisance to the user when not.


Notbremse

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Appendix

IDSN 4002
SENIOR LEVEL THESIS ONE

Humber ITAL / Faculty of Applied Sciences & Applied Technology
Bachelor of Industrial Design / FALL 2020
Catherine Chong / Sandro Zaccolo

FTA-4 THESIS TOPIC APPROVAL

This project/assignment constitutes 5% of total mark for the course

Start: Week #4 / Sep-28
Due: **Week #5 / Oct-05**

THESIS TOPIC APPROVAL:

Student Name:	Henry Boy
Topic Title:	How Might We Enhance Personal Micro-Mobility in Hamburg, Germany?

Abstract

Hamburg has one of the highest amounts of personal car ownership and short distance car trips in Germany. Hamburg's infrastructure is not equipped for such a high number of vehicles, which leads to difficulty parking; high amounts of traffic and air/noise pollution. This can negatively impact User's mental health and physical health and the environment in and around Hamburg.

According to the federal ministry for traffic and digital infrastructure, in Hamburg the car usage for trips less than 9,5km is approximately 60% of all vehicle trips in Hamburg. Personal vehicles offer Users major benefits in regard to freedom movement and independence. Nonetheless, with a continuously growing population, global warming and an unprepared infrastructure, Users and Stakeholders need a better solution for short distance personal transportation.

This report will examine how might we enhance personal micro mobility in Hamburg, Germany. It will therefore analyse and consider Users of current mobility solutions, its stakeholders; and the environment of use. The problem of micro mobility offers a great opportunity for in-depth study of ergonomics, human interaction design, user experience design to create a solution that enhances the human lifestyle whilst being socially and environmentally responsible.

Student Signature(s):	Henry Boy
Date:	05 / 10 / 2020

Instructor Signature(s):	Catherine Chong Sandro Zaccolo
Date:	28 / 10 / 2020

Chong, Kappen, Thomson, Zaccolo

PANEL ON
RESEARCH ETHICS

Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Henry Boy

has completed the Tri-Council Policy Statement:
Ethical Conduct for Research Involving Humans
Course on Research Ethics (TCPS 2: CORE)

Date of Issue: **13 July, 2020**

IDSN 4502
SENIOR LEVEL THESIS TWO

Humber ITAL / Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / WINTER 2021
Catherine Chong / Sandro Zaccolo

CRITICAL MILESTONES: APPROVAL FOR CAD DEVELOPMENT & MODEL FABRICATION

Student Name:	Henry Boy
Topic / Thesis Title:	Enhancing Micromobility

THESIS DESIGN APPROVAL FORM

Thesis design is approved to proceed for the following: [X] **CAD Design and Development Phase**

Comment: CAD progress well as of week #7/March 1st, detailing of handle to be refined.

Thesis design is approved to proceed for the following: [X] **Model Fabrication Including Rapid Prototyping and Model Building Phase**

Comment: Design development progress well as of week #7/March 1st, once CAD is completed, can move forward to model fabrication from week #8 onward.

Instructor Signature(s):

CatherineChong SandroZaccolo

Date:	10th March 2021