Parking spaces for micromobility

Exploring the challenges and possibilities for the municipality of Amsterdam

CTB3000: Bachelor End Project

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TUDelft

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by

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Preface

This report presents the results of my Bachelor of Science end thesis project in Civil Engineering, in the domain of Transport and Planning. Prior to writing this thesis I already did an internship at felyx, a shared e-moped provider, which also inspired me to write my end thesis in the micromobility field. The purpose of this project was to optimize parking spaces for micromobility in a municipality of my own choice, which is Amsterdam.

The project involved a comprehensive review of several existing solutions and an analysis of the user data of micromobility provider Check. An essential follow-up step to this data analysis is a review of the spatial design plans of the municipality of Amsterdam.

I would like to thank my supervisors, Yufei Yuan and Sina Nordhoff as well as my fellow students who reviewed my progress on a weekly basis. Next, I would also like to thank Niels van Oort for assisting me with the GPS data analysis. Lastly, I would like to thank Anouk van der Laan from Check for providing me with the data needed for the GPS data analysis.

T.H. Braaksma
Delft, June 2023

Summary

This thesis focuses on addressing parking challenges caused by shared e-mopeds in Amsterdam and proposes strategies to increase dedicated parking spaces. The goal is to improve the city's accessibility by ensuring that parking issues don't disrupt shared e-moped services. The research examines bans on shared mobility services in other cities, stakeholders involved, popular ride-end locations, and potential solutions offered by the municipality.

The analysis of bans in other cities provides insights into the reasons behind them, including rapid market growth, inadequate regulations, and poor cooperation between local authorities and providers. Understanding these factors is crucial to avoid similar challenges in Amsterdam.

Four key stakeholders are identified: the municipality, shared e-moped providers, users, and non-users. While the municipality and providers support accessibility, citizens often encounter parking hindrances. From the 50 citizens interviewed, 32% do not use shared mobility and from that percentage, 94% experience hindrance. Understanding the influence and interests of these stakeholders is important for decision-making.

By analyzing GPS data, popular ride-end areas for shared e-mopeds are identified. This information helps strategically place dedicated parking spaces, enhancing accessibility and convenience for users. Customized solutions tailored to each location's needs are emphasized.

The municipality envisions three approaches to mitigate parking issues and improve accessibility. Firstly, expanding no-parking zones would restrict shared e-mopeds from parking in certain areas. Secondly, reducing free-floating parking and expanding the hub system would provide structured parking options. Lastly, utilizing shared e-mopeds for dynamic parking, such as during public transport maintenance, optimizes their usage and minimizes hindrances.

Based on the findings, recommendations are proposed. Encouraging active collaboration among stakeholders through a dedicated working group is suggested. Conducting pilot projects allows for evaluation and data-driven decision-making. Technological measures, such as requiring users to upload pictures of parked e-mopeds and implementing smart parking systems, enhance the utilization and management of dedicated spaces.

In conclusion, this thesis provides insights into increasing dedicated parking spaces for shared e-moped providers in Amsterdam. Addressing parking issues is highlighted as crucial for sustaining shared e-moped services. Further research is recommended to evaluate existing policies and the variability of popular parking areas during peak hours. Implementing the proposed recommendations contributes to a more accessible and efficient transportation system in the city.

Contents

1 Introduction

Micromobility, the collective term for lightweight vehicles such as e-bikes, e-mopeds, or stand-up scooters, has become a popular mode of transport in many urban areas around the globe. This mode of transport is often offered as a shared mode of transport and is called shared micromobility. With shared micromobility, the provider buys and owns all the vehicles and in return offers them to its users at a varying cost. Because the users don't own the vehicle, they can park it somewhere, and later on they don't have to ride the same vehicle home, like one would have with a private bike for example. This allows shared micromobility to be a flexible transport option. Because the providers offer their vehicles to their users, they are in most cases also responsible for the vehicles they provide and thus the parking of it (EU, Squire Boggs, & Giovanni, 2023).

According to Howe (2021), there were already 104.000 shared e-mopeds in 2021, which were available in 36 countries. From the summer of 2021 up to the end of 2022, there were 770 e-mopeds located in Amsterdam and over 6000 rides were made each day (Gemeente Amsterdam, 2023). Next to the flexibility mentioned above, there are many other advantages to this mode of transport, such as; offering a last-mile transport solution and reducing traffic congestion (Asensio, Apablaza, & Lawson, 2022). Another big advantage is the influence on sustainable transport, as a recent report on the CO_2-emissions of a felyx e-moped revealed that the only modes of transport to beat e-mopeds in terms of greenhouse gas emissions are bikes and e-bikes (EY & felyx, 2023).

Apart from all the benefits, adapting the streets in a way to allow easy parking for micromobility remains a big hurdle to overcome. Too few allocated parking spaces and technological restrictions result in (partially) blocked pavements, forcing pedestrians to walk on the roads or bike lanes and thus creating unsafe traffic situations, as displayed in Figure 1.1. In Amsterdam, 75 percent of the complaints about shared e-mopeds are related to poor parking (Gemeente Amsterdam, 2023). If not remedied, this could lead to the non-renewal of the permit for offering shared e-moped services or its withdrawal.

Figure 1.1: Example of hindrance experienced due to poor parking (ikwilvanmijnscooteraf, n.d.)

Shared micromobility comes in many shapes and forms, heavily depending on each country's legislation. In Munich for example, there are the stand-up scooter, the e-bike, and the e-moped (McKinsey and Company, Heineke, Kloss, & Scurtu, 2019). Next to legislation, personal preference and other factors such as the need for a driver's license also play a role in which option is being chosen.
The small stand-up scooter is a very familiar option, even though they are not allowed in every country such as the Netherlands. Companies that offer this vehicle are Lime and Bird for example. There is also the e-bike, a very traditional alternative now seen more in the Netherlands and other European countries. These are offered by for example GO-sharing and Lime. Next, there are the e-mopeds, which are provided by companies such as felyx, Check, and GO-sharing.

Table 1.1: Different micromobility vehicles

Name of the type of vehicle	**Picture of the vehicle**
Stand-up e-scooter	
E-bike	
E-moped	

In Amsterdam, a so-called 'free-floating' parking policy is governed. This means that users can park the e-mopeds wherever they want, as long as it is within a designated area. In an interview conducted with an employee from one of the e-moped providers, it became clear that this area is partially determined by the providers, and partially by the municipality. The entire interview can be found in Appendix C. This cooperation between the municipality and the providers can be effective, but can also lead to a conflict of interest, with the municipality wanting to increase the accessibility of the city and the providers aiming for revenue maximization. However, from the same interview, this appeared not to be the case.
The designated area is marked in the app via colored polygons, as can be seen in Figure 1.2. If the user wants to park the e-moped outside the marked area, a pop-up message appears telling the user to move to a location within the colored area to end the ride. This principle of applying a virtual perimeter for a geographic area is called geofencing (Akkerman, 2020). Examples of geofenced areas in Amsterdam are the Haarlemmerdijk, Hogeschool van Amsterdam, and large touristic areas such as the Dam and Rembrandtplein (Gemeente Amsterdam, 2023).

Figure 1.2: Screenshot of the geofenced service area (Check, 2023)

In the current situation, over 75 percent of the complaints received on the shared e-mopeds are about parking (Gemeente Amsterdam, 2023). According to the municipality, this is mainly due to the free-floating parking policy. However, according to the providers, the tools currently applied to decrease the number of complaints received have been proven to be effective. In the future, the municipality wants to be more in control of the parking.

1.1. Research goal

In this thesis, the focus is on defining dedicated parking spaces for shared e-mopeds in the city of Amsterdam. The reason for picking Amsterdam as the city of choice is because it has one of the largest micromobility markets in the Netherlands and is internationally recognized as one of the earliest adapters to micromobility (McKinsey and Company & Heineke, 2022).

1.2. Research questions

Many news articles and literature studies, such as García-Palomares, Gutiérrez, and Latorre (2012), state that parking spaces for micromobility cause hindrance to non-micromobility users because of a lack of regulation and too little dedicated space. Because every city is unique regarding its infrastructure, legislation, and other shared vehicle types, it is hard to draw conclusions or think of opportunities in a different city. In other words, these articles and their solutions are very location specific and thus there is little research into dedicated parking spaces for shared e-mopeds in Amsterdam.
Therefore, the main research question can be noted as:

How can the number of dedicated parking spaces for shared e-moped providers in Amsterdam be increased to maximize the accessibility of the city?

To be able to answer this question, four sub-questions need to be answered first. These questions are:

- Which are the stakeholders involved, what is their interest, and what is their power in creating dedicated parking spaces?
- What have been the reasons to ban micromobility solutions from a number of cities across the globe?
- What are the main areas where rides end and how many rides end in those areas?
- What are the possibilities that the municipality of Amsterdam can offer to accommodate more parking spaces?

1.3. Research approach

Subquestion 1

The first subquestion is answered by performing a stakeholder analysis. This is done to identify the stakeholders and their interests, needs, and expectations. Understanding the stakeholders will help decide on possible solutions and opportunities to solve parking issues. The stakeholders that will be addressed are the municipality of Amsterdam, the providers of the e-mopeds, and the citizens of Amsterdam. For the municipality of Amsterdam, this is done based on the 'Handreiking deelmobiliteit en hubs in gebiedsontwikkeling' or 'Handbook shared mobility and hubs in area development' of July 2022. Regarding the e-moped providers and citizens, interviews are held. The results will be presented in a power-interest grid.

Subquestion 2
As the second subquestion is based on situations that happened in the past, the answer can be found by performing a literature study. The emphasis will be on finding cities that have a comparable amount of vehicles per square kilometer of the service area, as this provides a fair comparison. For example, an area with 10 e-mopeds per square kilometer is more likely to lead to parking hindrances than an area with only 1 scooter per square kilometer. The sources for this literature study will be SCOPUS, Google Scholar, and news articles.

Subquestion 3
The third subquestion is answered by analyzing GPS data (latitude and longitude) from an e-moped provider over a period of one month. This way, a map can be made to display the endpoints of moped rides. Only the endpoints are used as these provide accurate insights into where users are traveling to, and the end location of a ride is the starting point of another ride. These locations can be clustered based on their distance from each other. Next, these clustered locations display what popular end locations of rides are. With those locations, the number of monthly rides that are in that cluster can be calculated. This can be used to determine the amount of dedicated parking spaces needed at a certain location.

Subquestion 4
The last subquestion is answered by analyzing the current and future spatial design plans of the municipality of Amsterdam. From these design plans, possible parking spaces could be extracted which in turn can be aligned with the main areas where rides end.

Main research question
To answer the main research question, first, the stakeholder analysis will be done. This will help to understand the interests of the stakeholders in subquestions three and four. Subquestion two will present the challenges that comparable municipalities failed to deal with and will therefore be the foundation on where opportunities present themselves. Subquestions three and four give insights into where the two major stakeholders want the parking spaces to be. The results from subquestions two, three, and four are all based on the insights obtained from subquestion one and together will answer the main research question. Figure 1.2 displays an overview of the suggested approach.

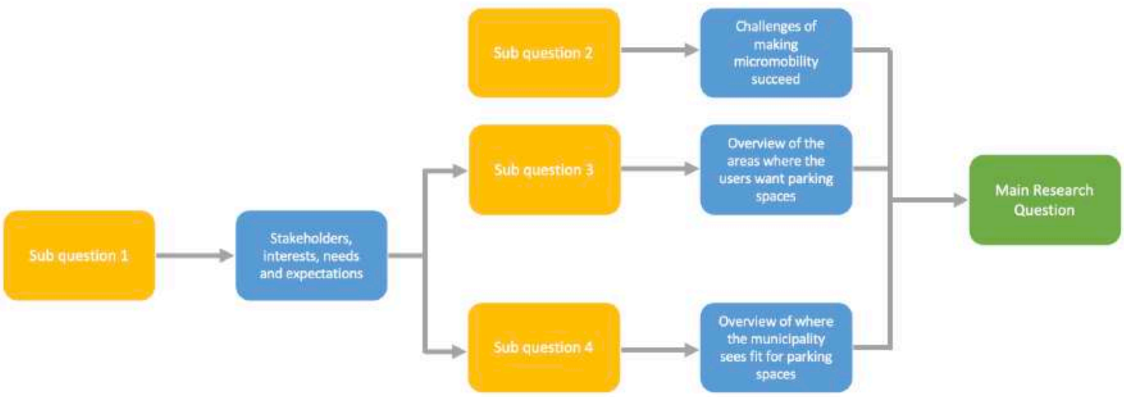

Figure 1.3: Suggested research approach

1.4. Relevance

1.4.1. Social relevance

As of June 2023, shared e-moped providers can submit their visions on offering shared e-mopeds in Amsterdam to obtain a permit to do so. The municipality is open to this form of mobility as it increases the accessibility of the city and therefore reduces mobility poverty (Gemeente Amsterdam, 2023). As mentioned by one of the shared e-moped providers, dedicated parking spaces are expected to decrease the number of complaints received regarding poorly parked e-mopeds. Answering the question of how the number of dedicated parking spaces for shared e-mopeds can be increased helps e-moped providers obtain a permit and thus increase the accessibility of the city. Next to that, the dedicated parking spaces can also serve as an example to other municipalities experiencing similar complaints.

1.4.2. Scientific relevance

Other research, such as Sandoval, Geffen, Wilbur, Hall, and Dubey (2021) also used clustering algorithms to identify high-demand parking locations. However, as far as the author is aware, there is no research on how clustering algorithms can be used to identify high-demand locations for the city of Amsterdam and how this can be used to increase the number of dedicated parking spaces.
Next to that, a large portion of the research that has been done on micromobility, or shared mobility, uses data from during the COVID-19 pandemic. As stated by Li, Zhao, Haitao, Mansourian, and Axhausen (2021), the outbreak of the coronavirus disease significantly influenced people's travel behavior. This research uses data from post-COVID and thus gives results where COVID is playing a smaller part.

1.5. Thesis outline

Chapter 2 describes the methodology. Chapter 3 contains the results of a literature review. The stakeholders will be addressed in Chapter 4, followed by a data analysis on the end-locations of shared e-moped rides in Chapter 5. Chapter 6 contains an overview of the current and future spatial design plans of the municipality of Amsterdam. Lastly, Chapter 7 contains the conclusion and recommendations.

2 Methodology

This chapter describes the different research approaches in depth. It describes the methods used to answer the sub-questions stated in the Introduction. The first section covers a literature study and how this responds to the second sub-question. Section 2.2 explains how the Stakeholder analysis has been performed to answer the first sub-question. Next, Section 2.3 dives into the GPS-data analysis and how it answered the third sub-question. The last section explains how the municipality's spatial design plans and vision are reviewed to answer the last sub-question.

2.1. Literature study

For the literature study articles were sought after, with keywords being: 'shared micromobility', 'shared moped', 'shared scooter', 'ban', 'scooter ban', 'micromobility ban', and 'shared scooter ban'.

2.2. Stakeholder analysis

To understand the interest of the stakeholders, a stakeholder analysis is done. The stakeholders represented in the analysis are the municipality of Amsterdam, an e-moped provider in Amsterdam, and citizens of Amsterdam. In the end, a power-interest grid is made to summarize the findings.

2.2.1. Municipality of Amsterdam

The municipality of Amsterdam published its 'Handreiking deelmobiliteit en hubs in gebiedsontwikkeling' loosely translated into 'Handbook shared mobility and hubs in area development' in July 2022. The handbook covers the ambitions, policies, and programs that the municipality is enforcing. This handbook will therefore be the source for reviewing the municipality in the stakeholder analysis.

2.2.2. Provider

Contrary to the municipality, a clear vision of parking spaces for the shared e-moped providers can not be found in the literature or online sources. Therefore, an interview with an employee from one of the shared e-moped providers was conducted, whereafter the transcript was analyzed by ChatGPT to find the key takeaways from the interview. The transcription of this interview can be found in Appendix C.

2.2.3. Citizens of Amsterdam

As there is no specific research on what the interest of the shared e-moped users in Amsterdam is, a stakeholder analysis on their behalf can not yet be written. However, to be able to do this, several interviews with users are held. These interviews are conducted in person, on the streets of Amsterdam. Due to limited time, the target group is 50 citizens. How the questions are drawn up can be found in Appendix B.

2.3. GPS-data analysis

The goal of the GPS data analysis is to figure out what popular parking areas for shared e-mopeds are. This will give insights into where the users of the e-mopeds want their rides to end. Later on, this information is used to see which of these locations can be turned into dedicated parking spaces regarding the municipality's future spatial design plans and how many spaces would be needed at that location.

2.3.1. Preparing the data

The data being used is obtained through a shared e-moped provider in Amsterdam. The provider currently offers 385 active shared e-mopeds, enabling roughly 6000 rides per day in the period ranging from the summer of 2021 to the end of 2022 (Gemeente Amsterdam, 2023). The data provided was received as a CSV file, with three entry values; month,end_latitude,end_longitude. Every row symbolizes the data from a ride that was made during the month from which the data was obtained. Data from two months, September and December, is used to analyze the difference between the high- and low season as well whereby the September data represents the high season and December is the low season.

2.3.2. Plotting the data

The received data is input into a coding script. With this script, an interactive map of Amsterdam is created with the received data plotted on top of it.

These data points are clustered via a K-means clustering algorithm. This clustering algorithm groups data points with similar distances from each other together in a cluster. The author of the code determines how many clusters the data points will be assigned to, this number is called the k-number. Next, the center of these clusters is calculated to determine the centroid of each cluster (DataScience, n.d.). In this case, the provider of the data wants to maintain a maximum distance between the user and an available e-moped of 225 meters. To find a k-number that represents this maximum distance, the following formula is used:

$$\text{k-number} = \frac{\text{Total service area of Amsterdam}}{\pi \times (\text{maximum distance between a user and an available shared e-moped})^2} \tag{2.1}$$

Although this might not guarantee a maximum distance of 225 meters at all times, it does display what the most popular areas are and thus where the most dedicated parking spaces are needed. In appendix D the used code can be found. Figure 2.1 displays how the data points are clustered together to form the centroids of each cluster. Just as an example, 32 data points, and 4 clusters are used.

(a) Data points **(b)** Clusters with corresponding centers **(c)** Best locations for parking spaces

Figure 2.1: Example of the Python code with 32 data points and 4 clusters, map from OpenStreetMap

2.3.3. Interpreting the data

After applying the Python code, it is clear what ideal locations for dedicated parking spaces would be. However, these ideal locations might coincide with geofenced locations or parking-free locations. Because of the size of the dataset, this is not expected as a higher sample size increases the confidence interval of the projected centroids (NEDARC, n.d.).

If this still were to happen, a centroid that is located outside the geofenced service area will therefore be moved to the nearest possible location inside the geofenced area.

2.4. Review of spatial design plans

The municipality of Amsterdam is currently working on its ’Shared Mobility Note 2023’. However, a concept version was already made available. This concept version was analyzed to see what possible implementations the municipality is thinking of, and what the challenges along the way are.

Next to the ’Shared Mobility Note 2023’ the municipality also published a vision for mobility hubs. Currently, there are multiple hub pilots ongoing in various neighborhoods in Amsterdam such as ’de Baarsjes’, ’Frans-Hals buurt’, and near the Olympic Stadium (Gemeente Amsterdam, 2022). This document is also reviewed to understand the role the municipality of Amsterdam expects mobility hubs to play in the future and to see if the locations found with the GPS analysis can be combined with possible hub plans.

3
Literature study

As mentioned earlier, there are many forms of shared mobility. Two forms that are often mixed up are the e-moped and the stand-up e-scooter or kick-scooter. These vehicles differ in many aspects, for example, the e-moped is larger in size and can travel at higher speeds, and the stand-up e-scooter is smaller and is allowed on pavements.
In the literature there is much research done on the stand-up e-scooters, but very little on the e-mopeds. This chapter describes the results from literature studies on shared mobility, shared e-mopeds, and bans on micromobility in other cities. Therefore three cities are reviewed, Dallas, Paris, and Utrecht as the bans in these cities gained a lot of attention in the media.

3.1. Literature on shared e-mopeds

The Ministry of Infrastructure and Water Management conducted research on the impact of Light Electric Vehicles, and one of the findings was on the user base of these vehicles. Shared e-moped users are mainly millennials, students, tourists, ex-pats, and freelancers. Their reasons for using the shared e-mopeds vary from fun to environmental reasons. Within the users, it is also noticed that there is a certain seasonal variability, in spring and summer the usage is higher compared to winter (Knoope & Kansen, 2021). Next to that, there is also a variability during the day with a morning peak and an afternoon peak, of double the size of the morning peak (Faber, Durand, & Zijlstra, 2020).

Another interesting result is on the average distance traveled, this is determined to be 2.3km, which suggests that the shared e-moped is used more as a replacement for the bike and public transport than the car (Knoope & Kansen, 2021).
Research from Pérez-Fernández and García-Palomares (2021) looked at parking places for e-mopeds as well, however, their research is done on Madrid specifically and was done via a Geographic Information System (GIS) model and 200 parking spaces. ”With this distribution of 200 parking spaces, just over 170,000 of the origins of trips would be covered at a distance of 200 m, amounting to 72% of the total.”. The distance used, 200 meters, is comparable to the distance used in this research, 225 meters, and thus makes this a relevant paper.

The municipality of Amsterdam recognizes the growth in shared mobility in the city and is willing to work on the development and availability of shared mobility (Gemeente Amsterdam, 2023). However, the hindrance experienced is not something they take lightly. To stimulate providers to work on parking hindrances as well, a permit system will come into play. Every two years this can be renewed or terminated. At the moment, the permit is a temporary permit, to explore the influence of shared e-mopeds on the accessibility of Amsterdam (Gemeente Amsterdam, 2023). No research has been done on where dedicated parking spaces in Amsterdam should be and how the current number of dedicated parking spaces can be increased.

3.2. Literature on micromobility bans

3.2.1. Dallas

When the shared stand-up e-scooters first came to Dallas, they were received with open arms, seen as a way to improve mobility and help citizens get around the city easier. Nevertheless, in September 2020, the City of Dallas decided to terminate the pilot program, leading to the removal of 8.500 e-scooters from the streets. The municipality justifies this by referring to public safety concerns and complaints from residents as the main reasons (Steele & Keomoungkhoun, 2020). Other reasons were the usage by minors, the usage for street racing, and the blocking of sidewalks due to parking issues (Krause & Jaramillo, 2020). However, there was a lot of opposition to this ban, which is supported by the majority of comments on social media regarding the Dallas scooter (Aman & Smith-Colin, 2021). Therefore the debate was opened again, leading to a return of the shared e-scooters, but under stricter regulations and with 82 percent fewer vehicles (Bailey Jr., 2022; FOX 4 Staff, 2022)

3.2.2. Paris

In 2018 Paris was one of the frontrunners in adapting the shared stand-up e-scooter. However, due to the quick rise in popularity, and poor regulation, companies and municipalities have difficulty catching up, according to Relman (2023). Next to that, citizens argue that the users disrespect traffic and parking rules. This resulted in many Parisians wanting to get rid of the scooters as soon as possible (Dillet, 2023). Recent numbers reveal that over a period of 4 years, there were 459 accidents of which 3 were fatal (Giuffrida, 2023).
Eventually, this resulted in a referendum in 2023, where between 86 and 92 percent of the votes supported a ban (Giuffrida, 2023).

3.2.3. Utrecht

In the Netherlands, on the first of October in 2021, the shared e-mopeds made its entrance in Utrecht (micromobiliteit.nl, 2021). 300 shared e-mopeds were made available for a period of 18 months, where after the municipality of Utrecht decided not to extend the permit. The board of the municipality stated they did not see enough benefits from the shared e-mopeds and have a preference for other modes of transport such as bikes and shared e-bikes which are also more beneficial to citizens' health (RTL Nieuws, 2022). The main reason for not extending the permit was that the shared e-mopeds were used for distances that could also be traveled by bike or shared e-bike (RTL Nieuws, 2022). If other nearby municipalities would implement the shared e-mopeds, like in Amsterdam with Amstelveen and Diemen, the municipality of Utrecht would re-open the discussion (Gemeente Utrecht, 2022). Next to that, the municipality saw that the shared e-bikes were easier to apply in the city's infrastructure, as they used the already existing bike parking spaces, and thus less hindrance was experienced (Gemeente Utrecht, 2022).

3.2.4. Conclusion

The three cities mentioned above all have their own reasons for the bans they experienced or are experiencing. However, three major causes for the bans can be found; the fast growth of the shared mobility market, poor regulation, and bad cooperation between the municipality and the shared mobility providers. These three causes should be taken into account when expanding the number of e-mopeds in the city of Amsterdam.

4 Stakeholders

This chapter describes the different stakeholders. The first section represents the municipality of Amsterdam. The second section is about the e-moped providers, for which an interview with a shared e-moped provider was held. The transcription of this interview was inserted into chatGPT to find the key takeaways. These takeaways and the transcription can be found in Appendix C. The third section goes into the citizens of Amsterdam, for which interviews with 50 citizens of Amsterdam were held. The result of these interviews, and how these questions were made up, can be found in Appendix B. Lastly, all the stakeholders are represented in a power-interest grid.

4.1. Municipality of Amsterdam

The municipality of Amsterdam is actively participating in the transformation of the city into a liveable, safe, and responsible urban environment. With a focus on reducing car dependency and promoting alternative forms of transportation, they are working towards gradually decreasing the number of cars while increasing the usage of bicycles, public transport, and green spaces. To achieve these goals, shared mobility is recognized as a crucial instrument (Gemeente Amsterdam, 2022).
The municipality recognizes that currently good accessibility is only achieved in the center and that an increase in accessibility in the suburbs is essential.
With the aim of optimizing space efficiency and improving air quality, the municipality intends to transition from experimental permits to two-year permits regarding shared e-moped usage (Gemeente Amsterdam, 2023). This shift showcases the municipality's influence in shaping the mobility landscape.

4.2. Shared e-moped providers

During the past years, pilots were held with the shared e-mopeds in Amsterdam. From June 2023 onwards, shared e-moped providers can submit their plans for shared e-mopeds in Amsterdam to obtain a two-year permit (Gemeente Amsterdam, 2023). Amongst other aspects, these plans also cover how the providers are planning on dealing with parking issues. The providers with the most promising plans will obtain a two-year permit. Via this permit system, the providers are stimulated to decrease the number of parking complaints received.

The hindrance and complaints that are currently being experienced due to poor parking are not something the providers take lightly. An interview with one of the e-moped providers was held for this section and revealed that this remains one of the biggest issues still present with their service despite measures already taken. These measures include uploading a picture of the parked e-moped or users giving a thumbs-up/thumbs-down for a parked e-moped when they reserve it. Receiving a thumbs-down rating too many times may result in an account ban.
As can be seen in Appendix C, the interview also revealed that the providers see parking behavior as a shared responsibility between the providers, the users, and the municipality. The cooperation between the municipality and the providers seems to be good, with both parties satisfied. What the providers would like to see improve is the bond between the police and themselves, to be able to forward fines

obtained by users for bad parking more efficiently.
As an example of the cooperation between the municipality and the providers, a discussion on a hub system was held. Timely opening the conversation on this and having the discussion led to the shared e-moped providers also being open to this concept. The interview also revealed that the providers expect the hub system to decrease the number of complaints received.

In the end, the municipality will remain the party with the most influence as they have the power to make the regulation. As can be seen in Appendix C, this is always done with input from the providers, so the providers also have an influence on the regulations to some extent.

4.3. Citizens of Amsterdam

4.3.1. Users of the shared e-mopeds

Citizens who use shared e-mopeds in Amsterdam are key stakeholders in the analysis. From the interviews conducted with citizens (as can be seen in Appendix B), it was found that only a small portion of the citizens who use shared e-mopeds experience hindrance more than once a month. As it is human nature to primarily notice negative aspects, Neuhaus Ph.D (2019), these citizens may be more inclined to share concerns rather than positive experiences regarding the parking of shared e-mopeds. Therefore, it is crucial to monitor the citizens who use shared e-mopeds and address their concerns to ensure a positive user experience and maximize accessibility.

4.3.2. Non-users of the shared e-mopeds

Citizens who do not use shared e-mopeds are also important stakeholders in the analysis. The municipality of Amsterdam aims to create a livable and sustainable urban environment by reducing car dependency and promoting alternative transportation Gemeente Amsterdam (2023). Although the majority of the citizens interviewed are users of shared e-mopeds, the citizens who do not use them appear to experience more hindrance (as observed in the interviews, Appendix B). The municipality should not overlook these concerns and should actively keep non-users informed about the measures being taken to address hindrances. This way all citizens feel listened to and involved in the process of improving accessibility in the city.

4.4. Power-interest grid

A power-interest matrix is made to visualize the different stakeholders and how these relate to each other (Solitaire Consulting, 2020). The color of the icon displays the potential impact they can have, red is negative, blue is neutral, and green is positive. Figure 4.1 displays the power-interest grid for the stakeholders assessed in this chapter.

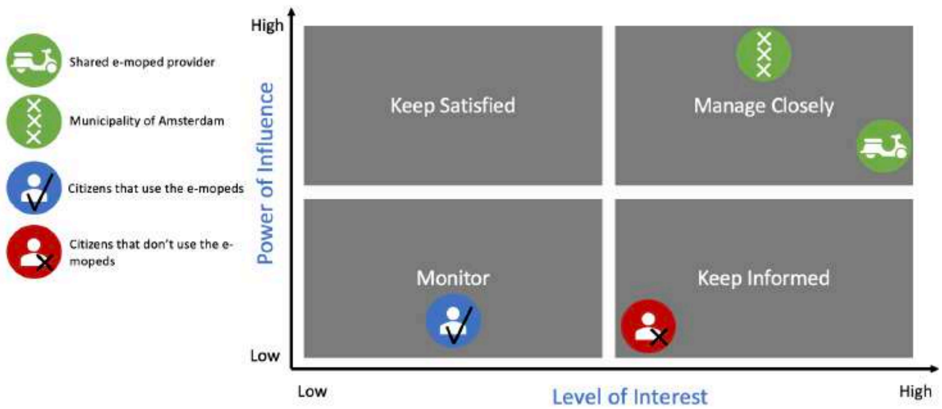

Figure 4.1: Power-interest grid of the stakeholders

The shared e-moped providers have the highest interest in increasing the number of dedicated parking spaces as this will likely decrease the number of complaints received, and thus increase the chances of a new permit. After all, they need the e-mopeds to make as many rides as possible to generate

profits, which will not happen if the e-mopeds are not even allowed in the city. They do have a certain power regarding the regulation but are still very dependent on the municipality.
The municipality of Amsterdam wants to increase the accessibility of the city. To do that, shared e-mopeds are seen as a fundamental instrument. Facilitating shared e-mopeds, and thus the parking of it is of high interest. The municipality also has the power to hand out permits and allocate dedicated parking spaces.
From the interviews held with citizens of Amsterdam, it became evident that citizens that use the shared e-mopeds more frequently experience less hindrance on poorly parked shared e-mopeds compared to citizens that don't use the shared e-mopeds or use them less frequently. Therefore, the citizens that use the shared e-mopeds should be monitored to ensure that they will still use the shared e-mopeds when dedicated parking spaces are implemented.
Citizens that don't use the shared e-mopeds experience more hindrance and are thus more likely to submit complaints. However, they hold the same power as the citizens that do use the shared e-mopeds.

5
Analyzing ride-end locations

This chapter covers the analysis of GPS data from the shared e-mopeds. The focus is on identifying optimal locations for dedicated parking spaces. To achieve this, a k-means clustering technique is used to cluster the GPS data points, thereby enabling the identification of concentration areas regarding the end locations of e-moped rides. The resulting clusters represent potential optimal parking spaces. The code used for this analysis can be found in Appendix D. By identifying the main areas where rides end and determining the number of rides that end in those areas, the demand for dedicated parking spaces can be assessed. This analysis allows us to recommend an appropriate increase in the number of dedicated parking spaces in these locations, strategically maximizing the accessibility of the city for shared e-moped users.

5.1. Determining the number of clusters

To use a k-means clustering algorithm, the number of clusters that the data points will be assigned to, known as the k-number, needs to be known in advance. As stated in the Methodology chapter, this is determined by Formula 5.1.

$$\text{k-number} = \frac{A_{\text{Amsterdam}}}{\pi \times r_{\text{max}}^2} \quad \left[\frac{\text{m}^2}{\text{m}^2}\right] \tag{5.1}$$

where:

- $A_{\text{Amsterdam}}$: Refers to the entire area covered by the shared e-moped service in Amsterdam, measured in square meters.
- r_{max}: Specifies the maximum distance that a user is willing to travel to access an available shared e-moped.

The total service area from one of the shared e-moped providers was not previously known. Therefore a JSON file was assessed via QGIS where multiple polygons from the service area were added up to form a total service area of roughly 32,5 km^2.
The data provider wants a maximum distance of 225 meters for a moped to be conserved. This is to maintain the attractiveness of using shared e-mopeds, and not to defer to other modes of transport. To maintain this distance, the service area is divided by the area of a circle, with a radius of 225m. This way the number of clusters is determined.
This gives a k-number of 204, meaning that there are 204 locations needed where dedicated parking places should be implemented to cover the entire service area when taking a maximum distance between the user and a shared e-moped of 225 meters into account.

5.2. Seasonal dependency

When comparing the data between the months of September and December, a big dissimilarity is in the number of rides made. In September 2022 this was equal to 137.350 compared to 114.967 in December 2022. When looking at the locations of the clusters from both months, Figure 5.1, the differences can be seen to be small. Due to the limited time for this research, we further only use the data from the month with the most rides, September.

Figure 5.1: Clustered locations of GPS-data from months December (red) and September (green), map from OpenStreetMap

5.3. Results from the data

In Figure 5.2, the data points of the rides made in September 2022 can be seen. As there is a high number of rides made, nearly the entire city is covered in the data points. However, when these data points are clustered, the map becomes clearer, this can be seen in Figure 5.3.

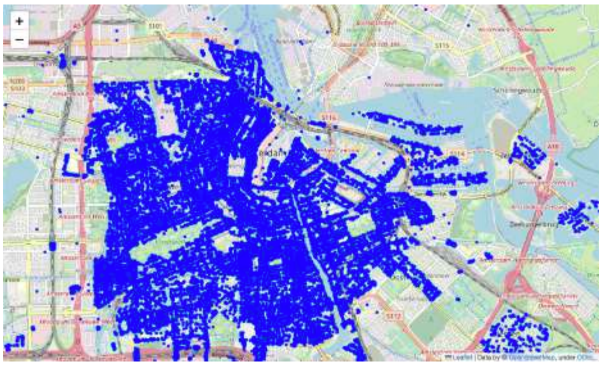

Figure 5.2: Map with all the data points from the month of September, map from OpenStreetMap

Figure 5.3: Maps with the centroids of the clusters, map from OpenStreetMap

However, this does not clearly provide any information regarding the accessibility of the city, as it is a goal the municipality aims to achieve through shared mobility (Gemeente Amsterdam, 2023) nor about the maximum distance the providers want to govern. Figure 5.4 gives more insight into this.
In general, with the clustered locations a large part of the city is covered, and the maximum distance of 225 meters is governed. However, in some locations, the circles overlap. Although this is unfavorable

Figure 5.4: Coverage of the city with a radius of 225m, map from OpenStreetMap

for the maximum distance, this does display that those locations have a high concentration of rides that end in that area. This is therefore also a valuable insight.

5.4. Determining the number of parking spaces needed per cluster

If the number of parking spaces per cluster is known, then practical solutions can be looked into. The average number of parking spaces needed is given by Formula 5.2.

$$n_{\text{avg, cluster}} = \frac{x_{\text{daily, cluster}}}{s_{\text{daily, moped}}} \tag{5.2}$$

$$s_{\text{daily, moped}} = \frac{T_{\text{rides, Sept}}}{N_{\text{days, Sept}} \times N_{\text{scooters}}} \tag{5.3}$$

where:

- $n_{\text{avg, cluster}}$: Represents the average number of parking spaces available for a cluster.
- $x_{\text{daily, cluster}}$: Refers to the average daily number of rides that end in a specific cluster.
- $s_{\text{daily, moped}}$: Represents the average daily number of rides per individual e-moped.
- $T_{\text{rides, Sept}}$: Represents the total number of rides made in September.
- $N_{\text{days, Sept}}$: Refers to the number of days in September.
- N_{scooters}: Represents the number of e-mopeds.

In September, the average daily number of rides that end in a cluster, $x_{\text{daily, cluster}}$, equals 22.44. Assuming all 385 e-mopeds are active, the average daily number of rides per e-moped, $s_{\text{daily, moped}}$, equals 11.89 and is calculated by using Formula 5.3.
Consequently, the average number of parking spaces for a cluster is 2. Given that the data used is from one of the shared e-moped providers, and two shared e-moped providers are active, the average number of parking spaces for a cluster becomes 4, assuming both service providers operate the same, maximum allowed, number of e-mopeds.

If fewer shared e-mopeds were active due to for example maintenance, this would result in more rides made per e-moped and thus fewer parking spaces needed per cluster. Therefore the assumption that all e-mopeds are active is a safe assumption to estimate the maximum number of parking spaces needed.

The data obtained only contained data on a monthly basis. Therefore, this does not give insights into the course of the required parking spaces on an hourly basis, which is desired regarding rush hours. Further investigation is necessary to explore the impact of rush hours on the number of parking spaces in a dedicated parking area.

6

Spatial design plans of the municipality of Amsterdam

In the years leading up to 2050, at least 150.000 new households will be established in Amsterdam and because the rest of the municipality will grow as well, the pressure on the accessibility of the city increases (Gemeente Amsterdam, 2023). To accommodate this increase, the municipality wants to upscale shared mobility as well. This means the providers will be allowed to offer 600 shared e-mopeds per provider instead of 385. This supports better accessibility in areas with poor public transport accessibility but requires good collaboration between the municipality and the providers.
In this chapter, the spatial design plans and vision for the municipality of Amsterdam will be reviewed and applied to three situations.

6.1. Future situation

6.1.1. No-parking zones

One of the things the municipality wants to change with the new permits is the so-called no-parking zones. In the current experiment, these were focused on 9 main areas, often crowded, tourist areas. The current no-parking zones will be retained and even expanded wherever necessary, for example, to areas that providers already excluded.
Next to that, sidewalks narrower than 1.50m will be excluded from the service area because of a higher chance of hindrance occurring (Gemeente Amsterdam, 2023).

6.1.2. Scale down on free-floating

Scaling down on free-floating parking can be done in multiple ways. A popular remedy in crowded locations is switching a private car parking space for multiple shared e-moped parking spaces. The difficulty with this lies in citizens voluntarily needing to hand in parking licenses. If this is possible, also private mopeds will be allowed to park (Gemeente Amsterdam, 2023). In interviews held with citizens of Amsterdam, only 1 out of 8 permit holders was willing to hand in their parking license in exchange for dedicated moped parking spaces.
Allowing private mopeds to park in dedicated shared e-moped parking areas can potentially impact the customer experience, as well as hindrance, as the availability of parking spaces will be impacted. Private mopeds are not connected to the ride-planning software of shared e-moped providers. As such, a planned available parking space with a shared e-moped ride may not be available, forcing the driver to find another space, or resulting in the driver parking the shared e-moped outside the dedicated parking area, possibly causing hindrance.

Another remedy is the expansion of hubs. Four types of hubs are being experimented with in Amsterdam; neighborhood-, district-, city- and regional hubs. Each hub has its own implementation and location guidelines, as presented in Table 6.1. In general, hubs are a node in a multimodal mobility network, serving different modes of transport and their infrastructures (Gemeente Amsterdam, 2021).

Table 6.1: Overview of different hubs and applications

	Neighborhood hub	District hub	City Hub	Regional Hub
Location	Neighborhood streets	Central in the district, good public transport connection	Near train and metro stations	Along highway, public transport station
Implementation	Public spaces, car parking spaces	Above- or underground built facility	Station with shared mobility options	Above ground built facility

Within these hubs, designated parking spaces for shared e-mopeds should be allocated. However, sometimes the implementation of a physical hub is not possible. Therefore, the current method of geofencing will be retained as well.
It still is possible for users to park outside the applied borders, and thus it may occur that more mopeds are parked in this location than there is room for it, therefore the shared e-moped providers can ask the users the upload a picture of the parked moped to mitigate this.
This is also recommended as in the interview with one of the e-moped providers it became evident that this is already seen as a proven method for stimulating good parking behavior.

6.1.3. Dynamic Parking

Amsterdam is a city where often maintenance or events are ongoing. Adapting to these cases requires flexibility, which is hard to do with public transport. Hence, the municipality wants the shared e-moped providers to contribute to this. However, for this research dedicated parking spaces are reviewed to develop a long-term solution. As Dynamic Parking will be embedded as a temporary solution, this will not be considered further.

6.2. Implementation

In this section, the municipality's future plans are applied to three practical locations. As noted earlier, the average daily number of rides that end in a cluster, the mean, is equal to 22.44. The standard deviation is equal to 12.45, as calculated with a Python code that can be found in Appendix E.
The three practical locations looked into are locations that represent the mean minus the standard deviation (SD), the mean, and the mean plus the standard deviation.
Although using this method of the mean and standard deviation has its limitations, it still provides useful insights about the dispersion of the data. With the limited time for this research, this method is chosen.
Table 6.2 displays the three possibilities that will be reviewed. The 'Cluster values' represent the number of rides that end on average on a daily basis in a cluster and are found using the same calculations as done earlier in Section 5.4. n_{avg} represents the number of dedicated parking spaces needed.

Table 6.2: Overview of three different options assessed

	Original values	Number of the cluster	Cluster values	n_{avg}
Mean - SD	10.00	47	9.90	2
Mean	22.44	195	22.70	4
Mean + SD	34.89	91	34.70	6

6.2.1. Mean minus the standard deviation

To provide more insight into the process, cluster 47, displayed in Figure 6.1 and located near the Haarlemmerweg will be further assessed. This cluster has an average daily number of rides of 9.90, which is similar to the mean minus the standard deviation, of 10.00.

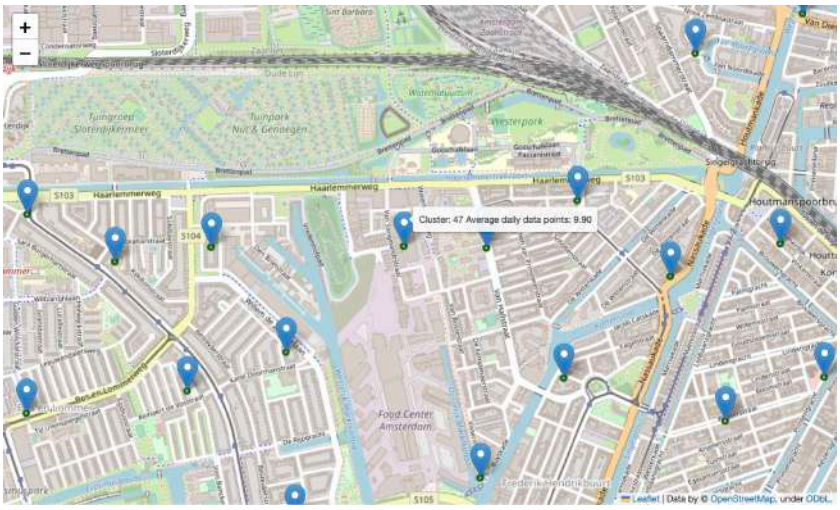

Figure 6.1: Map that displays the average daily data points in cluster 47, map from OpenStreetMap

The van Slingelandtstraat is full of warehouses and small offices. The cluster in this area has a need for 2 dedicated parking spaces, as can be seen in Table 6.2.

When looking at the location in more detail, the sidewalks can be seen to be too narrow all around and thus are not an option for implementing dedicated parking spaces. In the vertically placed red-marked areas, Figure 6.2, there are driveways for the warehouses. These are thus also unfavorable.
On the left side of the Shell station, it is possible to implement parking spaces. However, the only option available would be to replace a car parking space with shared e-moped parking spaces. This is not an ideal situation as it would create more parking spaces than necessary. Two suitable locations are at the corners of van Slingelandtstraat, where the sidewalks are significantly wider, allowing for space allocation without causing inconvenience. Another possibility is at the Greenwheels location, but introducing a hub there would also result in an unnecessary amount of parking spaces.

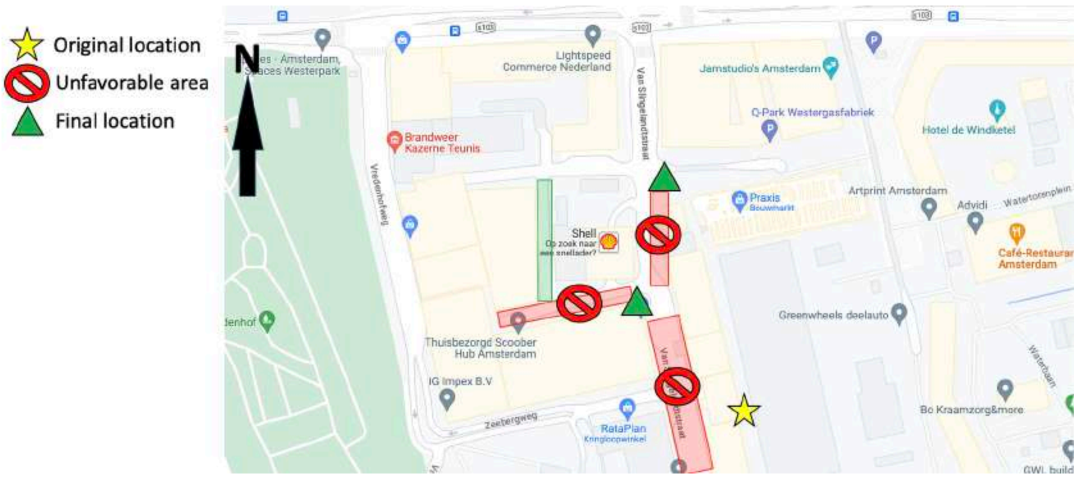

Figure 6.2: Map displaying van Slingelandtstraat location analysis, map from Google Maps

Next, to clarify that the specific location is dedicated only to shared e-mopeds, signs should be implemented. To stimulate proper parking, distinct borderlines for every e-moped parking space should be applied, as seen in Figure 6.3.

Figure 6.3: Dedicated parking spaces on the sidewalk near the Olympic Stadium in Amsterdam

6.2.2. Mean

The cluster displayed in Figure 6.4, cluster 195, located near the corner of the Kinkerstraat and Jan Pieter Heijestraat will be further assessed as this has a comparable number of average daily rides that end in that cluster as the mean of all the clusters.

Figure 6.4: Map that displays the average daily data points in cluster 195, map from OpenStreetMap

The Kinkerstraat connects the Kinkerbuurt with the Da Costabuurt. As this is seen as a crowded shopping street, it is impractical to implement dedicated parking spaces on this street (Gemeente Amsterdam, nd). The Jan Pieter Heijestraat has two options, one south of the Kinkerstraat and one north of the Kinkerstraat. The latter would be located around a loading and unloading area and is therefore also unfavorable.

North of the Kinkerstraat, in the Hasebroekstraat, there is a residential area, with car parking spaces for license holders next to the sidewalks. Between the wide sidewalk and the car parking spaces, there are bike parking spaces. The aforementioned no-parking zones are thus irrelevant here as the sidewalks are well over 1.50 meters wide. An overview of the location analysis is displayed in Figure 6.5.

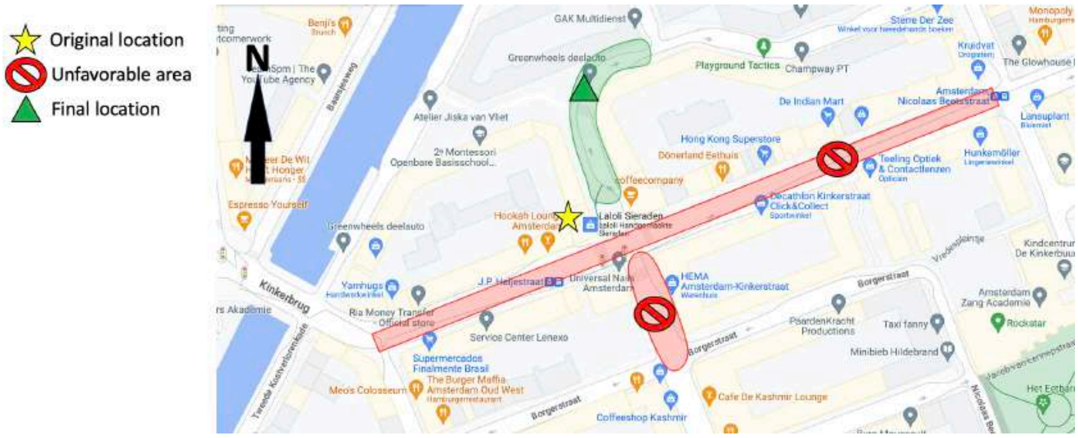

Figure 6.5: Map displaying Kinkerstraat location analysis, map from Google Maps

A popular form of scaling down on free-floating parking, switching licensed car parking spaces for multiple moped parking spaces, can be implemented.
Another possibility would be implementing a neighborhood hub. Further down the street, there are two dedicated car-sharing parking spaces. Implementing a neighborhood hub would be most beneficial as it enables better accessibility in the city and the effort is relatively small because the car-sharing spaces are already there.
For the implementation, the municipality is enforcing a policy to reduce the number of cars on the streets. With this policy, the number of licenses is also decreased (Gemeente Amsterdam, 2021). As for this specific location, the number of parking spaces needed is equal to the average number of parking spaces needed for a cluster, 4 parking spaces need to be implemented. This is achieved by exchanging one car-parking space.

6.2.3. Mean plus the standard deviation

The cluster displayed in Figure 6.6, cluster 91, has an average amount of daily data points of 34.70. This is comparable to the mean plus the standard deviation, which has a value of 34.89. This cluster is located near the Rijksmuseum, on the Weteringschans.

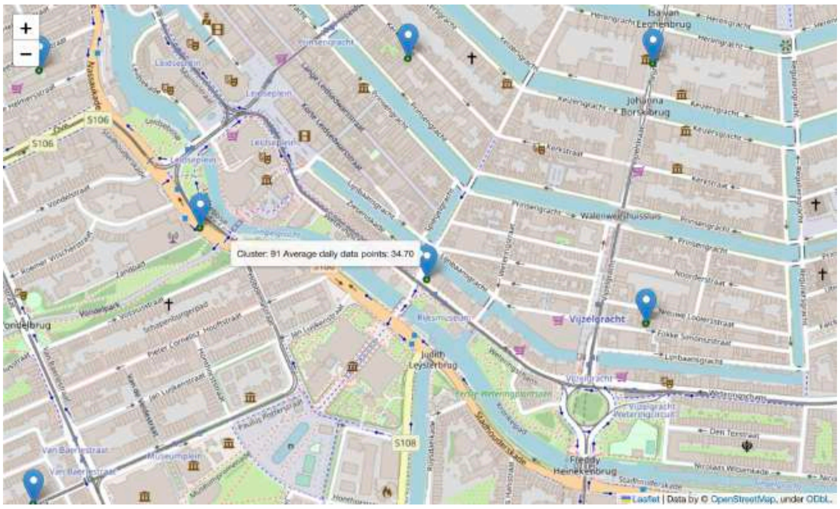

Figure 6.6: Map that displays the average daily data points in cluster 91, map from OpenStreetMap

South of the Weteringschans, the Rijksmuseum is located which attracts large groups of tourists. The sidewalks are wide enough to implement shared e-moped parking spaces, but due to the large number of tourists passing by, this is not a good fit. The area south of the Weteringsschans is therefore unfavorable for implementing dedicated parking spaces up to where the red-marked area in Figure 6.7 ends.

Currently, the Weteringschans is under construction, with wider cycling lanes returning and fewer parking spaces for cars. As the sidewalks are less than 1.50 meters wide, implementing parking spaces on the sidewalks is not possible and thus the Weteringschans is largely an unfavorable street to implement dedicated parking spaces. This leaves The Zieseniskade as a valid option, as there are several car parking spaces on this street and this is relatively close to the original cluster location.

For this cluster, 6 dedicated parking spaces are needed. To make getting on and off the moped convenient, and allow accessible parking, two adjacent car-parking spaces would be needed on the Zieseniskade.
Another possible option presents itself on the Weteringschans, in the direction of Vijzelgracht. There is a dilation of the sidewalks which is marked with the right green triangle in Figure 6.7. To make this possible, easy access to the sidewalks should be ensured. The entire location analysis can be seen in Figure 6.7.

Figure 6.7: Map displaying Weteringschans location analysis, map from Google Maps

6.2.4. Conclusion

For situations with fewer parking spaces needed than the average or mean situation, it is unfavorable to exchange car-parking spaces because this might create more dedicated shared e-moped parking spaces than needed. Other solutions, such as dedicated parking spaces on wide sidewalks would be more beneficial.
In situations similar to the average or mean situation, various options could be implemented, dependent on the surroundings. Combining existing dedicated car-sharing parking spaces has the advantage of allocating a hub system and thus serves a bigger purpose than just that of the shared e-moped users.
When the number of dedicated parking spaces is higher than the average, larger areas need to be redesigned. More than one car parking space is needed to make this possible. The implementation of dedicated parking spaces is a highly location-specific task, with many aspects influencing the optimal location choice.

7
Conclusion and recommendations

This chapter provides the conclusion and recommendations from this research. The first section covers a summary of the findings. Section 7.2 gives more insights into the recommendations, whereas section 7.3 will present the final conclusion.

7.1. Summary of findings

The aim of this research was to find out how the number of dedicated parking spaces for shared e-moped providers in Amsterdam could be increased to maximize the accessibility of the city. Four subquestions were addressed; identifying the stakeholders and assessing their influence and interest, reviewing reasons for micro-mobility bans in other cities, analyzing where the main end locations of rides and how many rides end in those locations, and what the possibilities are that the municipality can offer. The following key findings have been established:

Stakeholders
The four identified stakeholders encompassed the municipality of Amsterdam, the shared e-moped providers, users, and non-user of shared e-mopeds. Although the municipality and the providers are supporting the accessibility of the city, the majority of the citizens experience parking hindrances of shared e-mopeds to some extent. Key findings from interviews with 50 citizens revealed that certain age groups and non-users reported experiencing hindrance, highlighting the need to address these concerns.
The influence that the stakeholders have varies, with the municipality holding the decision-making power. In this decision-making process, the municipality is closely collaborating with the shared e-moped providers.

Micromobility Bans
The research conducted revealed that micromobility bans in other cities were primarily driven by the fast growth of the shared micromobility market, poor regulation, and bad cooperation between the local municipality and the shared micromobility providers. These findings suggest important factors to account for regarding the city of Amsterdam.

Ride End Areas
The GPS data analysis indicated popular areas where shared -e-moped rides ended. By focusing on the areas found, dedicated parking spaces can be strategically placed to maximize accessibility and convenience for the users.

Possible implementations
The municipality envisions three ways in which shared e-mopeds can cause less hindrance and contribute to better accessibility in the city. First, it plans to expand the no-parking zones. Next, it aims to scale down free-floating parking and expand the hubs system. Lastly, shared e-mopeds can be utilized for dynamic parking, for example, during public transport maintenance. The emphasis lies in

the recognition that each location requires a tailored solution, as there is no one-size-fits-all approach.

7.2. Recommendations

Based on the findings and analysis, the following recommendations are proposed to increase the number of dedicated parking spaces for shared e-moped providers in Amsterdam, and with that maximize the city's accessibility:

Stakeholder collaboration
Encourage active collaboration between the stakeholders involved. Create a dedicated working group to handle the challenges and opportunities of establishing designated parking spaces. This group should conduct regular feedback sessions to ensure progress is being made.

Pilot locations
Start pilots in a number of areas to assess the impact of dedicated parking spaces on accessibility and user behavior. Evaluate these pilots, and use the data from the pilot as a foundation for future decision-making processes.

Technological measures
To improve the use of dedicated parking spaces, users should be obliged to upload a picture of the parked e-moped. Next to that, smart parking systems can be assessed to make parking easier and provide real-time information on parking availability. Private mopeds parked in shared parking areas remain a challenge. A solution could be to develop dedicated shared e-moped parking areas instead of mixed ones.

7.3. Conclusion

In conclusion, this study shows how dedicated parking spaces for shared e-moped providers in Amsterdam can be increased. Further research is needed to evaluate the effectiveness of the current policy where citizens voluntarily hand in their parking licenses and to examine the variability of the locations of popular parking areas during peak hours on an hourly basis. This research would offer valuable insights into the placement of dedicated parking spaces and promoting sustainable mobility in Amsterdam.

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A
Planning

Figure A.1 displays the weekly thesis planning.

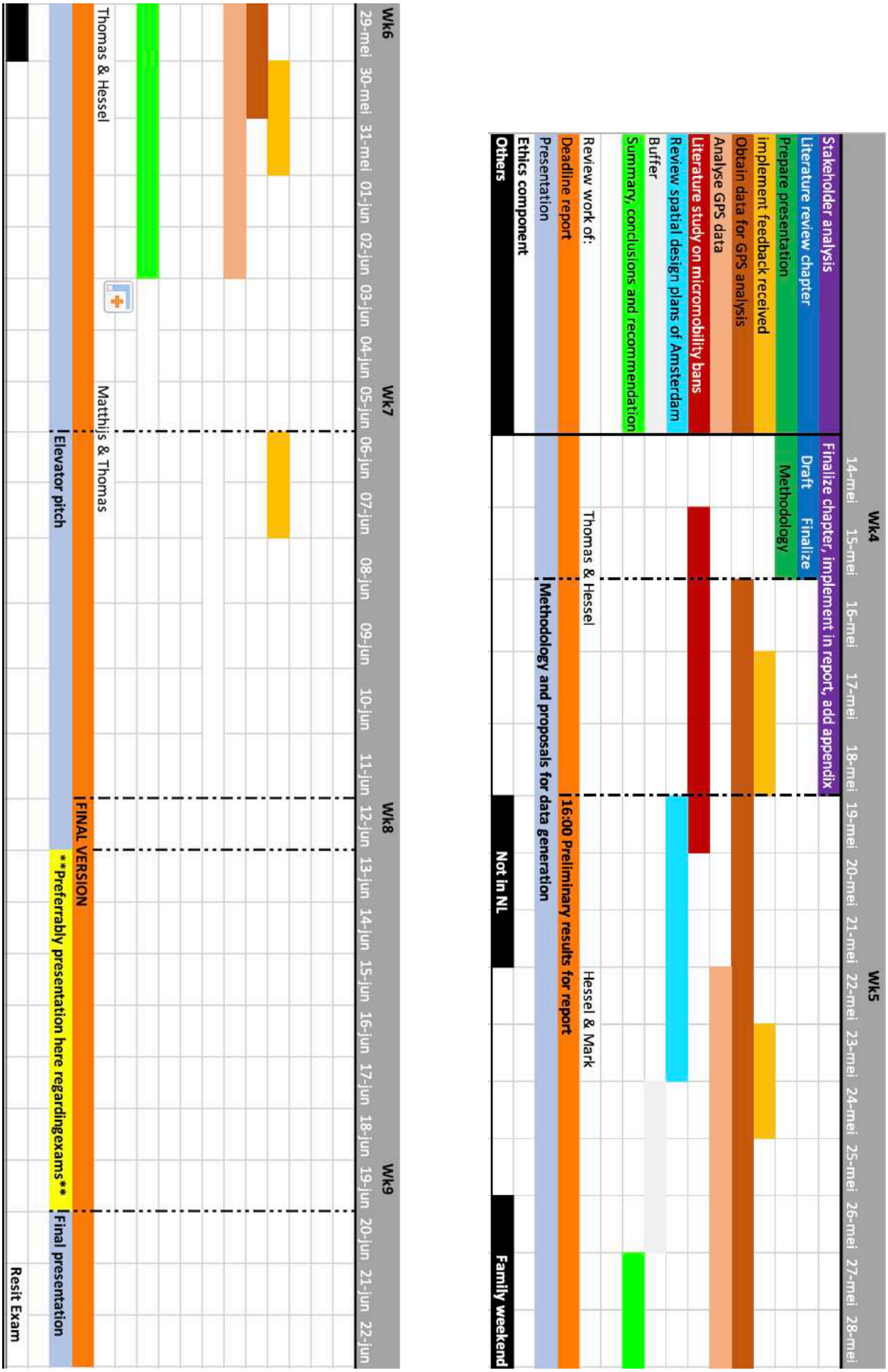


Figure A.1: Planning BEP

B

Interviews with 50 citizens

In this Appendix, a brief explanation of how the survey questions are built up will be given. Consequently, the results will be displayed.

B.1. Question explanation

Q1: Age group & Q2: Gender
This question helps gather demographic information to analyze how different age and gender groups perceive and use shared e-mobility options.

Q3: Do you use shared mobility? & Q4: How often?
These questions help understand the existing user base and their experiences, providing insight into whether there is a correlation between users/non-users and how often they experience hindrance.

Q5: Purpose of your usage?
Identifying the primary purpose behind shared e-moped usage helps pinpoint key locations for dedicated parking spaces, maximizing accessibility for work/school, leisure, or a combination.

Q6: How far would you be prepared to walk to get to an e-moped?
Understanding acceptable walking distances informs the optimal placement of dedicated parking spaces, ensuring accessibility and convenience for shared e-moped users.

Q7: Do you experience hindrance? & Q8: How often?
These questions aim to identify challenges faced by users and non-users, it is used to see if there is a correlation between the frequency in which users make rides and the hindrance they experience.

Q9: Do you have a parking permit? & Q10: Would you be prepared to swap it for dedicated parking spaces for shared e-mopeds?
Question 9 filters out part of the citizens interviewed, after which the willingness to swap parking permits provides insights into the acceptance and effectiveness of the current policy.

B.2. Results

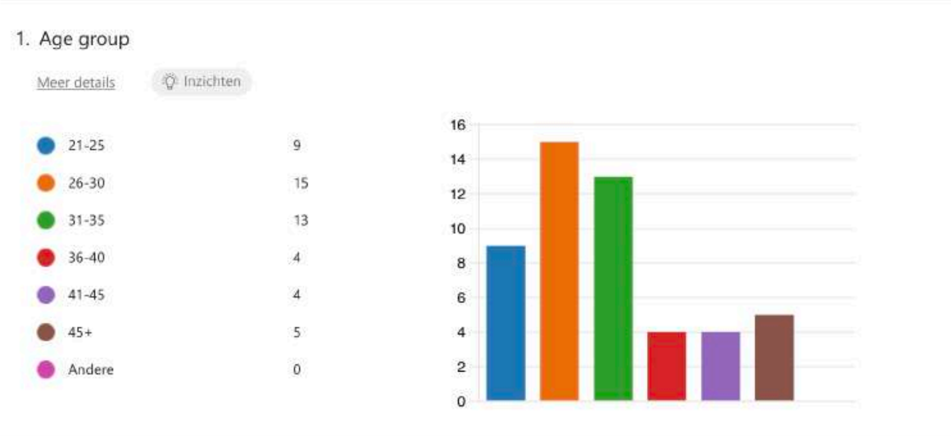
B.2.1. Key findings

- In the age group 26-30, 100% answered 'Yes' to using shared mobility or not.
- 10% of the respondents answered '45+' to question 1, from this 10%, 100% answered 'Yes' to experiencing hindrance.
- 32% of the respondents don't use shared mobility, from which 94% answered 'Yes' to experiencing hindrance.

- 6% of the respondents use shared mobility on a daily basis, from this 6% all of them use shared mobility mostly for work/school, they don't experience hindrance and are prepared to walk only 0-5 minutes.

B.2.2. Question results

Q1 & Q2 Shared mobility is used more by the age groups 21-25, 26-30, and 31-35. There is no clear correlation based on gender.
Q3 & Q4 Daily users of shared mobility appear to experience less hindrance compared to non-users or less frequent users.



4. How often?

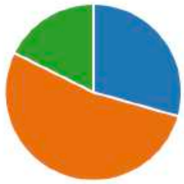
Meer details Inzichten

Daily	3
Weekly	15
Monthly	12
Yearly	4

5. Purpose of your usage?

Meer details Inzichten

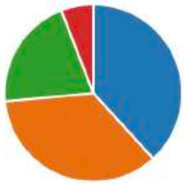
Work/School	10
Leisure	18
Combination	6
Andere	0



6. How far would you be prepared to walk to get to an e-moped?

Meer details Inzichten

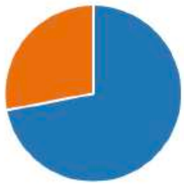
0-5 minutes	13
5-10 minutes	12
10-15 minutes	7
15+ minutes	2



7. Do you experience hindrance?

Meer details

Yes	36
No	14

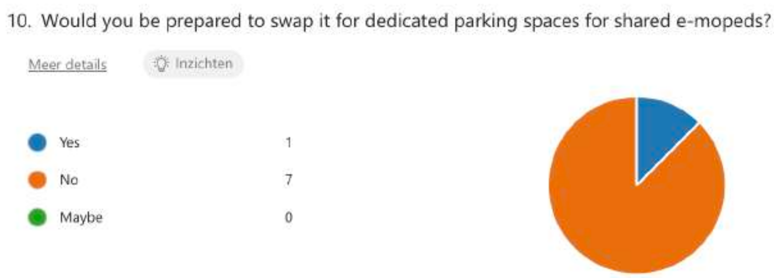


8. How often?

Meer details Inzichten

Daily	3
Weekly	8
Monthly	14
Yearly	11


9. Do you have a parking permit?
Meer details
Inzichten
Yes 7
No 42
Not yet 0


10. Would you be prepared to swap it for dedicated parking spaces for shared e-mopeds?
Meer details
Inzichten
Yes 1
No 7
Maybe 0

C

Interview with shared e-moped provider

C.1. Key takeaways from the interview

The entire transcript was analyzed with ChatGPT to find the key aspects of five segments; Parking hindrances and responsibilities, adapting to parking regulations, excluded areas and pilots, collaboration with the Municipality, and the impact of the hub system and flexibility. The key findings follow below.

C.1.1. Parking Hindrances and Responsibilities

- Parking hindrances are a major issue, and the provider collaborates with municipalities to address them.
- Responsibilities for proper parking behavior are shared among providers, the municipality, and users.
- The provider aims to stimulate good parking behavior and takes actions against improper parking.

C.1.2. Adapting to Parking Regulations

- Narrow sidewalks in Amsterdam necessitate adapting parking regulations.
- The provider emphasizes the importance of parking locations being near customers.
- Converting car parking spaces into shared e-moped parking hubs is suggested.

C.1.3. Excluded Areas and Pilots

- Certain areas, such as private properties and areas with many complaints, are excluded from the service area.
- Some exclusions and parking arrangements may be part of ongoing pilots or initiatives.

C.1.4. Collaboration with the Municipality

- The relationship between the provider and the municipality is pleasant and cooperative.
- The municipality seeks input and opinions from the provider.
- Collaboration is described as mutually beneficial, with the provider involved in discussions and decision-making.

C.1.5. Impact of Hub System and Flexibility

- A hub system may improve battery swap operation (BSO) efficiency.
- Commercially, a hub system may not be advantageous due to availability and accessibility concerns.
- The shared e-moped industry is shifting towards hub systems, with advantages and disadvantages.

C.2. Transcript

Interviewer: TB
Okay, thanks for making time for this interview. First of all, could you maybe briefly introduce yourself? And what your role is at *COMPANY NAME*?

Interviewed: E-moped provider (EP)
Hi, I'm *EMPLOYEE NAME*, and I work at *COMPANY NAME* for over a year now. With my work, I'm in close contact with many municipalities which I really enjoy.

TB
Okay, thanks. The first question I had was what your view on parking hindrances for e-mopeds is, and the responsibility that comes with that?

EP
Yeah for our department, this is probably one of the biggest issues that are dealing with and also a big point that we are discussing when talking to municipalities. For us *COMPANY NAME* it really is something that we are working on together with the municipality and we try to innovate wherever we can.
The responsibility question can be nuanced. I think we, the providers, but also the municipality and the users carry this responsibility. We as providers should do whatever we can to stimulate good parking behavior, and whenever they park wrong also act on it. For us, this is first a warning, the second time a fine, and eventually excluding a user from our service.
Our role is limited to some extent, if someone uses one of our mopeds, they can park it wherever they want within our service area. However, we cannot prevent the poor parking itself. Just like when someone uses a private moped. What is seen is that because our mopeds have a familiar color and name, citizens tend to complain more about our mopeds than private mopeds, but it's also up to the user to park appropriately.
Lastly, for the municipality, it's also important to have conversations about the service area. Especially here in Amsterdam, with an old center and small sidewalks. Next to that, it is also important to improve the bond between the police and the providers. In that way, when a fine is sent out, for example, we can communicate this with the user. Another example is when they receive many complaints about a certain area if they communicate this with us, we can adapt our service area. Finally, Amsterdam is planning on working with a hub system, with which we expect the complaints to reduce a lot.

TB
Okay, thanks I think that answers my question well.
You already mentioned the narrow sidewalks in Amsterdam, I read that with the new permits parking here will also not be allowed anymore. How do you plan to adapt to this regulation? Example giving, turning a car parking space into multiple shared e-mopeds parking spaces.
EP
In Amsterdam specifically we see that the 1,5m is indeed not enough, so we are planning on removing this.
Making a brief detour, what remains very important for *COMPANY NAME* is that the e-mopeds are parked near our customers. If a user is asked to walk over 200m, the readiness to use one of our e-mopeds drops by over 50 percent.
What we would like to see from the municipality, is that they guarantee is that users will only need to walk 200-250m before riding an e-moped. The way that usually happens is indeed by turning car parking spaces into hubs.
Oh and if you want me to be more direct in my answers, that is possible hahaha, just let me know.

TB
Hahaha no thanks, it's great this way.
Another thing that caught my attention is that now, the service area is quite large. However, there are also certain areas that are not in the service area, such as the Haarlemmerdijk, Hogeschool van Amsterdam, Roeterseilandcomplex and more. Are these areas filtered out by you or the municipality?

EP
Yeah that can happen because of multiple reasons.
To get started with Roeterseilandcomplex and the Hogeschool van Amsterdam for example, that is an area which is private property, belonging to the institutes themselves. Nor the municipality nor the providers have any say in this matter.
For Haarlemmerdijk, I'm not very familiar with Amsterdam, so I don't actually know why that area is excluded, but a second reason could be hindrance where either the municipality or we decide to exclude it.

TB
Okay very clear, thank you.
Apart from the entirely excluded areas, I also saw that around the Negen Straatjes, there is an area with a lot of tiny island-like parking spots. I was curious as to whether these were placed on purpose, or if this was something that you were piloting or so.

EP
Is this the area near Rembrandtplein that you are referring to?

TB
Let me check just to be sure.
I'm referring to the area underneath the flower market, so de Weteringbuurt. Hahah quite far from the negen straatjes. But there you can see one very large area from the 'Grachtengordel' which is excluded.
I was wondering if this was a pilot on the 250m maximum distance thing or if it was caused by hindrance.

EP
I'm a bit in between thoughts because as you may know, the municipality is piloting a hub system near Rembrandtplein, so it could be possible that this is something that's part of that pilot. That's what I'm suspecting, so it indeed is a pilot. But if you're really interested, you can send an e-mail to *NAME OF COWORKER* he can probably tell you more.

TB
Okay thanks, then something that I also vaguely remember from conversations I had with *NAME OF COWORKER*, is that the municipality is really trying to stimulate you, the providers as much as possible.
I remember the permits are given out based on a point system, in which every provider delivers plans on certain aspects for which they can earn points. In the end, the two providers with the most points get the permit.
Could you maybe tell me something about this process, and how this takes shape in Amsterdam?

EP
On the permits, it's good to know that our permit already passed its date. It has been elongated because soon a new permit system will come into play. With that, all the providers can indeed submit their plans again where after two providers will be chosen.
How the point system exactly works, I also don't really know, but in general, we are intensively working together with the municipality. We have a meeting every two weeks in which we discuss basically all their requests and pilots regarding shared e-mopeds.

TB
Okay, I understand. I was actually curious as to what your relationship was like, and that it's not destructive or something like that. But if I'm hearing you that's not the case here.

EP
Yeah to say that for Amsterdam, they are one of the best municipality's to work with. They are very focused on the bureaucratic apparatus in Amsterdam, to roll the shared e-mopeds out as well as possible. Our contact is very tight and they always ask for our input and opinion. So in that system, there is in no way a sense of them forcing us to do certain things.
Concluding the cooperation is really really pleasant, and I believe that goes both ways. Hahaha at least I hope! No but, that's what I experienced, and I spoke with them quite a lot hahaha.

TB
Hahaha okay, thanks.
One of the other things I was curious about, something that I was also involved in was improving the Battery Swap Operation Efficiency (BSO efficiency). I can imagine that if mere hubs were to come, and free-floating parking is downscaled, the BSO efficiency only increases. Is that something you also notice? And do you still consider it bad to lose flexibility if the competitor also loses flexibility?

EP
Yeah, I think you can say a hub system is commercially seen not better for us. Especially because of availability and accessibility reasons, but you also get some things back for it. It indeed is the case that your BSO is easier to run from a hub system.
However, the knife cuts both edges. There's kind of a twist going on in the entire shared e-moped world. There is more orientation towards hubs and we as *COMPANY NAME* decided to embrace that with both advantages and disadvantages.
At the end, it is hard to determine whether it's to our advantage or not.

TB
Okay, I think I can understand that thanks. I think that was it from my side, do you happen to have any questions for me?

EP
No not really, if you want more information however I can recommend you send an email to *NAME OF COWORKER*. During my time I was always present at meetings with the municipality, but *NAME OF COWORKER* was there for even longer and I'm sure he's willing to help you out with for example the efficiency and the cooperation questions.

End of conversation

D

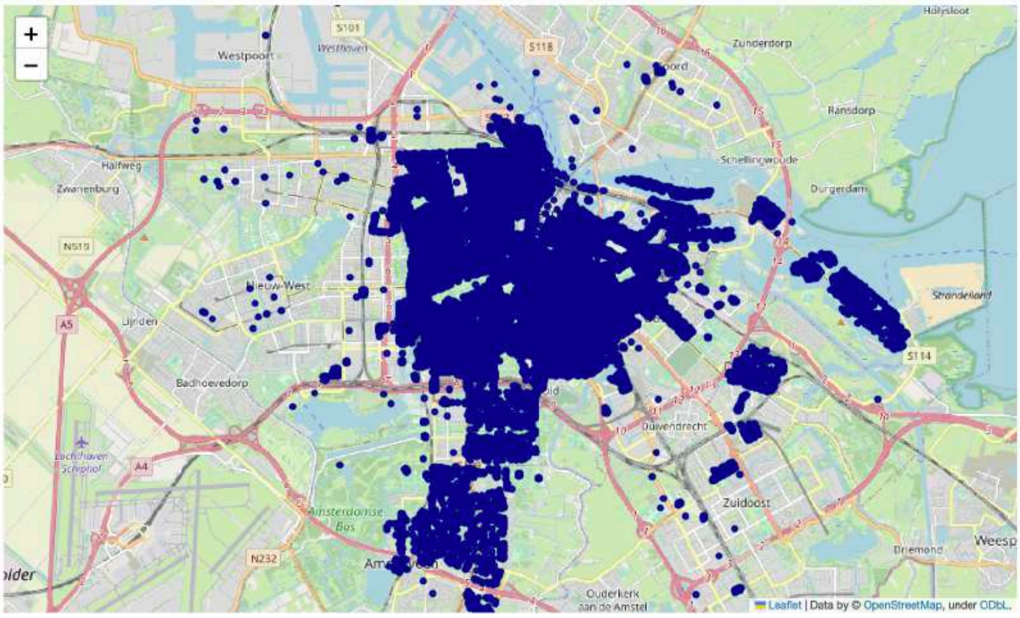
Clustering Python code

The ’folium’ package needs to be installed prior to running the Python code.

```
In [1]: import pandas as pd
        import math
        import folium
        from sklearn.cluster import KMeans

In [2]: def calculate_k_number(total_service_area, radius):

            total_service_area_m2 = total_service_area
            surface_area = math.pi * (radius ** 2)

            k_number = total_service_area_m2 / surface_area

            return k_number

        total_service_area = 32446963.981  # meters^2
        radius = 225  # meters

        k_number = calculate_k_number(total_service_area, radius)
        print("The k-number is: {:.2f}".format(k_number))

        The k-number is: 204.01
```

In [3]:
```python
df = pd.read_csv('september_endpoints.csv')

coords = df[['end_latitude', 'end_longitude']].values

map = folium.Map(location=[52.3680, 4.9036], zoom_start=13)

for index, row in df.iterrows():
    coordinates = [row['end_latitude'], row['end_longitude']]
    folium.CircleMarker(location=coordinates, radius=2, color='darkblue', fill_color='darkblue').add_to(map)

map
```

Out[3]:



In [2]:
```python
df = pd.read_csv('september_endpoints.csv')

coords = df[['end_latitude', 'end_longitude']].values

kmeans = KMeans(n_clusters=204).fit(coords)
cluster_centers = kmeans.cluster_centers_

map_clusters = folium.Map(location=[52.3680, 4.9036], zoom_start=13)

for center in cluster_centers:
    coordinates = [center[0], center[1]]

    folium.CircleMarker(location=coordinates, radius=3, color='darkgreen', fill_color='darkgreen').add_to(map_clust
map_clusters
```

Out[2]:

In [3]:
```python
map_circles = folium.Map(location=[52.3680, 4.9036], zoom_start=13)

for center in cluster_centers:
    coordinates = [center[0], center[1]]

    folium.CircleMarker(location=coordinates, radius=3, color='darkgreen', fill_color='darkgreen').add_to(map_circl

    folium.Circle(location=coordinates, radius=225, color='darkgreen', fill_color='green', fill_opacity=0.3).add_to

map_circles
```

Out[3]:

In [4]:
```python
labels = kmeans.labels_

unique_labels = set(labels)
total_points = len(labels)
average_points_per_cluster = total_points / len(unique_labels)

print(f"Average number of data points per cluster during the month September: {average_points_per_cluster:.2f}")
```

```
Average number of data points per cluster during the month September: 673.28
```

In [5]:
```python
daily_average = average_points_per_cluster / 30

print(f"Daily Average for September: {daily_average:.2f}")
```

```
Daily Average for September: 22.44
```

In [6]:
```python
cluster_counts = pd.Series(labels).value_counts()

map_clusters = folium.Map(location=[52.3680, 4.9036], zoom_start=13)

for i, center in enumerate(cluster_centers):
    coordinates = [center[0], center[1]]
    count = cluster_counts[i]
    average_monthly_data_points = count / 30

    folium.CircleMarker(location=coordinates, radius=3, color='darkgreen', fill_color='darkgreen').add_to(map_clust

    folium.Marker(location=coordinates, tooltip=f"Cluster: {i+1}\nAverage daily data points: {average_monthly_data_

map_clusters
```

Out[6]:

E

Python code for the mean and standard deviation

The following Python code is used after the Python code from Appendix D to obtain an Excel file 'Cluster_Data.xlsx' and to find the mean and standard deviation.

```
In [13]: table_data = []

         for i, center in enumerate(cluster_centers):
             count = cluster_counts[i]
             average_monthly_data_points = count / 30

             table_data.append({
                 'Cluster': i + 1,
                 'Latitude': center[0],
                 'Longitude': center[1],
                 'Average Daily Data Points': average_monthly_data_points
             })

         df_table = pd.DataFrame(table_data)

         df_table.to_excel('Cluster_Data.xlsx', index=False)
```

```
In [8]: import matplotlib.pyplot as plt

        mean_daily_data_points = df_table['Average Daily Data Points'].mean()
        std_daily_data_points = df_table['Average Daily Data Points'].std()

        print(f"Mean of Average Daily Data Points: {mean_daily_data_points:.2f}")
        print(f"Standard Deviation of Average Daily Data Points: {std_daily_data_points:.2f}")

        plt.figure(figsize=(8, 6))
        plt.hist(df_table['Average Daily Data Points'], bins=10, edgecolor='black')
        plt.xlabel('Average Daily Data Points')
        plt.ylabel('Frequency')
        plt.title('Distribution of Average Daily Data Points')
        plt.grid(True)

        plt.axvline(mean_daily_data_points, color='red', linestyle='--', label=f'Mean: {mean_daily_data_points:.2f}')
        plt.axvline(mean_daily_data_points + std_daily_data_points, color='green', linestyle='--',
                    label=f'Mean + Std Dev: {mean_daily_data_points + std_daily_data_points:.2f}')
        plt.axvline(mean_daily_data_points - std_daily_data_points, color='green', linestyle='--',
                    label=f'Mean - Std Dev: {mean_daily_data_points - std_daily_data_points:.2f}')

        plt.legend()
        plt.show()
```