



UNIVERSAL WIRELESS CHARGING SOLUTION FOR SHARED ELECTRIC MOPEDS

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Colophon

Design of a universal charging solution for shared electric mopeds

Thesis

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Preface

With the completion of this thesis, I have completed six years of study at the Industrial Design Engineering faculty at the Delft University of Technology. During that time, I participated in many unique projects and gained a priceless set of design skills that, hopefully, will help me have a successful career in the field of design. I became interested in design during my time in Delft because it combines creativity and technical know-how to produce a product that is not only aesthetically appealing but also practical and functional. It allows me to use my creativity to solve real-world problems, which I also aimed to perform during this project. Let me start by stating that I could not have completed this project without the many people who have directly and indirectly contributed:

To my chair and mentor, Erik Thomassen and Ruud van Heur, I would like to express my gratitude for your valuable advice and assistance throughout this project. Their assistance went beyond simple supervision since they constantly inspired and motivated me with their positive attitude. They led engaging conversations that improved my ability to prioritize and extend my perspective. They helped a great deal, and without them, I would not have been able to finish this project.

Thanks also to Teun Verwijmeren, who guided me as a company mentor through this project. You motivated and stimulated me with your

knowledge about everything related to industrial design engineering and the subject of mobility. Your ideas and input contributed a lot to the outcome of the project. Moreover, thank you to the whole TILER team for offering me the possibility to shape my own project, a nice working environment, and expertise. Also, thank you to everyone willing to participate in interviews, observations, and tests.

Thirdly I would like to thank all the external parties involved; Niels Schouten (Fabrique Invent), Mike de Jong (Fabrique Invent), Peter Swart (municipality Arnhem), Titia Bijma (municipality Nijmegen), Melissa Kempers (municipality Delft), Sjoerd Hofman (Felyx) and Berenice van Gessel (Check). Thank you for taking the time to talk to me and share your expertise and insights on your field of expertise. A special thanks to Van der Linde Fietsen for lending me one of their electric mopeds for prototyping and validating the concept.

Also, a special thanks to the personnel working at the PMB workplace at the faculty of Industrial Design Engineering. They were always happy to help me build my prototype and explain the manufacturing procedures.

Lastly, thanks to my fellow students, friends, roommates, and family for supporting me in all kinds of ways throughout the project.

And for you as a reader, have fun reading this thesis and get inspired by the future of shared mobility.

Enjoy!





Abstract

Shared mobility has been present longer than you imagine. In the 1940s, the idea of sharing bicycles started in Switzerland. However, the modern manifestation only became popular about a decade ago, but since then, the market for sharing vehicles has grown significantly. In recent years, different ridesharing services have been popping up. In particular, shared mopeds are on the rise in The Netherlands. Pollution and congestion require us to rethink how we move around and new technologies make sharing continuously easier and more convenient.

However, operating shared mobility comes with its own set of challenges, and one major hurdle is the task of keeping all the vehicles charged. Shared moped providers integrated their mopeds into cities using a free-floating system: the user can leave and park the moped everywhere in the service area. With these mopeds spread out in the city, the providers are using a system called battery swapping to charge all these mopeds. However, the free-floating system has led to mopeds being randomly parked everywhere, causing inconvenience in cities. Sidewalks and streets are cluttered with parked mopeds, obstructing the residents' movement. Furthermore, the battery swapping service is an expensive charging method, requiring vans, personnel, and storage locations.

The start-up TILER is currently developing a universal wireless charging solution for e-bikes, using the kickstand and a tile placed in the pavement to charge an e-bike. By integrating the current charging technology of TILER during this project, Mick was created. Mick is a wireless charger designed specifically for electric mopeds. Mick incorporates a charger into the kickstand of the moped, allowing for effortless charging by simply parking the moped on the accompanying charging tile embedded in the pavement.

By integrating TILER's current charging technology, Mick not only offers a convenient and reliable way to keep shared e-mopeds charged, but it also helps bring order to the cityscape as the mopeds will be neatly parked on their designated spots. This design effectively addresses the challenges associated with bulk charging batteries in the commercial logistic domain, eliminating the need for chaotic charging cabinets and multiple adapters. Moreover, it reduces the reliance on human responsibility, which often leads to reliability and scalability problems, not to mention fire hazards.

Mick's innovative design not only enhances the charging experience but also improves the overall user experience of the shared mobility system, making it a promising solution for the future.

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CHAPTER ONE

INTRODUCTION

This chapter introduces the context of this master thesis by providing a short introduction to shared mobility, the aim of the design project and how the project is approached.

- 1.1 Context Introduction
- 1.2 Project Focus
- 1.3 Project Approach



1.1 Context

Introduction

1.1.1 Shared Electric Mopeds

In the Netherlands, the number of electric mopeds has increased significantly. Already in 2022, e-mopeds make up more than half of all new moped purchases (Correspondent, 2022). These e-mopeds are becoming more and more popular for private use and in the shared mobility sector. Sharing fleets are a fast-growing market in which user groups such as hotels, healthcare organizations, cities, and delivery services use light electric vehicles (LEVs). The term LEVs refers to electric-driven vehicles that travel relatively short distances, such as electric bikes, e-mopeds, electric scooters, and electric cargo bikes (Light electric vehicles (LEVs), 2021). Furthermore, businesses like Felyx, GO sharing, and CHECK are reshaping urban areas with their shared e-bikes and e-mopeds (Pointer, 2021). However, one of the disadvantages of shared electric transportation is the time and effort that goes into charging. The providers of these shared transportation modes must guarantee a fully charged battery, which can only be done by manually swapping the battery, as the e-bikes and e-mopeds cannot be charged on the streets (Felyx, 2021).

1.1.2 The Company

TILER has developed a new solution for charging e-bikes without having to manually change the battery or be connected to a wire. It all started with a patent from the TU Delft. This patent describes a technology that creates a powerful, flexible, and efficient way of inductive energy transfer. TILER developed this technology further to be integrated into the LEV market (The Green Village, 2021). The inductive energy transfer is integrated into the shape of an outdoor tile, which can be easily installed into the already existing pavement (Bowden, 2021). This tile is simply connected to the closest energy plug of a building. On the other side, the e-bike is equipped with a special kickstand placed on the tile to enable the charging process (The Green Village, 2021). Their smart charging technology uses inductive charging as efficiently as plugged charging. TILER's goal is to be a part of a micro-mobility network to reduce the use of cars in cities and put people and nature back into the center (TILER, z.d.).



Figure 1: Yearly worldwide growth of number of mopeds (Aanen, 2020)

1.2 Project Focus

A future step for TILER is integrating their wireless charging solution into more LEVs, such as shared electric mopeds, to create publicly available charging tiles throughout the city. Currently, there are no wireless charging solutions for e-mopeds on the market. The market's charging solutions are either bulky charging stations, battery swapping, or using a wired adaptor. In the future, TILER wants to integrate its already existing wireless charging solution with other light electric vehicles, including mopeds, to create a seamless mobility network.

TILER wants to integrate its wireless technology into shared electric mopeds. Currently, shared electric mopeds are rising, especially in The Netherlands. Therefore, TILER is interested in this market. The focus of this project is on charging electric mopeds and how to integrate their technology into this market. Due to

ongoing developments - vehicles, trends, regulations - it is essential to gather insights about the near future of this domain and craft a plausible strategy prior to developing a charging solution. Researching wireless charging in this context will be a starting point for developing a concept design to charge shared electric mopeds.

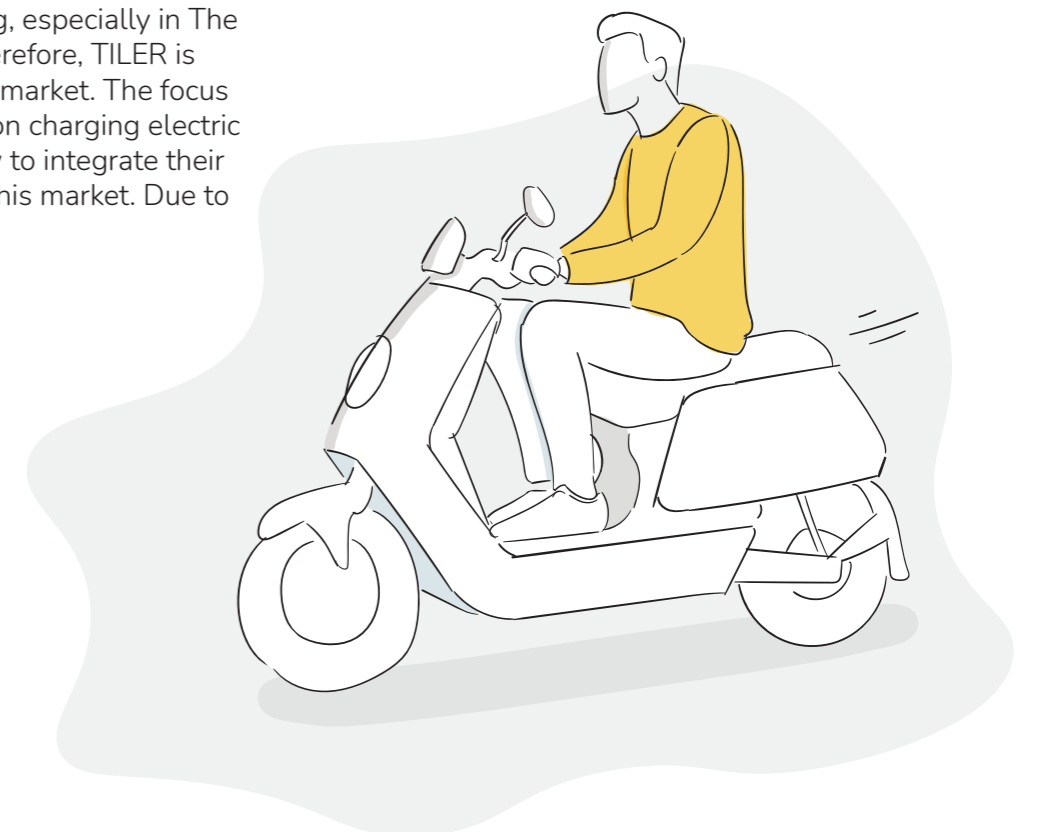


Figure 2: Triple Diamond

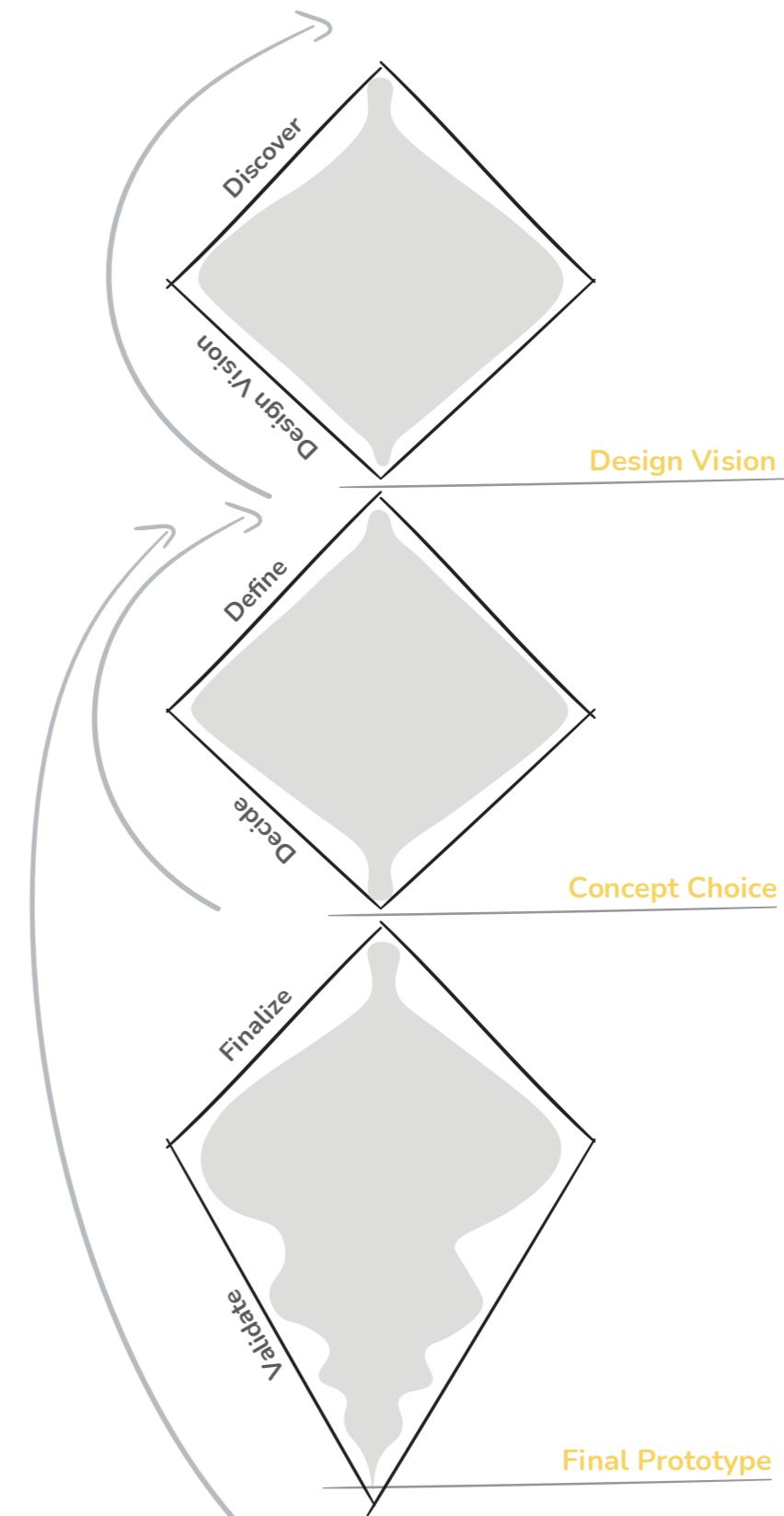
1.3 Project Approach

During this project, the main framework is a variation on the triple diamond (figure 2). Four main phases are used to reach the result: discover, define, develop and decide, and finalize. To find validation for the question: 'Why develop a charging solution for light electric vehicles?' I will first research developments in urban mobility.

1.3.1 Triple Diamond

The following chapters are based on the project's six phases, which are divided into:

- 1) **Introduction:** The starting point of this project, the context, the defined aim, and the project's approach are chosen. See Appendix 1 for the project brief.
- 2) **Discover:** The context of the potential users and environment is studied to understand the needs and opportunities better.
- 3) **Define:** A design goal is formulated to define a direction for designing.
- 4) **Develop:** Iteratively ideated, designed, and tested possible interactions and solutions to reach the formulated design goal.
- 5) **Decide:** One concept direction is chosen to further develop based on gained research insights.
- 6) **Finalize:** The concept is optimized by bringing it back into the end user's context and integrating test conclusions into the design. A final design is visualized and prototyped. The final concept is evaluated by testing it with potential users. As a result, further recommendations for development and implementation are shared.



1.3.2 Research and Design Activities

The three diamonds have several research and design activities (figure 3). In the actions that followed, thoughts and findings were included and verified. A brief explanation for each activity can be found on this page.

Discover

To get a clear overview of the current situation, subjects regarding shared electric mopeds are investigated. The context research starts by better understanding the cities' current infrastructure. Furthermore, the current way of charging shared electric mopeds and their downsides are investigated. Also, mopeds' design and interaction with the users are researched.

For the initial **literature review**, I used platforms such as 'Google Scholar' and 'Scopus'. These platforms allow me to use precise criteria and boundaries, such as keywords and subjects to be included in the review. The literature review was focused on current trends and services regarding sharing vehicles, especially sharing mopeds. This initial search formed the base of the project background. Also, more specific research questions emerged, and gaps in knowledge became evident. To fill those gaps I did some more specific research including

interviews and field research.

Interviews and questionnaires

with stakeholders gave me more insights on current events and systems. **Field research** and visiting charging locations from shared moped providers, provided me with knowledge on the current way of operating shared vehicles and their downsides.

Define

With the insides of the research a design goal can be formulated. This is done by looking at the main takeaways from the research and combining them. Also, requirements for the final design are set.

Develop

Individual **brainstorming sessions** are conducted multiple times, getting inspired by various activities and generating ideas by stimulating creativity. Brainstorm sessions with fellow students are conducted to use the different perspectives and new energy to boost the design process in different phases. Also **low-fidelity prototypes** are build in order to test an idea, interaction or principle. Different method, such as **how-to's**, **morphological chart** were also used to generate ideas. Small interactions, prototypes or idea directions are tested during interaction tests with fellow students or future users to gain insights in the usage.

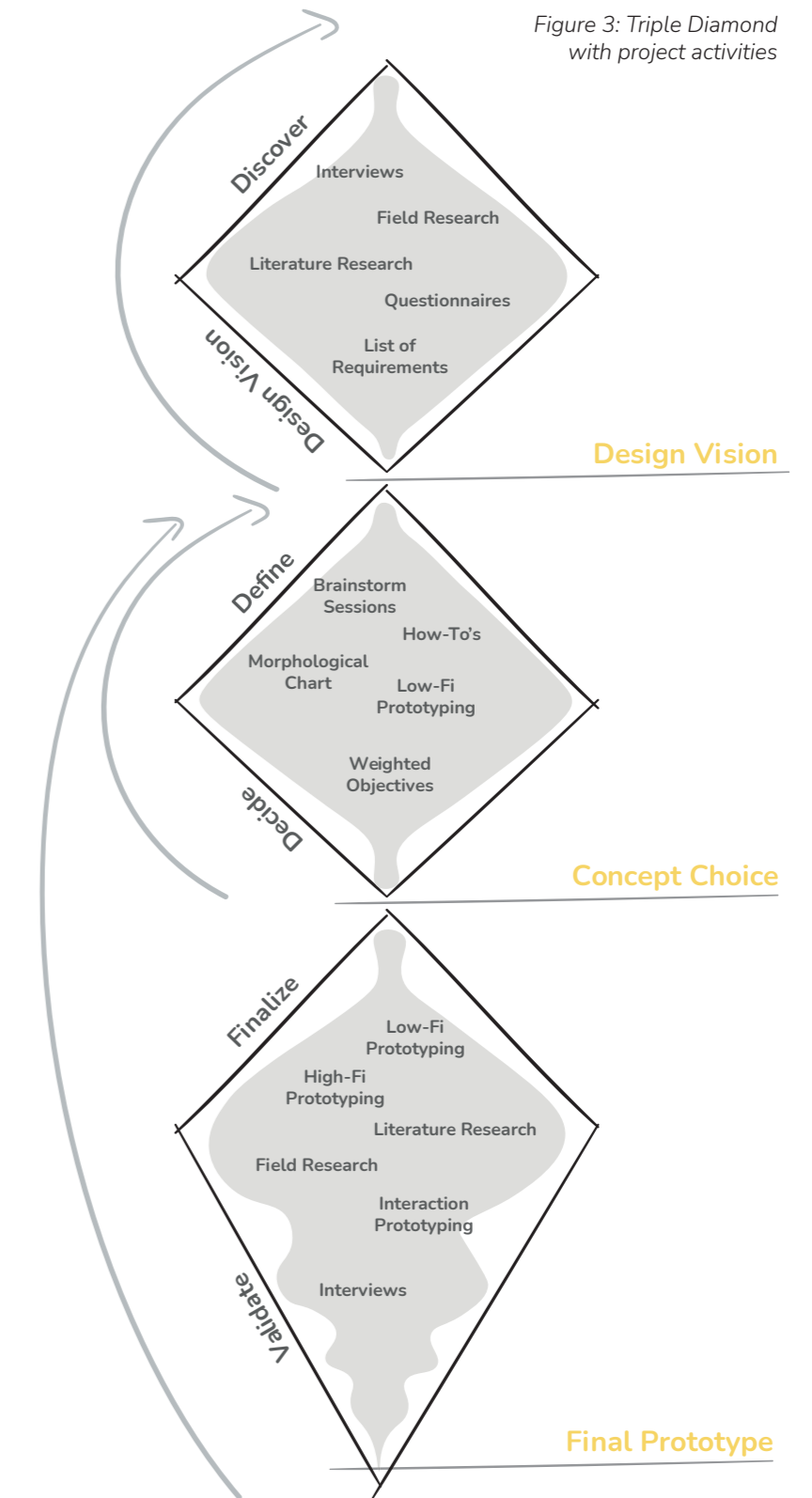
Develop

After creating multiple ideas and concepts, they were tested to see which concept has the most potential. By setting wishes, a decision on the final concept was made.

Finalize

The concept was worked out further by drawing and testing with low-fidelity prototypes. Furthermore, **interaction prototyping** was used together to validate the design. For this, high-fidelity prototypes were made using 3D-printed models to test the final design.

Figure 3: Triple Diamond with project activities



CHAPTER TWO

DISCOVER

A deep dive into the context is done in this thesis chapter. Different subjects are investigated regarding shared electric mopeds ✳ such as infrastructure, shared mobility, and charging solutions.

- 2.1 Introduction: A brief overview of the contents
- 2.2 Changing Cities
- 2.3 Electric Mopeds and Shared Mobility
- 2.4 Charging Electric Mopeds
- 2.5 The Company: Tiler Charge
- 2.6 Key Take Aways



2.1 Introduction: a brief overview the contents

This chapter has six sections: an introduction, four midsections, and a conclusion. The four midsections each dive into a different aspect that is related to the subject of shared mobility. First, starting with broad research and gradually conversing deeper into the subject. The subsections contain the following:

2.1 Introduction

This section introduces the following research. It explains the approach of the research and provides a clear overview of the contents of this chapter.

2.2 Changing Cities

Within this section, I dive deeper into the current infrastructure of cities. It is important to get an understanding of the current environment in which I need to design for. Research by collecting data from literature and conducting interviews with municipalities gives me an overview of the current situation, potential future changes, and design opportunities.

- 2.2.1 Changing Cities
- 2.2.2 Mobility Hubs and Sharing Economy
- 2.2.3 Regulations
- 2.2.4 Future of Dutch Cities

2.3 Electric Mopeds and Shared Mobility

Within this section, I dive deeper into the subject of sharing electric mopeds. The current situation of shared electric mopeds in the Netherlands is analyzed. The positives and downsides are analyzed, which later form design criteria.

- 2.3.1 Shared Mobility
- 2.3.2 MAAS (Mobility As A Service)
- 2.3.3 The Rise of Electric Mopeds
- 2.3.4 Why are (Shared) E-Mopeds Popular
- 2.3.5 Downsides of (Shared) E-Mopeds

2.4 Charging Electric Mopeds

An overview of the current charging solution is made in this section. Literature research, field research, interviews, and visiting charging locations of sharing moped providers paint a picture on the current charging solutions of (shared) electric mopeds.

- 2.4.1 Charging Solutions for (Shared) E-Mopeds
- 2.4.3 Overview of Charging Solutions

2.5 The Company: TILER Charge

A closer look at the company TILER and its innovative charging solution for electric bikes is taken in this section. Their stakeholders are mapped by doing a stakeholder analysis. Also, their charging technology is investigated.

- 2.5.1 TILER Charge
- 2.5.2 Stakeholders of TILER Charge
- 2.5.3 Charging Technology of TILER Charge

2.6 Key Take Aways

Lastly, this chapter is closed off with a conclusion and key takeaways which are collected in this research. These takeaways form the basis of the design vision in the next chapter.



2.2 Changing Cities

2.2.1 Changing Cities

Between 2000 and 2017, half a million houses were built in urban areas. Till 2030 an increase of more than 700 thousand homes is expected by the Central Bureau of Statistics in the Netherlands (Hannema, 2019).

Due to the substantial increase in housing in cities, it is becoming increasingly crowded and congested. The reason why the traffic and congestion are growing is because of the number of cars on the road. When people move toward the cities, they often bring their cars. However, the cities do not have enough space for a large car increase. Municipalities do not know how to manage this growth. Nijmegen and Arnhem expect ten thousand new residences by 2030. Due to the decreasing amount of space in cities for parking and on the roads, both cities are concerned. The increase in cars can also lead to more traffic jams and longer travel times (M. Kempers, personal communication, December 21, 2022)(T. Bijma, personal communication, January 10, 2023).

Due to the increasing number of people in the city, municipalities want to make the streets feel less busy. For example, the municipality of Arnhem is actively working to remove unnecessary objects on the streets, such as traffic signs, to clean the cityscape (P. Swart, personal communication, December 19, 2022). Additionally, cars are the main source of urban air pollution. According to researchers from the University of California and the Institute for

Transportation and Development, leaving the car at home and using a bike or public transport to reach your destination is the most effective way to tackle climate change (JC, 2014). These cars also take up valuable space, which can be used for parks, bike lanes, and sidewalks. Thus, one of the municipalities' biggest challenges is reducing the number of personally owned cars in the cities. Municipalities work to invest in public transportation networks because it is already an excellent way to limit the usage of cars. Additionally, vehicle-sharing services can take the place of owning a car. Sharing vehicles gives people the opportunity to have access to vehicles without owning them.

Municipalities in Delft, Arnhem, and Rotterdam also try to promote active transportation. In these cities, walking and cycling are the number one priority (M. Kempers, personal communication, December 21, 2022)(T. Bijma, personal communication, January 10, 2023). Therefore, more bike lanes and sidewalks are built to create more accessibility to execute active transportation. Moreover, it promotes increased physical exercise, which is good for the residents' health. This is also advantageous for e-bikes and e-mopeds because they can also travel on these roads.

Figure 4: Mobility hub at train station (source: Sweco, n.d.)



2.2.2 Mobility Hubs and Sharing Economy

The city's infrastructure is developing to comply with all the new needs of its residents. Sharing economy is rising, which is transforming transportation industries drastically.

A future development cities are integrating are mobility hubs. These hubs are part of area development and try to manage urban areas to make them more livable and accessible. The hubs can be located in different locations, such as residential areas, cities, train stations, and airports. A mobility hub is mostly used to switch from one mode of transport to another. Some hubs also have spaces for meeting up, living, and working. Mobility hubs aim to bundle transport flows, merge facilities, and boost the use of shared mobility and electrification (Solutions, 2022).

Cities like Nijmegen and Arnhem are already working on various projects to incorporate the hubs into the city. However, they still do not have a clear strategy for integrating these hubs most effectively. They see the potential to use mobility hubs to reduce the number of personally owned cars and pollution on the streets. Therefore, they are conducting pilot projects and examining how many

vehicles they have, where they should be located, and what the demands of the residents are. For example, they initially thought that all the types of electric vehicles should come together in one hub, however, people have different needs in different parts of the city (P. Swart, personal communication, December 19, 2022).

“You hear, for example, that there is less need for cargo bikes in the center than in a residential area because people would need them for bigger groceries at the Praxis or a shopping center.”

- P. Swart

At the mobility hubs, people can switch to different modes of transport. Shared vehicles play a big role in this. Car-, moped-, scooter-, and bike-sharing services allow people to rent a vehicle for a short period of time without having to own the vehicle themselves. This can also contribute to reducing the number of cars on the road. Another future development, which also increases the use of shared mobility, is a shift in the sharing economy. As the world population becomes more connected, the sharing economy will likely increase dramatically over the next decade. Collaborative consumption and asset sharing will become the norm, transforming industries such as travel and

Figure 5: Future vision of reduced cars on city Streets Traffic (Source: Moovel)

tourism, transportation, real estate, and many others (Gottschalk, 2022).

2.2.3 Regulations

Cities in the Netherlands have set the goal to be climate neutral by 2050. The current CO2 emissions should be reduced by 49 percent to reach this goal. This has consequences for petrol and diesel transportation. Municipalities can introduce zero-emission zones in cities from 2025 (Bogers, 2023). (Shared) electric vehicles are on the rise because of these new regulations. However, cities do not have a definite plan on how to regulate these new rules. Arnhem is already installing a charging network for when electric cars will emerge, but they are still waiting to introduce shared electric mopeds (P. Swart, personal communication, December 19, 2022). Although Delft initially welcomed shared mopeds, they added the requirement for a permit for the providers by the end of 2022 to better manage the number of vehicles in the city after getting complaints from residents. (M. Kempers, personal communication, December 21, 2022).

Thus, regulations are constantly changing as the mobility sector constantly is innovating. Transitioning to a seamless and sustainable transportation network is the goal of municipalities, but they still are looking at how to integrate this best.

2.2.4 Future of Dutch Cities

Concluding, a vision for the future is developed. Municipalities aim to reduce the number of cars in cities because of less space and pollution. Without these cars, they want to create a seamless transportation network. Active transportation will be a priority, and therefore, the city will be designed for pedestrians and cyclists with wide sidewalks, protected bike lanes, and plenty of green spaces. Moreover, public transport should be the main mode of transport in combination with shared mobility. Different shared vehicles should be available for different needs. It can also be a great solution for the last mile. Personal car ownership is greatly reduced as most people opt for shared electric vehicles, bikes, and other forms of transportation. Congestion and pollution are greatly reduced as well. However, municipalities are still unknown on how to adapt to this future development precisely.

Currently, cities are running pilots to test a future concept regarding mobility hubs and sharing vehicles. In the future, these trials can be a great starting base for developing a new city infrastructure with accompanying regulations. Overall, the future city is designed to be sustainable, livable, and efficient, focusing on reducing pollution and congestion while also providing convenient and accessible transportation options for all residents.



2.3 Electric Mopeds and Shared Mobility

2.3.1 Shared Mobility

Shared mobility has been present longer than you imagine. In the 1940s, the idea of sharing bicycles started in Switzerland. However, the modern manifestation only became popular about a decade ago, but since then, the market for sharing vehicles has grown significantly. In recent years, different ridesharing services have been popping up, such as peer-to-peer sharing (driving a stranger's private car) and shared e-bikes, scooters, and mopeds (Heineke et al., 2021). The use of shared transportation services, such as car-sharing, bike-sharing, and ride-hailing, as an alternative to owning a personal vehicle is referred to as shared mobility. This provides users with a vehicle for their personal needs without owning and maintaining it.

Shared mobility has become more popular over the last years as the costs of owning a personal vehicle are rising, environmental concerns, and shared transportation modes are becoming more convenient and flexible. In addition to traditional shared

mobility services, emerging technologies have the potential to change the way we think about transportation. For example, electric moped-sharing and autonomous vehicle-sharing services are gaining acceptance in several areas. A shared mobility network can make use of a variety of vehicles. These include electric cars, scooters, bikes, and mopeds (Shared-Use Mobility Center, 2020). Micro-mobility is increasingly recognized as a promising mode of urban transport, particularly for its potential to reduce private vehicle use for short-distance travel (Abduljabbar et al., 2021).

Shared electric mopeds have exploded in the Netherlands in the last few years. In 2020 the market showed a growth of 794%, the biggest growth in the world. These mopeds are not only popular in the Netherlands. All around Europe, India, Taiwan, and the United States, more and more providers of shared e-mopeds are being introduced (Heineke et al., 2021). Shared e-mopeds are vehicles that can be rented and used for short trips in urban areas (RTL Nieuws, 2022). These shared electric mopeds are offered by different companies in The Netherlands. Currently, the biggest shared moped providers are Felyx, Check, and Gosharing. Felyx currently has 8000 shared mopeds riding around in Europe. They also are the number one shared moped provider in The Netherlands and Belgium (RTL Nieuws, 2022).

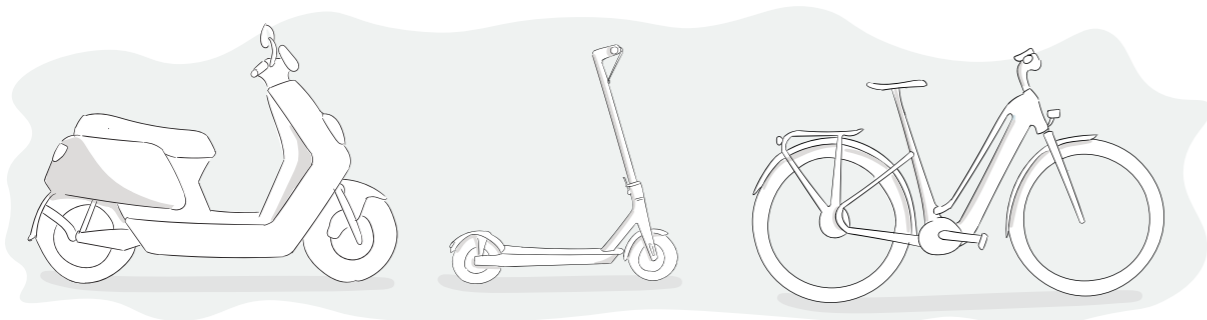


Figure 6: Shared mobility vehicles; e-Moped, e-Scooter, e-Bike

Figure 7: Shared electric mopeds on the streets (image source: ANP / Venema Media)



2.3.2 MAAS: Mobility as a Service

Mobility As A Service, also known as MAAS, is a transportation concept that aims to provide individuals with a more effective and easy way to access different forms of transportation. It usually entails combining many modes of transportation, including personal vehicles, buses, trains, bikes, and shared vehicles, into a single, streamlined service. By allowing users to quickly plan, reserve, and pay for their journeys through a single platform, MAAS hopes to provide a one-stop location for all their transportation needs. Anything from scheduling a ride-hailing service, reserving a bike or scooter, buying a train ticket, or reserving a parking space can be included in this.

MAAS aims to increase everyone's access to dependable, convenient transportation. By promoting the use of more ecologically friendly modes of transportation, it can also help to lessen traffic congestion and enhance the overall sustainability of transportation (MAAS Alliance, n.d.). Utilizing data and technology to enhance mobility options and lessen the need for private vehicle ownership is one of the core aspects of MAAS. For example, real-time traffic and transportation data can be used to optimize routes. Digital payments and mobile apps can also be used to streamline the booking and payment processes (Ministerie van Infrastructuur en Waterstaat, 2021).

2.3.3 The Rise of Electric Mopeds

Electric bikes and cars are widely known, but now the electric moped is also rising in The Netherlands. Not only for private use, but companies are also shifting from petrol mopeds to electric ones (Houten, 2021). At the beginning of 2021, more electric mopeds were sold than petrol mopeds in The Netherlands for the first time. Out of 18081 mopeds sold, 54 percent were electric. More people want to contribute to creating a more sustainable world and therefore choose to go electric. Additionally, when gas prices rise and the price difference between gasoline and electric mopeds decreases, choosing an electric moped becomes more enticing (NOS, 2022). Electric moped maintenance is frequently also less expensive, which can result in significant savings throughout owning an e-moped (Houten, 2021).

In addition, businesses are exploring using company mopeds rather than company cars in larger cities like Amsterdam, Rotterdam, and The Hague. By riding mopeds, people are generally arriving faster at their location. Especially around and in the center of bigger cities, people are getting stuck in traffic in the mornings and afternoons. Going by moped instead of by car helps them skip the traffic and arrive faster at work or home (MT/Sprout, 2022). Furthermore, the use of (electric) mopeds is cheaper than cars. Not only due to fuel consumption but also rising maintenance and insurance costs.

2.3.4 Why are (Shared) E-Mopeds Popular

Shared mopeds provide a distinct mode of mobility that can be a viable alternative to cars for many individuals. These cars have a variety of advantages that make them a tempting option for individuals seeking a convenient, cost-effective, and environmentally responsible mode of transportation.

Convenience & flexibility

Mopeds are very popular because of how convenient they are. Due to their size, mopeds can navigate urban streets more easily than cars. Moped drivers may be able to avoid traffic and shorten their commute thanks to this. Additionally, because mopeds are smaller than cars and do not require a dedicated parking space, parking one in congested city streets is easier on a moped than on a car. They can use this to park more reasonably close to their location without paying expensive parking fees (Aguilera-García, 2021).

Reduces Pollution

Electric mopeds produce zero emissions, which makes them a cleaner and more environmentally friendly option. A growing concern in urban areas is air pollution. Switching to electric mopeds can greatly help to reduce the air pollution created by gas-powered cars and mopeds (Bieliński & Ważna, 2020). More city now also creates zero emission zones in the center of the cities (Bogers, 2023) thus having an electric moped is a great advantage in these areas.

Another form of pollution cities experience is noise pollution. Gas-powered cars and mopeds provide a lot

of noise. The electric versions of these vehicles produce less noise, which can be a significant benefit in densely populated areas. Sharing this electric moped can also reduce the number of cars in cities which also helps to reduce traffic congestion.

Affordable & fun

Another benefit e-mopeds have compared to cars is cost. Monthly, an electric moped is less expensive especially for short trips or infrequent use. Owning a car in a city can also be more expensive because of parking permits, which is not obligated for mopeds. Furthermore, a lot of people experience mopeds as fun and enjoyable experience (Appendix 2: Results Questionnaire). Mopeds are easy to operate, which also makes them an easy option for those who do not feel comfortable riding a car.

2.3.5 Downside of (Shared) E-Mopeds

Shared mopeds have become a popular transportation option in many cities, offering a convenient and cost-effective alternative to cars. However, like any mode of transportation, shared mopeds have their own set of drawbacks that potential users should be aware of. In this chapter, the downsides of shared mopeds are explored, including the responsibility of the mopeds, nuisances in cities, and maintenance.

Private Versus Shared Use

Sharing mopeds instead of privately owning a moped has a lot of advantages concerning reducing costs and using up space. However, this also brings some downsides to it. Availability can also be

an issue, as shared mopeds may not be available at all times or in all locations. In addition, there may be hidden costs associated with using shared mopeds, such as fees for parking or exceeding the time limit. The availability and condition of shared mopeds can also be unpredictable, which can make them unreliable as a consistent transportation option. Shared mopeds may not offer the same level of personalization and customization as privately owned vehicles, and they typically have limited storage space.

Nuisance in Cities

Despite the benefits, issues concerning these upcoming shared e-mopeds are rising in cities in the Netherlands. More and more complaints about the way these mopeds are parked are becoming more prominent. The mopeds users are supposed to park properly on the pavement or designated parking spaces.

However, due to the free-floating concept, a lot of mopeds are parked in an inconvenient way, blocking pavement paths. Moreover, the service area ends at the city limits, causing problems for residents. If you ride a shared moped and reach the service area's border, you have two options: park on the border and leave the moped behind, or drive on and hope to soon enter a new service area where you can park your moped. The fact that many people pick the first option is evident in the apps of the moped-sharing providers, where parked mopeds are visible (Heesterbeek, 2021).

People with mobility issues cannot get through these mopeds and are forced to walk on cycle paths and streets (Pascoe,

2021). Users of the mopeds often park the moped on the most convenient place for them, which often are the sidewalks. This causes a lot of mopeds to create obstructions on the sidewalk. Not only for pedestrians but also causes a nuisance for people with handicaps. The mopeds are also illegally parked on handicap parking places which these people depend on (Radar, 2022).

Maintenance of the Mopeds

Shared mopeds often have visible damage to their bodies. People feel less responsible for the mopeds because they do not have ownership over them. This often results in more careless behavior while using the mopeds which causes more damage. This then also contributes to a shorter life span of the mopeds which makes them in the end, less sustainable than privately owned mopeds.

Research by the Knowledge Institute for Mobility Policy shows that the electric shared mopeds emit just as much CO2 per km (63 g CO2-eq/km) as the petrol variant in private ownership. In particular, the short lifespan (3.7 years) of the shared moped compared to the private moped (10 years) plays an important role in this (Notenboom, 2022). Safety is a major concern as a result of damaged mopeds, as shared mopeds may not be subject to the same level of maintenance and safety checks as privately owned vehicles.

Safety Issues

Drivers of the mopeds also often drive on the sidewalk. The lack of noise that the mopeds produce is perceived as dangerous. As a result, passers-by do not hear the moped coming. Moreover, because the payment method is paying per minute, more people try to reduce their traveling time to pay less. This often makes them drive less safely and faster to reduce their traveling time (Radar, 2022).

2.4 Charging Electric Mopeds

Electric mopeds need to be charged to be able to use them. There are many different ways of charging an e-moped. Removing the battery and charging it outside the moped is mostly used. Electric mopeds, most of the time, use lithium-ion batteries. These batteries are used because they have a high energy density: the quantity of energy stored per their physical weight. They also have a long lifespan, which means they may be discharged and recharged, or “cycled,” several times and still retain their storage capacity. However, good management of the batteries is needed to retain efficiency (ESG, 2023).

Typically, an electric moped’s battery may be removed and charged at home. This makes it simple to charge a privately owned electric moped at home. But in the shared electric

moped sector, they also use this way of charging, however, they build a whole system around it (R. Stadman, personal communication, December 16, 2022). Mopeds are shared in a variety of ways. You have shared services for people to use in the city. They offer their mopeds through a free-floating service around the city. These services often use so-called ‘battery swappers’ to drive around and switch batteries of mopeds that are too low. Delivery services are another industry that makes use of electric mopeds. They use their electric vehicles to make deliveries.

Lastly, electric mopeds are used in the tourism industry to rent to visitors. All of them use different ways of charging their electric mopeds. Below are a few companies mapped out and their ways of charging the moped. During this analysis, the advantages and disadvantages of this way of charging are analyzed. This information can, later on, be used to create concepts.



Figure 8: Battery swapper loading batteries into car (source: Check)

Figure 9: Check charging and maintenance location rotterdam



2.4.1 Shared e-Moped Service: Check

How do they charge?

The moped fleet-sharing providers all use the same technique of charging their mopeds: battery swapping. A person, also called a battery swapper, will drive around the city in a van filled with batteries. They start their day by logging into the Check manager application. Within this application, the battery swappers can see all mopeds and filter them on battery percentage, most of the time they filter for around 30%. Mopeds with less than 10% battery are shown in red on the map, and the others are green. The battery swapper will fill their car or van with fully charged batteries and calculate a route to swap the batteries. The batteries will be taken out by the battery swapper and replaced by fully charged ones. Once collected the batteries will go back to their distribution center and are charged inside containers (figure 9).

What are the main advantages?

The battery swapping system makes it convenient for the users, as the mopeds that are online are always charged. Moreover, users do not need to plan their trip to a charging hub in advance.

What are the main disadvantages?

The operational costs are high as the shared moped providers need to have a location, vans, and personnel to charge and swap all the batteries. Moreover, more batteries and vehicles are needed to operate the business, and is, therefore, less sustainable. Also, the batteries are constantly taken in and out of the moped and chargers. This can cause contacts to be damaged more easily. When damaged batteries get charged, they can cause fire or even explode. This is a frequent concern at Check cause several batteries caught on fire, forcing them to move their facilities outside (K. Ruiter, personal communication, January 17, 2023). This way of charging works together with the free-floating concept. Currently, mopeds

are parked inappropriately on the sidewalk blocking pedestrians and disabled people. Lastly, the mopeds are not parked in the same spot, making it hard to know if a moped is available nearby when needed.

2.4.2 Tourist rental service: Forza Scooter Verhuur

How do they charge?

Forza scooter rental rents out electric choppers. They charge the batteries inside their warehouse/building. They do not have a specially designed charging spot inside their building. The batteries are spread over the building and connected to the electricity inside. They charge the batteries indoors, especially for safety reasons (fear of burning out) (Forza, personal communication, December 1, 2022).

What are the main advantages?

The costs are lower because they do not need extra equipment or supplies to charge our mopeds.

What are the main disadvantages?

The batteries are charged inside their own building and they do not have a specially designed charging station for their batteries. This, therefore, takes up space inside the building (Forza, personal communication, December 1, 2022). Moreover, there is a risk of batteries catching on fire inside the building.

2.4.3 Delivery service: Dominos

How do they charge?

Dominos uses electric bikes and mopeds to deliver their food. But, 90 percent of their electric vehicles are bikes. They park their electric

vehicles most of the time in front of their establishment. When their electric vehicles are not in use, the batteries are taken out and put in the firebox. In this firebox, the batteries are charged when empty. Also, when Dominos is closed, they park their vehicles inside to prevent theft and vandalism (D. Dalfsen, personal communication, January 12, 2022).

What are the main advantages?

When the vehicles are not in use the batteries are always charging. Thus, when a delivery is needed, the vehicle is ready and charged immediately.

What are the main disadvantages?

If the battery is damaged or not properly maintained, it can overheat and catch fire while charging. If the battery is damaged, overcharged, or exposed to high temperatures, it can explode, causing serious injury or damage. Because Dominos has to take out the batteries of the vehicle and charge the batteries inside, there is a bigger risk concerning damaging the batteries, and therefore the risk of fire or exploding is bigger.

The batteries are charged inside their own building inside a battery box. This also takes up space inside the building. Lastly, the battery boxes they use are around 4000 euros per box. This, therefore, makes keeping batteries inside more expensive. Handling the batteries by unqualified personnel is also a risk for damaging the batteries easier (D. Dalfsen, personal communication, January 12, 2022).

2.4.4 Battery Swapping Network: Gogoro

How do they charge?

The network enables urban riders to simply stop at a station, drop off their depleted batteries, and pick up fully charged ones in a matter of seconds (figure 10). This is an alternative to trying to charge at home or work. Streamlined refueling enables Gogoro to deploy and scale throughout densely populated cities as customer demand requires, with greater efficiency (Tobin, 2022).

What are the main advantages?

Battery swapping as a subscription service removes the cost of the battery – which can be 30% of the total cost of an electric vehicle – from what the customer pays. It ensures that riders

always have access to optimized, high-performance batteries versus owning a battery that has diminishing performance. The batteries are smart, and because they own all of the batteries and the battery swapping network, they are able to monitor every battery to ensure it is operating efficiently and safely and can anticipate issues before they occur (Tobin, 2022).

What are the main disadvantages?

An EV charging station has a higher cost because of construction, installation, and maintenance. On average, an EV charging station can cost between 2000 and 10,000 euros per dock (Peng, 2023). Moreover, more batteries are needed to ensure enough fully charged batteries for their users, which therefore also raises the costs.



Figure 10: Battery swapping network gogoro (Source: Gogoro)

Figure 11: Ola electric hypercharger (source: Ola Electric)



2.4.5 Charging Network: Ola Electric

How do they charge?

When the user arrives at the hyper charger, they take the available charger out of the station and insert it into the port for the scooter (figure 11). While charging, the charger latches into the scooter's charging port, causing the scooter dashboard to display "Hyper charging." It will indicate when the battery is 70% charged. They can press the "Stop Charging" button on the scooter's dashboard when they want to unhook the charger, then wait for the message to say "Unplug the charger now" to show on the screen. (Ola Electric, n.d.).

What are the main advantages?

Fixed charging station moves the mopeds from parking anywhere on the streets to an organized and specially design parking spot. This reduces the pollution of mopeds on the streets. Moreover, a key benefit is their fast charging. 75 km can be loaded in just around 18 minutes. In comparison, achieving the same with a home

charger will take much more time (Daniels, 2022).

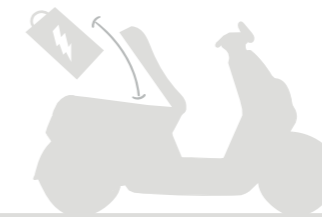
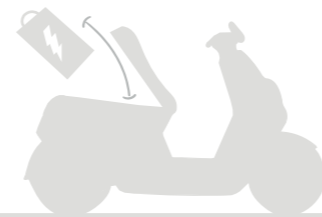
What are the main disadvantages?

The Ola Electric charging network also works with fixed charging stations. Just like Gogoro, costs are higher because of the construction, installation, and maintenance of these stations.

2.4.6 Conclusion

In conclusion, there are many different ways to charge an electric moped, with the most common method being to remove the battery and charge it outside the moped. However, proper management of the batteries is needed to maintain efficiency. One major concern that many experience is safety and fire risk of batteries. The services and companies that take out the battery to charge as a method of charging, experience this risk more often as batteries get more easily damaged. Although this system is convenient for users, but it has high operational costs and is not always sustainable.

2.4.7 Summary of Charging Solutions



Wired charging with plug

Battery swapping by consumer

Battery charging with plug

What is it?

A docking station for electric vehicles (EVs) is a structure that provides a connection point for charging the batteries of an electric vehicle. Docking stations for EVs are typically found in public areas, such as parking garages or streets, and allow drivers to conveniently charge their vehicles while they are away from home.

Battery swapping is a process in which the battery of an electric vehicle (EV) is removed and replaced with a fully charged battery by the supplier of the EVs. The goal of battery swapping is to allow EV drivers to quickly and easily extend the range of their vehicles by replacing the depleted battery with a fully charged one.

Moped can be charged with a wired charging plug. The user takes the charger out of the station and insert it into the port for the scooter. While charging, the charger latches into the scooter's charging port. These charger can often be found at fixed charging docks, but do not have a need for a charging dock.

Battery swapping is a process in which the battery of an electric vehicle (EV) is removed and replaced by the user itself with a fully charged battery at specially designed battery stations. The goal of battery swapping is to allow EV drivers to quickly and easily extend the range of their vehicles by replacing the depleted battery with a fully charged one.

The Battery can be taken out of the moped. When personally owning a moped, the company will provide the consumer with a charger which fits the battery. The charger can be plugged in at home and the battery can be charged inside.

Advantages

- + Efficient to manage, leading to higher reliability for the customer
- + Set location from where the journey can be started
- + Some comfort because it can assure users that vehicles are available
- + Keep urban space well managed

- + Convenient: consumer can leave the vehicle where ever they want
- + Users do not need to plan their trip/find nearby docking station
- + Fast charged mopeds

- + Efficient to manage, leading to higher reliability for the customer
- + Set location from where the journey can be started
- + Some comfort because it can assure users that vehicles are available
- + Keep urban space well managed

- + Lower operational costs for providers (no need for battery swapping personal, vans, etc.)
- + Convenient: consumer can leave the vehicle where ever they want
- + Fast charged mopeds

- + Low cost, no need to install extra charging docks
- + Users do not need to plan their trip/find nearby docking station

Disadvantages

- Expensive: need for large number of docking stations & high cost of building/maintaining
- Bulky stations, impacting the cityscape difficult to determine good locations

- High operational costs (vans, personnel, location)
- Not sustainable (extra batteries and vehicles)
- Damage of batteries and fire risk
- Inappropriate ways of parking
- Users not sure of bike they want to rent is available

- Human error: charging because of human mistake or broken plugs.
- Cables hanging around
- Many different plugs needed

- Less convenient for user: needs to add time to their travels
- Expensive, need for large number of battery stations & cost of buiding/maintaining
- Damage of batteries and fire risk

- Damage of batteries and fire risk

2.5 Company: TILER Charge

TILER has developed a new way of charging electric bikes and hopes to integrate their technology into more light electric vehicles, such as electric mopeds and electric cargo bikes. They developed a kickstand with an accompanying tile to charge an e-bike (figure 12). They new charging solution can be revolutionary in the

shared mobility sector as it removes the hassle of constantly having to actively charge the e-bike batteries. In the following subchapters, important stakeholders of TILER are investigated and a closer look at the technology is taken.



Figure 12: Electric bike with TILER kickstand and tile (source: TILER)

2.5.1 Stakeholder Map

A stakeholder analysis has been made to review the important stakeholders that have an interest and influence on the shared moped service and thus on the charging process of these mopeds (Zanchetta, n.d.). This can lead to important insights for a wireless charging solution for electric mopeds.

In Appendix 3 provides a complete overview of the stakeholders, their interests, and influences. In this chapter, the stakeholders are placed in a power interest matrix, and a conclusion from the analysis is made.

In conclusion, the stakeholders have different interests and influences, however, they all impact the final design of the product. The users of the shared electric mopeds have an interest in a fast, convenient, and reliable charging solution. They do have an influence on the way the charging solution is designed as it needs to fit the needs of these users, thus listening to feedback about the design is important. However, they are not buying the product as it should already be installed in the infrastructure. Municipalities

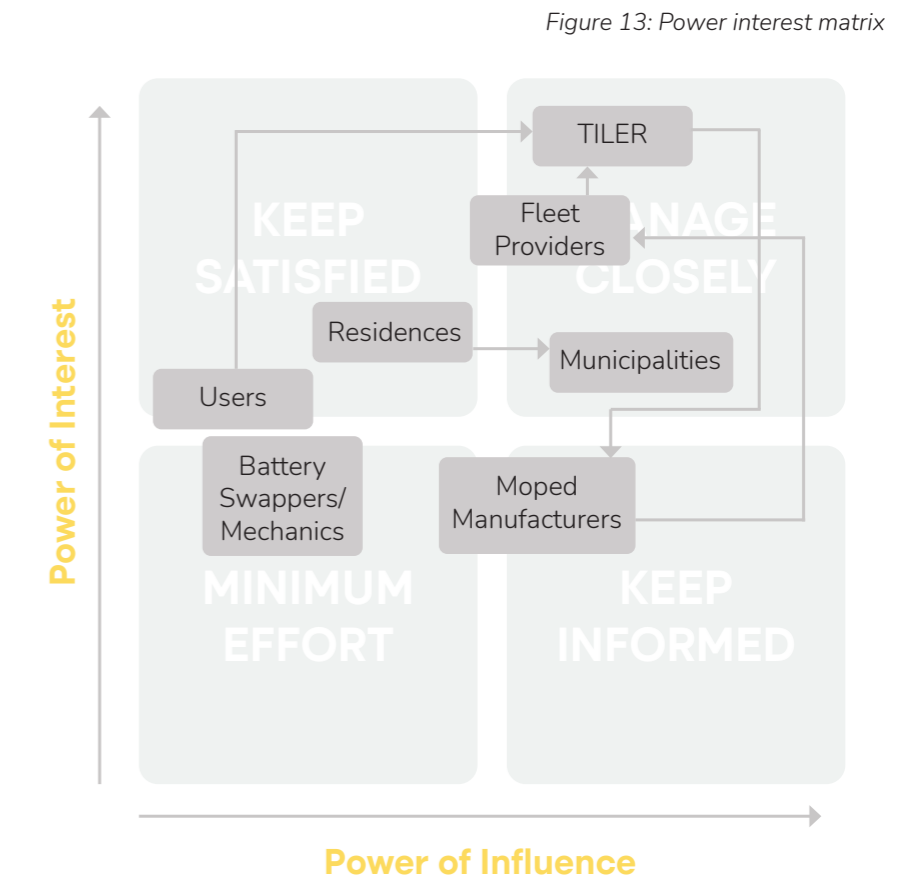


Figure 13: Power interest matrix

have a greater influence on the infrastructure of the cities. They want to create a sustainable, livable, and efficient infrastructure. Therefore a fitting charging solution that complies with the needs of the residents and their view on hubs is wanted. The municipalities (and insurance) can provide TILER with permits to place the product. The providers of shared electric mopeds have a greater interest as regulations are changing in cities. Because of the

high complaint rate of the residents, municipalities are looking to change the way of using these services. Thus it is important for these providers to adapt to the changing regulations. However, they also have a high influence on the way of charging as they can decide on which way of charging is most profitable and convenient for their business.

2.5.2 Technology

Even though wireless charging has been around for a while, it is now becoming more popular in the industry as a whole and making major advancements toward perfection for the first time in recent memory. Inductive charging and resonance charging are the two primary types of wireless charging (Luciano, 2017).

Inductive Wireless Charging

Wireless inductive charging technology transfers energy from a charging station (transmitter coil) to a charging device (receiver coil) via electromagnetic induction (figure 14). This is accomplished by employing two wire coils. A magnetic field is created when an electrical current travels through the transmitter coil at the charging station. Inductive coupling power transmission occurs by establishing an alternating magnetic field on the transmitter coil, which is subsequently turned into an electrical current in the receiver coil (figure 14).

The quantity of flux created by the transmitter coil and the proportion captured by the receiver coil determine the generated electrical current. The distance, size, and positioning of the receiver coil relative to the transmitter coil decide the “coupling factor” of the two coils. A higher coupling factor provides more efficient power transfer due to less loss and heating. (Frumusanu, 2015). Because the magnetic field generated by the primary coil radiates (about equally) in all directions, the flux decreases rapidly with distance. As a result, in order to intercept the most flux, the secondary coil should be placed as close to the primary as possible (Digikey, 2016).

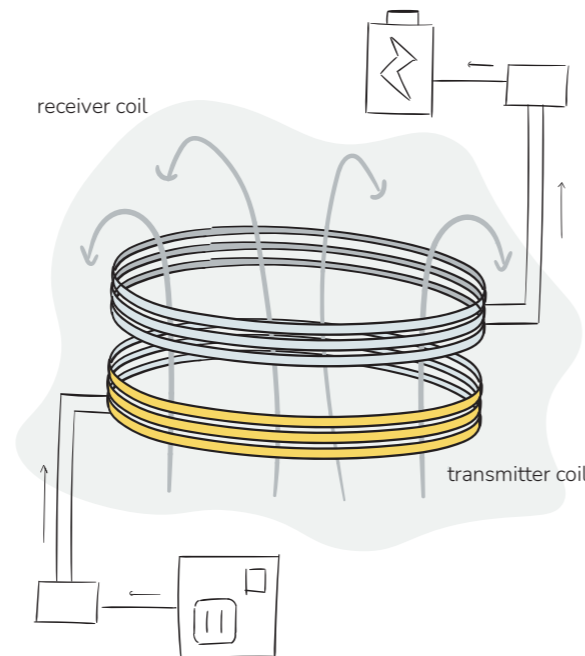


Figure 14: Inductive wireless charging

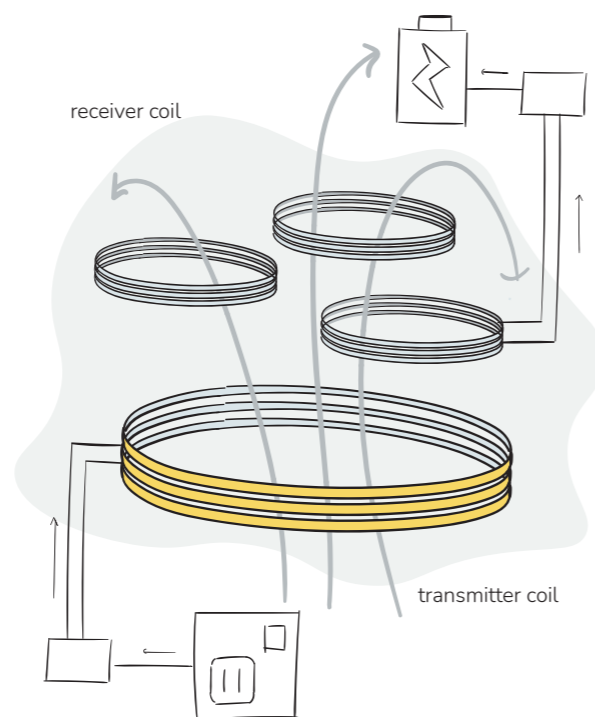


Figure 15: Resonance wireless charging

Resonance Wireless Charging

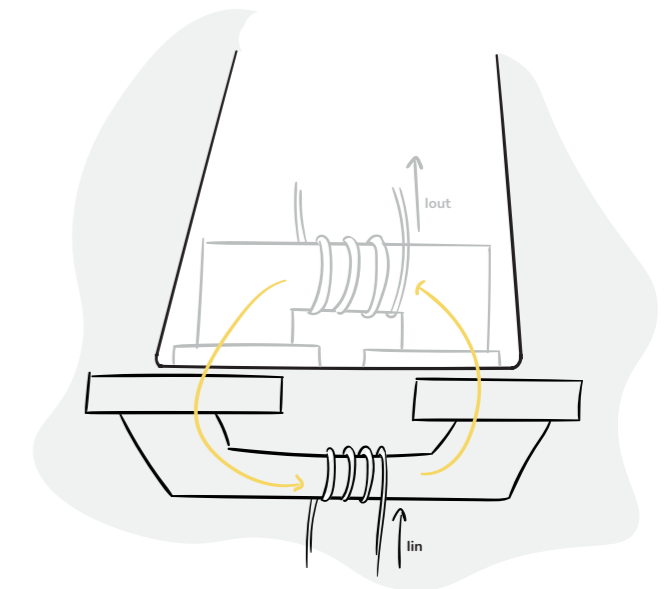
With resonance charging, two copper coils are used (figure 15). One coil is connected to a power source (transmitter coil) and the other one is connected to the device (receiver coil). These coils are tuned to the same electromagnetic frequency. The energy generated can be transferred from one object to another when they are put close enough and have the same resonance frequency. “The energy generated when an electromagnetic field between these objects is generated remains fixed in these objects rather than dispersing in space, which happens with inductive charging (TechTarget Contributor, 2008).

TILER Wireless Charging Technology

TILER uses the resonance wireless charging technique and has created their own version of it. They wirelessly transmit energy between a charging tile and a kickstand (installed on electric bikes) using inductive resonance (figure 16). Resonant wireless charging addresses the main drawback of inductive wireless charging; the requirement to closely couple the coils, which demands precise alignment from the user (Digikey, 2016).

The whole system is designed to be intuitive. When a vehicle’s kickstand is placed on the tile, battery charging automatically commences without requiring any additional effort from the user. The system utilizes electromagnetic resonant induction to wirelessly charge a battery. An electromagnetic field is generated in a primary coil, the magnetic field is passed through a unique patented Ferrite U-core to a secondary coil

Figure 16: Illustration of TILER charging technology



in the tip of the kickstand, which converts it into an electric current to charge any battery (Duijsen & Bauer, 2018). The core power transfer technology provides up to 500W of charging power (fast charging) with an 80-90% efficiency while utilizing a smaller surface area and allowing a greater degree of misalignment. Further, the charging tile is universal, as it can adjust its electronics (through dedicated electronics in the wire adapter) & charge 36V-58V batteries.

The charging tile is sturdy and can be installed either in-ground (flush with pavement) or into a plug-and-play platform that can be placed on top of existing floors. Additionally, a smart charging system is employed which analyzes use patterns, battery status of fleet, hub & vehicle state of charge levels - & this enables charging behavior to adjust & cater to the exact demand as well as help increase a battery’s lifespan by 6x.

2.6 Main Take Aways

- Cities are getting busier by the increase of residents, and thus also the number of cars in cities.
- There are not enough parking places for the increasing number of cars in the city centers.
- Municipalities thus aim to reduce the number of cars by investing in alternative ways of transport for people in cities.
- Shared vehicles could be a great solution for replacing privately owned cars.
- Municipalities are still uncertain of the future and how to implement the alternative modes of transport.
- Cities are actively running pilots and test to validate what would be the best way of introducing a shared vehicle network, including e-bikes and e-mopeds, and how to integrate this into the existing infrastructure.
- Battery swapping is the most common way of charging electric mopeds but cumbersome and unsafe.
- Poor maintenance of batteries causes a lot of batteries to have damage within shared moped sectors.
- One major concern that many experience is safety and fire risk of batteries. The services and companies that take out the battery to charge as a method of charging experience this risk more often as batteries get more easily damaged.
- TILER brings the solution in the form of their kickstand and tile, where there is no need for battery swapping.
- For the TILER charging solution close alignment of the coils is needed.
- The TILER charging solution is as efficient as plugged-in charging.

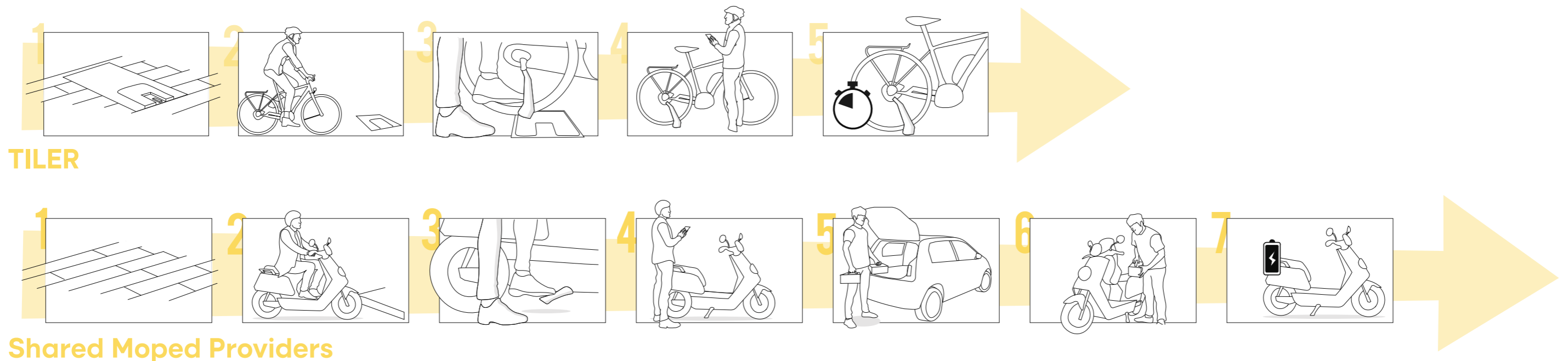


Figure 17: TILER vs shared moped providers way of charging their vehicles

CHAPTER THREE

DEFINE

From the collected research in Chapter 2 an design vision is formed to create a starting point for developing the new charging solution for electric mopeds.

3.1 Design Vision

3.2 Design Requirements



3.1 Design Vision

With the collected data, the most important subjects which are needed to create a viable, feasible, and wanted wireless charging solution for shared electric mopeds are collected. They are divided into three main values: convenience, environment, and universality. A full list of requirements has been made for the design to comply with. This list can be found in Appendix 4. With the values described on these pages, a design vision is created.

3.1.1 Convenience

Users must be able to correctly park the moped in order for the charging solution to function. Therefore, this procedure must be simple to follow and intuitive. Additionally, the currently shared mopeds should continue to operate easily rather than being made more challenging.

Ease of Use

Given how they are now used, mopeds are incredibly simple for their riders to operate because they do not require charging. Therefore, it is critical to maintain the utmost simplicity in this procedure to minimize the steps users must perform to park and charge their mopeds. The centerstand method of parking is currently problematic for certain people since the scooter is frequently too heavy to be parked.

When creating an electric moped parking/charging solution, it is crucial to remember this. In order for the coils to line up, users must park the moped properly. Therefore, the parking and charging processes must be simple for the user to understand in order to facilitate proper parking.

Park & Charge

The vision of TILER is to create an easy and fast charging solution for light electric vehicles. They want to simultaneously charge the vehicle as you park it to create more convenience.

3.1.2 Environment

The environment is changing. The current mopeds do not fit in the current environment and create a lot of issues of polluting the cityscape.

Fit in Cityscape

Cities are filling up and becoming busier by the minute. Municipalities strive to minimize objects in the urban environment. The current mopeds also cause an obstruction in the cityscape. Mopeds are parked all over the place without order. Therefore, a solution that fits into the cityscape and keeps mopeds parked nicely is wanted. It needs to be publicly accessible in a hub.

Reduce nuisance

The shared mopeds today cause a lot of nuisance in cities by obstructing the sidewalk due to the free-floating parking system. The fact that mopeds are parked everywhere is causing a lot of complaints from the public, who are inconvenienced. Additionally, mopeds are frequently parked in designated disabled parking spaces, which causes even more blockage for people with disabilities. These individuals must cross the street since they cannot maneuver past the parked mopeds on the sidewalk. Moreover, cities such as Delft and Arnhem are moving towards hubs in the future. They want to create stationary parking bases for all-electric vehicles. Not only to reduce pollution on the streets of all different types of vehicles but also to create a seamless traveling experience.

3.1.3 Universality

A universal solution for all electric mopeds is necessary to be able to fit all moped providers and moped versions. This also contributes to the ease of use of the charging solution as the users do not have to use different ways of charging between different mopeds.

Reliable

The charging system must be dependable in order to ensure that the mopeds are charged properly and to be able to give users a fully charged battery. This may also improve the overall Maas network's usability.

Safe

The new charging solution should be safe for the user but also for the moped. The battery needs to be protected and not be able to experience issues. Also, the user and other pedestrians should not be able to get hurt by the new design. In order to maintain the battery's health and to guarantee that consumers always have a fully charged moped available, the design should also enable the moped to be charged continuously and without interruption.

“Designing an intuitive and convenient universal wireless charging solution for shared electric mopeds to reduce nuisance and help create a seamless traveling experience which fits in the public urban environment.”

3.2 List of Requirements

From research into the current and future infrastructure, current charging solution and user testing, criteria have been formed which the design needs to comply with. The main criteria are listed below. The full list of requirements can be found in Appendix 4.

1 Convenience: The general layout should be simple to understand and use. This means that the final design should have low complexity to create a convenient user experience. The charging system should be developed with a focus on seamless integration with the moped’s parking routine to increase user convenience. Users may conveniently charge their mopeds without needing to make any additional changes or steps thanks to the integration of the charging feature into the parking process (parking = charging).

2 Universality: The final design must be adaptable to all e-moped models currently in use by shared moped service operators. The charging system should have a universal design that can be quickly modified to accommodate different sharing fleets’ vehicle types and distinctive branding since they may use it.

3 Product line: The moped charging system should be created in a way that is consistent with TILER’s entire product line in order to maintain visual harmony and brand consistency. It should incorporate similar design features, materials, and finishes to those found in TILER’s current product line. This makes sure that the entire product lineup adheres to a consistent and recognizable usability language.

4 Environment: The charging system should be created so that it may be installed in urban areas without standing out. It should take into account the architectural and design styles prevalent in cities, incorporating elements that harmonize with the surroundings while remaining visually appealing.

5 Hardware: The design of the charging system must avoid the use of conductive materials in a way that could interfere with the charging process. Non-conductive materials should be strategically positioned and integrated to prevent interference with wireless energy transfer between the charger and the moped.

6 Accessibility: To cater to the needs of moped users in public spaces, the charging system should be designed to enable installation in and on ground. In order to securely and seamlessly integrate the charging system into sidewalks, parking lots, or other designated public spots, the essential features and infrastructure must be made available. However, the product may be used at location where in-ground installation is not possible. Therefore, the product should also fulfil this requirement.

CHAPTER FOUR

DEVELOP & DECIDE

With the help of different ideation methods, multiple ideas and concepts have been created. In the end, the most promising concept is selected to develop further.

- 4.1 Design Methods
- 4.2 How to's
- 4.3 Morphological Chart
- 4.4 Concepts
- 4.5 Concept Selection



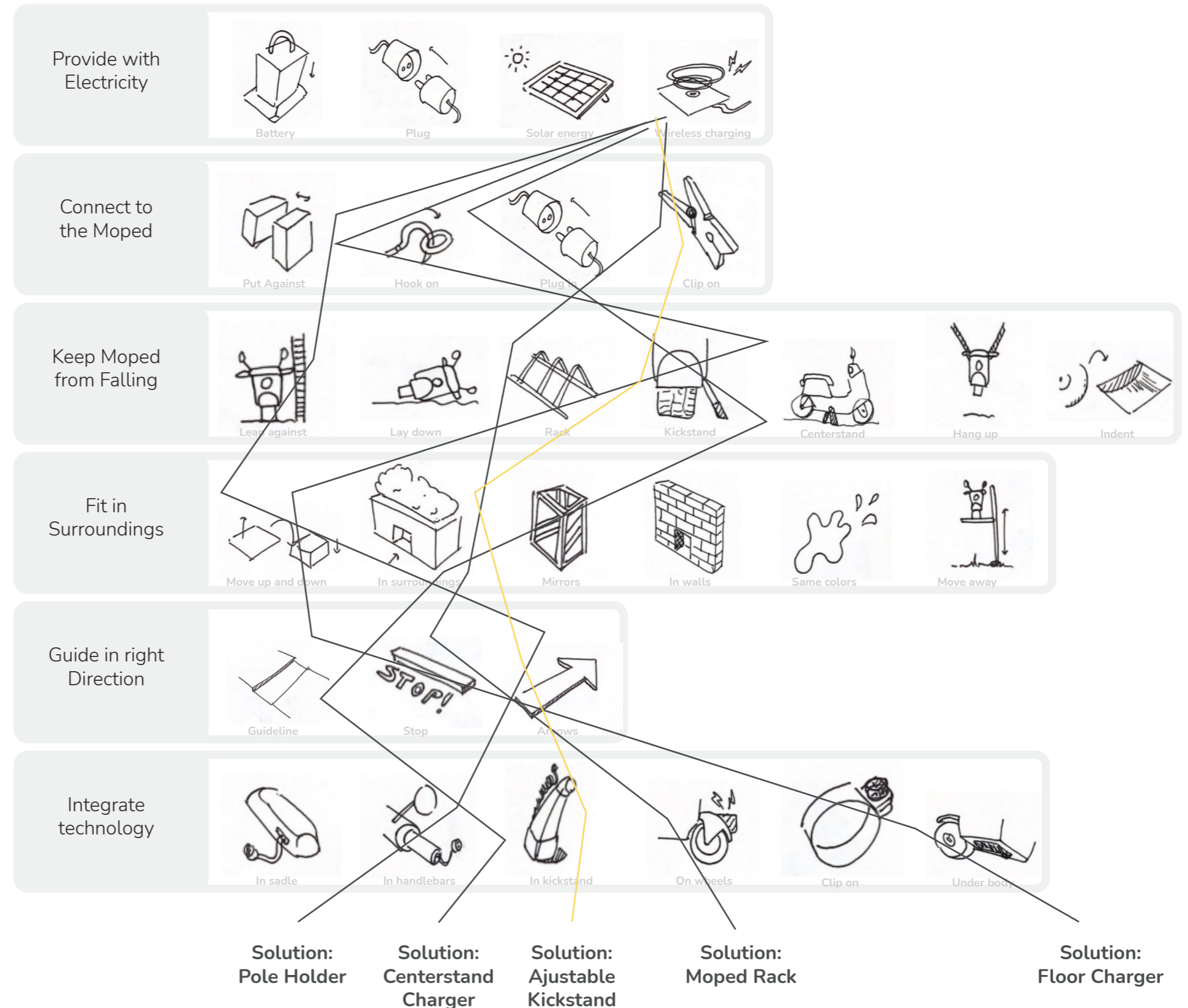
4.3 Morphological chart

After generating multiple solutions for the how-to questions, the solutions are added to a matrix. After adding all the solutions to the matrix, I started generating combinations, even those that seemed unlikely. This helped my creativity and explore different possibilities that I may not have considered otherwise (figure 19).

Once all possible combinations were generated, I evaluated them to identify the most promising ones based on my criteria. I did this by writing down positive and negative factors about the solutions (Appendix 5). With this, I considered their strengths and weaknesses and eliminated those that are not viable or desirable.

Finally, the most promising combinations are developed and refined further. The next pages show the most promising solutions.

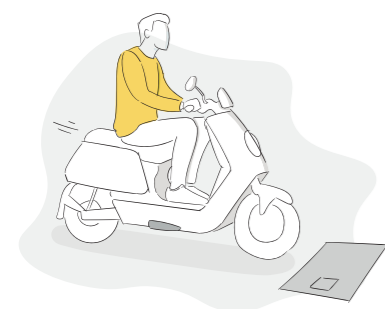
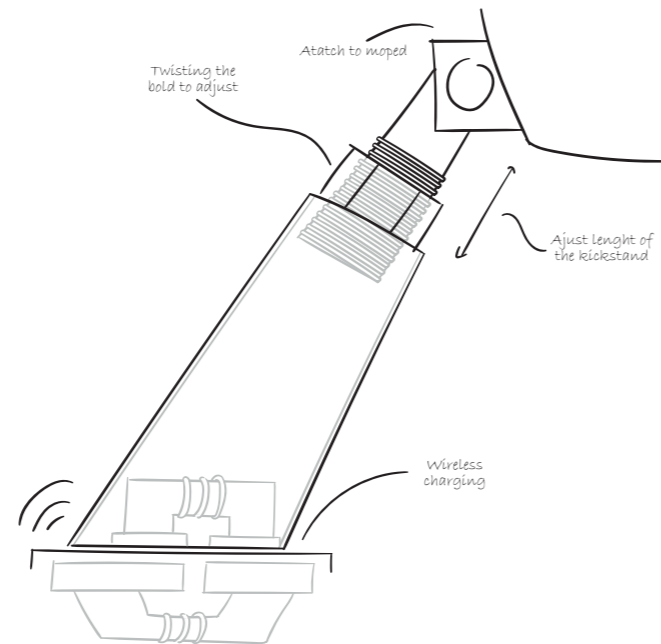
Figure 19: Morphological Chart



4.4 Concepts

4.4.1 Extendable Kickstand

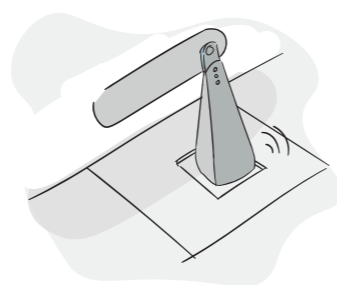
The extendable kickstand is also a variation on the TILER Charge e-bike charger kickstand. However, all models of mopeds have different dimensions which makes it impossible to produce one kickstand for all. Therefore, to make a universal version of this concept, the kickstand needs to be adjustable in size. If the length of the kickstand is adjustable, it can be fit onto different models of mopeds as the angle in which these mopeds need to comply to can be adjusted.



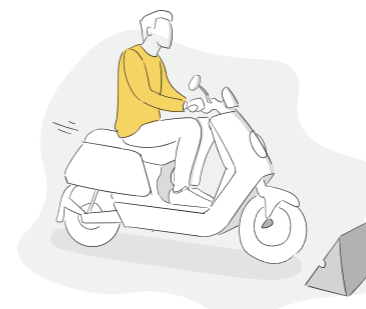
The user drives towards and over the tile



the user kicks out the kickstand on the tile



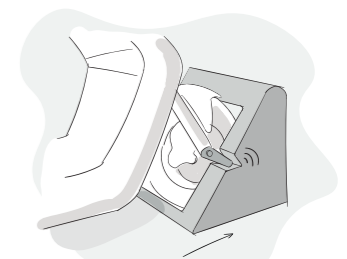
The kickstand wirelessly charges when parked



The user drives towards the moped rack



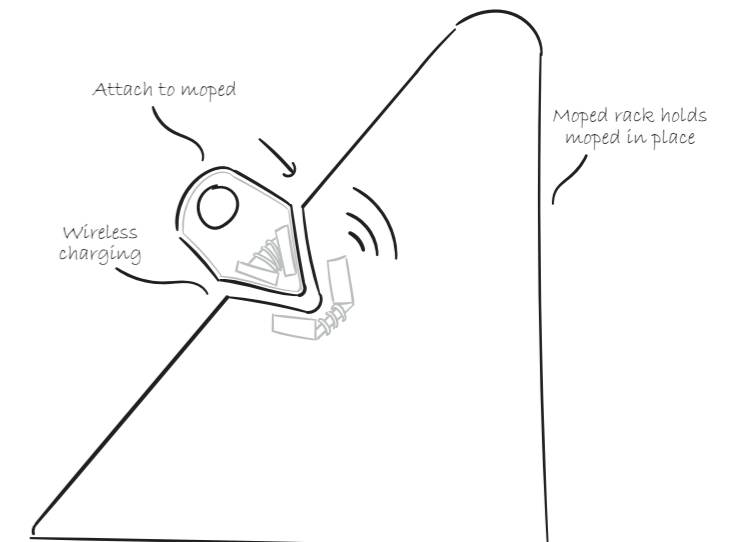
the user pushes the moped into the moped rack



The attachment on the wheel wirelessly connects

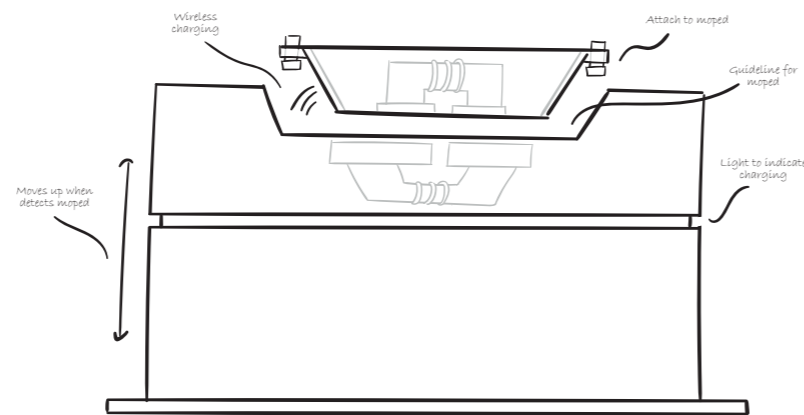
4.4.2 Moped Rack

The moped rack is inspired from existing bicycle charging docks. The moped will have an attachment on the front wheels. When the moped is parked in the moped rack, it will connect and wirelessly charge. Inductive charging can also be used for this concept, as the coil in the moped already aligns with the coil in the rack. The moped can be clamped into the rack and thus also serves as a stand.



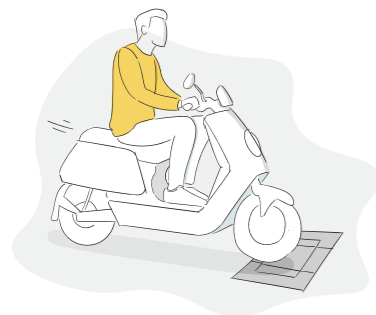
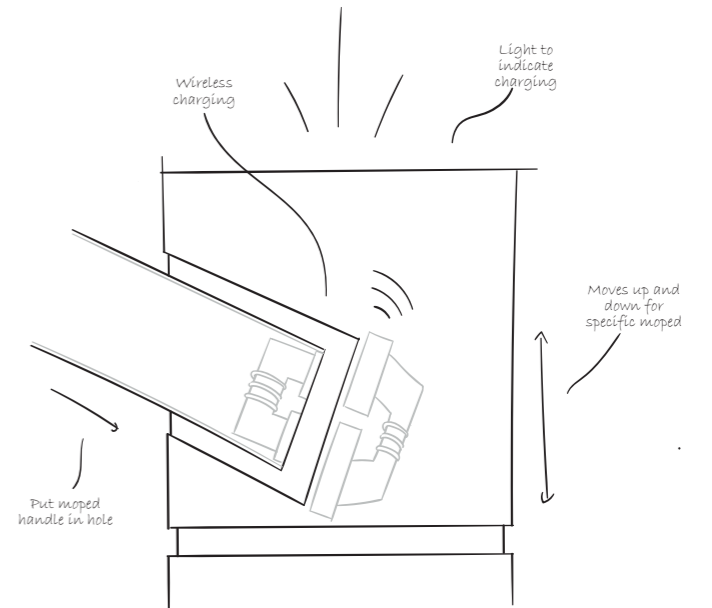
4.4.3 Under Body Charge

The under body charge is a wireless charger in the shape of a tile. The guidelines on the tile will guide the user to ride over it in the right direction. The tile will connect with the mopeds and get data on with brand and model the moped is. When the moped is parked on top of the tile (using the kick- or center stand) the tile will move upwards to the moped. The moped has a connector under the body. When the tile is in close proximity, the wireless charging will start. Moreover, because the tile knows which model the moped is, it will adjust in height to match the model.

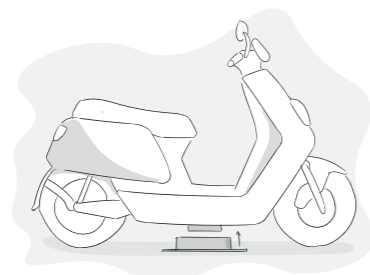


4.4.4 Pole Charger

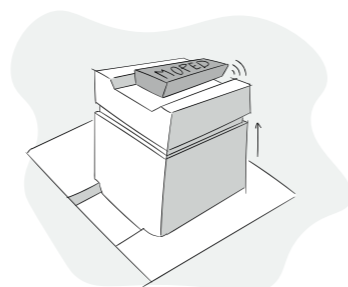
The pole charger is a wireless charger in the shape of a pole. It uses a different way of parking the moped. Users do not have to use the stands to park the moped, instead, they can simply 'lean' the moped against the pole. The pole has a hole for the handlebars of the moped. Inside the handlebars, electronics have been added to wirelessly charge through the handles. A light will give feedback that the moped is charging properly. When the user is in close proximity to the pole, the pole recognizes the model and adjusts in height. This way, the pole is universal.



The user drives over the charging tile with the moped



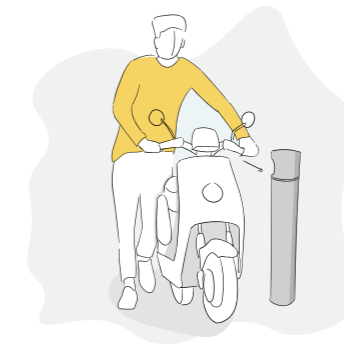
The user parks the moped directly over the tile



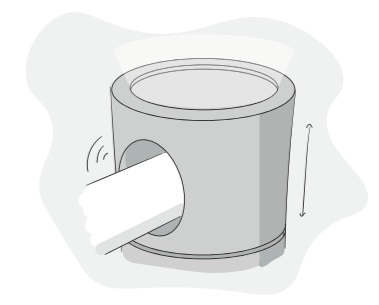
the tile will extend towards the moped to charge



The user drives towards the charging pole



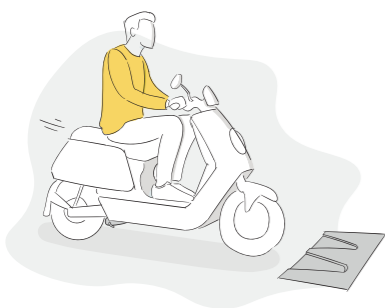
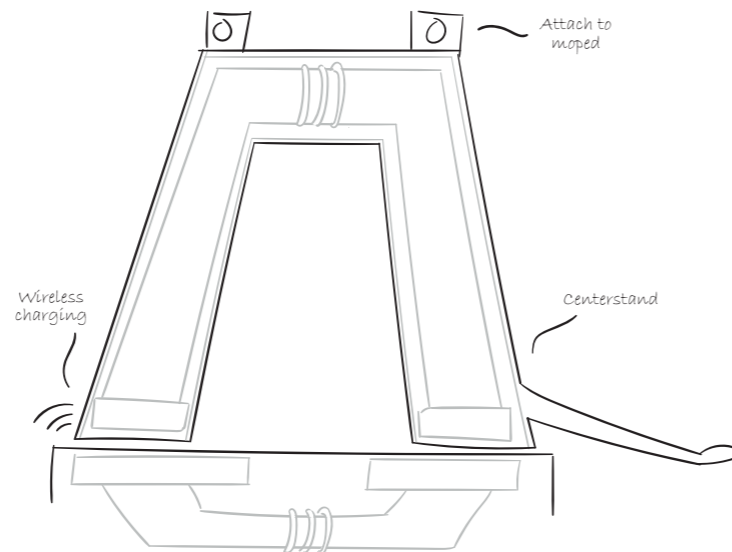
the users 'leans' the mopeds towards the pole



The handlebar is fitted in the pole to charge

4.4.5 Centerstand Charger

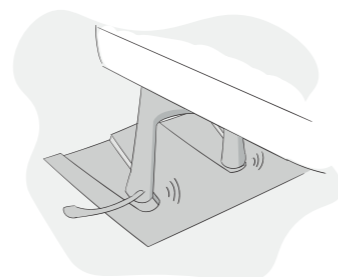
Finally, the center stand charger. This is also inspired by one of the first prototypes of TILER. Moped users often also use the center stand. Also, they are less prone to breaking. One issue people could have with the center stand is the precision with which they can park. Therefore, guidelines on the tile are added. The user can then push the stand into the right spot and tilt the weight of the moped over it. The guidelines will also help the user to tilt the moped, as it will clamp behind the guidelines.



The user drives towards the charging tile



the user will kick out the centerstand above the tile



The centerstand wirelessly charges with the tile

4.5 Idea Selection

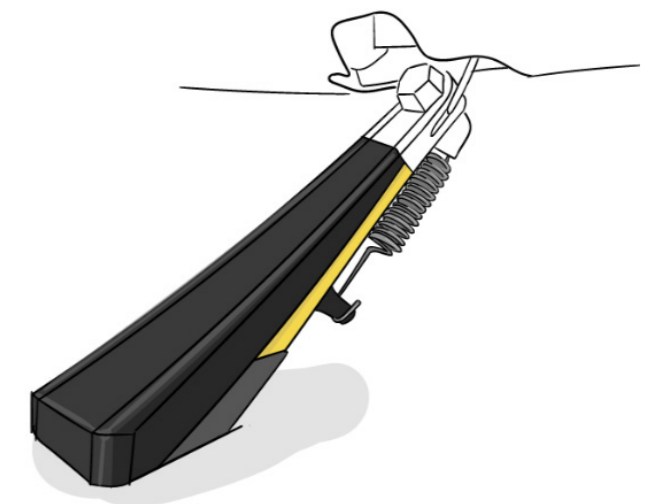
The best possible solution was selected after generating multiple concepts. The concepts were tested against a set of wishes. These wishes were created as boundary constraints. Using the weighted objective method, one concept is chosen. This method focuses on the principle of integrating the subjective weights based on my experience in the field and the information gathered for the criteria (Boeijen, van et al., 2017). The following wishes were set and given a weight:

- W1:** The design should have a high ease of use, low effort (20)
- W2:** Does not be an obstruction in the current infrastructure (15)
- W3:** The design should be a tile and kickstand (wish from TILER) (15)
- W4:** Use of product in the indoor environment should be possible (12)
- W5:** The product cost will be as low as possible (12)
- W6:** Low risk of breaking (12)
- W7:** Takes up little space in the environment (8)
- W8:** Low risk of vandalism/theft (6)

The most important wish is the usability of the product. It should be easy for the user to understand and also easy to operate. Operating the product should not require too much effort to make sure the moped is charging correctly every

time and not creating the risk of users to wrongly charge the moped. Furthermore, from research into cities (Chapter 2.2), it became clear that municipalities are focussing on cleaning their cities and making them more livable. Also, looking at the company TILER, they wish to create a seamless charging network for all light electric vehicles using the same tile. Therefore it is also important to take their wish into account as they will eventually manufacture the product (Chapter 2.5). Moreover, their current charging solution for e-bikes also makes it possible to integrate into indoor environments which is important as not everywhere it is possible to put a tile into the ground. Lastly, it is important that the product has a large lifespan and will not easily be stolen or vandalized.

Each concept is tested by giving a weight to each wish. Afterward, the scores are added up and one idea came out as the most promising: an extendable kickstand for electric mopeds. In Appendix 6 the total overview and reasoning behind the given scores is shown. In the next stage of the project, this idea is developed and tested further.



CHAPTER FIVE

FINALIZE

This chapter introduces the final design of the product. It goes into depth on the context in which it will be used, how the product will be made, and how much it will cost.

- 5.1 Storyboard
- 5.2 Design Vision
- 5.3 Design Overview
- 5.4 Design in Context
- 5.5 Shape and Aesthetics
- 5.6 Kickstand Mechanisms
- 5.7 Embodiment Design
- 5.8 Electronics
- 5.9 Assembly of the Product
- 5.10 Estimated Cost Price



Introducing: **MICK**

Mick is a wireless charger for shared electric mopeds. The charging solution provides an easy way of charging the batteries without taking them out. The product consists of a kickstand mounted to the moped and a tile that can be installed in the ground. With Mick, TILER creates a charging network for electric bikes and mopeds as the same tiles can be used. By using induction charging, the need for separate charging cabinets or battery swapping disappears: mopeds are charged through the pavement simply by parking

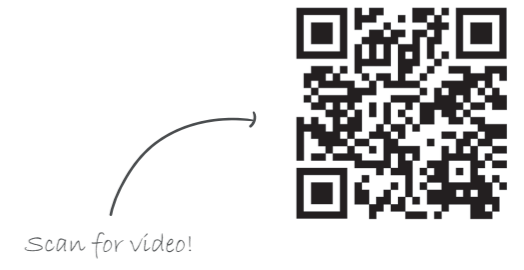
them on the charger. The product is designed to be able to be mounted on different models of mopeds to make it universal. This is not only valuable for TILER, but also more understandable for the users as each shared moped provider can use the same way of charging.



Figure 20: Render of final design

Storyboard

Renting the moped



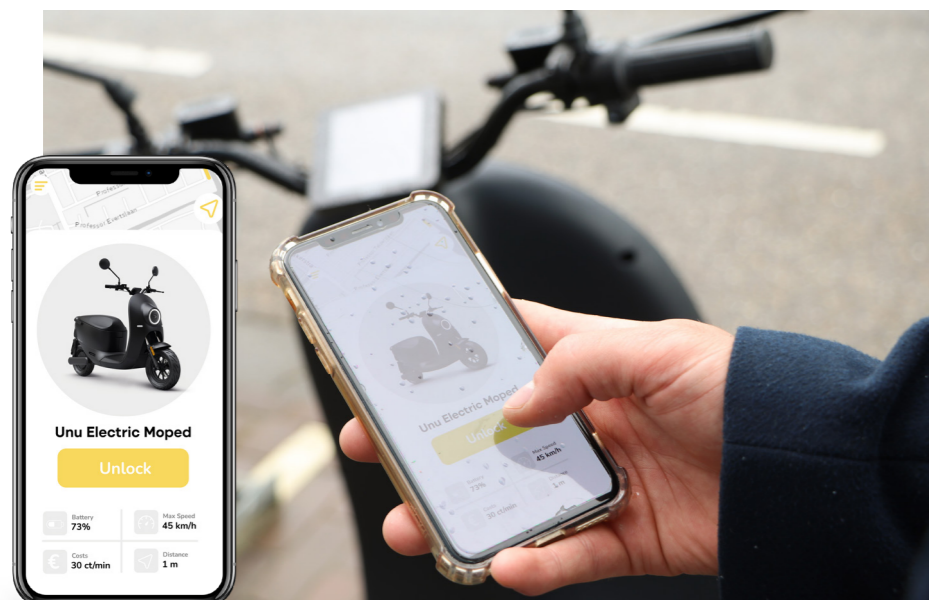
At first the users will open up an application of the shared moped providers to locate a closeby moped to rent.



Inside the application, the users receives information about the moped and can reserve their preferred one.



The user will walk towards their reserved moped. When in close proximity, the user will open up the application again.



When arrived, the user can now unlock the moped inside the application.



After unlocking the moped, the user will take a seat on the moped and kick in the kickstand using their foot.



Now the user can drive away with a fully charged moped to their preferred destination!

Returning the moped



After using the moped, the user will return the moped to a hub location with the charging tiles.



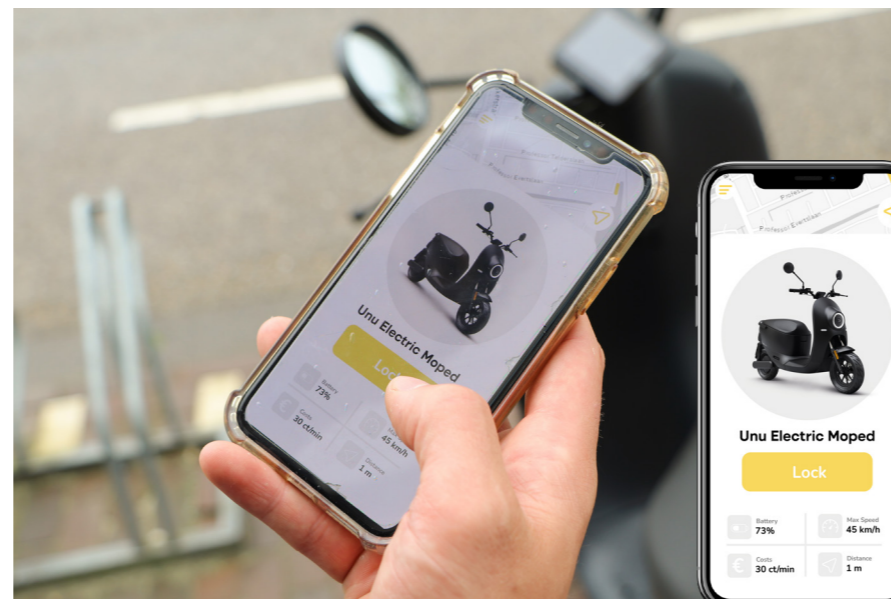
The user will drive over the tile and kick out the kickstand to place it on the yellow square.



The light in the tile gives the user the indication that the moped is parked correctly and currently charging.



After correctly parking the moped, the user will open up their application again.



Only when parked correctly, the user can lock the moped inside the application.



After locking the moped, the user can walk away. The moped is now charging for its next ride!

5.2 Design Vision

The design vision created in Chapter 3 was concluded from three essential factors: convenience, environment, and universal. These factors have been tackled during the design process.

Convenience

The new kickstand for electric mopeds eliminates the need to take the batteries out of the moped to charge them. Currently, shared moped providers execute a system with battery swappers, which is more prone to human error. This can result in poor handling of the batteries and, therefore, a higher chance of batteries breaking. This new charging system removed this part of the charging process and enhanced the mopeds' battery life. Moreover, this new charging method introduces a new interaction with the moped. The charging issues that providers of shared mopeds experience are solved by introducing 'parking equals charging'. This not only enhances the battery life of the mopeds but also reduces the costs of regulating a battery swapping service. There is no longer any need for providers to actively manage charging thanks to the fully automated process. Instead, simply positioning the moped in the proper location will do. The convenience of the users is not interrupted by this new concept. Charging the mopeds requires no extra steps for the users. They simply

park and at once charge the mopeds. This results in mopeds that are always charged when someone wants to use one.

Environment

The new charging solution maintains the cleanliness of the street. Users must park their mopeds on authorized tiles, and thus the parking of mopeds can be monitored by municipalities. This eliminates the nuance produced by free-floating and offers a more aesthetically pleasing city perspective because the mopeds are neatly parked next to each other. There is no hindrance to the city view while the mopeds are in use and not parked on the tile. Since the tiles are flush with the pavement, they do not contribute to the surroundings or block the surrounding scenery.

Universality

The final design is intended to accommodate a variety of moped models and can be altered to fit different mopeds. It is important to have a universal kickstand to make it understandable for the user. This also contributes to the ease of use of the charging solution as the users do not have to use different ways of charging between different types of mopeds. Also, this new charging solution can create a charging network with all light electric vehicles.

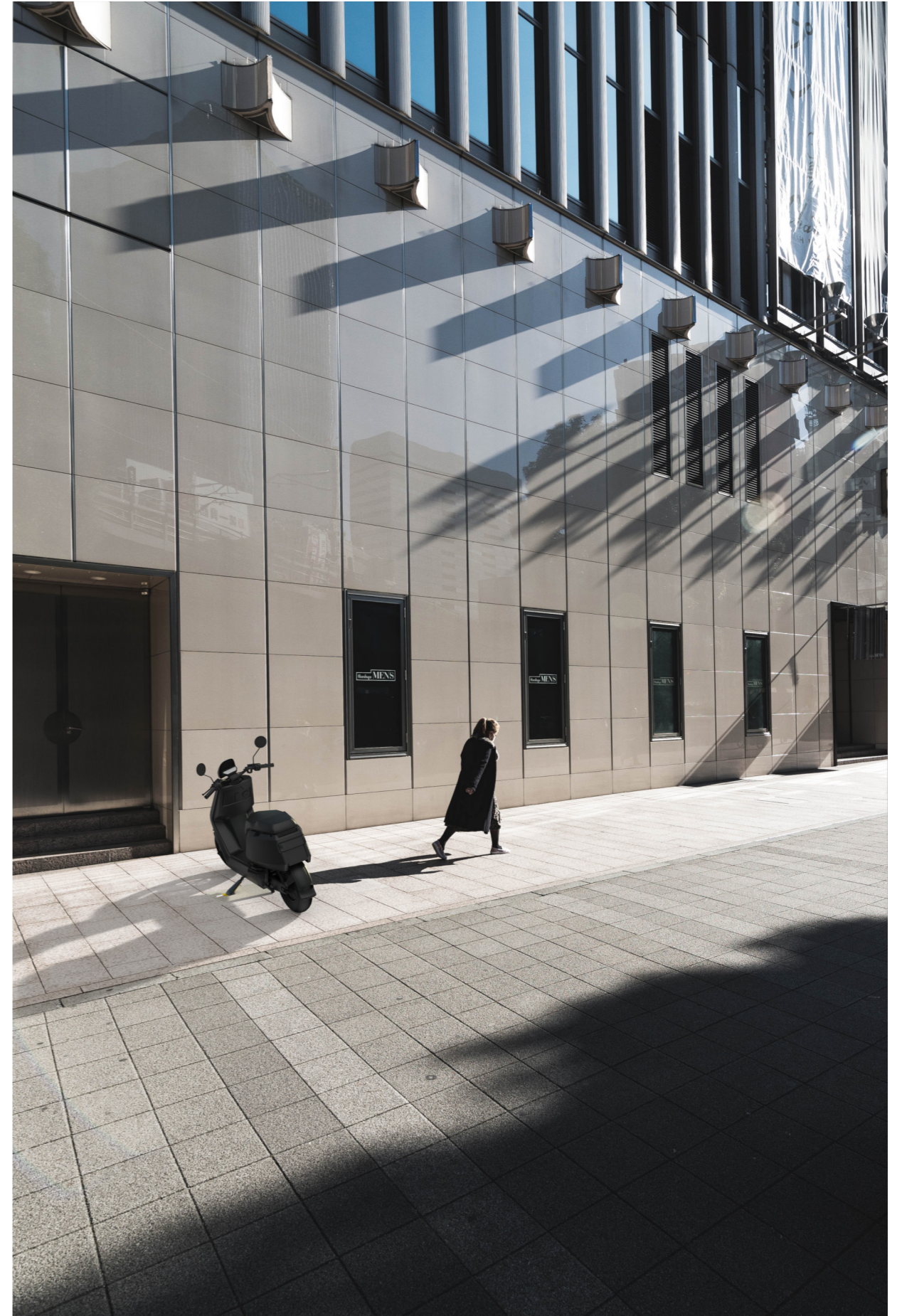


Figure 21: Render of moped in context

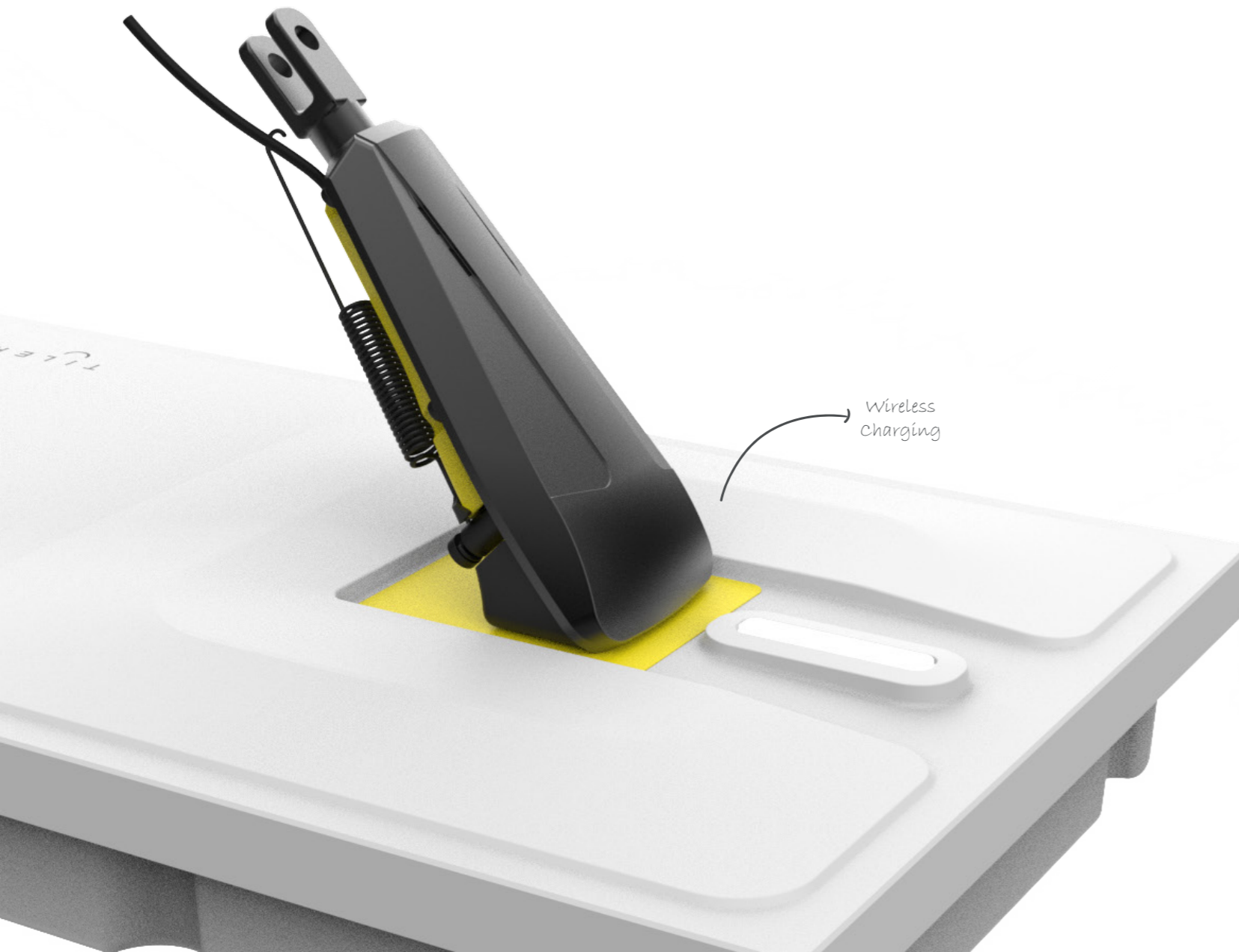
5.3 Design Overview

The final design developed during this project is the new kickstand for electric mopeds. This kickstand can also work with the already existing TILER tile.

This, therefore, creates a whole charging network with different light electric vehicles. The design of the

current tiles is not changed as not enough research into the usability of this tile has been done during this project.

In this overview, a few important factors of Mick are addressed. A closer look at the kickstand is given with its key features. In the following chapter, more features are explained in depth.



Wireless Charging

The moped is charged using wireless charging. By placing the kickstand on the tile, the moped immediately begins to charge. When the kickstand is placed on the tile, a current is passed through the coils inside the kickstand and tile. For the inductive charging to work, the coils need to be aligned. Therefore, an indent and yellow square on the tile guides the user to place the kickstand in the right location. When the moped is parked correctly, a light next to this square provides feedback to the user.

Outside Proof

Because Mick is mainly used outside, Mick must withstand outside environments. Therefore, to realize a waterproof fit around the kickstand, the plastic cover ensures a snug, watertight fit. The embossed ridge on the aluminum housing creates a seal with the plastic housing, preventing rainwater from protruding. The electronics are sealed off in a separate compartment to create resistance against immersion. The cable gland transfers the cables while ensuring the electronics are sealed off.

Design for Repairability

To replace broken or damaged parts inside the kickstand, it is important that they can easily be accessed. The kickstand is simply opened by removing the mechanical fasteners for inside access in case of failed hardware or other issues. The foot is replaceable in case of wear. The plastic foot acts as a barrier between the housing and the ground. It is assumed that frequently parking the heavy moped wears out the feet over time, necessitating the replacement of these components over time.

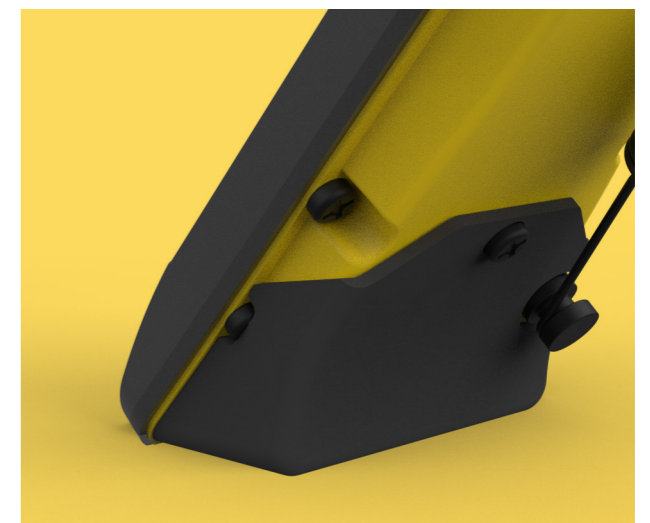
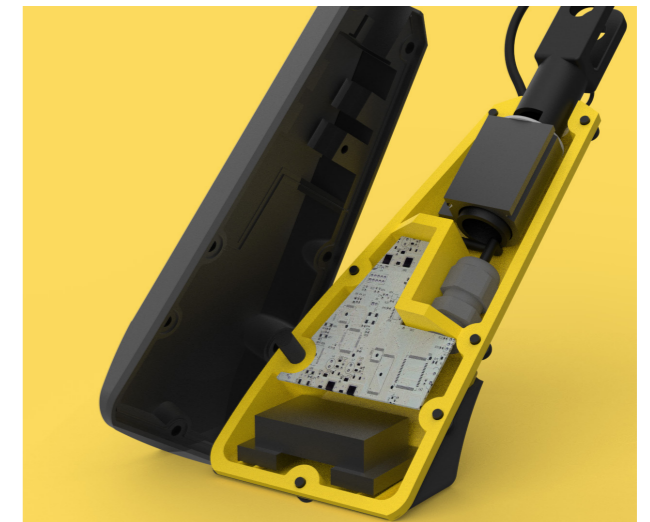
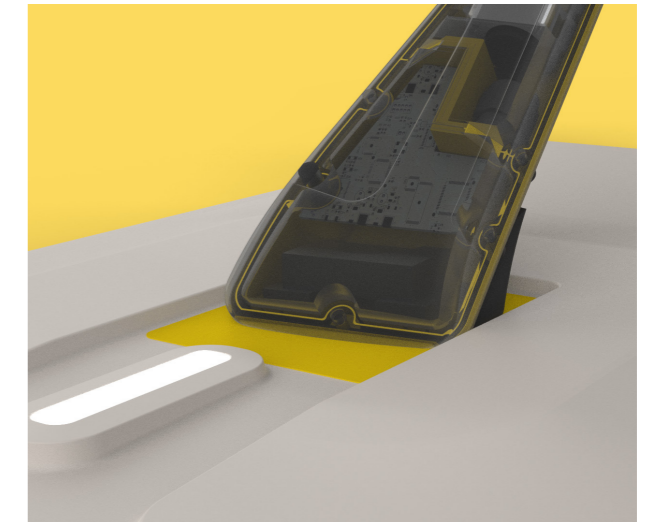


Figure 22: Close-up renderings

5.4 Design in Context

5.4.1 Mobility Hubs

Instead of the free-floating system shared moped providers use now, fixed parking locations will be added around the city. These parking locations provide the 'park and charge' service. Instead of, for instance, using a car, people can use the electric mopeds for short-haul drives. After using it, they can simply park near their end location. Thus these shared mopeds can reduce cars in cities by providing a convenient alternative mode of transportation for short trips. People with access to shared mopeds are less likely to use their own cars for short trips, such as running errands or commuting to work. This can reduce the number of cars on the road, reducing traffic congestion, air pollution, and carbon emissions. Shared mopeds also occupy less space than cars, making them a more efficient use of urban space. They can be parked in designated areas or on the street, freeing up parking spaces that individual cars would otherwise occupy.

Battery information is transferred between the kickstand and the tile. The charger can be monitored remotely by the hub manager. The cloud connection in the tile enables fleet management systems to automatically alert the driver responsible for parking in case of a mishap by sending alerts through a smartphone application. Also, hub managers can be alerted in case of a malfunctioning charger or an incorrectly parked moped. Remote monitoring is necessary to avoid empty batteries at inconvenient moments, especially in unsupervised hubs.

5.4.2 Stakeholders

Municipalities want to integrate fixed parking for shared mopeds in city centers instead of the free-floating system. The main reason is the nuisance created by the haphazardly parked mopeds. When switching to fixed parking, the way of charging will be different. A big advantage that Mick has over battery swapping is the lower costs on the operational side. Less staff and other parts of this system, such as vans, storage locations, etc., are needed to swap the batteries constantly. However, Mick still needs partial workers for the maintenance of the mopeds. The tiles can send a message when a moped is parked incorrectly or has technical problems. Someone will have to check the charging locations and address any damage. The entry costs for this system will be higher because of the investments needed for the tiles and kickstands. Still, the operational costs will be much lower (J. Koudijs, personal communication).

A charging network has to be integrated into the cities to facilitate this way of charging (figure 23). Investments of stakeholders need to be made to develop this network further. In the past years, the government mainly financed the installation of chargers. But since the Dutch government has stated that installing charging infrastructure is a market activity, the business case should be profitable RVO (2017). Thus shared moped providers, such as Check and Felyx, will be mainly responsible for providing this system.

Also, as EV adoption increases, the electricity demand increases. The Moped batteries need to be charged, and this can have an impact on the electricity grid. So-called 'smart' charging determines when the EV charges or returns energy to the grid. To develop a new charging infrastructure using the tiles, the costs of upgrading the grid because of increased peaks should be considered when determining the distribution of benefits and costs of both solutions (Eising et al., 2014).

To validate this scenario, interviews are done with Delft, Arnhem, and Nijmegen municipalities and shared moped providers Check and Felyx. Both parties are asked whether they are prepared to make these investments to offer a shared mobility network in the cities, further enlightened in Chapter 6: Evaluate.

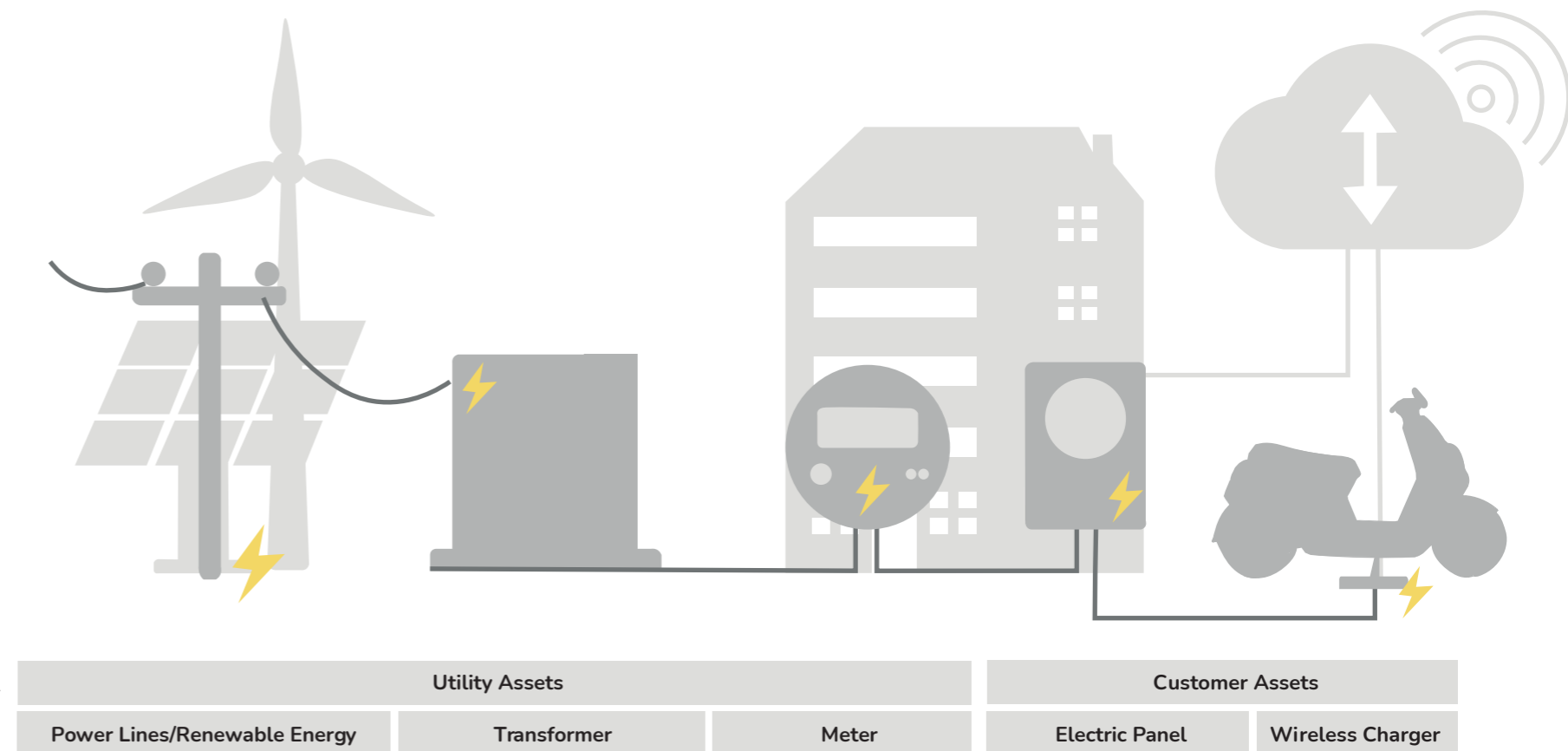


Figure 23: Charging network in cities

5.4.3 Instalation and Service

For the installation, no technician is required. The tiles are installed into the ground and connected to the closest power source. The location of the tiles can be determined by looking at the best parking spots for mopeds. The kickstand is assembled and installed in-house. Specific assembly manuals are created for different models of mopeds. The kickstand is attached to the pivot point on the moped. A spring is then attached to the kickstand and moped. Lastly, the electronics of the kickstand are connected to the battery of the moped.

5.4.4 Outside Environment Proof

With this watertight seal the product has an IP rating. An IP Rating (also known as an Ingress Protection Rating) shows the effectiveness of electrical enclosures in blocking foreign bodies such as dust, moisture, liquids, and accidental contact (Clarion Security Systems, 2022). The e-bike kickstand has IP69K and IP67 ratings (personal communication. Verwijmeren, T, 27-02-2023). The IP67 means that the enclosure is rated to be protected from immersion, but only at a depth of 1 meter and for 30 minutes. The IP69K rating means that the enclosed area is protected from total dust ingress and from steam-jet cleaning (Clarion Security Systems, 2022). These ratings are important as the kickstand is mainly used in outside environments and should be able to withstand (heavy) rain, dirt, and cleaning. The top section cannot be

sealed off as the axis needs to be able to rotate and therefore have no resistance. Therefore, it is decided to seal off the electronics and not the top section. Rain and dirt can enter this section through the hole for the axis. To prevent water from building up in the housing, slits on the aluminum and plastic housings are made to drain the water. Moreover, a sliding bearing is added to the axis to make sure the axis keeps working while small particles of dirt enter the mechanism. However, more details in the design of the rubber seal make sure that the product is watertight, for example, the distance between screw holes and the stiffness of the housing. For the development of this product, the current geometric of the e-bike kickstand is used. Thus, to determine if this product has the same IP rating, more testing needs to be done.

5.4.5 Safety

Temperature control is crucial for avoiding dangerous circumstances. When batteries are charged, heat is produced, thus, it is important to control the temperature to lower the risk of fire and early deterioration. The moped, the battery's state of charge, and the battery temperature can all be communicated by the tile to the hub manager. Temperatures beyond a given threshold can be avoided to prevent fire by momentarily reducing the voltage and amperage. This method is already used in the current charger and, as may be inferred from the criteria, is as crucial in electric mopeds.

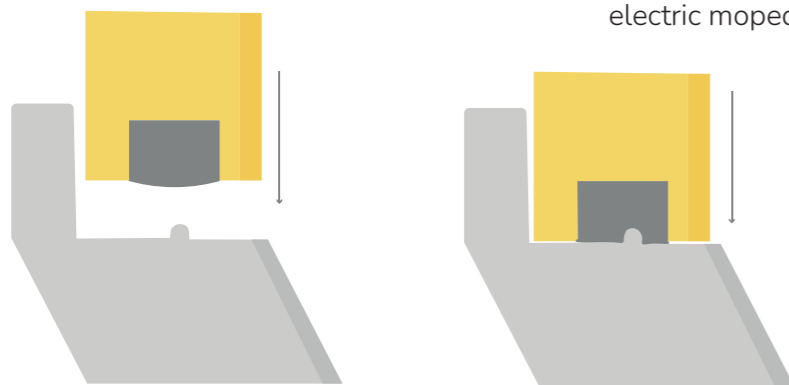


Figure 24: Creating seal by pressing two parts together



Figure 25: Render of moped in context

Shape and Aesthetics

5.5.1 Appearance

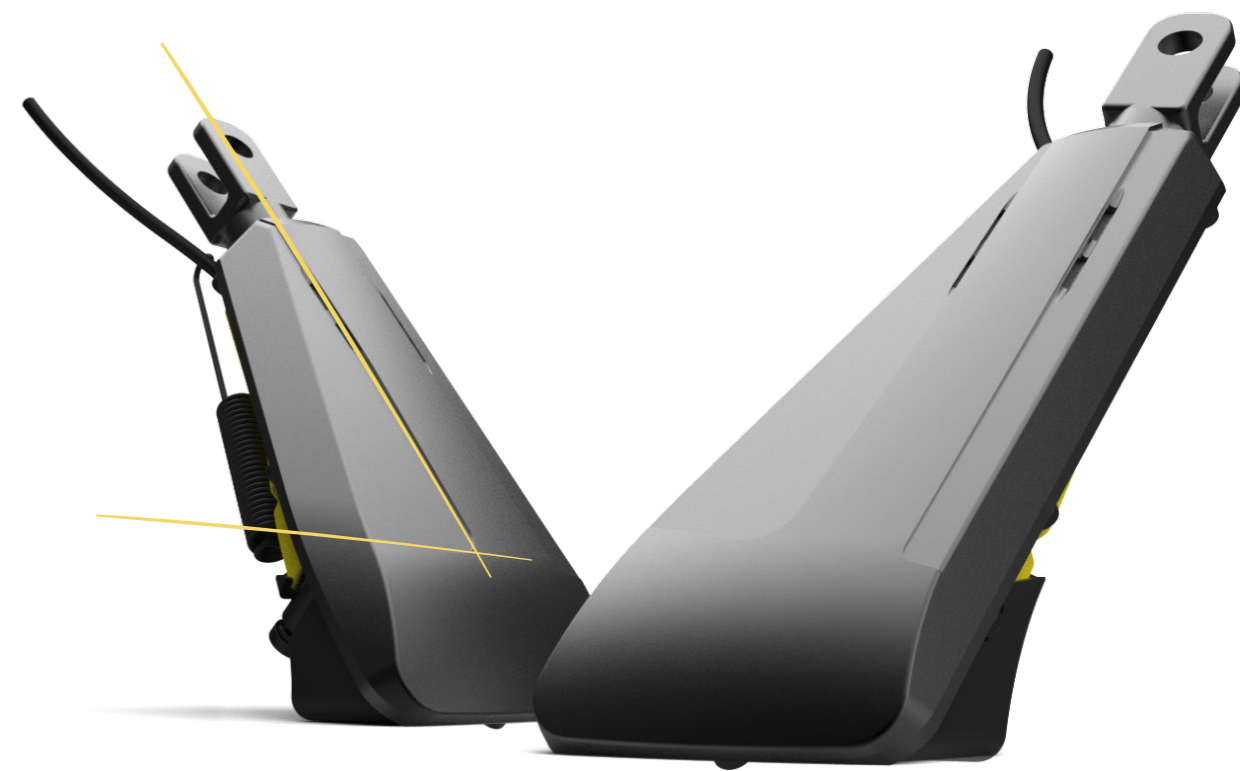
The kickstand is designed to fit with different types of mopeds. Therefore, the primary shape of the original kickstand is followed. However, to be able to fit all the electronics into the kickstand, the overall shape is larger. To make the kickstand visible smaller, lines and aesthetic adjustments have been made. The raised body along the middle makes the kickstand look optically slimmer than it is and the slanted sides insinuate a smaller overall frame. Moreover, lines on the front part of the kickstand have been added to make it more understandable for the user how the kickstand works.

5.5.2 Shape

The global shape of the charger is a result of the working principle of the kickstand that needs to stay the same, while the charging components - PCB and ferrite coil - need to be housed inside. Kickstands of different models of mopeds are all designed to fit their own model, thus looking all dissimilar. However, the kickstands all have similarities as the main working principle of the kickstand is the same for all. The geometry of the charger is chosen to retain the original pivot point of the kickstand with the ground, to make sure the moped stays upright while parking, so it cannot tip over and fall. The new

kickstand design retains the original point of support with the ground, guaranteeing a stable parked moped.

The original functionality of the kickstand is therefore kept unchanged with the addition of the charger accessory.



5.5.3 Personalizable

The kickstand is designed to work together with sharing fleets to offer easy charging solutions. Each moped from each service has a different look. Therefore, the kickstand can be personalized to fit each brand of sharing fleet. The overall look and feel will remain the same, however, the colored plastic housing can be changed to fit the brand. For example, if the moped is green, the housing can also be green to match the moped. This creates a unity with the moped, but it remains recognizable as the same charging solution with the different providers.

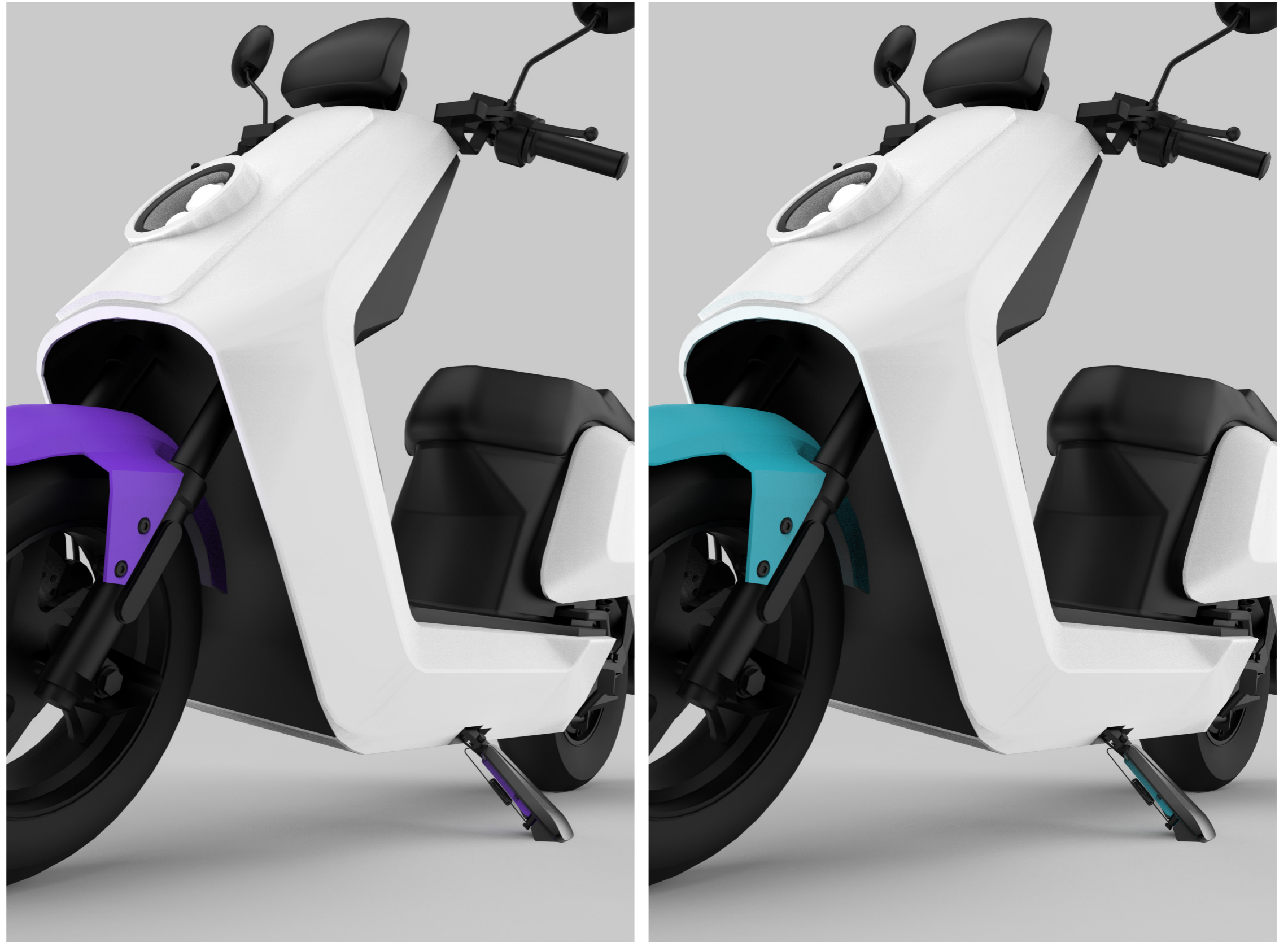


Figure 28: Render example personalizable

Figure 29: Pictures of final prototype in use



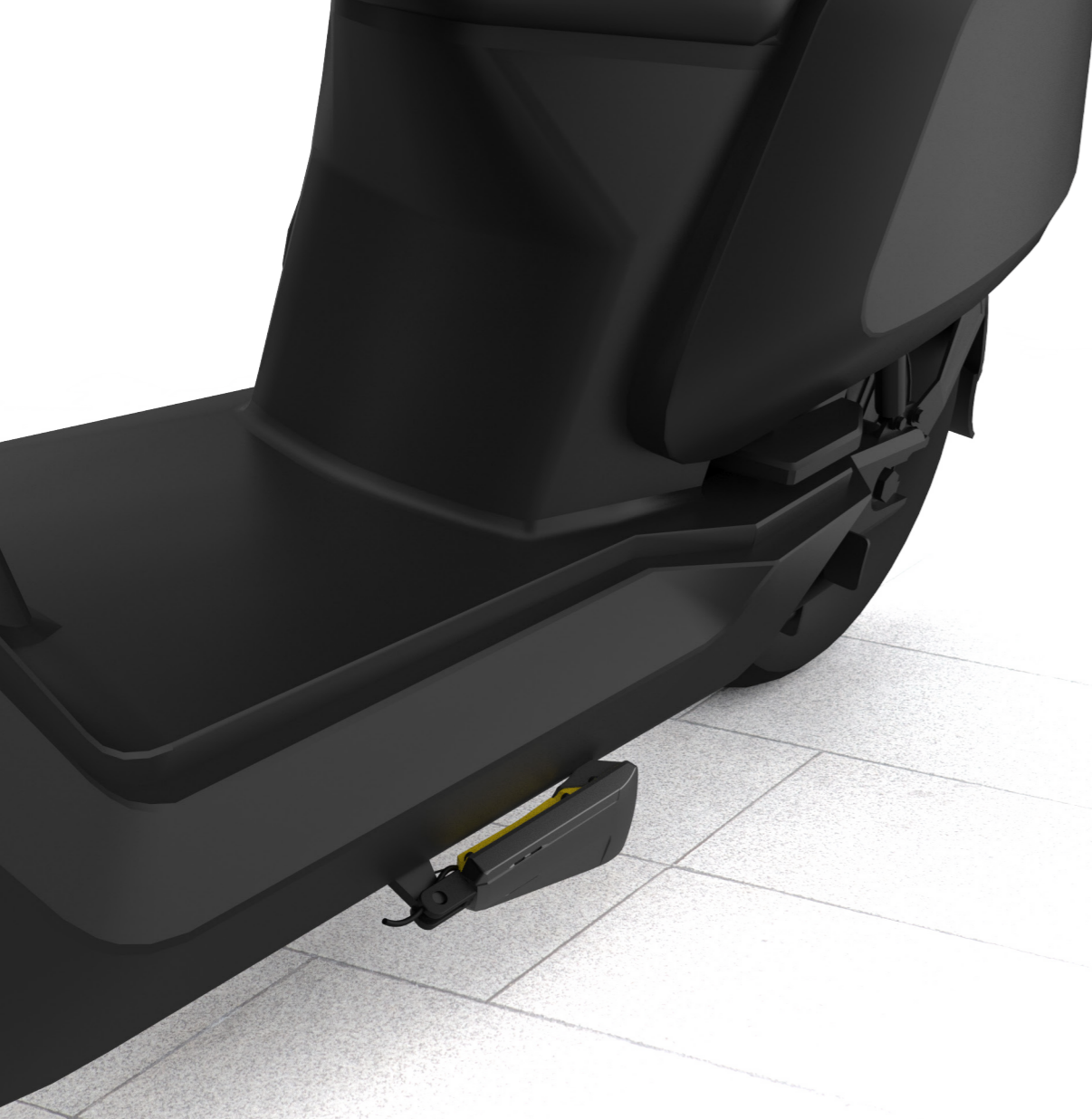


Figure 30: Render kickstand

Kickstand Mechanisms

The mechanism of a kickstand for a moped is typically quite simple. It consists of a metal leg that can be kicked out from the frame of the moped to provide support when the vehicle is parked. The leg is attached to the frame with a mounting bracket welded to the frame. The kickstand mechanism typically includes a locking mechanism using a spring

that keeps the kickstand in place when deployed, preventing it from collapsing while the moped is parked. To deploy the kickstand, the rider uses a lever located near the footrest. This lever is attached to the kickstand mechanism, allowing the rider to deploy or retract the kickstand with a simple foot flick. When not in use, the kickstand can be retracted by pushing it up with the foot. The kickstand has a spring-loaded mechanism that retracts and keeps the kickstand in place.

5.6.1 Rotating Mechanism

Shared moped providers use already existing mopeds to provide their service. Therefore, the design of the moped cannot be changed. Thus the new design of the kickstand has to be placed on the current pivot point on the moped. Therefore, the main mechanism of how a kickstand works is integrated into the new kickstand. However, a problem that occurred while designing the new kickstand was the alignment of the coil with the tile. The way of attaching the kickstand to the moped is fixed as it was not wanted to change the design of the moped itself. Therefore, the angle at which the kickstand is kicked in and out is already determined. After creating and testing the first 3D-printed prototypes, it became clear that the coil did not align with the tile when folded out. When aligning the coil correctly, the kickstand sticks out too much (figure 31). Therefore, a rotating mechanism was created to solve this problem. This rotating mechanism ensures that when the kickstand is folded out, the coil is aligned, and when the kickstand is folded in, the kickstand is flush with the body of the moped and, thus, not in the way of the legs of the user.

The mechanism is explained in the following pages, and the components of the mechanism are further enlightened in Chapter 5.7: Embodiment Design.



Figure 31: Pictures kickstand sticking out

Rotating Mechanism

The rod which is connected to the moped has a circular shape. The universal part of the kickstand can rotate around this rod. This part is pulled by a spring to the right position. Within the aluminum housing, a stop mechanism is added to make sure the kickstand does not rotate more than needed. Figure 32 explains this mechanism in steps.

1. The kickstand is flush on the side of the moped when kicked in. The spring will create tension and pull on the side of the body.
2. The rider will use their foot to kick out the kickstand by exerting force on the kickstand.
3. When the rider kicks the kickstand out, they are overcoming the force of the spring's tension, which is trying to keep the kickstand in its stored position against the side of the moped.
4. At this point, the kickstand will rotate around the shaft toward its parked position. This is happening because the spring is still creating tension, so the kickstand is rotated towards its position with the least tension.
5. After kicking out the kickstand, it is still not completely rotated to its preferred position. When adding the weight of the moped onto the kickstand when parking, the kickstand will rotate further to its flattest position and thus rotate into place.
6. Once the rider has kicked the kickstand out to its fully extended position, the tension in the spring will decrease to its lowest point. The kickstand is now completely rotated, and the moped is parked stable on the kickstand.



5.6.2 Angle of Moped Parked

A moped kickstand should be positioned at an angle that allows the vehicle to remain stable and upright, without the risk of it tipping over. The European directive states that kickstands need to be able to hold a moped on a transverse tilt at an angle of six degrees. To test if the kickstand complies with this directive, mopeds are put on a platform that can be tilted. The vehicle must remain stable when the parking platform is tilted by each of the required amounts and the requirements have duly been met (EUR-Lex - 32009L0078 - EN - EUR-Lex, n.d.).

The height of the mounting piece on the frame of the moped is already determined by its design. For example, the height of the piece of the Unu moped - when put on the kickstand - is 120 mm (Appendix 8). This directive is, therefore, the determining factor for the length of the kickstand. For the moped to be tilted with a maximum of six degrees when put on a kickstand, the kickstand will have an angle of 45 degrees with a length of 170 mm, to remain stable.

5.6.3 Spring Loaded

The spring on the backside of the moped has multiple functions.

- The spring needs to be able to carry the weight of the kickstand when not in use.
- The spring needs to be able to overcome its tension point when kicked out.
- The spring needs to be able to rotate the kickstand to make sure that the kickstand is flush with the moped when not in use.

- The spring needs to exert enough tension on the kickstand to act as a shock demper when riding the moped - for instance - on bumpy roads.

The kickstand has a spring-loaded mechanism that makes it simple for the rider to raise and lower it as needed (figure 33). The spring contracts when the kickstand is lowered and expands as the kickstand is raised, lifting the kickstand and freeing the way (Kopernik, 1984). The current springs on the moped kickstand are already designed to follow these requirements. However, the new charging kickstand has a bigger weight than the current kickstand. Therefore, calculations have been made to investigate the need for a stronger spring with a higher tension (Appendix 11). Also, the connection point for the spring on the new kickstand has a lower position. Thus the spring also needs to be longer.

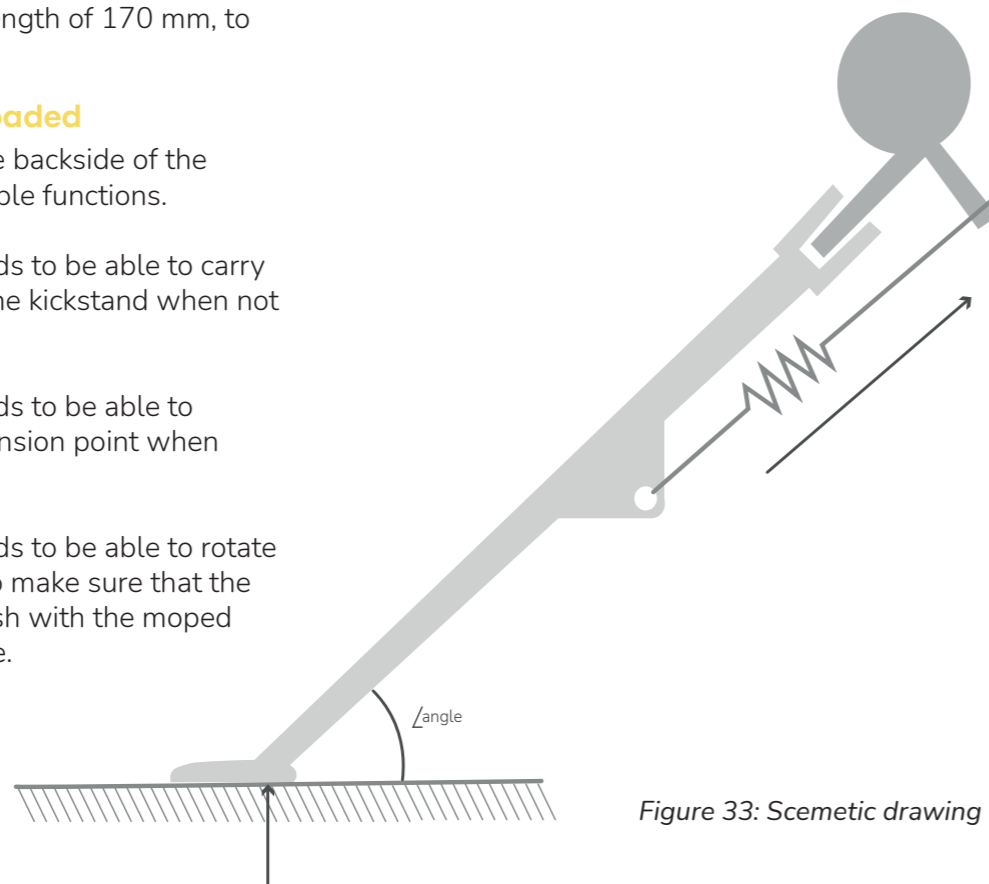


Figure 33: Schematic drawing

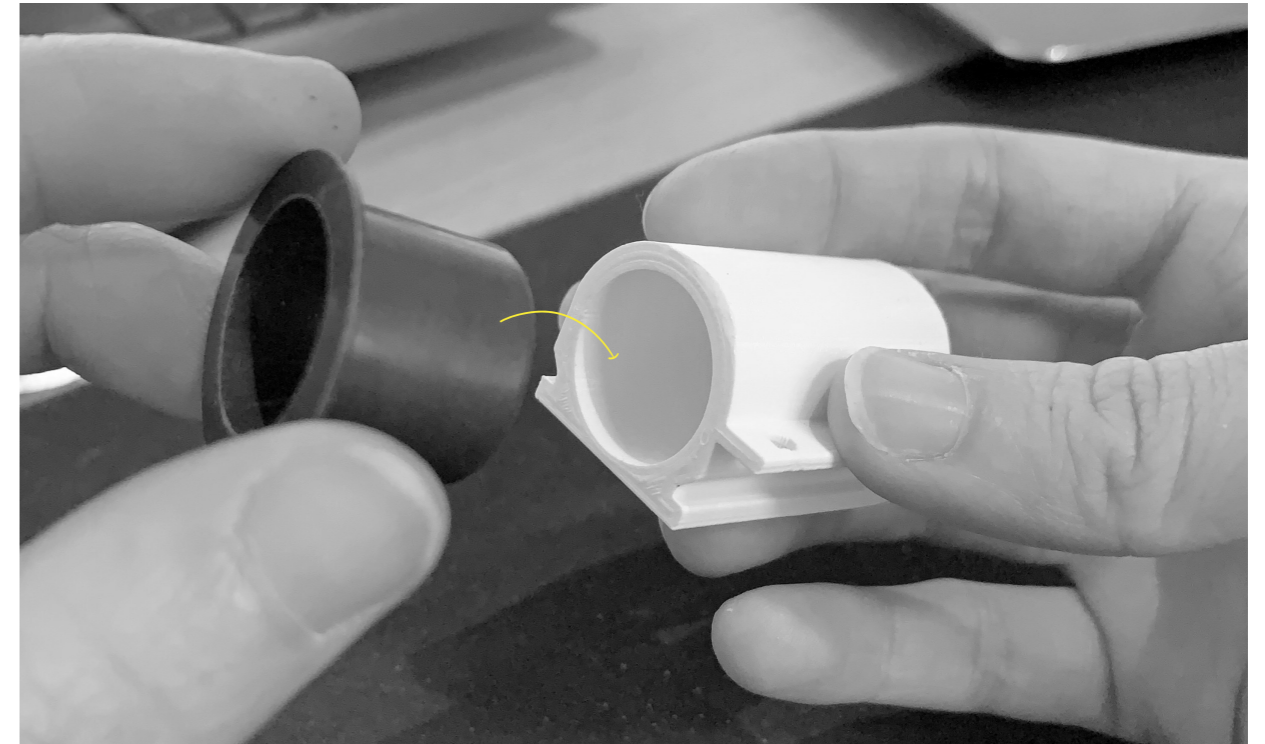


Figure 34: Sliding bearing in profile

5.6.4 Sliding Bearing

Inside the aluminum housing, a sliding bearing is placed (figure 34) for multiple reasons. Sliding bearings are bearings that only generate sliding friction. The shaft is positioned in between the sliding surface to facilitate sliding movement. Sliding bearings are lightweight and have a long operating life while introducing minimal vibrations or noise. The bearing ensures that the load between a stationary part (the shaft) and the rotating part (universal kickstand) acts with minimal friction. Sliding bearings have the ability to support large loads while rotating at high speeds. However, damage may occur over time if a sliding bearing is subjected to a force load. Force load may develop when the bearing is pushed or pulled perpendicular to its intended direction of motion. As a result, the bearing may eventually fail due to uneven wear. It is crucial to ensure a sliding bearing does not experience force load to prevent damage. This can be accomplished by properly aligning the bearing and

shaft and ensuring the bearing is secured firmly (Neita Techniek B.V., 2023). The bearing in the wireless charging kickstand is not experiencing high force load, as the moped's weight - and thus force - is transferred to the aluminum housing. The sliding bearing used in this product will be a PTFE sliding bearing. These bearings are self-lubricating, maintenance-free, and have a high load capacity and, therefore, a good fit within this design (THN, 2021).

Figure 35: Kickstand in context render



5.7 Embodiment Design

The final design of the kickstand has gone through multiple ideation and prototyping phases (Appendix 9).

The design has been optimized by testing 3D-printed models and adjusting them when needed (figure 36). The starting point of designing this kickstand for mopeds was the current design of

the kickstand for electric bikes from TILER.

TILER wants to create a charging network for all small electric vehicles, such as electric bikes, mopeds, and cargo bikes. Therefore, it is important to make the product recognizable as a TILER product to clarify usability for users.



Figure 36: Different 3D-printed models

The kickstand consists of two parts: a universal part and a connection piece for the mounting on the moped (figure 37). As seen in Appendix 7, mopeds differ in size, weight, and design. Kickstands are designed for a specific brand and model moped and therefore differ in length and mounting technique. To reduce the costs of making a whole different kickstand for the different kinds of mopeds, the kickstand is thus divided into two parts.

The universal part houses the electronics to charge the moped. The connection piece is designed to be able to fit different mopeds.



Figure 37: Render inside product

Figure 38: Picture final prototype



Parts Overview

The total product consists out of 13 parts. Some parts (1, 4, 5, 6, 7, 12, 11, 13) are designed in-house and manufactured elsewhere. Other parts (2, 3, 8, 9, 10) are bought-in parts. In figure 39, an overview of all the parts is shown. This overview is made to showcase each individual part in this design. For each parts that is designed during this project, a technical drawing is made. Please note that the technical drawings I have provided are not

examined and should be used for reference only. These drawings are detailed, precise plans that convey information about how an object functions or is constructed.

Appendix 10 shows the final technical drawing packing, which can be sent to the manufacturer. Each part has a specific design, furthermore explained in the following sub-chapters.

Nmbr	Name	Material	Qnty	Type	Page Number
1	Steel Shaft	Alloy Steel	1	In house	p. 103
2	Sliding Bearing	PTFE	1	Buy-in	
3	Cable	-	1	Buy-in	
4	Plastic Housing	ABS	1	In house	p. 105
5	Spring Axis	Alloy Steel	1	In house	
6	Spring	Alloy Steel	1	Buy-in	
7	Plastic Foot	HDPE	1	In house	p. 107
8	Srews	Alloy Steel	6	Buy-in	
9	Coil	-	1	Buy-in	
10	Cable Glant	PA	1	Buy-in	
11	PCB	-	1	In house	
12	Aluminium Profile	Aluminium	1	In house	p. 101
13	Aluminium Housing	Aluminium	1	In house	p. 98

Table 1: Parts overview

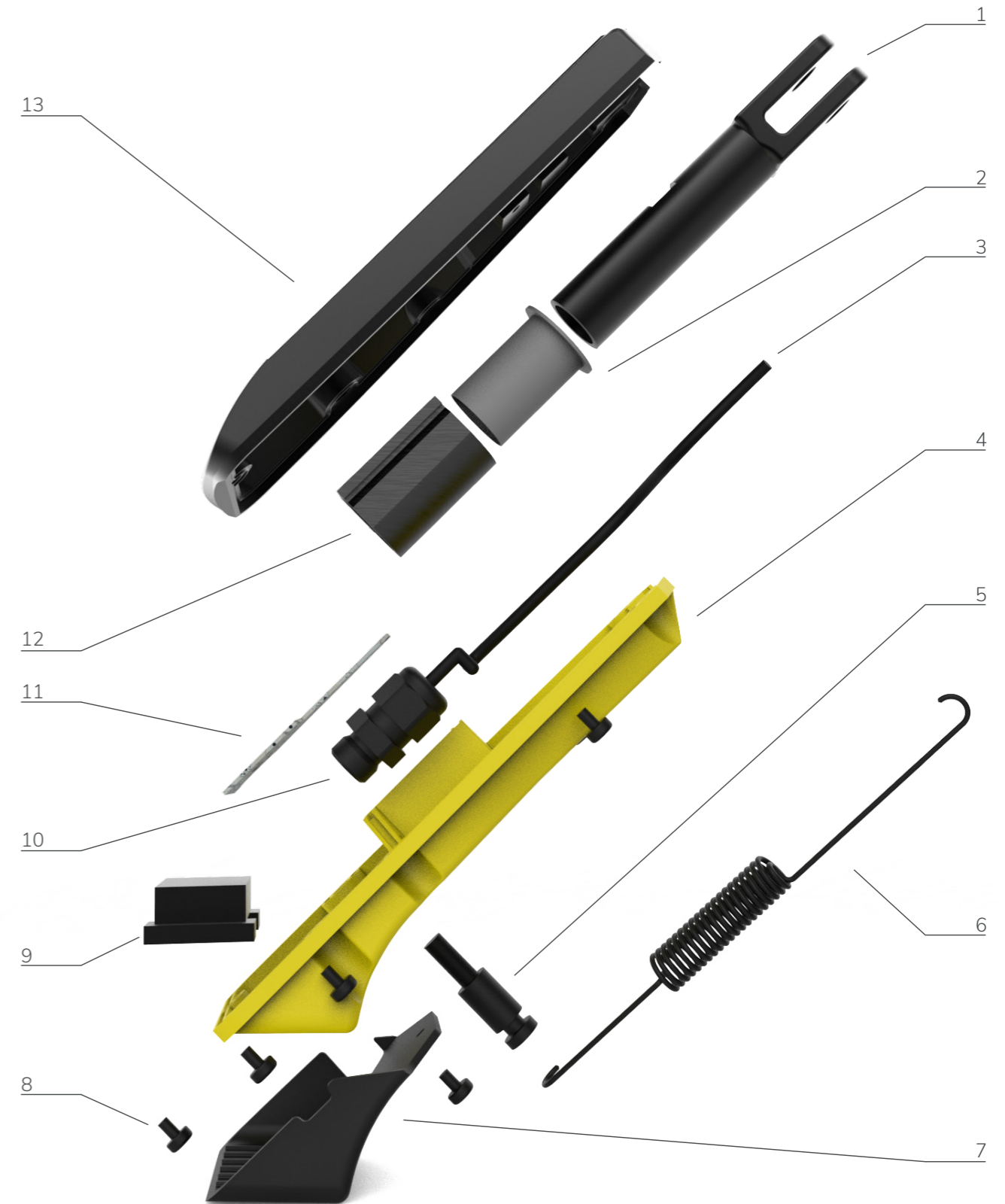


Figure 39: Render parts overview

5.7.1 Aluminium Housing

The aluminum housing on the front of the kickstand carries the weight of the moped (Appendix 11). The shaft which is connected to the moped, is also connected to this aluminum housing. The aluminum housing makes contact with the ground. In order to retain the mechanical strength of the kickstand, this 2mm thick casing was designed to adequately transfer the load exerted without experiencing undesired deformation. The outside of the housing is rounded to retain the rigidity of the shaft down along the kickstand. The casings slanted wall created extra stiffness. The housing is intended to protect the kickstand's structural integrity.

Production Method

The production method used to create this aluminum housing is high-pressure die casting. This manufacturing method makes high-quality, complex-shaped aluminum parts with excellent surface smoothness and dimensional accuracy. Molten aluminum is injected at high pressure into a steel mold, also known as a die, which is designed to generate the appropriate shape of the item in this process. High pressure is applied during this process, which enables the production of parts with complex shapes and very thin walls that would be challenging or impossible to make using other manufacturing techniques, which is important for the design of the kickstand. Also, it guarantees stable products with consistent structures; this results from its properties, such as its ability to effectively transfer heat from the mold and guarantee faster product formation (GREFEE mold company, 2023).

Material

Aluminum was mainly chosen for its ability to transfer heat. The PCB inside has components that heat up to 90 degrees. The thermal conductivity of aluminum is relatively high. This implies

that they warm up very rapidly and efficiently transmit heat (Tempelman et al., 2014). Moreover - after powder coating - the housing will be very resistant to wear and strain. The coating resists wearing, chipping, fading, and scratching. Because of its toughness, it works well for metal parts that are exposed to sunlight and other external elements.

Hooks

To be able to hold the shaft inside the aluminum housing, an aluminum profile is attached to the housing. First screws were used to connect this profile to the housing. However, after multiple prototypes and consulting design experts from Fabrique Invent Bv. (N. Schouten & M. de Jong, personal communication, 14-03-2023) it was decided to use hooks

instead of screws to attach this profile to make the shaft alignment sturdier. The hooks (figure 41) on the inside of the aluminum housing have multiple purposes. The essential purpose is to be able to attach the aluminum profile to the housing that holds the shaft. To create these hooks in the housing, pins must be added to the mold to

create overhanging material. The pins in the mold create holes in the outside of the housing. These holes serve as water drainage as the upper part of the body is not watertight. The hooks simplify the assembly process as the profile only has to be slit into the housing instead of using screws to attach it.

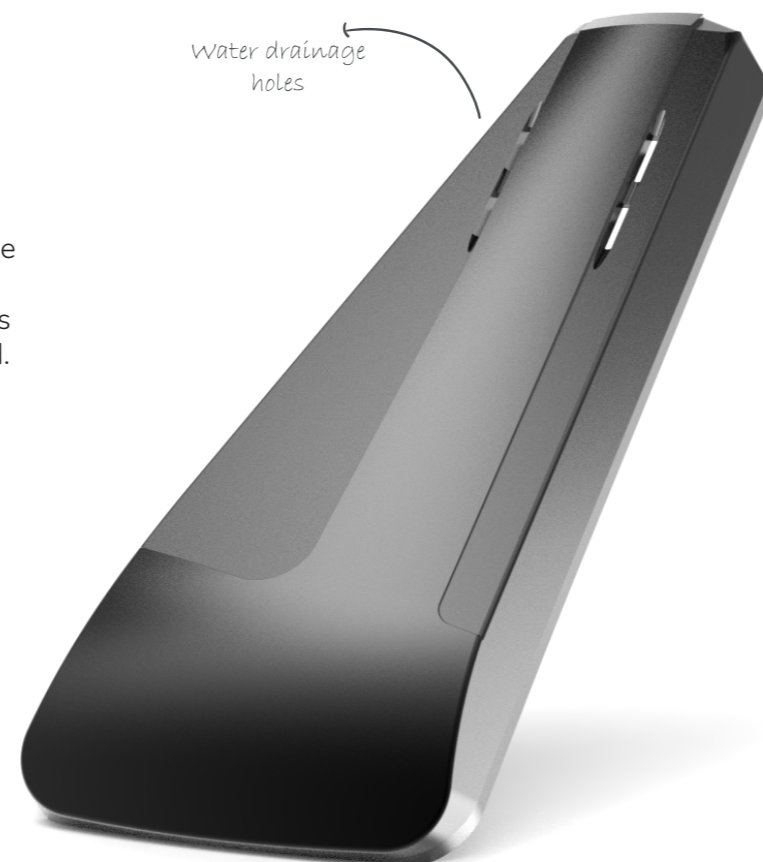


Figure 40: Aluminium housing render

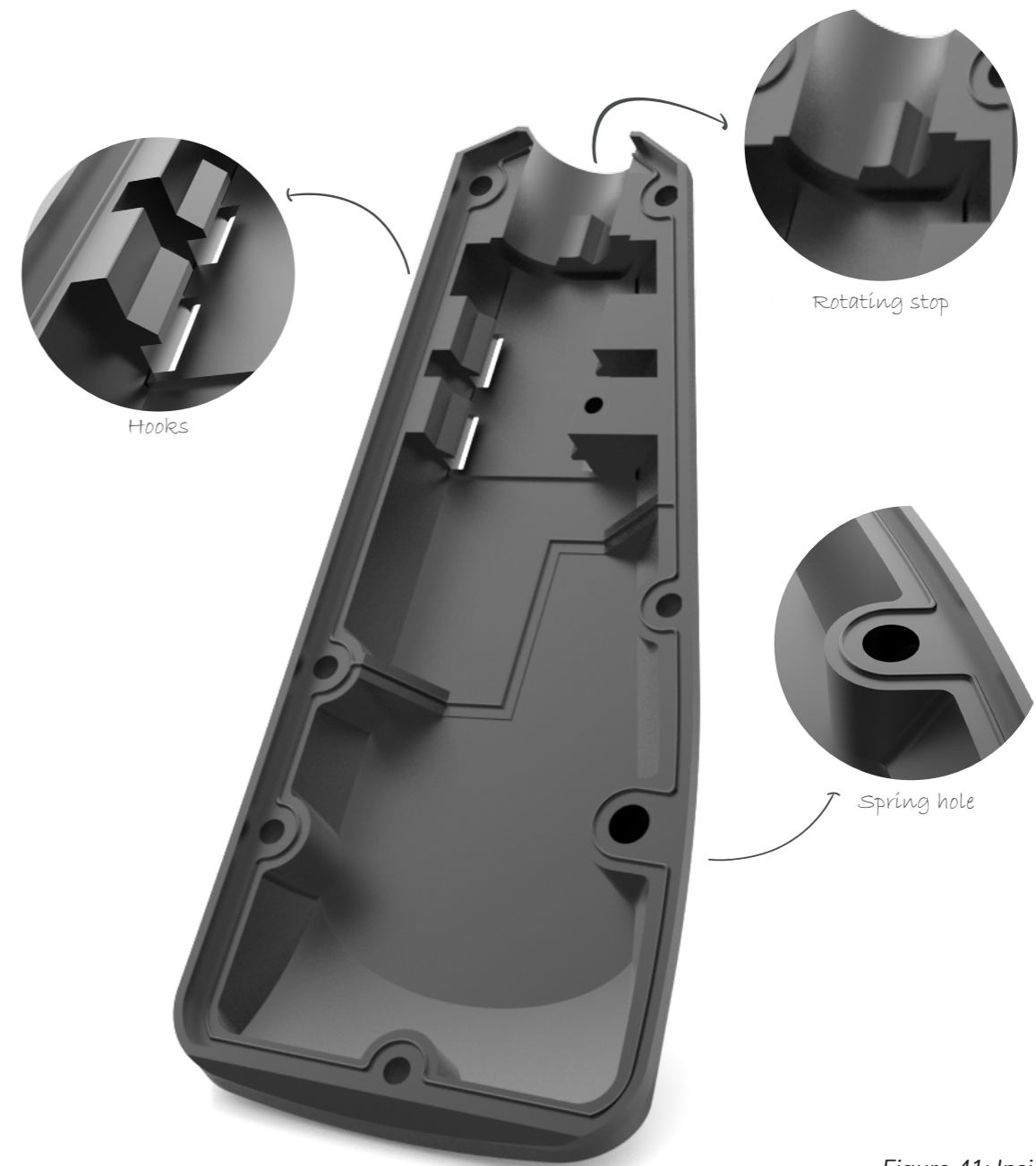


Figure 41: Inside aluminium housing render

Rotating Stop

At the top of the aluminum housing, material sticks out (figure 42). This has two functions. It ensures that the shaft cannot turn more than 90 degrees. Also, when the moped is parked, most of the load will be exerted on this piece. Therefore, it is important that this piece can hold all this load. In Appendix 11, calculations on the final dimensions are made.

Spring Pole

In the aluminum housing, a hole is added to put in a specially designed bolt. This bolt will serve as the attachment for the spring. Instead of adding two holes: one for a screw and one for the spring pole, these were combined into one spot (figure 43). Moreover, this hole is going to experience high loads as the spring has a continuous tension on this part. Therefore, the walls must be thick enough to withstand these loads without deformation.

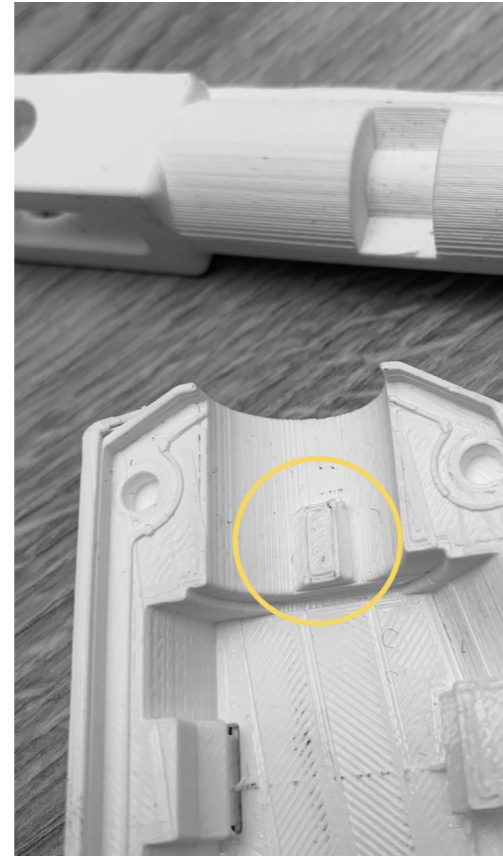


Figure 42: Rotating stop

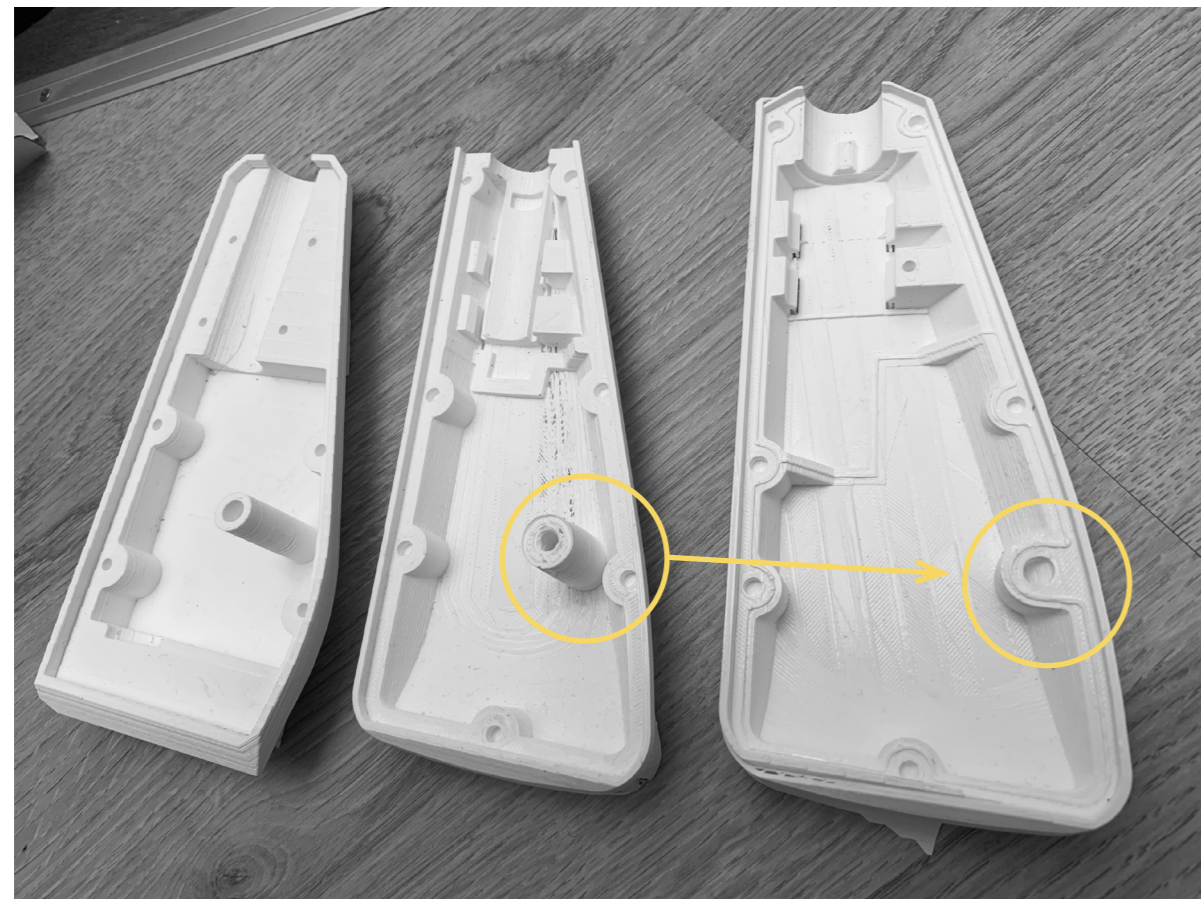
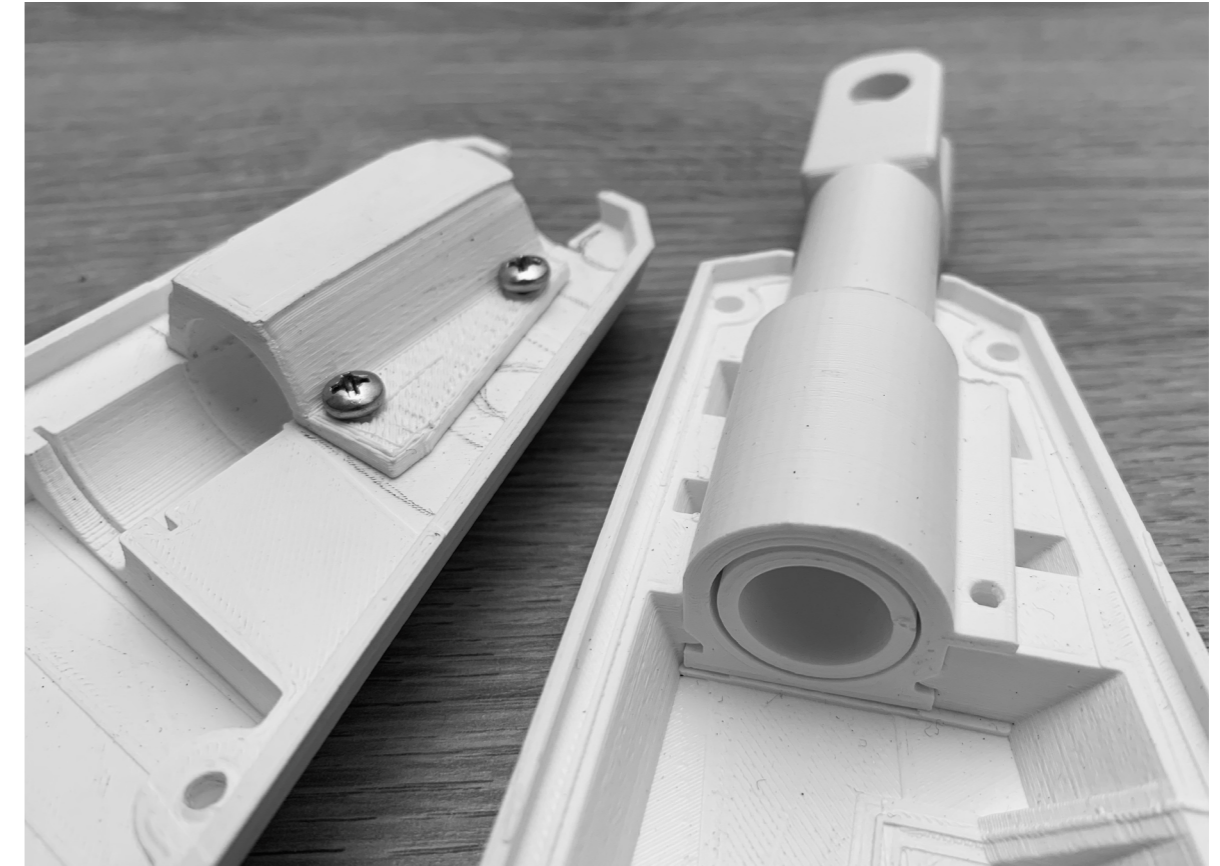


Figure 43: Spring pole development

Figure 44: Aluminum profile development



5.7.2 Aluminum Extruded Profile

The aluminum extruded profile is an alignment tool for the steel shaft. Together with a sliding bearing, the steel shaft rotates inside this profile. This profile is a separate component because it facilitates the assembly of the entire product and because high-pressure aluminum die casting cannot incorporate it into the aluminum housing.

The aluminum extruded profile serves as an alignment tool for the steel shaft. With a sliding bearing, the steel shaft rotates inside this profile. As mentioned, the profile was first attached to the aluminum housing with screws. However, this creates two halves in which the shaft needs to rotate. This can cause misalignment and, thereby, friction on the shaft.

Therefore, after ideating, the profile was designed to have a closed circular hole for the shaft for perfect alignment (figure 44).

Production Method

The chosen production method for this part, is aluminum extrusion. This method is chosen because of the simple shape of the part. Moreover, one of the key advantages of aluminum extrusion is its ability to create complex shapes with tight tolerances and consistent quality, which is important as the shaft needs to have a tight fit and still be able to rotate freely. Additionally, aluminum extrusions have a high strength-to-weight ratio, are corrosion-resistant, and can be easily recycled (Tempelman et al., 2014).

Material

Aluminum is the chosen material mainly because of the production method. Due to aluminum's tendency to experience thermal expansion, these temperature variations may impact the material's behavior. This implies that the aluminum will expand as the temperature rises and contract when the temperature falls (Tempelman et al., 2014). It is preferred that the aluminum profile and aluminum housing are the same material to achieve consistent performance because using the same material will enable both parts to behave similarly.

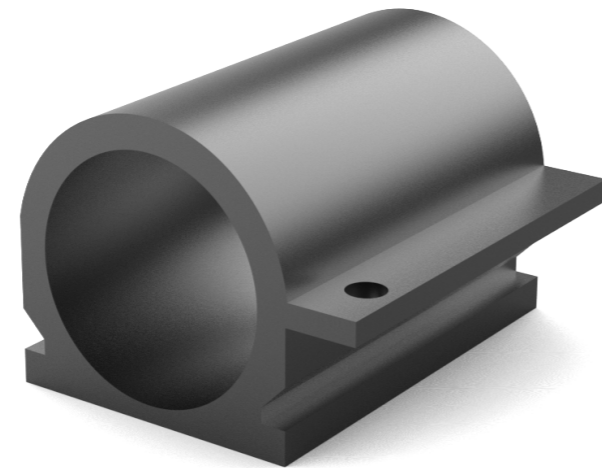


Figure 45: Render Aluminium Extruded Profile



Figure 46: Evaluation session with Niels Schouten & Mike de Jong (Fabrique Invent)

Figure 47: Shaft development



5.7.3 Steel Shaft

The kickstand is attached to the moped by a mounting piece. This mounting piece is welded to the frame of the moped and is designed to be strong and durable enough to support the weight of the moped when it is parked. The kickstand is then attached to the mounting piece using a pivot point. This pivot point allows the kickstand to swing outward from the frame when it is deployed and to swing back up against the frame when not in use. A metal shaft is pivot-mounted to this mounting piece to connect the moped frame to the universal kickstand part. Before incorporating the rotating mechanism the shaft was attached to the aluminum housing using screws. However, with this new iteration, the shaft is no longer a fixed piece and needs to rotate inside the housing, and thus the design is changed accordingly (figure 47).

Specific Design

As discussed in Appendix 7, mopeds differ in size and weight. Moreover, the way the kickstands are connected to the mopeds is designed specifically for the type of moped. The main difference between the kickstands is the length. As seen in Appendix 8, from the collected dimensions of kickstands, the difference between the shortest and longest kickstands is 25 mm. An interchangeable in-length connection shaft is created to be able to fit on a variety of mopeds in order to connect the universal part of the kickstand to the moped. To develop the shaft, three types of mopeds are selected. These mopeds are selected because they have the biggest variety in length and connection (Appendix 8). The final design is a metal shaft that can be manufactured in different lengths for the different models of mopeds. Moreover, the mounting piece also differs in thickness.

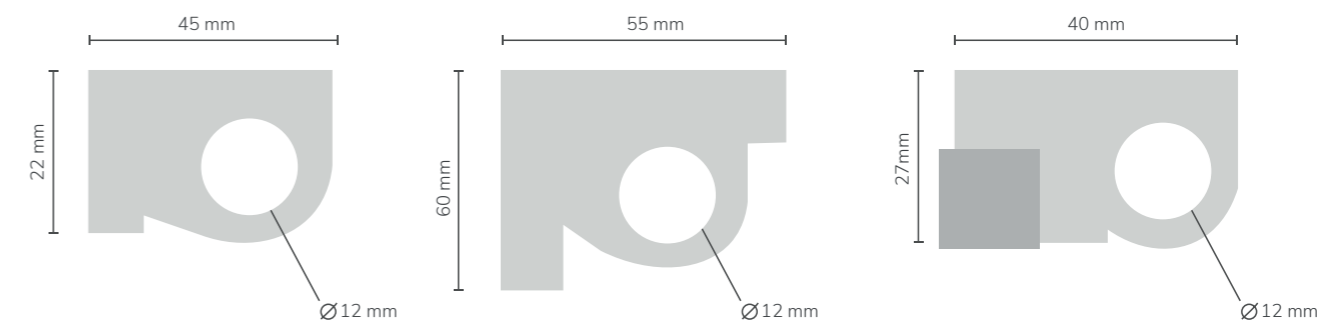


Figure 48: Differences between mounting locations

Figure 49: Render steel moped connector



However way less than the difference in length. The most important factors are the thickness of the mounting piece and the diameter of the pivot hole. The thickness is fairly the same - only 1 mm difference - and the diameter for the pivot connection point is the same on these models (figure 48). Therefore, to solve this, a simple washer can be added to overcome this 1 mm difference and make sure the shaft fits.

Design and Mechanical Properties

The 18 mm thick round metal shaft is stiff. This is because the circular shape of the rod allows it to distribute stress evenly around its circumference, whereas a flat or square profile would concentrate stress at its corners, leading to potential weak points. Also, the circular shape resists bending and flexing more effectively because it has a greater moment of inertia. This means that it is better able to resist bending or torsional forces, which further enhances its stiffness and resistance to bending (McHone Industries, 2021). The diameter of the rod has been chosen to balance the requirements for strength, stiffness, and weight (Appendix 11). Moreover, the diameter should be large enough to support these properties but not so large to add unnecessary weight or bulk to the kickstand. Within this metal shaft, slits on different heights will be made to fall into place in the aluminum housing. This prevents the shaft from falling out of the housing and also functions as a rotation stop so the kickstand cannot rotate more than 90 degrees.

Production Method

To produce this shaft, multiple fabrication techniques are used. For

the pivot point connection, a steel sheet is cut in shape and then bent. The shaft itself is also cut to size, and afterward, a CNC machine will cut out the slits. These two pieces are then joined together by welding using heat and pressure to create a strong bond.

Material

The chosen material for this piece will be steel. After analyzing current kickstands of mopeds, steel is a popular material for kickstands because it is strong, durable, and relatively inexpensive (Jain, 2023). Kickstands are designed to support the weight of a stationary moped, and steel is able to withstand the weight and provide stability, which is also the aim of the new kickstand.

5.7.4 Plastic Housing

The backside of the kickstand is a plastic housing. This plastic housing is designed to house the electronics and coil. The shape is mostly determined by the shape and size of the coil. On the bottom of the part, the coil is located. The coil is located close to the ground to ensure efficient power transfer between the kickstand and the tile. This housing is attached to the aluminum housing by screws, which makes assembly and repairability easy. In Figure 50, the ideations of the inside of the plastic housing are seen. The final shape has two compartments; on the bottom is the space for the PCB and coil, and on the top is the space for the rotating mechanism. The bottom compartment is sealed off, and a cable gland inside the housing transfers the wires to the top and outside of the housing.

Production Method

The plastic housing will be injection molded. The main reason is that injection molding allows for producing complex shapes and geometries, including parts with intricate details and thin walls (Net, 2023). This can lead to a more efficient design that requires fewer parts and reduces overall assembly costs.

Material

The plastic material is mainly chosen so it does not interfere with the magnetic flux of the coil. Due to interference with the flux flowing through the ferrite cores, applying metal nearby is undesirable. (Olsen, 2020), so unwanted conductivity nearby should be avoided. The type of plastic that has been chosen for this product is ABS. This thermoplastic material offers several advantages. ABS is known for its scratch resistance, which



Figure 50: Plastic housing development

is ideal for this product as it needs to maintain its appearance over time. ABS is often used as a housing for products such as vacuums and kitchen appliances. Additionally, ABS is a recyclable material that adds to the product's sustainability (Tempelman et al., 2014).

Watertight

To create a watertight seal with the aluminum housing, a channel is integrated into the edges of the plastic part. In this channel, a rubber packing is fitted. This rubber packing creates a watertight seal by tightening the aluminum part on the plastic part (Chapter 5.4.4). This ensures that the electronics are protected. Moreover, a hole is added inside the housing to fit a cable gland. An electrical cable gland is a tool used to fasten and secure the end of a cable to a piece of machinery. A cable gland's primary function is to relieve strain on the cable, preventing harm to the cable or the equipment it is attached to from stress on the cable. Cable glands are made to seal off the area where the cable enters the device, shielding its internal parts from

moisture, dirt, and dust (CMP Products Ltd, n.d.). This cable gland needs to be added as the compartment of the electronics needs to be sealed off, but a cable still needs to be connected to the battery of the moped. Additionally, it's crucial to release the strain on this cable because it will shift due to the kickstand's spinning mechanism. And by preventing this movement and strain, it is ensured that the PCB and coil will remain in place and not break. A rubber cable tube is added to create an extra seal and prevent as much dirt and water from coming into the compartment of the mechanism (figure 52).

Figure 52: Example rubber cable tube

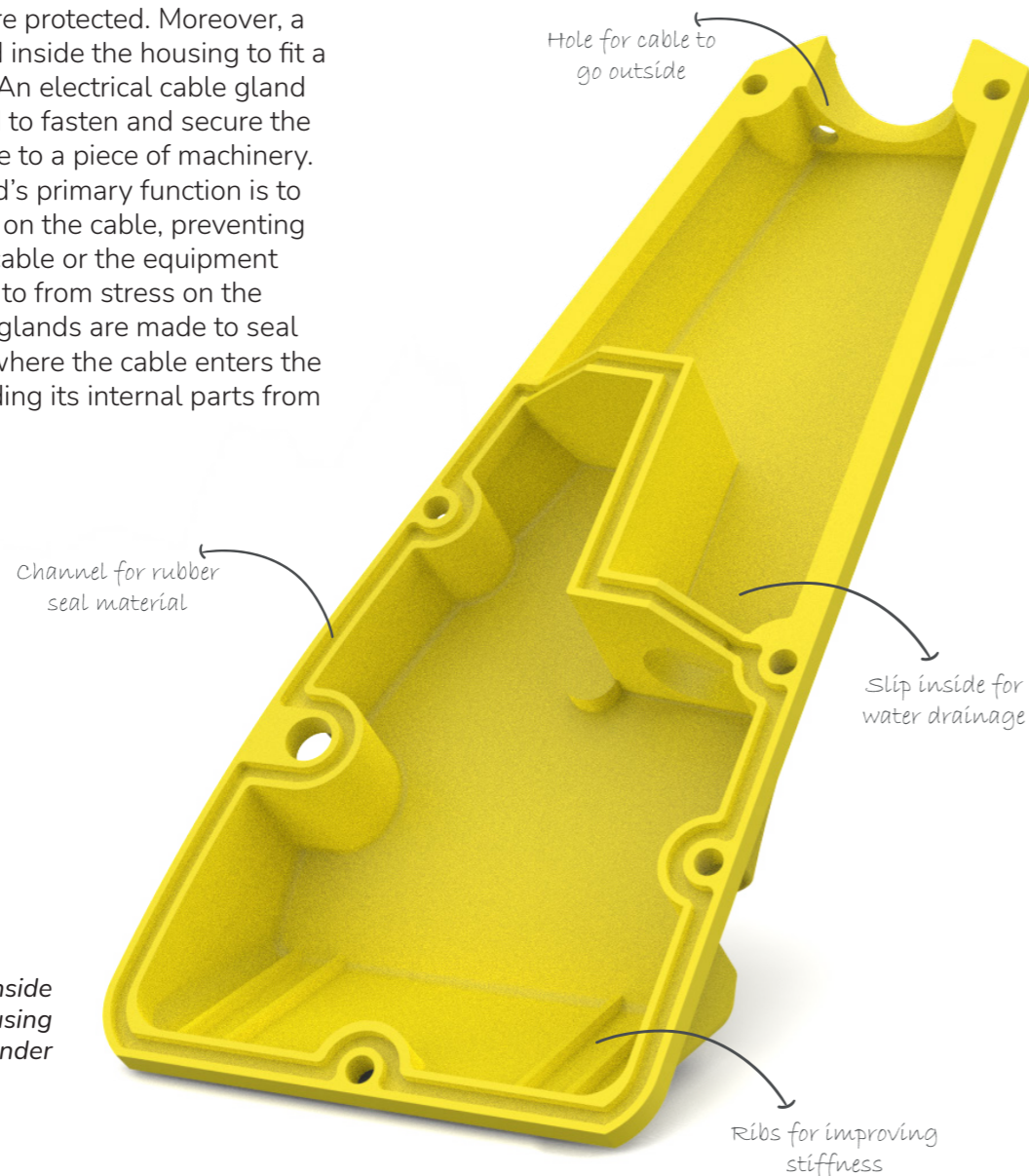
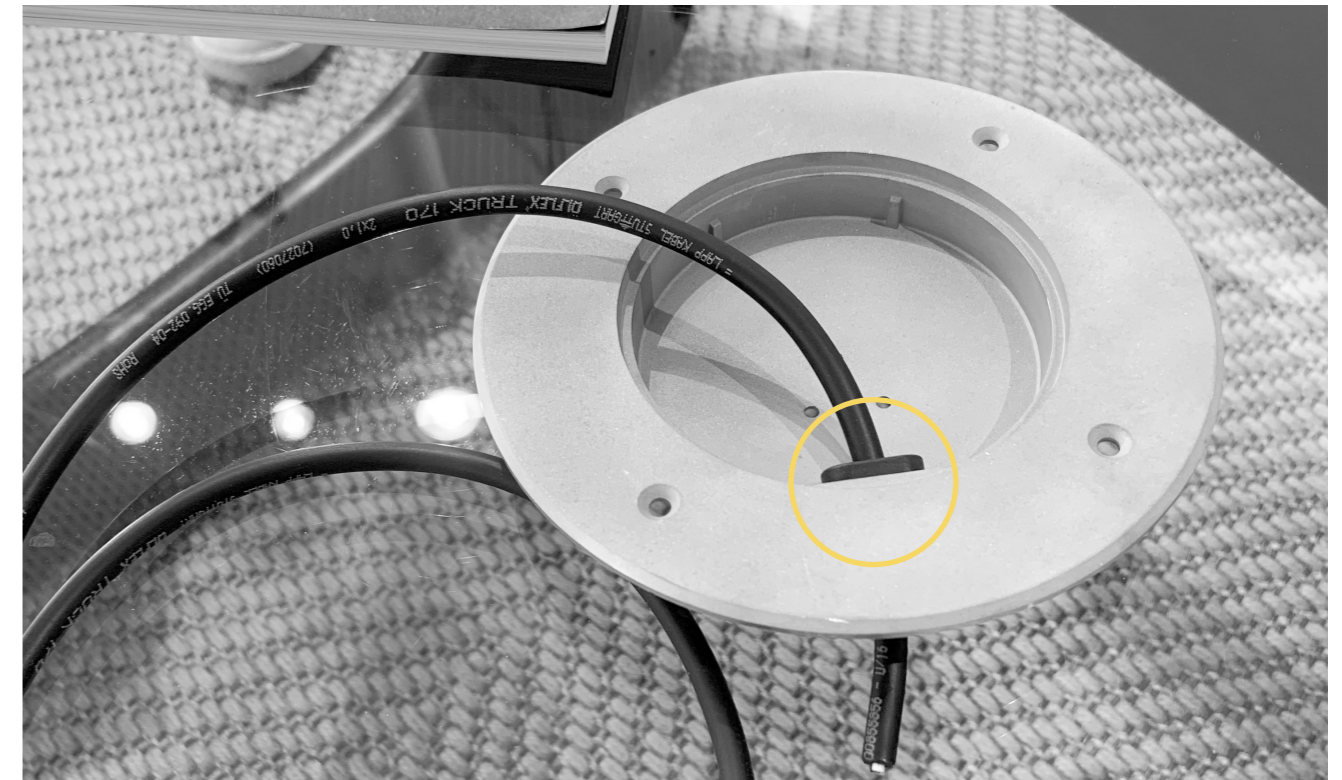


Figure 51: Inside plastic housing render

Plastic Foot

The plastic foot is designed for the protection of the kickstand (figure 53). It acts as a protection layer between the ground and the housing of the kickstand. Parking the heavy mopeds repeatedly can cause the kickstand to wear out over time. To reduce damage to the kickstand housing this separate foot can be replaced, which is cheaper than replacing the bigger housing parts of the kickstand. The foot can easily be shrewed into the ABS housing because inserts are placed at the back of this. When this

piece is damaged, it is easily detached and replaced by a new one. Since the kickstand will be subject to high forces from the weight of the moped, the cap is supported by ribs in the housing to improve its stiffness. A 2 mm uniform wall thickness is applied to the housing for sufficient strength.

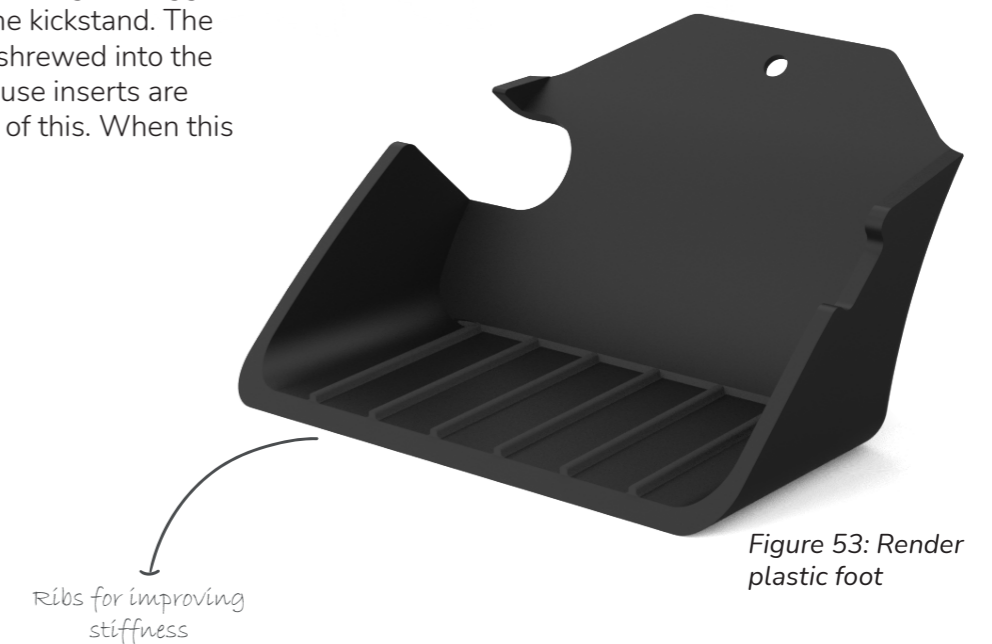


Figure 53: Render plastic foot

5.8 Electronics

TILER's current technology for charging electric bikes can also be implemented into electric mopeds. In Chapter 2.5.2, the technology is explained. As mentioned in Chapter 5, the technology to successfully charge any bicycle battery using wireless power transfer is one of the main assets of TILER. This chapter outlines how the wireless power transfer works in this concept specifically while also discussing the technology changes in the future (figure 54).

5.8.1 Future Developments

TILER is still developing its software and hardware and is aiming to make some changes to the current system. In the near future, TILER is reducing the size of the coil and PCB to be able to reduce the size of the kickstand and easily implement their technology into different light electric vehicles. They claim to reduce the height of the coil by two-thirds and to reduce the total size of the PCB by two-thirds (J. Koudijs, personal communication, 8-03-2023).

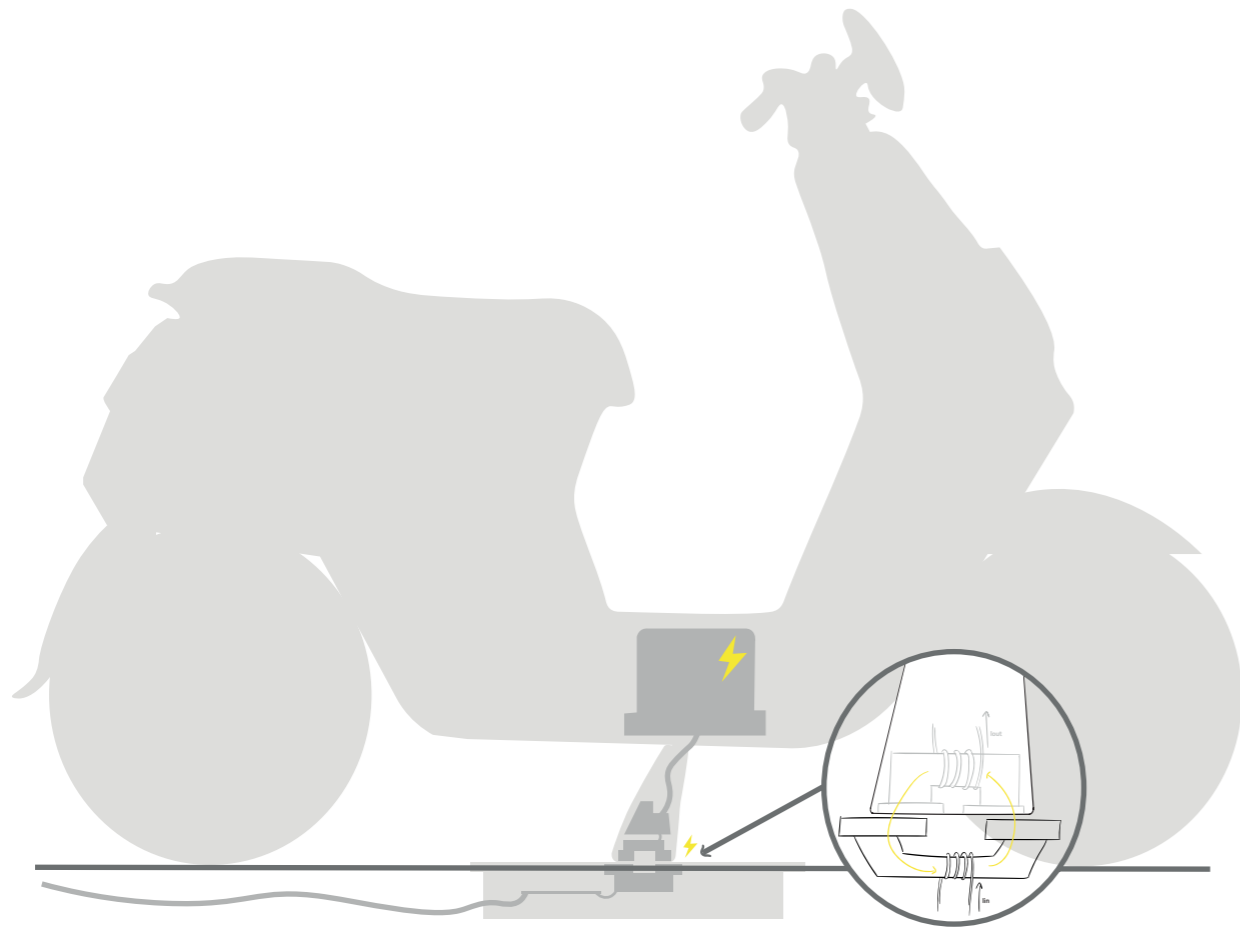
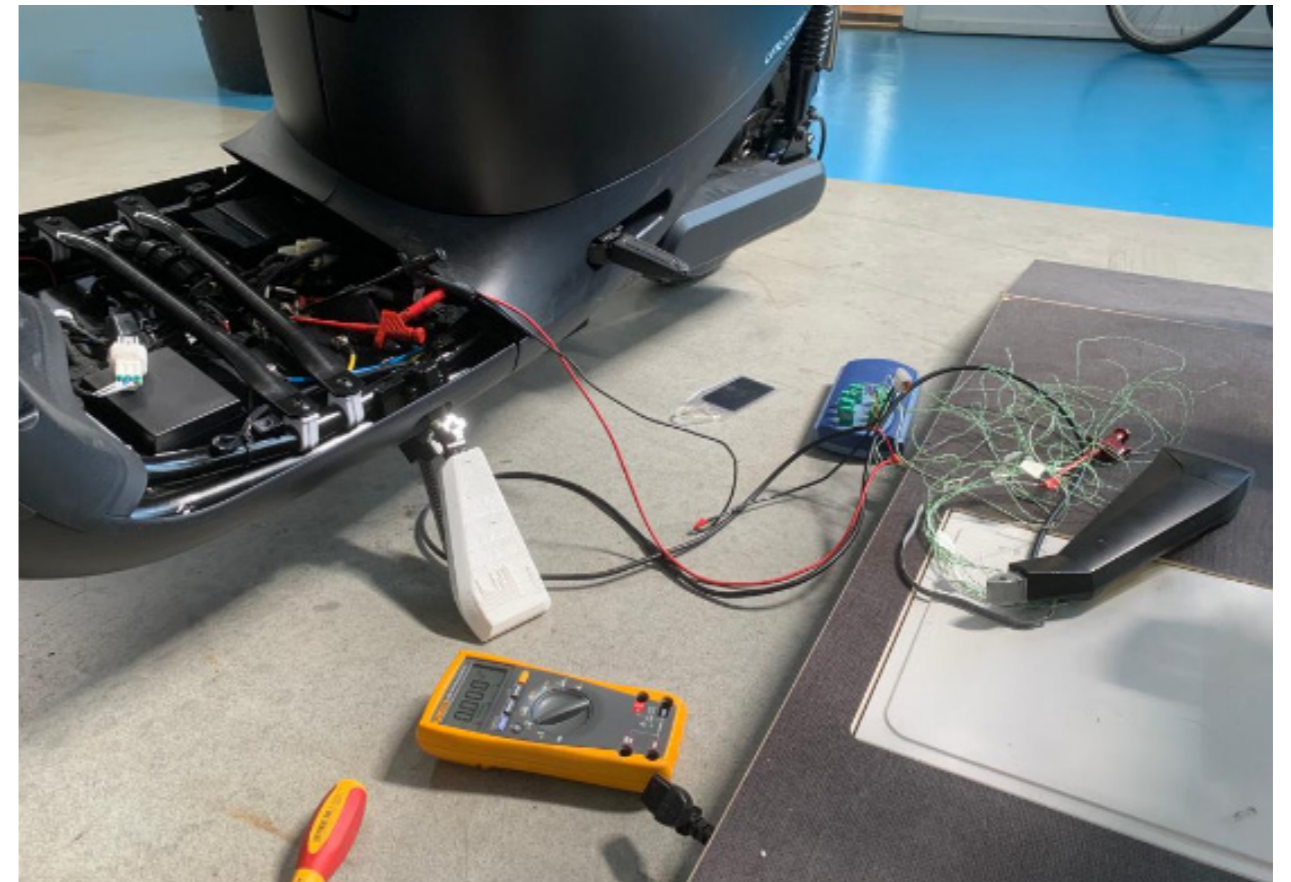


Figure 54: Schematic drawing charging system

Figure 55: Connecting moped battery to TILER kickstand



5.8.2 Connection with Moped Battery System

To validate the assumption that the current system can charge the battery of a moped, tests have been conducted. The current TILER kickstand has been connected to the battery of the moped. The kickstand output was connected at the point where the battery connects to the motor drive in parallel (figure 55). Ideally, they would like to connect it at that point always by creating a splitter and putting our kickstand between the motor and the battery, but that may vary with each application (V. Skrekas, personal communication, 12-04-2023).

5.8.3 Implementation into the Design

The final kickstand is designed together with the dimensions of the new coil and PCB. The coil must be placed as close to the ground as possible to create efficient energy transfer. This is done by placing the coil on the bottom of the kickstand with only the thin walls of the housing and protection piece in between the bottom coil and the tile coil. Furthermore, enough room for the PCB has been added, as well as for the cable gland. The cable is led to the outside by clapping it into hooks integrated into the walls of the plastic housing.

Figure 56: Drawings assembly steps

5.9 Assembly of the Kickstand

The assembly of the product happens in a few steps (figure 56). The kickstand has two main housings: aluminum housing and plastic housing. Each housing houses different components and can be assembled individually.

5.9.1 Assembly of the Electronics

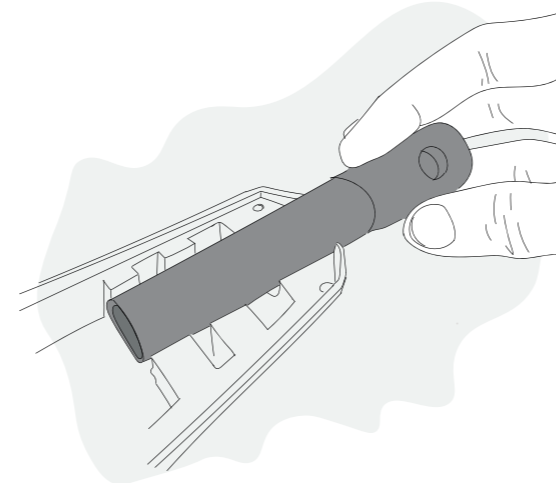
The plastic housing houses the electronics. First, the coil is put into place in the housing. The PCB can then be placed and connected to the coil. The wires of the PCB are then connected to the cable gland. Finally, the cable can be moved - through the rubber cable tube - through the housing to the outside of the kickstand.

5.9.2 Assembly of the Mechanism

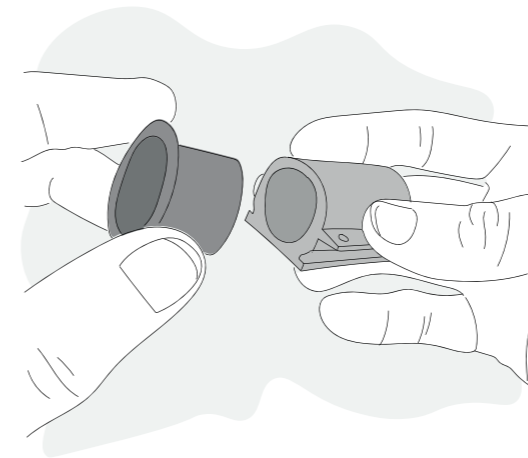
To assemble the mechanism, first, the shaft will be put into place. The shaft is first put in place because the slit needs to fall into the shaft. Then, the aluminum profile is slit onto the shaft and underneath the hooks. This profile is attached to stay in place with one screw.

5.9.3 Total Assembly

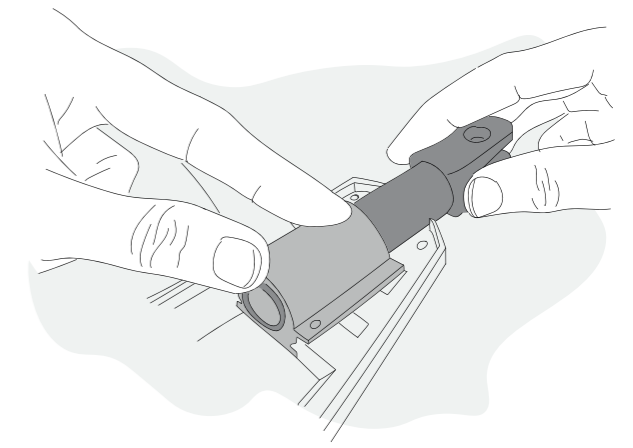
After assembling each housing, they can be put on top of each other. By simply screwing in the screws, the two houses are connected, and also the watertight seal is created. The plastic feet can be connected to the plastic housing by screwing it into the inserts. Lastly, the bolt for the spring can also be screwed into place. After assembling the product, the kickstand can be mounted on the mopeds pivot point with a bolt. Then, a spring will be added to keep the kickstand in place. Lastly, the cable from the kickstand will be connected to the battery of the moped.



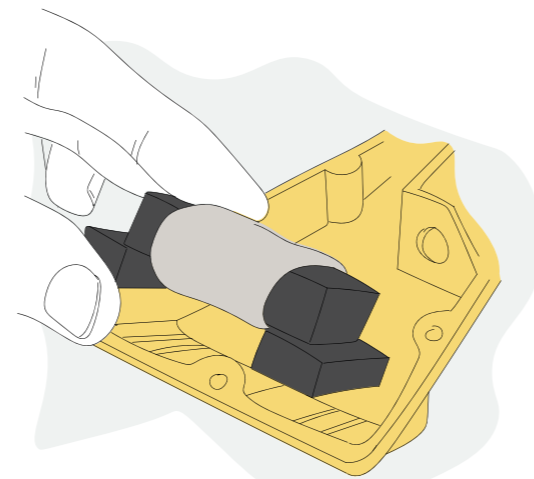
1. Lay the shaft inside the housing



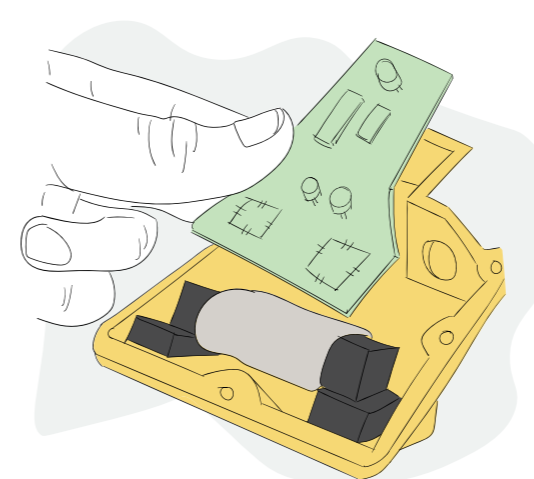
2. Put the bearing into the profile



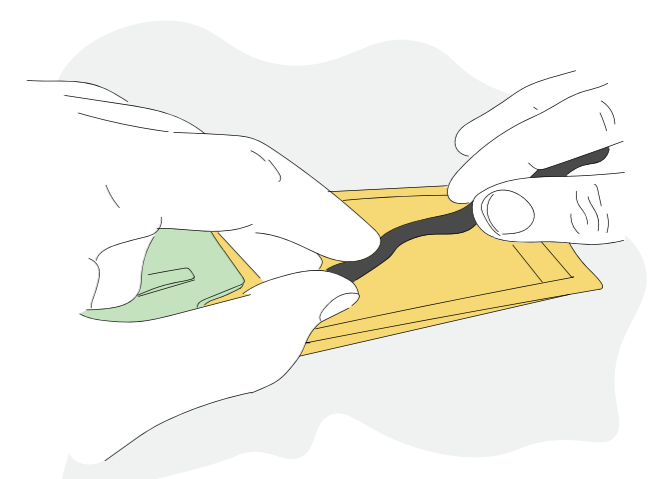
3. Slide the profile into the housing



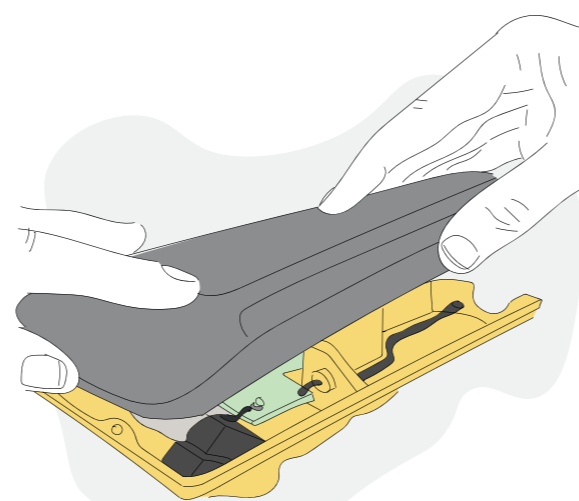
4. Put the coil into the housing



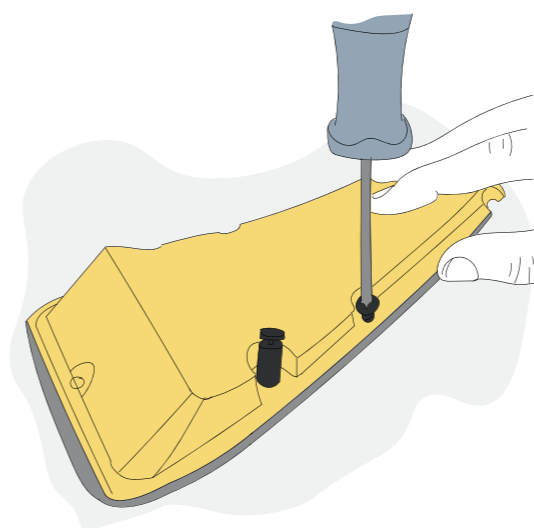
5. Put the PCB into the housing



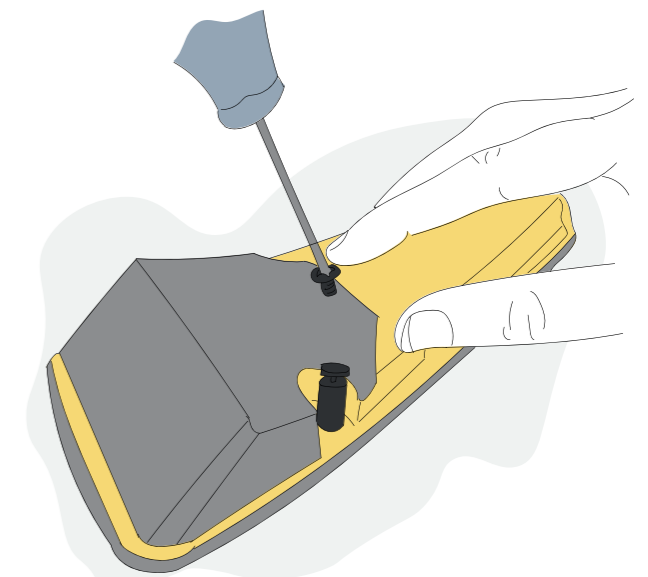
6. Connect the wire to the PCB and coil



7. Put the housings together and flip



8. Screw in the screws



9. Screw the foot to the housings

5.10 Estimated Cost Price

To test the feasibility of this kickstand, an estimated cost price has been made. To estimate the product's cost price, each part is reviewed, together with components that are bought-in, using the cost price calculation framework following Industriële productie, Kals et al. (Appendix 12). Assumptions regarding machine hours and labor costs are made to create a realistic cost price. Moreover, the market price of the materials taken from bron.

The product consists of four main parts, with each a different production method. The designs of the aluminum and plastic housing have been validated by the company QoCreators (Appendix 13). They are a Dutch contract manufacturer and product development partner, specializing in developing, manufacturing and

assembling hardware products made of steel, aluminum or plastics, in Shanghai, China (QoCreators B.V., Haarlem, n.d.). A cost price is estimated based on a production of 5.000 pieces (Appendix 10). This number is seen as realistic for use of shared mopeds, but higher production numbers might be possible if the product is introduced to the international market.

5.10.1 Costs Per Part

Aluminium housing

The aluminum housing is produced by high pressure die casting. QoCreators have made an estimation of the design and tooling cost to manufacture the aluminum housing. After using their costs for the mold and tooling, the total cost came to 1.10 euros (Appendix 12).

Plastic housing and foot

The plastic housing is produced by injection molding. Using injection molding comes with relatively high initial investment costs, as the required molds can be costly. This makes injection molding less interesting for the production of low quantities, but with future alternative versions and applications of the product, the initial investment will be worth it. As mentioned, QoCreators estimated the design of the plastic housing. The final estimated cost price of this part is 0.71 euros. There is no estimation of the price of the plastic foot. However, a reasonable estimation can be made by looking at the weight and complexity of the design. The estimated price of the foot will be 0.56. In

total, the plastic parts have a cost of 1.25 euros (Appendix 12).

Aluminium profile

The aluminum profile will be made by aluminum extrusion. The production method is relatively cheap compared to the other methods used for this product. Tool costs for extrusion dies that are used in normal architectural and industrial applications can range from \$400 to \$1,000 (Team, 2022). After creating the aluminum profile, a hole needs to be machined in each part to be able to connect it to the aluminum housing. The final estimated cost price per product will be 0.68 euros (Appendix 12).

Steel Shaft

The steel shaft consists of a steel tube and a steel bent sheet. The production methods used to make this part are bending, welding, and machining. To estimate the costs of this part, the costs for the material and production are added up. The total for this part will be 1.01 euros (Appendix 12).

Electronics

The cost of the electronics is known by the project team and company. However, due to the confidentiality of certain information classified as company secrets, it is not possible to include those details in the report.

Buy-in Components

Other components include the spring, screws and sliding bearing. The fasteners on the current e-bike of TILER

are estimated to cost approximately 2 euros and will thus be similar in the moped kickstand. The sliding bearing will be 0.36 per piece (Droogloop Lager | Kracht.nl, n.d.), and the spring will be approximately 4 euros (708547: ES 3,6X18X111, n.d.), which comes to a total of 6.52 euros.

5.10.2 Total Estimated Cost Price

The total cost is also discussed with the project team and company. However, due to the confidentiality of certain information classified as company secrets, it is not possible to include those details in the report.

If the product is sold to shared moped providers, it does not have to be the same price as if it were sold in stores. However, TILER does want to make some profit to facilitate the design and operational costs needed to develop the product. Thus, we can look at the wholesale selling price. Profit, brokering, and overhead margins should be added to the total cost price.



Figure 57: Render Kickstand with clear housing

CHAPTER SIX

EVALUATE

Within this final chapter, the final product will be tested by during user tests. Also, the design is validated by experts in design and with stakeholders, such as municipalities.

6.1 Interaction Prototyping

6.2 Evaluating with Stakeholders



Figure 58: Testing with participant

6.1 Interaction Prototyping

6.1.1 Interaction Prototyping One

To test the interaction with this first prototype a test setup has been made (figure 57). The current tile of the TILER charger for e-bikes has been printed out and taped onto the ground to simulate this tile laying somewhere in the ground. This tile has been used to test if there also need for adjustments on the tile to make parking the moped easier. Furthermore, the interaction between the user and the rotating mechanism needs to be tested. It is important to know how potential users will react when the kickstand rotates. The tests have been done with six participants. three of the participants have more experience with riding mopeds as they owned them themselves, and the three other participants have little experience with mopeds as they have driven them a hand full of times in their lives.

6.1.2 Main Insights

Participants with little experience with mopeds needed one time to readjust the position of the moped.

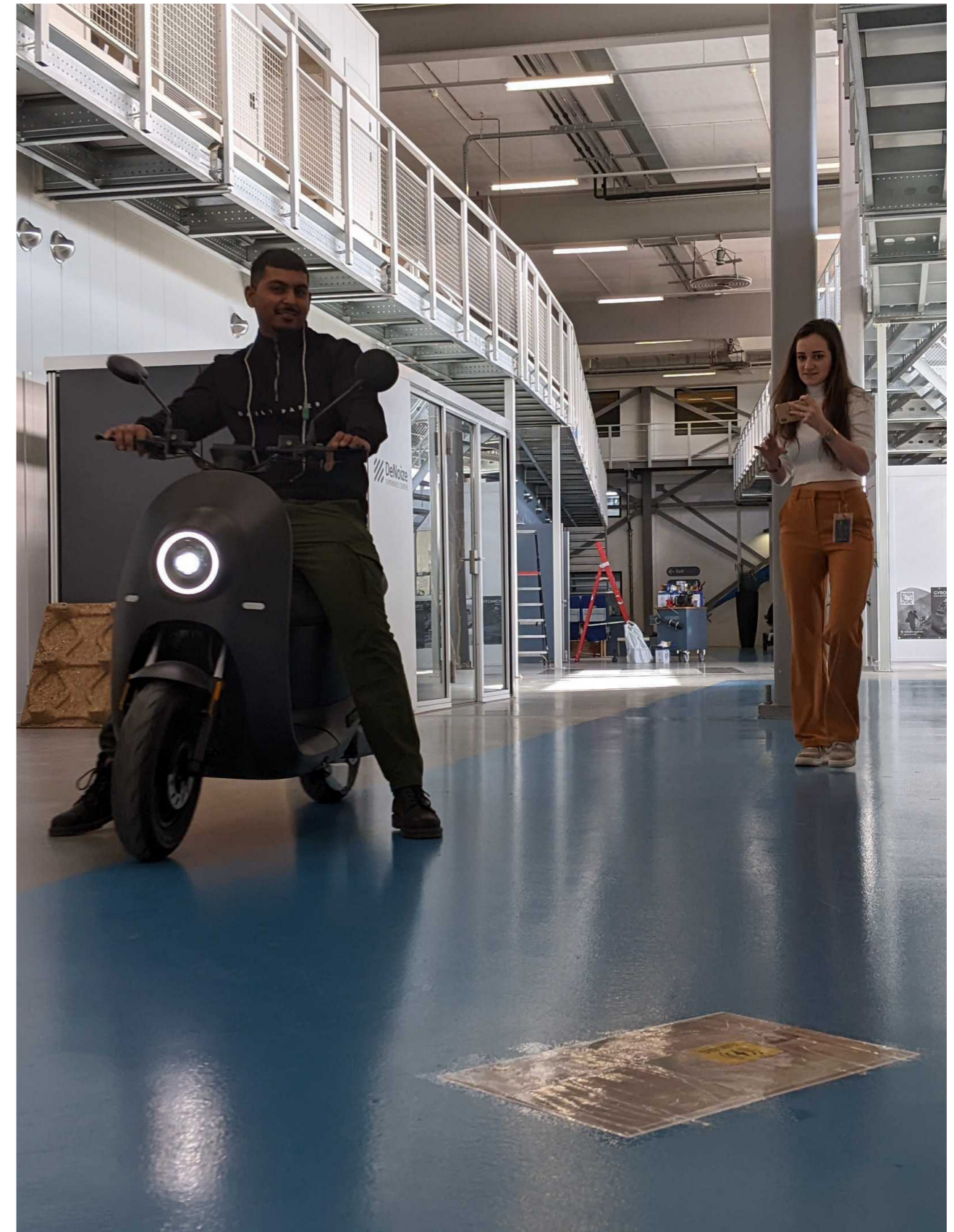
Estimating when to turn to be able to park the moped currently can be difficult as the moped has a large turning circle.

The participants with experience riding on a moped did not need to adjust their position when parking. One participant tried to rotate the kickstand himself.

The participants mentioned that the design of the kickstand looks like it belongs on the moped.

It was very understandable how to use the new kickstand mainly because it is a familiar mechanism.

An indication - for instance on the tile - where the moped needs to align would be preferred by 4 out of six participants.



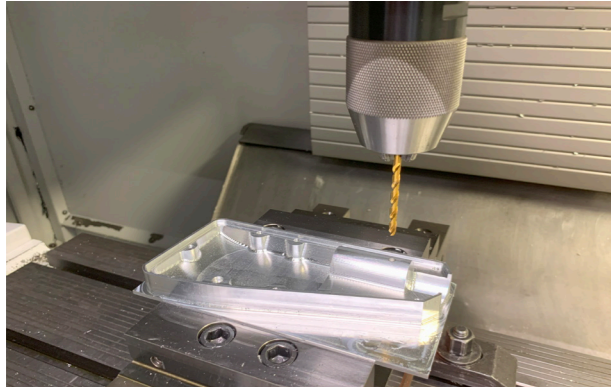


Figure 59: The aluminium housing is being machined to be a working prototype

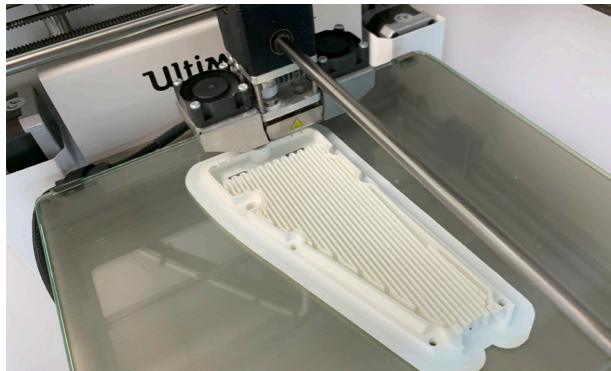


Figure 60: The plastic housing is made using 3D printers



Figure 61: The final aluminum machined housing together with the plastic housing, shaft and screws.

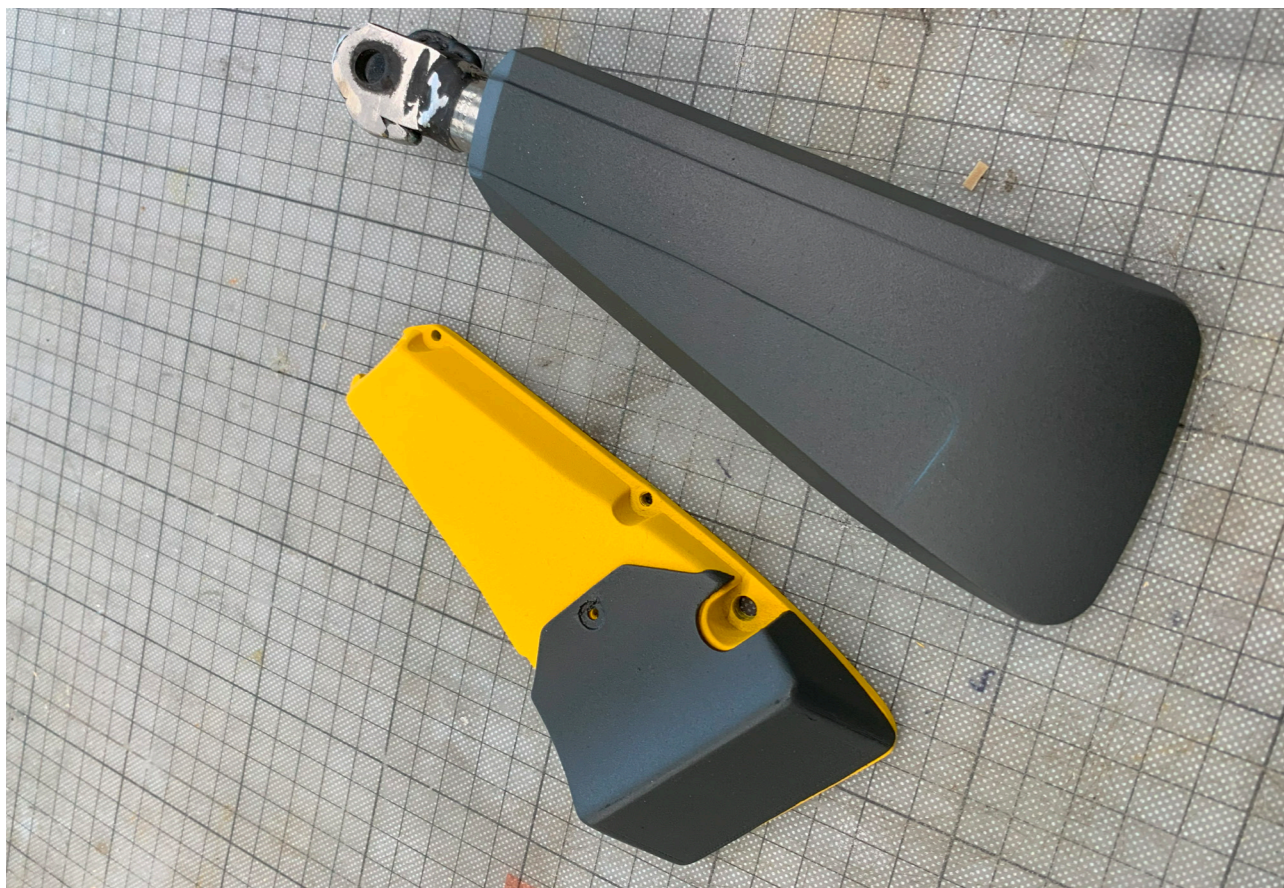


Figure 62: Final prototype after sanding, priming and painting

6.1.3 Final Prototype

After analyzing insights obtained from previous prototypes, a final iteration was developed to resemble and operate like the ultimate product. This last prototype encompasses a functional rotating mechanism, the desired visual appearance, and a conceptual version of the current tile (figure 63). The primary observation derived from initial tests indicated that parking the moped with precision could still pose a challenge. Consequently, a tile concept was devised to assess whether it could address this issue. Subsequent interaction tests revealed that providing a steering indication on the tile would assist in estimating the kickstand's position. To serve this purpose, an indentation was incorporated into the tile to serve as a guide for the moped's wheels. It is assumed that by driving over this marked line, users would reliably position the kickstand above the correct location. Thus, this concept was employed during these tests. Additionally, it was crucial to validate the functionality of the rotating mechanism and ensure that users could comprehend how the kickstand operates without being confused by

its rotation. The final prototype was installed on the Unu electric moped. To gather feedback and insights, the final prototype was discussed with TILER employees and peer students (n=5) who were potential users. The following aspects were the focal points of these discussions:

- How do users perceive the rotating mechanism of the kickstand while flipping in and out the kickstand? Is it understandable?
- With the adjusted tile, will precise parking be easier?

The participant is asked to drive the moped from a distance toward the tile. The participant is told to make sure the moped is charging without precisely explaining how to do this. This is done to observe the interaction of the participant with the tile and if the use cues are clear enough for the user how to use it. During the test, the participant is observed. Afterward, the participants are asked a few questions about the interaction and use of the product.



Figure 63: Tile concept for electric mopeds

6.1.4 Main Insights

The insights can be divided into two main categories: interaction with the tile and interaction with the kickstand. The summarized results are presented below:

Interaction with the tile

All participants clearly understood that they needed to park the moped on the yellow square of the tile. The bright yellow square served as a clear indicator for positioning the kickstand correctly. With the updated tile setup, only 2 participants needed to make slight adjustments to park in the right location. They mentioned not noticing the line on the tile, but both believed they had to ride over the middle of the tile, resulting in the need for readjustment. However, three participants mentioned that the line provided them with an indication to ride over it, which helped them align perfectly above the yellow square.

Interaction with the kickstand

All participants easily understood how to use the kickstand, as its operation was similar to that of regular bike and moped kickstands. However, two participants did not notice the kickstand's rotation:

"I only noticed that the kickstand rotates because you told me so!" - Anonymous Participant

On the other hand, three participants did notice the rotation. One participant attempted to rotate the kickstand further before placing it on the ground. Two participants noticed the rotation but parked the moped correctly after a

brief hesitation. They mentioned that they were unaware of the need for rotation, causing them to be hesitant out of fear of damaging the kickstand.

"If I knew beforehand that it was supposed to rotate then I would not have been so hesitant." - Anonymous Participant

Participants also mentioned that after using the product once, they would be less hesitant during subsequent uses because they would be aware of the rotation requirement. Furthermore, all participants expressed their approval of the kickstand's design. They found that it fit the moped well and appeared to be an integral part of it. Additionally, three participants appreciated how the kickstand neatly folded in and aligned flush with the moped.

Overall, the design of the charging kickstand Mick, was well-received. Participants considered it a clever way to charge the moped and expressed their willingness to use the product. They all agreed on the concept and its integration in the process of using shared e-mopeds. However, it is important to note that testing with only five participants provides valuable insights but does not yield statistically significant data. To further evaluate the product, a larger test group would be necessary.



6.2 Important Stakeholders

Next to validating the product interaction with potential users, it is also important to validate with important stakeholders. This is useful information for TILER as they would want to know if this product and system would be feasible to be integrated into city infrastructure and shared mobility systems. Therefore, interviews with the municipalities of Delft, Arnhem, and Nijmegen and shared mobility provider Check and Felyx have been conducted. Since the entry costs for this system are higher, a higher investment will be required to install the charging network. That is why it is important to talk to the stakeholders to what extent they see potential and would want to invest in this.

6.2.1 Validating with Municipalities: Delft Arnhem and Nijmegen

Municipalities play a big role in the final interaction of Mick in the public environment. For Mick to work, charging tiles need to be installed throughout the city. Therefore, municipalities are crucial stakeholders. By interviewing representatives from municipalities from Arnhem, Delft, and Nijmegen, valuable insights into the real-world implication are gained.

All the municipalities were intrigued by the final solution and see potential in the future integration of Mick into the city, however, they all had no definitive answer on how to do this.

“We want to reduce the amount of object in the city and clean up the city view, thus this concept will positively help with this target!” - P. Swart

Currently, there are no shared mopeds available in Arnhem because of the nuisance they are creating in different cities. However, Arnhem is allowing the shared moped to iterate into the city in the near future, with more regulations. They want to offer the shared moped with fixed parking places, instead of the free-floating system to prevent randomly parked mopeds in the streets (P. Swart, personal communication, 3-05-2023). Nijmegen is also slowly moving towards fixed parking places for the same reason. Shortly, Nijmegen is releasing an evaluation report with the result that around busy and nuisance locations, the shared mopeds need to be parked in fixed locations. However, outside of the city center, they are still using the free-floating system as it is harder to determine where to place the parking

location without causing people to have to walk too long to be able to find a shared moped or bike (T. Bijma, personal communication, 9-05-2023). Moreover, Delft has already designated parking places for these shared vehicles in the city center and is also working towards a hub system. In the near future, they are setting up their first hub for shared vehicles in the city center (M. Kempers, personal communication, 9-05-2023). These developments are beneficial for Mick as they also work with fixed parking places which can reduce the nuisance these vehicles create in city centers.

However, when talking about the implementation of this concept, all municipalities are not certain how to do it. Regulations regarding shared mobility, especially, shared mopeds are still in their infancy and thus are still developing as we speak. Arnhem for instance, believes that the shared mobility providers need to be responsible for the placement of the tiles and investment of the system as offering the vehicles and renting them out is their revenue model which the city does not have to pay for (P. Swart, personal communication, 3-5-2022). On the other hand, Delft and Nijmegen do want to partly invest if

Mick really does reduce the amount of privately owned cars in the cities. However, more research needs to be done to determine this factor (M. Kempers, personal communication, 9-05-2023)(T. Bijma, personal communication, 9-05-2023).

Concluding, municipalities such as Arnhem, Delft, and Nijmegen do see potential in this concept. They would like to integrate this into the city if it helps to reduce the number of cars. However, they also believe that shared moped providers play a big role in the investment of this concept.



6.2.2 Validating with Shared Moped Providers: Check and Felix

During the evaluation process of the prototype, in addition to conducting interviews with various municipalities, key individuals such as Felyx's area manager, Sjoerd Hofman, and Check's head of operations, Berenice van Gessel, were personally engaged (S. Hofman, personal communication, 10-05-2023; B. van Gessel, personal communication, 15-05-2023). These shared mobility providers play a significant role as stakeholders, as they can serve as a crucial bridge for integrating the concept into the shared mobility sector. The product was presented through a comprehensive display of multiple pictures and videos, allowing for a thorough review.

Upon reviewing the concept, both Felyx and Check expressed a high level of enthusiasm for Mick. They particularly appreciated how the product seamlessly integrates the charging process into the shared e-moped usage, recognizing its immense value in reducing the costs associated with charging the e-mopeds. S. Hofman stated,

"I think another way of charging the mopeds will become inevitable, given that by far the largest costs we have is swapping the batteries and everything related to it."

- S. Hofman (Felyx)

Both parties acknowledged that the most substantial expense they face is battery swapping and all its associated requirements, such as infrastructure, vans, personnel, and storage locations necessary to ensure safety. This aspect comprises a significant portion of their costs, making it compelling for them to explore alternative solutions.

"If we can reduce the costs produced by the battery swapping by letting customers charge the mopeds themselves, that would be great!"

- B. van Gessel (Check)

Considering the trend of cities moving towards designated parking spaces, Felyx and Check recognized the inevitability of this shift. However, they also acknowledged that it becomes progressively less feasible to facilitate charging hubs in areas with lower demand. Designing 20 hubs in a residential area, for instance, may not be attractive. Therefore, the future scenario will likely involve a combination of free-floating systems and charging hubs. This hybrid approach aims to minimize infrastructure requirements while still ensuring convenience. Within city centers, both companies see the potential for implementing charging hubs, thereby reducing the

need for numerous vans, personnel, and storage locations dedicated to battery swapping. Felyx specifically mentioned the simplicity of using tiles as charging solutions, as they can be seamlessly incorporated into the cityscape.

Both Felyx and Check expressed curiosity about the technical aspects of Mick. Check, for instance, employs two different moped brands, namely Nui and Segway, and wanted to verify the compatibility of Mick with their existing fleet. Felyx, on the other hand, primarily utilizes Nui mopeds for their sharing service, but S. Hofman highlighted that the models of these mopeds change on an annual basis. Consequently, he raised concerns about implementing the necessary hardware to ensure compatibility across various moped types, considering the potential cost implications and the need for trained personnel to install and repair the kickstand and moped. Although this particular thesis did not delve into a complete plan for implementing the kickstands, it is recommended that TILER, invest further in this aspect.

To summarize, both Check and Felyx displayed significant interest in Mick, especially if the system can offer

cost advantages compared to their current charging methods. While they had inquiries regarding the technical details and implementation of Mick, further research is required to address these questions thoroughly.



Figure 65: Logos of Felyx and Check

7 Future Recommendations

In conclusion, the research conducted in this thesis has provided valuable insights into the charging of shared electric mopeds. However, as with any research project, there is always room for further exploration and discovery. Based on the findings and conclusions of this thesis, several recommendations are identified for future research. These recommendations are designed to build upon the knowledge and insights gained during this thesis and to help advance the design of the kickstand.

Firstly, it is important to note that the embodiment of the kickstand is currently still in its prototyping phase. The different parts designed during this project are not yet ready for the manufacturing process. The aim of this project was to create a working prototype that can be further developed into a real product. However, choices regarding materials, production methods, and design need to be further researched and developed, potentially in collaboration with companies that specialize in this process.

Secondly, Mick incorporates a rotating system to ensure that the kickstand is flush with the moped and does not cause damage to users or mopeds. However, further research needs to be done to assess the durability of this mechanism. Shared mopeds are often used by different users, increasing the

risk of parts breaking. It is recommended to test this mechanism for longer periods and under more challenging conditions to ensure its robustness.

Thirdly, as mentioned in the thesis, assumptions regarding future developments of the electronics were made based on the knowledge of the TILER team. To make the product work, the current hardware used in the e-bike kickstands needs to be scaled down by two-thirds. Additionally, establishing a database of all types of batteries and how to connect them is necessary, as each brand and model of moped has slight variations in hardware requirements between them.

User testing with the final prototype was not conducted in a fully realistic setting. While the tests demonstrated the potential of Mick as a successful charging infrastructure for shared mopeds, it is advised to conduct testing in actual shared mobility hubs before proceeding to production. The current state of the prototype only simulates the interaction, but the next step would involve building a small series of prototypes that already incorporate charging and connectivity with the mobile application. Through pilot studies with these prototypes, more insights can be gained regarding how Mick is used in practice and what requirements are crucial for the final product.

User testing also provided insights into the interaction with the tile. As initially assumed, the tile may need adjustments to facilitate easier parking of the moped. Mopeds are more challenging to maneuver than electric bikes, making precise parking of the kickstand on the designated square more difficult. After testing the prototype together with the current tile, it became apparent that users struggle to estimate where the kickstand will end up. Therefore, a concept tile was used during the final tests to explore the difference. These tests showed that an indicator on the tile can assist users in guiding the kickstand to the correct position. However, these tests involved a small sample group, warranting further testing and ideation on the design of the tile for use with mopeds.

In addition, it is recommended to consider the broader aspects of the Mick charging system, including its operational framework, funding, and profitability. It is critical to understand how the system will charge the mopeds and the associated workflow. Determining the funding structure is crucial. Municipalities, shared moped providers, and users themselves may contribute to the implementation and maintenance costs. Collaboration among stakeholders is required to build a sustainable financial model. Moreover, considering profitability is important. Identifying potential revenue streams, such as charging fees

or forming partnerships, can help the system's profitability. A cost-benefit analysis will reveal information on its profitability.

Lastly, after validating the design with municipalities and shared moped providers, research into the integration of the product into the city infrastructure is necessary. All stakeholders have shown interest, but they also agreed that a combination of free-floating systems and Mick would be the best solution. Therefore, it is important to listen to their feedback and collaborate with them to further develop this concept. Additionally, developing a comprehensive cost analysis for the implementation of Mick is crucial, as stakeholders would be more inclined to invest if Mick proves to be more cost-effective compared to their current charging methods.

In conclusion, while this thesis has provided valuable insights, there are still areas that require further research and development. By addressing the recommendations mentioned above, TILER can continue to enhance the design of Mick and pave the way for its successful integration into the shared mobility sector.

8 Final Conclusions

After dedicating five months to this project, an innovative universal charging solution for shared e-mopeds has been successfully developed. Leveraging TILER's integrated charging technology, wireless charging of mopeds has become a reality simply by parking the moped's kickstand on a specially designed tile. To cater to the unique requirements of publicly shared electric mopeds, the TILER kickstand for e-bikes underwent a transformation and was tailored to fit the market needs of shared mopeds.

The process of this graduation project involved conducting a comprehensive analysis of the contextual landscape, allowing for a profound understanding of the challenges faced by both users and providers of shared e-mopeds, as well as their future expectations. Charging emerged as one of the primary obstacles in the operation of shared mopeds. Furthermore, engaging with municipalities to discuss city infrastructure investments provided valuable insights into desired implementations within city centers. It became evident that the current random parking of mopeds was causing disruptions in urban areas. To address these issues and devise an ideal charging solution, a design vision was formulated (as outlined in Chapter 3) that encompassed key criteria such as universality, convenience, and integration into the cityscape.

Mick, the result of this endeavor, seamlessly integrates charging into the process of using shared e-mopeds by

offering a simple and intuitive “park and charge” system. By effortlessly placing the kickstand on the designated tiles, the moped initiates inductive charging. The design of the kickstand ensures it stays out of the way when riding a moped. Through a cleverly designed rotating system, the kickstand remains flush with the moped when in use, while simultaneously aligning the coils within the kickstand and tile for efficient charging when parked.

Mick provides a convenient, user-friendly, and reliable solution for maintaining charged e-moped fleets. Not only does it enhance the charging experience itself, but it also has the potential to alleviate the current nuisances associated with mopeds in cities. By facilitating the retrieval and return of mopeds to designated hubs, Mick eliminates the need for the existing battery swapping systems employed by shared moped providers. Furthermore, it ensures that the mopeds are neatly parked, avoiding any obstructions to the cityscape. Together with TILER's current e-bike charger, Mick can play a pivotal role in shaping the future of the shared mobility sector by offering a standardized charging solution for all types of light electric vehicles.

In summary, the development of Mick represents a significant milestone in the quest for efficient charging infrastructure for shared e-mopeds. The project's findings and innovations hold great promise for revolutionizing the shared mobility landscape, ultimately providing enhanced charging capabilities and contributing to the overall sustainability and convenience of urban transportation systems.

Figure 66: Pictures final prototype in use



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